MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

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The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

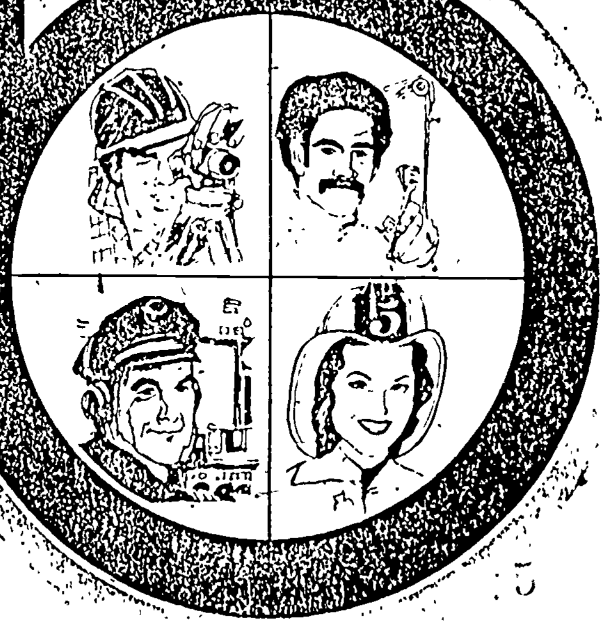
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University 1960 Kenny Road Columbus Ohio 43210
Tel (614) 486-3655 Cable CTVOCEDOSU/Columbus Ohio

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education



Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

ELECTRICIAN

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Electricity-Electromagnetism - Programmed Text	Page 534
Transformers - Programmed Text	Page 572

Developed by

United States Air Force

Development and Review Dates

May 1, 1975

D O T No.:

824.281

Occupational Area:

Building and Construction

Target Audiences:

Grades 10-adult

Print Pages

560

Cost:

$11.25

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
			No. of pages									
Block I – *Electrical Fundamentals*	•	•	72		•	★	•	★	•	★	•	•
Block II – *Nonmetallic Sheathed Cable*	•		52		•	★	•	★	•	★	•	

★ Materials are recommended but not provided.

Course Description

Electrician I and II contains the first two blocks of a five block course of study. Blocks III, IV, and V are included in a second course, **Electrician III, IV, and V** (course 3-18 in this catalog). Training in this five-block series covers electrical fundamentals, using tools and test equipment, installing service entrances, installing and performing maintenance on interior wiring systems in nonmetallic sheathed cable and conduit, motors and motor installation, and fire alarms, intrusion alarms and cathodic protection systems. The first four units of Block I are not suitable for vocational programs because they contain military specific materials. These units were deleted. The remaining sections in Blocks I and II are suitable.

Block I — *Electrical Fundamentals*

Unit 5 — **Electrical and Electronic Fundamentals** (14 hours class instruction, 3½ hours shop)
Unit 6 — **Meters** (2 hours class instruction, 1 hour shop)
Unit 7 — **Ohm's Law and Series Circuits** (4 hours class instruction, 5 hours shop)
Unit 8 — **Parallel Circuits** (2½ hours class instruction, 3½ hours shop)
Unit 9 — **Series, Parallel Circuits** (2½ hours class instruction, 3½ hours shop)
Unit 10 — **Transformers, Rectifiers, and Power Supplies** (6 hours class instruction, 4 hours shop)

Block II — *Nonmetallic Sheathed Cable*

Unit 1 — **National Electrical Code, Electrical Terminology, and Blueprint Reading** (3 hours class instruction, 3 hours shop)
Unit 2 — **Conductors and Overcurrent Protective Devices** (3 hours class instruction, 3 hours shop)
Unit 3 — **Hand Tools** (2¼ hours class instruction, 3/4 hour shop)
Unit 4 — **Single-Phase Service Entrances and Panelboards** (4 hours class instruction, 2 hours shop)
Unit 5 — **Non-Metallic Sheathed Cable** (8 hours class instruction, 13 hours shop)
Unit 6 — **Lighting Systems** (3 hours class instruction, 3 hours shop)
Unit 7 — **Troubleshooting Nonmetallic Sheathed Cable** (3 hours class instruction, 7 hours shop)

Student materials include workbook material and study guides for each unit. Six programmed texts are also provided for student use. Instructor materials include a plan of instruction for the course and lesson plans for each unit. These contain an outline of instruction, objectives, activities, materials and tools needed, text assignments, and references. Transparencies and films are suggested but are not provided.

PLAN OF INSTRUCTION
(Technical Training)

ELECTRICIAN

SHEPPARD TECHNICAL TRAINING CENTER

1 May 1975 - Effective 15 May 1975 with Class 750515

LIST OF CURRENT PAGES

This POI consists of 46 current pages issued as follows:

Page No.	Issue
Title	Original
A	Original
i	Original
1 thru 40	Original
Annex (3 pages)	15 May 73

DISTRIBUTION: ATC/TTMS-1, AULD-1, SGPM-1, TGE-100, TTOT-1, TTOX-1, TTOR-1, TTE-1, CCAF/AY-2

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DEPARTMENT OF THE AIR FORCE
USAF School of Applied Aerospace Sciences (ATC)
Sheppard Air Force Base, Texas 76311

PLAN OF INSTRUCTION 3ABR54230-1
(PDS Code AJZ)
1 May 1975

FOREWORD

1. PURPOSE. This plan of instruction prescribes the qualitative requirements for Course 3ABR54230-1, Electrician, in terms of criterion objectives presented by units/modules of instruction, and shows duration, correlation with the training standard, support materials, and instructional guidance. It was developed under the provisions of ATCR 50-5, Instructional System Development, and ATCR 52-7, Plans of Instruction.

2. COURSE DESCRIPTION. This technical training course trains airmen to perform duties prescribed in AFM 39-1 for Electrician, AFSC 54230. Training includes security, safety, career structure, electrical fundamentals, using tools and test equipment, installation of service entrances, installation and maintenance of interior wiring systems in nonmetallic sheathed cable and conduit, motors and motor installations, fire alarms, intrusion alarms, and cathodic protection systems. Related training covers driver education, supplemental military training, troop information program, moral leadership, commander's calls/briefings, etc.

3. EQUIPMENT ALLOWANCE AND AUTHORIZATION. Training equipment required to conduct this course is listed in Equipment Authorization Inventory Data Number 3ABR542300000. Training equipment authorizations for this course are based on the following Tables of Allowance:

TA 403	General Purpose Tools (WRAMA)
TA 486	Civil Engineering Electrical Instruments and Control Shop Line Construction and Maintenance, Appliance Shop and Family Housing Repair Equipment (WRAMA)
TA 504	Food Service (Nontactical) (WRAMA)

NOTE: Group size is shown in parentheses after equipment listed in column 3 of numbered pages of this POI.

4. MULTIPLE INSTRUCTOR REQUIREMENTS. Units of instruction which require more than one instructor per instructional group are identified in the multiple instructor annex to this POI.

5. REFERENCES. This plan of instruction is based on SPECIALTY TRAINING STANDARD 54230/50/70, 2 December 1970; Change 1, 14 January 1972; Change 2, 6 March 1973; Change 3, 18 April 1973; Change 4, 25 February 1974; Change 5, 7 November 1974, and Course Chart 3ABR54230-1, 20 March 1975.

FOR THE COMMANDER

Leonard A. Hamilton

LEONARD A. HAMILTON, Col, USAF
Chief, Dept of Civil Engineering Tng

Supersedes Plan of Instruction 3ABR54230-1, 13 July 1973
OPR: Department of Civil Engineering Training
DISTRIBUTION: Listed on page A

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MODIFICATIONS

Units 1 - 4 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

5. Electrical and Electronic Fundamentals	18 (18/0) Days 2, 3, and 4	Column 1 Reference: 5a, 5b, 5c, 5g, 5h — STS Reference: 6a
a. Given information on the electron theory of electricity and a list of applicable terms and definitions, match each term with the correct definition.	(2/0)	Column 1 Reference: 5a, 5d, 5e, 5f — STS Reference: 6b; Column 1 Reference: 5i — STS Reference: 6i
b. Given information on the electron theory of electrical current flow, complete statements pertaining to current flow in conductors.	(2/0)	**Instructional Materials** SG 3ABR54230-1-I-5, Electrical and Electronic Fundamentals WB 3ABR54230-1-I-5, Electrical and Electronic Fundamentals 2TPT-3100-01, Introduction to Electrical Symbols 2TPT-3112-04, Electricity - Electromagnetism
c. After observing examples of electrical current and voltage wave forms, draw a diagram for AC, DC and pulsating DC wave forms.	(2/0)	**Audio Visual Aids** FLC 16/98, Principles of Electricity AVA-719, Reactance, Capacitive TF1-5443a, Basic Electricity, Inductance in AC Circuits TF1-5443b, Basic Electricity, Capacitance in AC Circuits AVA-718 Reactance, Inductive TVK 30-205, Inductance Transparencies, Electrical Fundamentals

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVE	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
d. Given information on the theory and application of magnetism and a list of terms and definitions, match each term with the correct definition.	(2/0)	**Training Equipment** Trainer, Electrical Fundamentals (8) Trainer, Missile System Electronic Circuitry (8) Trainer, Reactance Comparison (8) Oscilloscope (8)
e. Given information on the theory and application of magnetism, complete statements pertaining to the application of magnetism.	(2/0)	**Training Methods** Discussion and Demonstration (14.5 hrs) Performance (3.5 hrs)
f. Using previously given information on the theory of magnetism, a galvanometer, magnet, soft iron bar and a length of copper wire, perform an experiment to produce an electrical current.	(2/0)	**Instructional Environment/Design** Classroom (14.5 hrs) Laboratory (3.5 hrs) Group/Lockstep
g. Given information on reactance in AC circuits, complete statements pertaining to inductive and capacitive reactance.	(3/0)	**Instructional Guidance** Discuss the construction of matter and electron theory, explaining the definitions, unit of measurement and symbols for voltage, current and resistance. Using electrical fundamentals trainer, demonstrate the characteristics of voltage, current and resistance. Introduce and show film FLC 16/98. Discuss the basic laws of magnetism and demonstrate their application. Discuss the different types of reactance in a circuit and how it affects alternating current. Demonstrate electromotive force and electromagnetic induction, using the fundamentals trainer. Use the reactance comparison trainer to show results of reactance in RL and RC circuits. Introduce and show films TF1-5443a, TF1-5443b, TVK 30-205, AVA-718, and AVA-719. Show and explain basic symbols used in electronic fundamentals. References: TO 31-1-141-2, Basic Electronics Technology and Testing Practices, Chapter 3; Basic Electricity, Vol 1, Van Volkenburgh.
h. Using the information given on reactance and a list of terms and definitions, match each term with the correct definition.	(2/0)	
i. Given a programmed text, identify symbols used in electrical and electronic fundamentals.	(1/0)	

UNIT OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
6. Meters	3 (3/0) Day 5	Column 1 Reference: 6a, 6b STS Reference: 5b
a. Given information on multimeters, complete statements on the selection, use and care of electrical test instruments.	(2/0)	**Instructional Materials** SG 3ABR54230-1-I-6, Meters WB 3ABR54230-1-I-6, Meters TO 33A1-4-5-11, Insulation Test Sets TO 33A1-12-48-1, Multimeter TO 33A1-12-126-1, Multimeter
b. Given information and provided a trainer with six problems, use the multimeter and answer all problems.	(1/0)	**Audio Visual Aids** Transparencies, Meters **Training Equipment** Trainer, Multimeter (8). Multimeter, TS/297U (1) Ohmmeter, AN PSM2A (8) Multimeter, Clamp on Type, AN/USM-33 (8) Trainer, Conductor (8) **Training Methods** Discussion and Demonstration (2 hrs) Performance (1 hr) **Instructional Environment/Design** Classroom (2 hrs) Laboratory (1 hr) Group/Lockstep

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS) 2	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Discuss the purpose and use of the voltmeter, ohmmeter, ammeter, multimeter, and megometer. Demonstrate multimeter controls, meter connections and readings of different scales by using the multimeter trainer. Demonstrate the procedures for resistance, continuity checks, voltage and amperage readings. Emphasize the importance of multimeters for use during circuit troubleshooting.
7. Ohm's Law and Series Circuits	9 (9/0)	**Column 1 Reference** — **STS Reference** 7a — 6a, 6c, 6d, 6i
a. Given Ohm's law formula and two known values, solve for the unknown.	Days 5, 6 (3/0)	7b, 7c — 5b, 6a, 6c, 6d, 6e, 6i, 8o(2), 8o(4) 7d — 6a, 6d, 6i
b. Given instructions on a series circuit, use the conductor trainer to construct a series circuit.	(2/0)	**Instructional Materials** SG 3ABR54230-1-I-7, Ohm's Law and Series Circuits WB 3ABR54230-1-I-7, Ohm's Law and Series Circuits 2TPT-3100-02, Ohm's Law, Series Circuits 2TPT-3101-01, DC Circuits-Series Circuits
c. Using the previously constructed series circuit, measure and record the voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate the resistance and power.	(2/0)	**Audio Visual Aids** Transparencies, Ohm's Law and Series Circuits
d. Given series circuit problems, use Ohm's law to solve for unknown values.	(2/0)	**Training Equipment** Trainer, Conductor (1) Trainer, Electrical Fundamentals (8) **Training Methods** Discussion and Demonstration (4 hrs) Performance (5 hrs)

PLAN OF INSTRUCTION NO 3ABR54230-1	DATE 1 May 1975	BLOCK NO. I	PAGE NO 8

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
		Instructional Environment/Design Classroom (4 hrs) Laboratory (5 hrs) Group/Lockstep **Instructional Guidance** Discuss the definition, application, construction and characteristics of series circuits. Explain Ohm's law and demonstrate how to use Ohm's law formula to calculate unknown values of voltage, current, resistance and power. Demonstrate construction, operation, and characteristics of series circuits, using the conductor trainer and electrical fundamentals trainer. References: TO 31-1-141-2, Basic Electronics Technology and Testing Practices, Chapter 3; Basic Electricity, Van Volkenburgh, Vol II.
8. Parallel Circuits a. Given instructions on a parallel circuit, use the conductor trainer to construct a parallel circuit. b. Using the previously constructed parallel circuit, measure and record the voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate the resistance and power c. Given parallel circuit problems, use Ohm's law to solve for unknown values.	6 (6/0) Day 7 (2/0) (2/0) (2/0)	**Column 1 References** / **STS Reference** 8a, 8b — 5b, 6a, 6c, 6d, 6e, 6i, 8o(2), 8o(4) 8c — 6a, 6d, 6i **Instructional Materials** SG 3ABR54230-1-I-8, Parallel Circuits WB 3ABR54230-1-I-8, Parallel Circuits 2TPT-3101-02, DC Circuits Parallel **Audio Visual Aids** Transparencies, Parallel Circuits **Training Equipment** Trainer, Conductor (1) **Training Methods** Discussion and Demonstration (2.5 hrs) Performance (3.5 hrs)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
		Instructional Environment/Design Classroom (2.5 hrs) Laboratory (3.5 hrs) Group/Lockstep Instructional Guidance Discuss the definition, application, construction, and characteristics of parallel circuits. Explain application of Ohm's law and demonstrate how to use formula to calculate unknown values of current, voltage, resistance, and power.
9. Series-Parallel Circuits a. Given instructions on a series-parallel circuit, use the conductor trainer to construct a series-parallel circuit.	6 (6/0) Day 8 (2/0)	Column 1 Reference / STS Reference 9a — 5b, 6a, 6c, 6d, 6e, 6i, 8o(2), 8o(4) 9b — 5b, 6a, 6c, 6d, 6e, 6i, 8o(2), 8o(4) 9c — 6a, 6d, 6i
b. Using the previously constructed series-parallel circuit, measure and record the voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate the resistance and power.	(2/0)	Instructional Materials SG 3ABR54230-1-I-9, Series-Parallel Circuits WB 3ABR54230-1-I-9, Series-Parallel Circuits Audio Visual Aids Transparencies, Series-Parallel Circuits
c. Given series parallel circuit problems, use Ohm's law to solve for unknown values.	(2/0)	Training Equipment Trainer, Conductor (1) Training Methods Discussion and Demonstration (2.5 hrs) Performance (3.5 hrs) Instructional Environment/Design Classroom (2.5 hrs) Laboratory (3.5 hrs) Group/Lockstep

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION HOURS	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Discuss the definition, application, construction, and characteristics of series parallel circuits. Explain application of Ohm's law and demonstrate how to use formula to calculate unknown values of current, voltage, resistance and power. References: TO 31-1-141-2, Basic Electronics Technology and Testing Practices, Chapter 3; Basic Electricity, Van Volkenburgh, Vol II.
10. Transformers, Rectifiers, and Power Supplies	10 (10/0) Days 9, 10	Column 1 Reference / STS Reference 10a, 10b, 10c, 10d — 6g 10e, 10f — 6h 10g — 6b, 8o(3) 10h — 6b 10i — 6h
a. Using a schematic and nomenclature pertaining to transformers, label the three main parts.	(1/0)	
b. Given an incomplete schematic and required information, draw the secondary windings of a transformer, including the output voltage value.	(2/0)	Instructional Materials SG 3ABR54230-1-I-10, Transformers, Rectifiers and Power Supplies WB 3ABR54230-1-I-10, Transformers, Rectifiers and Power Supplies 2TPT-3103-15, Transformers
c. Given a drawing of a transformer showing the number of primary and secondary turns and the applied voltage and current, use the turns ratio formula to determine the secondary voltage and current.	(1/0)	Audio Visual Aids Transparencies, Transformers, Rectifiers, Power Supplies TF 5279A, Magnetic Amplifiers Training Equipment Oscilloscope (8)
d. Given a list of statements, a schematic and required information, complete statements pertinent to use of transformers in electronic circuits.	(1/0)	Trainer, Missile System Electronic Circuitry (8) Trainer, Battery Charger (8) Trainer, Electrical Fundamentals (8)
e. Given a schematic and nomenclature pertaining to rectifiers, label the main parts.	(1/0)	Training Methods Discussion and Demonstration (6 hrs) Performance (4 hrs)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
f. Using the schematic of a rectifier circuit, trace one alternation of current through the circuit by using arrows to indicate direction of current flow.	(1/0)	Instructional Environment/Design Classroom (6 hrs) Laboratory (4 hrs) Group/Lockstep
g. Given a list of incomplete statements and required information, complete statements pertaining to batteries.	(1/0)	Instructional Guidance Discuss transformer nomenclature, theory, operation, construction, and connections. Explain operating principles, construction, connections and application of rectifiers, battery chargers, magnetic amplifiers and transistors. Demonstrate on oscilloscope the rectified wave forms both filtered and unfiltered. Introduce and show film TF 5279A, Magnetic Amplifiers. Explain how transformers and rectifiers are used to construct electrical and electronic power supplies.
h. Given a list of questions pertaining to electrical and electronic power supplies and required information, answer questions on use of power supplies.	(1/0)	
i. Given a drawing of a magnetic amplifier, label the three main parts.	(1/0)	
11. Related Training	20	Reference: TO 31-1-141-2, Basic Electronic Technology and Testing Practices, Chapter 3: Basic Electricity, Van Volkenburgh, Vol II.
12. Measurement Test and Test Critique	2/0 Day 10	

PLAN OF INSTRUCTION	COURSE TITLE Electrician	
BLOCK TITLE Nonmetallic Sheathed Cable		

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
1. National Electrical Code, Electrical Terminology and Blueprint Reading	6 (6/0) Day 11	Column 1 Reference: 1a, 1b, 1c — STS Reference: 4f, 6i Column 1 Reference: 1d — STS Reference: 7a, 7b, 7d
a. Given a National Electrical Code (NEC), list its purpose and scope.	(1/0)	**Instructional Materials** SG 3ABR54230-1-II-1, National Electrical Code, Electrical Terminology and Blueprint Reading WB 3ABR54230-1-II-1, National Electrical Code, Electrical Terminology and Blueprint Reading National Electrical Code National Electrical Code and Blueprint Reading, K. L. Gebert
b. Given a National Electrical Code and a list of electrical terms, write the definition of each term.	(1/0)	
c. Given a National Electrical Code and selected electrical problems, list the correct answer to each problem.	(2/0)	**Audio Visual Aids** Transparencies, Symbols Electrical Blueprint, TAG 6065
d. Given a blueprint, NEC, and selected electrical installation problems, identify locations and list the wiring requirements for electrical component installation to meet National Electrical Code and blueprint specifications.	(2/0)	**Training Methods** Discussion and Demonstration (3 hrs) Performance (3 hrs) **Instructional Environment/Design** Classroom (3 hrs) Laboratory (3 hrs) Group/Lockstep

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS) 2	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Explain the purpose, scope and use of the NEC (Article 90). Define electrical terms in Article 100 of the NEC. Discuss the arrangement of the NEC. Show and explain symbols used for common electrical equipment. Demonstrate the method for reading a blueprint, using a blueprint and a list of symbols.
2. Conductors and Overcurrent Protective Devices	6 (6/0) Day 12	Column 1 Reference / STS Reference 2a, 2b, 2c, 2d / 7b 2e / 9h
a. Given the National Electrical Code and a list of conductor sizes and insulation types, list the amount of current each conductor will carry.	(2/0)	**Instructional Materials** SG 3ABR54230-1-II-2, Conductors and Overcurrent Protective Devices WB 3ABR54230-1-II-2, Conductors and Overcurrent Protective Devices National Electrical Code
b. Given the National Electrical Code and a list of circuits, list the proper size conductor to use in accordance with the National Electrical Code.	(1/0)	National Electrical Code and Blueprint Reading, K. L. Gebert **Audio Visual Aids** Transparencies, Conductors and Overload Devices
c. Given the National Electrical Code and a list of overcurrent devices, select facts pertaining to the different types of overcurrent devices in accordance with the National Electrical Code.	(1/0)	**Training Equipment** Trainer, Conductor Size and Protective Devices (8) Trainer, Circuit Breaker (2) Tester, Multi-Amp, MS 1(A) (8)
d. Given a list of overcurrent devices and the National Electrical Code, select the correct overcurrent device to meet the NEC requirements.	(1/0)	**Training Methods** Discussion and Demonstration (3 hrs) Performance (3 hrs) **Instructional Environment/Design** Classroom (3 hrs) Laboratory (3 hrs) Group/Lockstep

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION HOURS	3 SUPPORT MATERIALS AND GUIDANCE
e. Observe the steps for testing a molded case circuit breaker with an MS1(A) tester in accordance with the manufacturer's specifications.	(1/0)	Instructional Guidance Discuss the different types and sizes of conductors and material used for insulation and their limitations according to the NEC. Discuss the American Wire Gage and conductor sizes that are not covered by the AWG. Discuss the purpose, types, and sizes of overcurrent protective devices and the NEC requirements. Demonstrate the operation and use of the MS1(A) tester and circuit breaker testing.
3. Hand Tools a. Given information and a set of selected hand tools, identify the use and care of each hand tool.	3 (3/0) Day 13 (3/0)	Column 1 Reference: 3a STS Reference: 5a(1) Instructional Materials SG 3ABR54230-1-II-3, Hand Tools WB 3ABR54230-1-II-3, Hand Tools Audio Visual Aids Transparencies, Hand Tools TF 1-4603, ABC of Hand Tools, Part I TF 1-4603, ABC of Hand Tools, Part II Training Equipment Hand Tool Set (8) Training Methods Discussion and Demonstration (2.25 hrs) Performance (.75 hr) Instructional Environment/Design Classroom (2.25 hrs) Laboratory (0.75 hrs) Group/Lockstep

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Identify and demonstrate the use and maintenance of the common electrician's hand tools. Emphasize to the students that the speed and accuracy with which they do their work depends upon their knowledge and use of hand tools. Stress safety.
4. Single-Phase Service Entrances and Panelboards a. Provided a booth area, hand tools, and a working drawing, install a single-phase 120/240 volt service entrance and grounded panelboard according to NEC specifications. b. Provided information, tools, and materials, connect and check the ground conductor to NEC specifications.	6 (6/0) Days 13, 14 (5/0) (1/0)	**Column 1 Reference** 4a, 4b **STS Reference** 7a, 7b, 7d, 8a(1), 8a(2), 8a(3), 8b, 8h, 8o(1), 8o(4) **Instructional Materials** SG 3ABR54230-1-II-4, Single-Phase Service Entrances and Panelboards WB 3ABR54230-1-II-4, Single-Phase Service Entrances and Panelboards National Electrical Code **Audio Visual Aids** Transparencies, Single-Phase Service TVS-54/5, 3 and 4 Wire Service **Training Equipment** Hand Tool Set (8) Trainer, Entrances and Panelboards (8) Multimeter, TS/297u (1) **Training Methods** Discussion and Demonstration (4 hrs) Performance (2 hrs) **Instructional Environment/Design** Classroom (4 hrs) Laboratory (2 hrs) Group/Lockstep

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Discuss the NEC requirements for service installation (Articles 200, 230, 250, and 300). Demonstrate the different parts used to make up a service. Discuss the different types of service entrances. Discuss methods of grounding. Explain the purpose of single-phase and three-phase entrances and panelboards. Stress safety. Have students connect and check ground.
5. Nonmetallic Sheathed Cable	21 (21/0) Days 14, 15 16 and 17	Column 1 Reference — STS Reference 5a — 6i, 7a, 7b, 7d 5b — 5a(3) 5c, 5d, 5e, 5f — 8e, 8g, 8h, 8i, 8j, 8m, 8o(1), 8o(2), 8o(4)
a. Given information pertaining to the construction characteristics, types, and uses of nonmetallic cable, list the correct answer to each problem by researching the information in the NEC.	(3/0)	**Instructional Materials** SG 3ABR54230-1-II-5, Nonmetallic Sheathed Cable WB 3ABR54230-1-II-5, Nonmetallic Sheathed Cable National Electrical Code
b. Given the necessary tools, equipment, and instructions, make and solder splices according to NEC specifications.	(3/0)	
c. Provided a work area and hand tools, install a circuit in nonmetallic cable containing a ceiling light, a single-pole switch and a duplex receptacle, according to NEC specification.	(6/0)	**Audio Visual Aids** TF 6027, Roughing in Nonmetallic Cable TVS 54/3, Three-and Four-Way Switches Transparencies: Nonmetallic Sheathed Cable and Splices; Installation of Nonmetallic Cables; Three-and-Four-Way Switches
d. Provided a work area and hand tools, install a circuit in nonmetallic cable containing a 220 volt receptacle, according to NEC specifications.	(3/0)	**Training Equipment** Hand Tool Set (8) Solder Equipment (4) **Training Methods** Discussion and Demonstration (8 hrs) Performance (13 hrs)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
e. Provided a work area and hand tools, install a circuit in nonmetallic cable, containing two three-way switches to control a ceiling light, according to NEC specifications.	(3/0)	Instructional Environment/Design Classroom (8 hrs) Laboratory (13 hrs) Group/Lockstep
f. Using the previously installed three-way switches, install a four-way switch according to NEC specifications.	(3/0)	Instructional Guidance Discuss and demonstrate the construction, types and use of nonmetallic cable. Have students splice, solder, and tape wire connections. Discuss the circuitry and connections of devices. Stress safety.
6. Lighting Systems	6 (6/0) Day 18	Column 1 Reference: 6a, 6b — STS Reference: 7a, 10j Column 1 Reference: 6c — STS Reference: 8m, 8o(1), 8o(2), 8o(4)
a. Given information pertaining to incandescent lighting and a list of problems, correctly solve each problem.	(2/0)	Instructional Materials SG 3ABR54230-1-II-6, Lighting Systems WB 3ABR54230-1-II-6, Lighting Systems National Electrical Code
b. Given information pertaining to fluorescent lighting and a list of problems, correctly solve each problem.	(2/0)	Audio Visual Aids Transparencies, Incandescent and Fluorescent Lighting
c. Provided a work area and hand tools, install a circuit in nonmetallic cable, containing a fluorescent light and a single-pole switch according to NEC specifications.	(2/0)	Training Equipment Trainers, Fluorescent Lights (8) Hand Tool Set (8) Training Methods Discussion and Demonstration (3 hrs) Performance (3 hrs)

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
		Instructional Environment/Design Classroom (3 hrs) Laboratory (3 hrs) Group/Lockstep **Instructional Guidance** Discuss types, construction features, uses, specifications, installation procedures, circuitry and operational characteristics of incandescent and fluorescent lighting. Have students install a fluorescent light circuit. Stress safety.
7. Troubleshooting Nonmetallic Sheathed Cable	10 (10/0) Days 19, 20	**Column 1 Reference** — **STS Reference** 7a, 7b — 5a(1), 5b, 9m, 10a, 10b, 10c, 10e, 10f(1), 10f(2), 10f(3), 10g, 10h, 10i, 10k 7c — 8i 7d — 5a(1)
a. Provided a multimeter and instructions, troubleshoot an energized (120/240 volt) electrical circuit to locate troubles inserted in the circuit by the instructor.	(4/0)	**Instructional Materials** SG 3ABR54230-1-II-7, Troubleshooting Nonmetallic Sheathed Cable WB 3ABR54230-1-II-7, Troubleshooting Nonmetallic Sheathed Cable
b. Provided a multimeter and instructions, troubleshoot a deenergized circuit to locate troubles inserted in the circuit by the instructor.	(4/0)	**Audio Visual Aids** TF 6078, Troubleshooting Electrical Circuits Transparencies, Troubleshooting
c. Given information pertaining to balancing branch circuits, balance the circuits installed.	(1/0)	**Training Equipment** Multimeter (1) Hand Tool Set (8)
d. Using tools and instructions provided, disconnect electrical circuits, sort material and store in designated storage facilities.	(1/0)	**Training Methods** Discussion and Demonstration (3 hrs) Performance (7 hrs)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		<u>Instructional Environment/Design</u> Classroom (3 hrs) Laboratory (7 hrs) Group/Lockstep <u>Instructional Guidance</u> Explain methods and procedures for troubleshooting circuits. Discuss the various types of troubles and the use of meters in locating circuit troubles. Explain how to balance branch circuits. Have students locate troubles inserted in their circuits. Stress safety.
8. Related Training	20	
9. Measurement Test and Test Critique	2/0 Day 20	

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/13May75	
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER I	BLOCK TITLE Electrical Fundamentals

LESSON TITLE: Electrical and Electronic Fundamentals (Days 2, 3, and 4)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
18 Hrs	0	18 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
5 and 6	1 May 1975	5

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainers, Electrical Fundamentals; Missile Systems Electronic Circuitry; Reactance Comparison Oscilloscope Projector, Overhead	Projector, 16mm	None	SG 1-5 WB 1-5 2TPT-3100-01, Introduction to Electrical Symbols 2TPT-3112-04, Electricity-Electromagnetism Transparencies, Electrical Fundamentals FLC 16/98, Principles of Electricity AVA 719, Reactance, Capacitive TF1-5443A, Basic Electricity, Inductance in AC Circuits TF1-5443B, Basic Electricity, Capacitance in AC Circuits AVA-718, Reactance, Inductive TVK 30-205, Inductance

CRITERION OBJECTIVES AND TEACHING STEPS

5a. Given information on the electron theory of electricity and a list of applicable terms and definitions, match each term with the correct definition.

(1) Construction of matter

(2) Parts of the atom

(3) Types of energy

5b. Given information on the electron theory of electrical current flow, complete statements pertaining to current flow in conductors.

(1) Voltage

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(a) Sources

(b) Fffect

(c) Symbols and terms

(2) Current

(a) Causes

(b) Effect

(c) Symbols and terms

(3) Resistance

(a) Types

(b) Effect

(c) Symbols and terms

5c. After observing examples of electrical current and voltage wave forms, draw a diagram for AC, DC, and pulsating DC wave forms.

(1) Describe the structure of sine waves

(2) Demonstrate wave forms

5d. Given information on the theory and application of magnetism and a list of terms and definitions, match each term with the correct definition.

(1) Theory and history of magnetism

(2) Terms concerning magnetism

(3) Types of magnets

(a) Permanent

(b) Temporary

5e Given information on the theory and application of magnetism, complete statements pertaining to the application of magnetism.

(1) Use of permanent magnets

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(2) Use of temporary magnets

5f. Using previously given information on the theory of magnetism, a galvanometer, magnet, soft iron bar and a length of copper wire, perform an experiment to produce an electrical current.

(1) Theory of generating of a voltage

(2) Generation of voltage

(a) Single-phase

(b) Three-phase

5g. Given information on reactance in AC circuits, complete statements pertaining to inductive and capacitive reactance.

(1) Inductance

(a) Theory

(b) Symbol and unit of measurement

(c) Effects

(d) Formula for calculations

(2) Capacitance

(a) Theory

(b) Symbol and unit of measurement

(c) Effects

(d) Formula for calculations

(3) Impedance

(a) Theory

(b) Symbol and unit of measurement

(c) Effects

(d) Formula for calculations

LESSON PLAN (Part I, General). CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

5h. Using the information given on reactance and a list of terms and definitions, match each term with the correct definition.

(1) Explanation of reactance terms

(2) Define Impedance

5i. Given a programmed text, identify symbols used in electrical and electronic fundamentals.

(1) Common electrical symbols

(2) Purpose for using electrical symbols

Course No: 3ABR54230-1
Day: 2, 3, 4

Branch Approval: Bobby J. Littlefield
Date: 14 May 1975

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

REVIEW:

Review subject matter covered in previous day or individual problem areas.

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (17 Hrs 45 Min)

PRESENTATION:

5a. Given information on the electron theory of electricity and a list of applicable terms and definitions, match each term with the correct definition.

(1) Construction of matter

(2) Parts of the atom

(3) Types of energy

5b. Given information on the electron theory of electrical current flow, complete statements pertaining to current flow in conductors.

(1) Voltage

(a) Sources

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(b) Effect

(c) Symbols and terms

(2) Current

(a) Causes

(b) Effect

(c) Symbols and terms

(3) Resistance

(a) Types

(b) Effect

(c) Symbols and terms

5c. After observing examples of electrical current and voltage wave forms, draw a diagram for AC, DC, and pulsating DC wave forms.

(1) Describe the structure of sine waves

(2) Demonstrate wave forms

APPLICATION:

WB 3ABR54230-1-I-5, Exercise 1, Electron Theory

CONCLUSION (Day 2)

SUMMARY:

Cover main points of lesson.

STUDY ASSIGNMENT:

Electrical and Electronic Fundamentals
SG 3ABR54230-1-I-5, Section II, Magnetism

INTRODUCTION (Day 3)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT:

Check workbook.

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

5d. Given information on the theory and application of magnetism and a list of terms and definitions, match each term with the correct definition.

(1) Theory and history of magnetism

(2) Terms concerning magnetism

(3) Types of magnets

(a) Permanent

(b) Temporary

5e. Given information on the theory and application of magnetism, complete statements pertaining to the application of magnetism.

(1) Use of permanent magnets

(2) Use of temporary magnets

(a) Electro-magnetism

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5f. Using previously given information on the theory of magnetism, a galvanometer, a magnet, soft iron bar and a length of copper wire, perform an experiment to produce an electrical current.

(1) Theory of generation of a voltage

(2) Generation of voltage

(a) Single-phase

(b) Three-phase

APPLICATION:

WB 3ABR54230-1-I-5, Exercise II,
2TPT3112-04, Electricity - Electromagnetism

CONCLUSION (Day 3)

SUMMARY:

Cover main points of lesson.

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STUDY ASSIGNMENT:

Electrical and Electronic Fundamentals
SG 3ABR54230-1-I-5, Section III, Reactance Inductance

INTRODUCTION (Day 4)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

Check workbook

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

5g. Given information on reactance in AC circuits, complete statements pertaining to inductive and capacitive reactance.

(1) Inductance

(a) Theory

(b) Symbol and unit of measurements

(c) Effects

(d) Formula for calculations

(2) Capacitance

(a) Theory

(b) Symbol and unit of measurement

(c) Effects

(d) Formula for calculations

(3) Impedance

(a) Theory

(b) Symbol and unit of measurement

(c) Effects

(d) Formula for calculations

5h. Using the information given on reactance and a list of terms and definitions, match each term with the correct definition.

(1) Explanation of reactance terms

(2) Define impedance

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5i. Given a programmed text, identify symbols used in electrical and electronic fundamentals.

(1) Common electrical symbols

(2) Purpose for using electrical symbols

APPLICATION:

WE 3ABR54230-1-I-5, Exercise III
2TPT-3100-01, Introduction to Electrical Symbols

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

Cover main points of lesson.

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REMOTIVATION:

STUDY ASSIGNMENT:

Meters - SG 3ABR54230-1-I-6

SG 3ABR54230-1-7, Ohm's Law and Series Circuits

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/13 May 75	
COURSE NUMBER: 3ABR54230-1	COURSE TITLE: Electrician
BLOCK NUMBER: I	BLOCK TITLE: Electrical Fundamentals
LESSON TITLE: Meters (Day 5)	

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
3 Hrs	0	3 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
7	1 May 1975	6

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Multimeter Trainer, Conductor Projector, Overhead Trainer, Ohmmeter Test Board	Multimeter, TS/297U Ohmmeter, AN/PSM-2A Multimeter, AN/USM-33	None	SG 1-6 SG 1-6 TO 33A1-4-5-11, Insulation Test Sets TO 33A1-12-48-1, Multimeter TO 33A1-12-126-1, Multimeter Transparencies, Meters Trainer Ohmmeter Testboard

CRITERION OBJECTIVES AND TEACHING STEPS

6a. Given information on multimeters, complete statements on the selection, use and care of electrical test instruments.

(1) Construction and theory of operation

(2) Purpose and types of meters

(3) Scale interpretation and proper procedures for meter use

(4) Connections required to safeguard meters

(5) Care and selection of meters

6b. Given information and provided a trainer with six problems, use the multimeter to answer all problems.

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(1) Continuity readings

(2) Connection for voltage readings

Course No: 3ABR54230-1
Day: 5

Branch Approval: Bobby Pittsley
Date: 14 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

Check workbook

REVIEW:

Review subject matter covered in previous day or individual problem areas.

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (2 Hrs 45 Min)

PRESENTATION:

6a. Given information on multimeters, complete statements on the selection, use, and care of electrical test instruments.

(1) Construction and theory of operation

(2) Purpose and types of meters

(3) Scale interpretation and proper procedures for meter use

(4) Connections required to safe guard meters

(5) Care and selection of meters

6b. Given information and provided a trainer with six problems, use the multimeter to answer all problems.

(1) Continuity readings

(2) Connection for voltage readings

APPLICATION:

WB 3ABR54230-1-I-6, Meters

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: None

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE TCETC/13May75	INSTRUCTOR
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER I	BLOCK TITLE Electrical Fundamentals

LESSON TITLE
Ohm's Law and Series Circuits (Days 5 and 6)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
9 Hrs	0	9 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
8	1 May 1975	7

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Conductor Trainer, Electrical Fundamentals Projector, Overhead	None	None	SG I-7 WB I-7 2TPT-3100-02, Ohm's Law, Series Circuits 2TPT-3101-01, DC Circuits-Series Circuits Transparencies, Ohm's Law and Series Circuit

CRITERION OBJECTIVES AND TEACHING STEPS

7a. Given Ohm's law formula and two known values, solve for the unknown.

(1) Theory of Ohm's law

(2) Principles of Ohm's law

(3) Three factors required to calculate a problem using Ohm's law

7b. Given instructions on a series circuit, use the conductor trainer to construct a series circuit.

(1) Definition of a series circuit

(2) Application of a series circuit

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(3) Characteristics of a series circuit

(4) Properties of a series circuit

7c. Using the previously constructed series circuit, measure and record the voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate resistance and power.

(1) Measurement of voltage and current

(2) Calculate for resistance

(3) Using the power formula, calculate power

7d. Given series circuit problems, use Ohm's law to solve for unknown values.

(1) Types of series circuit problems

(2) Solving for unknown values in series circuits

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Course No: 3ABR54230-1
Days: 5, 6

Branch Approval: Bobby G. Littlejohn
Date: 14 May 1975

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (8 Hours 45 Minutes)

PRESENTATION:

7a. Given Ohm's law formula and two known values, solve for the unknown.

(1) Theory of Ohm's law

(2) Principles of Ohm's law

(3) Three factors required to calculate a problem using Ohm's law

APPLICATION: None

CONCLUSION (Day 5)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-I-7, Ohm's Law and Series Circuits

INTRODUCTION (Day 6)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

7b. Given instructions on a series circuit, use the conductor trainer to construct a series circuit.

(1) Definition of a series circuit

(2) Application of a series circuit

(3) Characteristics of a series circuit

(4) Properties of a series circuit

7c. Using the previously constructed series circuit, measure and record voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate resistance and power.

(1) Measurement of voltage and current

(2) Calculate for resistance

(3) Using the power formula calculate power

7d. Given series circuit problems, use Ohm's law to solve for unknown values.

(1) Types of series circuits problems

(2) Solving for unknown values in series circuits

APPLICATION:

WB 3ABR54230-1-I-7,
Ohm's Law and Series Circuits
2TPT-3100-02, Ohm's Law, Series Circuits
2TPT-3101-01, DC Circuits - Series Circuits

EVALUATION:

Evaluate by oral, written questions, and/or observation of students performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

Cover main points of lesson.

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-I-8, Parallel Circuits

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/ 13May75	
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER I	BLOCK TITLE Electrical Fundamentals

UNIT TITLE: Parallel Circuits (Day 7)

LESSON DURATION

CLASSROOM LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	0	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
9	1 May 1975	8

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Conductor Projector, Overhead	None	None	SG I-8 WB I-8 2TPT-3101-02, DC Circuits Parallel Transparencies, Parallel Circuits

CRITERION OBJECTIVES AND TEACHING STEPS

8a. Given instructions on a parallel circuit, use the conductor trainer to construct a parallel circuit.

(1) Definition of a parallel circuit

(2) Application of a parallel circuit

(3) Characteristics of a parallel circuit

(4) Properties of a parallel circuit

8b. Using the previously constructed paralled circuit, measure and record the voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate the resistance and power.

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(1) Measurement of voltage and current

(2) Calculate for resistence

(3) Using the power formula calculate the power

8c. Given parallel circuit problems, use Ohm's law to solve for unknown values.

(1) Types of parallel circuit problems

(2) Solving for unknown values in parallel circuits

5-2

Course No: 3ABR54230-1
Days: 7

Branch Approval: Bobby G. Littlejohn
Date: 14 May 1975

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

Review subject matter covered in previous day or individual problem areas.

ATTENTION:

OVERVIEW:

MOTIVATION:

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BODY (5 Hrs 45 Minutes)

PRESENTATION:

8a. Given instructions on a parallel circuit, use the conductor trainer to construct a parallel circuit.

(1) Definition of a parallel circuit

(2) Application of a parallel circuit

(3) Characteristics of a parallel circuit

(4) Properties of a parallel circuit

8b. Using the previously constructed parallel circuit, measure and record the voltage or current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate resistance and power.

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(1) Measurement of voltage and current

(2) Calculate for resistance

(3) Using the power formula calculate the power

8c. Given parallel circuit problems, use Ohm's law to solve for unknown values.

(1). Types of parallel circuits problems

(2) Solving for unknown values in parallel circuits

APPLICATION:

WB 3ABR54230-1-I-8, Parallel Circuits
2TPT 3101-02, DC Circuits Parallel

EVALUATION:

Evaluate by ora[illegible]written question, and/ or observation[illegible]tudent's performance during lesson. [illegible]is may be accomplished at any time during lesson for increased effectiveness.

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CONCLUSION (10 Minures)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-I-9, Series Parallel Circuits

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/ 13May75	
COURSE NUMBER: 3ABR54230-1	COURSE TITLE: Electrician
BLOCK NUMBER: I	BLOCK TITLE: Electrical Fundamentals

LESSON TITLE: Series-Parallel Circuits (Day 8)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	0	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
10	1 May 1975	9

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainer, Conductor Projector, Overhead	None	None	SG I-9 WB I-9 Transparencies, Series-Parallel Circuits

CRITERION OBJECTIVES AND TEACHING STEPS

9a. Given instructions on a series-parallel circuit, use the conductor trainer to construct a series-parallel circuit.

(1) Definition of a series-parallel circuit

(2) Application of a series-parallel circuit

(3) Characteristics of a series-parallel circuit

(4) Properties of a series-parallel circuit

9b. Using the previously constructed series-parallel circuit, measure and record the voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate the resistance and power.

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(1) Measurement of voltage and current

(2) Calculate for resistance

(3) Using the power formula, calculate the power

9c. Given series-parallel circuit problems, use Ohm's law to solve for unknown values.

(1) Types of series-parallel circuit problems

(2) Solving for unknown values in series parallel circuits

Course No: 3ABR54230-1-I
Days: 8

Branch Approval: *Bobby S Littlejohn*
Date: *14 May 1975*

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

Review subject matter covered in previous day or individual problem areas. Review may be by questions, oral or written, guided discussion or as a summary.

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hrs 45 Min)

PRESENTATION:

9a. Given instructions on a series-parallel circuit, use the conductor trainer to construct a series-parallel circuit.

(1) Definition of a series-parallel circuit

(2) Application of a series-parallel circuit

(3) Characteristics of a series-parallel circuit

(4) Properties of a series-parallel circuit

9b. Using the previously constructed series parallel circuit, measure and record voltage and current exactly as indicated on the meters, then apply Ohm's law and the power formula to calculate the resistance and power.

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(1) Measurement of voltage and current

(2) Calculate for resistance

(3) Using the power formula calculate the power

9c. Given series parallel problems, use Ohm's law to solve for unknown values.

(1) Types of series parallel circuit problems

(2). Solving for unknown values in series parallel circuits

APPLICATION:

WB 3ABR54230-1-I-8, Series-Parallel Circuits

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

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CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-I-10, Transformers, Rectifiers and Power Supplies

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE: TCETC/13 May 75	INSTRUCTOR
COURSE NUMBER: 3ABR54230-1	COURSE TITLE: Electrician
BLOCK NUMBER: I	BLOCK TITLE: Electrical Fundamentals

LESSON TITLE: Transformers, Rectifiers, and Power Supplies (Days 9 and 10)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
10 Hrs	0	10 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
11 and 12	1 May 1975	10

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Trainers, Electrical Fundamentals; Missile System Electronic Circuitry, Battery Charger Oscilloscope Projector, Overhead	Projector, 16mm	None	SG I-10 WB I-10 2TPT-3103-15, Transformers, Transparencies, Transformers, Rectifiers, Power Supplies TF 5279A, Magnetic Amplifiers

CRITERION OBJECTIVES AND TEACHING STEPS

10a. Using a schematic and nomenclature pertaining to transformers, label the three main parts.

(1) Construction features of transformers

(2) Theory of transformer operation

(3) Use of transformers

10b. Given an incomplete schematic and required information, draw the secondary windings of a transformer, including the output voltage valve.

(1) Explanation of primary windings

(2) Explanation of secondary windings

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(3) Voltage and turns relationship

10c. Given a drawing of a transformer showing the number of primary and secondary turns and the applied voltage and current, use the turns ratio formula to determine the secondary voltage and current.

(1) Turns ratio for voltage

(2) Turns ratio for turns

(3) Turns ratio for amperage

10d. Given a list of statements, a schematic and required information, complete statements pertinent to use of transformers in electronic circuits.

(1) Transformer symbol and meaning

(2) Types of transformers used in electronic circuits

10e. Given a schematic and nomenclature pertaining to rectifiers, label the main parts.

(1) Theory of operation

(2) Types of rectifiers

(3) Uses in electronic circuits

10f. Using the schematic of a rectifier circuit, trace one alternation of current through the circuit by using arrows to indicate direction of current flow.

(1) Half wave pulsating DC

(2) Full wave pulsating DC

(3) Filtering

10g. Given a list of incomplete statements and required information, complete statements pertaining to batteries.

(1) Battery banks

(2) Battery chargers

10h. Given a list of questions pertaining to electrical and electronic power supplies and required information, answer questions on use of power supplies.

PAGE NUMBERS 64 AND 65 ARE MISSING
THE MATERIAL IS COMPLETE

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(1) Types of power supplies

(2) Uses of power supplies

(3) Theory of transistors

(4) Use of transistors

(5) Testing transistors

10i. Given a drawing of a magnetic amplifier, label the three main parts.

(1) Magnetic amplifier circuits

(2) Use of magnetic amplifiers

11. Related Training

12. Measurement Test and Test Critique

Course No: 3ABR54230-1
Days: 9, 10

Branch Approval: Bobby G. Little Jr.
Date: 14 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

Review subject matter covered in previous day of individual problem areas or written, guided discussion or as a summary.

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (9 Hours 45 Minutes)

PRESENTATION:

10a. Using a schematic and nomenclature pertaining to transformers, label the three main parts.

(1) Construction features of transformers

(2) Theory of transformer operation

(3) Use of transformers

10b. Given an incomplete schematic and required information, draw the secondary windings of a transformer indicating the out put voltage valve.

(1) Explanation of primary windings

(2) Explanation of secondary windings

(3) Voltage and turns relationship

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10c. Given a drawing of a transformer showing the number of primary and secondary turns and the applied voltage and current, use the turns ratio formula to determine the secondary voltage and current.

(1) Turns ratio for voltage

(2) Turns ratio for turns

(3) Turns ratio for amperage

10d. Given a list of statements, a schematic, and required information, complete statements pertinent to use of transformers in electronic circuits.

(1) Transformer symbols and meaning

(2) Types of transformers used in electronic circuits

10e. Given a schematic and nomenclature pertaining to rectifiers, label the main parts.

(1) Theory of operation

(2) Types of rectifiers

(3) Uses in an electronic circuit

APPLICATION:

WB 3ABR54230-1-I-10, Section I and II
Transformers, Rectifiers
2TPT 3103-15, Transformers

CONCLUSION (Day 9)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-I-10, Section III,
Power Supplies

INTRODUCTION (Day 10)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

Review subject matter covered in previous day or individual problem areas. Review may be by questions or written, guided discussion or as a summary.

ATTENTION:

OVERVIEW:

MOTIVATION:

PRESENTATION:

10f. Using the schematic of a rectifier circuit, trace one alternation of current through the circuit by using arrows to indicate direction of current flow.

(1) Half wave pulsating DC

(2) Full wave pulsating DC

(3) Filtering

10g. Given a list of incomplete statements and required information, complete statements pertaining to batteries.

(1) Battery banks

(2) Battery chargers

10h. Given a list of questions pertaining to electrical and electronic power supplies and required information, answer questions on use of power supplies.

(1) Types of power supplies

(2) Uses of power supplies

(3) Theory of transistors

(4) Use of transistors

(5) Testing transistors

10i. Given a drawing of a magnetic amplifier, label the three main parts.

(1) Magnetic amplifier circuits

(2) Use of magnetic amplifiers

APPLICATION:

WB 3ABR54230-1-I-10, Section III, Power Supplies

EVALUATION:

Evaluate by oral, written questions and/or observation of students performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

MOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR[redacted]0-1-II-1, National Electrical Code, Electrical Terminology and Blueprint Reading

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/15May75	
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER II	BLOCK TITLE Nonmetallic Sheathed Cable

LESSON TITLE
National Electrical Code, Electrical Terminology and Blueprint Reading (Day 11)

LESSON DURATION		
CLASSROOM LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	0	6 Hrs

POI REFERENCE		
PAGE NUMBER	PAGE DATE	PARAGRAPH
13	1 May 1975	1

STS/CTS REFERENCE	
NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Projector, Overhead	None	None	SG WB II:1 NATIONAL ELECTRICAL CODE NATIONAL ELECTRICAL CODE AND BLUEPRINT READING, K. L. GEBERT TRANSPARENCIES, SYMBOLS ELECTRICAL BLUEPRINT, TAG 6065

CRITERION OBJECTIVES AND TEACHING STEPS

1a. Given a National Electrical Code (NEC), list its purpose and scope.

(1) Introduction to the NEC

(a) Sponsor

(b) Publisher

(c) Purpose

(d) Scope

(e) Code arrangement

(2) Uses of the Code

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(a) Table of contents

(b) Index

1b. Given a National Electrical Code and a list of electrical terms, write the definition of each term.

(1) Table of contents

(2) Article 100

1c. Given a National Electrical Code and selected electrical problems, list the correct answer to each problem.

(1) Table of contents

(2) Index

(3) Articles

(4) Paragraphs

1d. Given a blueprint, NEC, and selected electrical installation problems, identify locations and list the wiring requirements for electrical component installation to meet National Electrical Code and blueprint specifications.

(1) Purpose of blueprints

(2) Use of symbols

(3) Reading a blueprint

Course No: 3ABR54230-1
Day: 11

Branch Approval: Bobby L. [signature]
Date: 21 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hours 45 Minutes)

PRESENTATION:

1a. Given a National Electrical Code (NEC), list its purpose and scope.

(1) Introduction to the NEC

(a) Sponsor

(b) Publisher

(c) Purpose

(d) Scope

(e) Code arrangement

(2) Uses of the Code

(a) Table of contents

(b) Index

1b. Given a National Electrical Code and a list of electrical terms, write the definitions of each term.

(1) Table of contents

(2) Article 100

1c. Given a National Electrical Code and selected electrical problems, list the correct answer to each problem.

(1) Table of contents

(2) Index

(3) Articles

(4) Paragraphs

1d. Given a blueprint, NEC and selected electrical installation problems, identify locations and list the wiring requirements for electrical component installation to meet National Electrical Code blueprint specifications.

(1) Purpose of blueprints

(2) Use of symbols

(3) Reading a blueprint

APPLICATION:

WB3ABR54230-1-II-1, National Electrical Code, Electrical Terminology and Blueprint Reading

EVALUATION:

Evaluate by oral, written questions and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-II-2, Conductors and Overcurrent Protective Devices

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/15May75	
COURSE NUMBER	COURSE TITLE
3ABR54230-1	Electrician
BLOCK NUMBER	BLOCK TITLE
II	Nonmetallic Sheathed Cable

LESSON TITLE

Conductors and Overcurrent Protective Devices (Day 12)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	0	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
14 and 15	1 May 1975	2

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Tester, Multi-Amp, MS 1(A) Trainer, Circuit Breaker Trainer, Conductor Size and Protective Devices Projector, Overhead	None	None	SG 11-2 WB 11-2 NATIONAL ELECTRIC CODE NATIONAL ELECTRIC CODE AND BLUEPRINT READING, K. L. GEBERT TRANSPARENCIES, CONDUCTORS AND OVERLOAD DEVICES

CRITERION OBJECTIVES AND TEACHING STEPS

2a. Given the National Electrical Code and a list of conductor sizes and insulation types, list the amount of current each conductor will carry.

(1) Article 310

(2) Types of conductors

(3) Conductor size

(4) Conductor insulation

(5) Location of conductors

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

2b. Given the National Electrical Code and a list of circuits, list the proper size conductor to use in accordance with the National Electrical Code.

(1) Conductors in cable or raceway

(2) Conductors in free-air

(3) Types of conductors

(4) Reducing load current in conductors

2c. Given the National Electrical Code and a list of overcurrent devices, select facts pertaining to the different types of overcurrent devices in accordance with the National Electrical Code.

(1) Purpose

(2) Types and sizes

2d. Given a list of overcurrent devices and the National Electrical Code, select the correct overcurrent device to meet the NEC requirements.

(1) Uses

(2) NEC requirements

2e. Observe the steps for testing a molded case circuit breaker, with an MS 1(A) tester in accordance with the manufacturer's specifications.

(1) Purpose of testing circuit breakers

(2) Operation of MS 1(A) tester

(3) Procedure for testing circuit breakers

Course No: 3ABR54230-1
Day: 12

Branch Approval: Bobby Littlejohn
Date: 21 May 74

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hours 45 Minutes)

PRESENTATION:

2a. Given the National Electrical Code and a list of conductor sizes and insulation type, list the amount of current each conductor will carry.

(1) Article 310

(2) Types of conductors

(3) Conductor size

(4) Conductor insulation

(5) Location of conductors

2b. Given the National Electrical Code and a list of circuits, list the proper size conductor to use, in accordance with the National Electrical Code.

(1) Conductors in cable or raceway

(2) Conductors in free air

(3) Types of conductors

(4) Reducing load current in conductors

2c. Given the National Electrical Code and a list of overcurrent devices, select facts pertaining to the different types of overcurrent devices in accordance with the National Electrical Code.

(1) Purpose

(2) Types and sizes

2d. Given a list of overcurrent devices and the National Electrical Code, select the correct overcurrent device to meet the NEC requirements.

(1) Uses

(2) NEC requirements

2e. Observe the steps for testing a molded case cirucit breaker, with an MSI (A) tester in accordance with the manufacture's specifications.

(1) Purpose of testing circuit breakers

(2) Operation of MSI (A) tester

(3) Procedure for testing circuit breakers

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APPLICATION:

WB 3ABR54230-1-II-2, Conductors and Overcurrent Protective Devices

EVALUATION:

Evaluate by oral written questions and/ or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-II-3, Hand Tools
SG 3ABR54230-1-II-4, Single Phase Service Entrances and Panelboards

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR	
TCETC/15May75		
COURSE NUMBER	**COURSE TITLE**	
3ABR54230-1	Electrician	
BLOCK NUMBER	**BLOCK TITLE**	
II	Nonmetallic Sheathed Cable	
LESSON TITLE		
Hand Tools (Day 13)		
LESSON DURATION		
CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
3 Hrs	0	3 Hrs
POI REFERENCE		
PAGE NUMBER	PAGE DATE	PARAGRAPH
15	1 May 1975	3

STS/CTS REFERENCE	
NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hand Tool Set Projector, Overhead	Projector, 16mm	None	SG II-3 WB II-3 Transparencies, Hand Tools TF 1-4603, ABC of Hand Tools, Part I TF 1-4603, ABC of Hand Tools, Part II

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Given information and a set of selected hand tools, identify the use and care of each hand tool.

(1) Identification of electrician's hand tools

(2) Correct use of each tool

(3) Maintenance of each tool

(4) Replacement of damaged or lost tools

Course No: 3ABR54230-1
Day 1:

Branch Approval: Bobby Littlejohn
Date: 21 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (2 Hours, 45 Minutes)

PRESENTATION:

3a. Given information and a set of handtools, identify the use and care of each handtool.

(1) Identification of electricians handtools

(2) Correct use of each tool

(3) Maintenance of each tool

(4) Replacement of damaged or lost tools

APPLICATION:

WB 3ABR54230-1-II-3. Hand Tools

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EVALUATION:

Evaluate by oral, written questions and/ or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/15May75	
COURSE NUMBER	**COURSE TITLE**
3ABR54230-1	Electrician
BLOCK NUMBER	**BLOCK TITLE**
II	Nonmetallic Sheathed Cable

LESSON TITLE

Single-Phase Service Entrances and Panelboards (Day 13 and 14)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	0	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
16	1 May 1975	4

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hand Tool Set Trainer, Entrances and Panelboards Multimeter, TS/297u Projector, Overhead	Projector 16mm	None	SG II-4 WB II-4 National Electrical Code Transparencies, Single-Phase Service TVS-54/5, 3 and 4 Wire Service

CRITERION OBJECTIVES AND TEACHING STEPS

4a. Provided a booth area, hand tools, and a working drawing, install a single-phase 120/240 volt service entrance and grounded panelboard according to NEC specifications.

(1) Services

(a) Drop

(b) Entrance

(c) Equipment

(d) NEC requirements (Articles, 200, 230, and 250)

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(2) Panelboard requirements

(a) Purpose

(b) Types

(c) Location

(d) Protective devices

(e) NEC requirements (Articles 240, 250, and 384)

4b. Provided information, tools, and materials, connect and check the ground conductor to NEC specifications.

(1) Purpose

(2) Conductor size

(3) Type of connection

(4) Type of electrodes

(5) Resistance to ground

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Course No: 3ABR54230-1
Days 13 and 14

Branch Approval: Bobby Littlejohn
Date: 1 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT.

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hours 45 Minutes)

PRESENTATION:

4a. Provided a booth area, handtools, and a working drawing, install a single-phase, 120/240 volt service entrance and grounded panelboard according to NEC specifications.

(1) Services

(a) Drops

(b) Entrance

(c) Equipment

(d) NEC requirements (Articles, 200, 230, and 250)

(2) Panelboard requirements

(a) Purpose

110

(b) Types

(c) Location

(d) Protective devices.

(e) NEC requirements (Articles 240, 250, and 384)

APPLICATION:

WB 3ABR54230-1-II-4, Single-phase Serivce Entrances and Panelboards, Project I

CONCLUSION DAY 13

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-II-4, Single Phase Service Entrances and Panelboards
SG 3ABR54230-1-II-5, Nonmetallic Sheather Cable

INTRODUCTION (Day 14)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

4b. Provided information, tools and materials, connect and check the ground conductor to NEC specifications.

(1) Purpose

(2) Conductor size

(3) Type of connection

(4) Type of electrodes

(5) Resistance to ground

APPLICATION:

WB 3ABR54230-1-II-4, Single Phase Service Entrances and Panelboards - Project 2

EVALUATION:

Evaluate by oral, written questions and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

LESSON PLAN (Part I, General)

APPROVAL OFFICE	INSTRUCTOR
TCETC/15May75	
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER II	BLOCK TITLE Nonmetallic Sheathed Cable

LESSON TITLE: Troubleshooting Nonmetallic Sheathed Cable (Days 19 and 20)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
10 Hrs	0	10 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
19	1 May 1975	7

STS CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hand Tool Set Projector, Overhead	Multimeter	None	SG II-7 WB II-7 TF 6078, Troubleshooting Electrical Circuits Transparencies, Troubleshooting

CRITERION OBJECTIVES AND TEACHING STEPS

7a. Provided a multimeter and instructions, troubleshoot an energized (120/240 volt) electrical circuit to locate troubles inserted in the circuit by the instructor.

(1) Types of circuit troubles

(a) Opens

(b) Shorts

(c) Grounds

(2) Troubleshooting methods and procedures

(3) Use of test equipment

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

7b. Provided a multimeter and instructions, troubleshoot a deenergized circuit to locate troubles inserted in the circuit by the instructor.

(1) Types of circuit troubles

(a) Opens

(b) Shorts

(c) Grounds

(2) Troubleshooting methods and procedures

(3) Use of test equipment

7c. Given information pertaining to balancing branch circuits, balance the circuits installed.

(1) Purpose

(2) Method

(3) Test equipment

7d. Using tools and instructions provided, disconnect electrical circuits, sort material and store in designated storage facilities.

Course No: 3ABR54230-1
Days 19 & 20

Branch Approval: Bobby Littlejohn
Date: 21 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (9 Hours 45 Minutes)

PRESENTATION:

7a. Provided a multimeter and instructions, troubleshoot an energized, 120/240 volt electrical circuit to locate troubles inserted in the circuit by the instructor.

(1) Types of circuit troubles

(a) Opens

(b) Shorts

(c) Grounds

(2) Troubleshooting methods and procedures

(3) Use of test equipment

7b. Provided a multimeter and instructions, troubleshoot a deenergized circuit to locate troubles inserted in the circuit by the instructor.

(1) Types of circuit troubles

(a) Opens

(b) Shorts

(c) Grounds

(2) Troubleshooting methods and procedures

(3) Use of test equipment

APPLICATION:

WB 3ABR54230-1-II-7, Troubleshooting Nonmetallic Sheathed Cable

CONCLUSION (Day 19)

SUMMARY:

STUDY ASSIGNMENT:

SG 3ABR54230-1-II-7, Troubleshooting Nonmetallic Sheathed Cable

INTRODUCTION (Day 20)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

7c. Given information pertaining to balancing branch circuits, balance the circuits installed.

(1) Purpose

(2) Method

(3) Test equipment

7d. Using tools and instructions provided, disconnect electrical circuits, sort material and store in designated storage facilities.

APPLICATION:

WB 3ABR54230-1-II-7, Troubleshooting Nonmetallic Sheathed Cable

EVALUATION:

Evaluate by oral, written questions and/or observations of students performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG AFS, .54, 55, 56, Publications
SG 3ABR54230-1-III-1, Publications

Course No: 3ABR54230-1
Days: 14,15,16, and 17

Branch Approval: [signature]
Date: 21 May 75

PART II

INTRODUCTION (5 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (20 Hours 45 Min)

Presentation:

5a. Given information pertaining to the construction characteristics, types, and uses of non-metallic cable, list the correct answer to each problem by researching the information in the NEC.

(1) Construction characteristics

(2) Types of cable

(3) Use for which cable is approved

(4) NEC installation requirements

APPLICATION: WB 3ABR54230-1-II-5, Nonmetallic Sheated Cable, Project 1

CONCLUSION (Day 14)

SUMMARY:

STUDY ASSIGNMENT: SG 3ABR34230-I-II-5
Nonmetallic Sheathed
Cable

INTRODUCTION (Day 15)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

5b. Given the necessary tools, equipment and instructions, make and solder splices according to NEC specifications

(1) Types of splices

(2) Splicing procedure

(3) Soldering procedure

(4) Taping

APPLICATION: WB 3ABR54230-1-II-5, Nonmetallic Sheathed Cable, Project 2

5c. Provided a work area and handtools, install a circuit in nonmetallic cable containing a ceiling light, a single-pole switch and a duplex receptacle, according to NEC specifications.

(1) Circuitry

APPLICATION: WB3ABR54230-1-II-5 Nonmetallic Sheathed Cable project 3

Conclusion (Day 15)

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STUDY ASSIGNMENT: SG 3ABR54230-1-II-5
Nonmetallic Sheathed Cable

INTRODUCTION (Day 16)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

5c. Continued

(2) NEC Requirement

5d. Provided a work area and handtools, install a circuit in non-metallic cable containing a 220 volt receptacle according to NEC specifications.

(1) Circuitry

(2) NEC requirement

APPLICATION: WB 3ABR54230-1-II-5, Nonetallic Sheathed Cable, Project 4

CONCLUSION (Day 16)

SUMMARY:

STUDY ASSIGNMENT: SG 3ABR54230-1-II-5, Nonmetallic Sheathed Cable

INTRODUCTION (Day 17)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

MOTIVATION:

PRESENTATION:

5e. Provided a work area and handtools, install a circuit in non-metallic cable, containing two three-way switches to control a ceiling light, according to NEC specifications.

(1) Circuitry

(2) NEC requirements

5f. Using the previously installed three way switches, install a four-way switch according to NEC specifications.

(1) Circuitry

(2) NEC requirement

APPLICATION: WB 3ABR54230-Nonmetallic Sheathed Cable. Project 5,6

EVALUATION: Evaluate by oral, written questions and/or observation of students's performance during lesson for increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT: SG 3ABR54230-1-II-6, Lighting Systems

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TCETC/15May75	
COURSE NUMBER 3ABR54230-1	COURSE TITLE Electrician
BLOCK NUMBER II	BLOCK TITLE Nonmetallic Sheathed Cable

LESSON TITLE: Lighting Systems (Day 18)

LESSON DURATION

CLASSROOM/LABORATORY	COMPLEMENTARY	TOTAL
6 Hrs	0	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
18	1 May 1975	6

STS/CTS REFERENCE

NUMBER	DATE
542X0, Changes 1, 2, 3, 4, and 5	2 Dec 70 (14 Jan 72, 6 Mar 73, 18 Apr 73, 25 Feb 74, 7 Nov 74)

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Hand Tool Set Trainer, Fluorescent Lights Projector, Overhead	None	None	SG II-6 WB II-6 National Electrical Code Transparencies, Incandescent and Fluorescent Lighting

CRITERION OBJECTIVES AND TEACHING STEPS

6a. Given information pertaining to incandescent lighting and a list of problems, correctly solve each problem.

(1) Design

(2) Classification

(3) Advantages

6b. Given information pertaining to fluorescent lighting and a list of problems, correctly solve each problem.

(1) Design

(2) Classification

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

(3) Advantages

6c. Provided a work area and hand tools, install a circuit in nonmetallic cable, containing a fluorescent light and a single-pole switch according to NEC specifications.

(1) Circuitry

(2) Mounting methods

(3) NEC requirements

Course No: 3ABR54230-1
Day 18

Branch Approval: Libby Littlejohn
Date: 21 May 75

PART II

INTRODUCTION (5 Minutes)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (5 Hours 45 Minutes)

PRESENTATION:

6a. Given information pertaining to incandescent lighting and a list of problems, correctly solve each problem.

(1) Design

(2) Classification

(3) Advantages

6b. Given information pertaining to fluorescent lighting and a list of problems correctly solve each problem.

(1) Design

(2) Classification

(3) Advantages

6c. Provided a work area and handtools, install a circuit in nonmetallic cable, containing a flourescent light and a single-pole switch according to NEC specifications.

(1) Circuitry

(2) Mounting methods

(3) NEC requirement

APPLICATION:

WB 3ABR54230-1-II-6, Lighting Systems

EVALUATION:

Evaluate by oral, written questions and/or observation of student's performance during lesson. This may be accomplished an any time during lesson for increased effectiveness.

CONCLUSION (10 Minutes)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

SG 3ABR54230-1-II-7, Troubleshooting Nonmetallic Sheathed Cable

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STUDY GUIDES 3ABR54230-I-1 thru 10

Department of Civil Engineering Training

Electrician

ELECTRICAL FUNDAMENTALS

July 1975

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

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Superseded material may be used until supply is exhausted.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-1-1
July 1975

ORIENTATION

OBJECTIVE

This study guide, along with ATS-5401 Slide Presentation in the Learning Resource Center, will acquaint you with the course organization, objectives, instruction, and measurement programs.

INTRODUCTION

This entire orientation study guide is an introduction. In it we will attempt to introduce you to the contents, policies, and objectives of the course for which you have been selected. In our initial introduction, we will attempt to cover the daily schedules, the instruction and measurement policies, the type of training materials used, and other items of particular interest to you as an entering student. Above all, we want you to feel welcome in our course and we will do everything we can to make your stay at Sheppard worthwhile and pleasant for you. The more you put into the course, the more you will get out of it.

Materials presented in the following pages will be under the major topic headings as follows:

* COURSE ORGANIZATION AND MEASUREMENT
* HIGH PERFORMANCE STANDARDS AND HONOR GRADUATE PROGRAM
* INSTRUCTIONAL METHODS AND TRAINING LITERATURE USED IN THE COURSE
* STUDY SKILLS AND STUDENT NOTEBOOK
* COURSE OPERATING POLICIES AND ALERT PROCEDURES
* SAFEGUARDING CLASSIFIED INFORMATION
* ACCIDENT PREVENTION AND SAFETY
* STUDENT CRITIQUE PROGRAM

COURSE ORGANIZATION AND MEASUREMENT

Arrangement of Materials

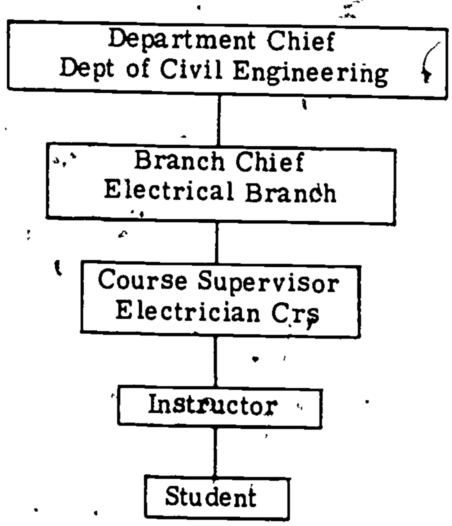
This course to which you have been assigned is organized in a manner to present you instruction in a progressive sequence. That is, fundamentals and principles are presented first and are followed by your practical performance to insure that you acquire both the knowledges and skills necessary to perform as an apprentice electrician. Your training begins with this study guide and will continue through the subjects of communications security, electrical fundamentals, electrical circuits, electrical circuit installation, and the installation and maintenance of certain electrical equipment.

The established sequence of instruction has proven to be very effective over a long period of course conduct. Many students have completed the course successfully in its present form. You can also successfully complete it. It will require much effort on your part, but then anything worthwhile requires effort.

Organizational Structure

For any large group of people to work together effectively, an organization must be established. This course is no exception, and here the operation must be effective to accomplish our mission of technical training.

Our organization is simple. All of our courses are assigned to training branches which are in turn a part of our department, Department of Civil Engineering Training. Our department is only one of the training departments which make up the USAF School of Applied Aerospace Sciences. The organizational structure of management and supervision is shown in the following "chain of command" type diagram.



The preceding diagram shows a simple straight line chain from you to the department chief. The department chief, of course, is responsible to the technical school commander, who in turn is responsible to the training center commander. What it actually means to you is that while you are in school, the instructor is your immediate supervisor who will help you in any way possible and will arrange for you to meet one of the supervisors or chiefs if the need should arise.

Course Objectives

A Criterion Objective is defined as, "The specification of the behavior which leads to or satisfies a job performance requirement or standard." Simply stated, for each element of training which you must successfully accomplish in this course, there will be a criterion objective. You must accomplish all of these criterion objectives. The instructor or supervisor will certify your accomplishment of criterion objectives on a Criterion Checklist as you progress through the course. He must document all criterion objectives as being satisfactorily attained prior to administering a measurement test at the established test point. You cannot be administered a measurement test for advancement to the next block or unit of instruction until you have accomplished all the criterion objectives for the unit in which you are assigned. Additional instruction will be provided if you need it; hard work and study on your part are very important.

Measurement and Grading Practices

From the above short discussion of course learning objectives, it is an easy transition into the course measurement and grading practices. Briefly stated, the two types of measurement you will be subjected to are the Criterion Progress Check and the Measurement Test. Since you must complete all criterion objectives for a unit of instruction prior to being administered the measurement test, the instructor will perform a continuing assessment of your progress in accomplishing the criterion objectives. He will observe your performance activities, insure that you complete all workbooks and may give you short written quizzes to satisfy himself that you have accomplished each criterion objective. Upon his satisfaction with the results of these criterion progress checks he will certify on the criterion checklist that you have accomplished the criterion objective in question. When you have completed all criterion objectives in a given unit or block of instruction he will certify that you are ready for the measurement test.

The Measurement Test is an objective type written test designed to measure knowledge as applied to specialty tasks. It is used to provide a permanent record of your progress and achievement in the course. The measurement tests you are administered may contain from 25 to 50 individual test items, usually in multiple-choice form. Remember, your accomplishment of these measurement tests will go on your permanent course attendance record. Do the very best you can to make good grades. It is well worth the effort.

The measurement test for a unit or block of instruction must contain at least one measurement item (question) for each criterion objective. It may have more than one question for each criterion objective, but must have at least one. You must apply yourself in all aspects of the course; self-study, attention during all discussions and demonstrations, and performance of all steps in the practical exercises assigned.

A fixed figure cannot be given you for the passing/failing grades required as these grades may be different for different tests. Your instructor will inform you at the beginning of each test what the minimum passing grade is. If you are well prepared and have done your work well, you need not be concerned with the minimum grades as you will likely score in the higher grades. Written instructions will be furnished you at the beginning of each test period. Read these instructions carefully; they affect YOUR future.

Questions missed on each test will be reviewed (critiqued) by the instructor and class to help you identify mistakes you made during testing. During these critiques, you will not be permitted to make notes as the rules for protection of measurement tests are very strict. You will be informed of your test scores as soon as possible after the test period. You probably won't fail any tests, but if you should, you will be given additional instruction and will be retested, or washed back to repeat the unit of instruction.

Counseling, Washback, and Elimination

If you should fail a test, the instructor or supervisor will discuss the failure with you and will counsel you on the best action to take. During these counseling sessions remember that the instructor or supervisor is interested in your problems. He has nothing against you and is only trying to arrive at the solution to whatever the problem was that caused you to fail. Be honest with him and discuss your problem. The discussion will benefit both of you.

Once you fail a test, three avenues are open: probationary continuation, washback, or elimination. If you, the instructor, and the supervisor feel that you are able to accomplish the materials in which you failed and at the same time acquire the materials in the next block, the instructor will recommend you for the probationary continuation. During this probationary period, you will be given remedial (extra) instruction outside of normal class hours. Upon completion of the periods of remedial instruction you will be retested and if you pass you will continue in the new block.

If you should fail your retest, the second option of washback will most likely be used. In this case, you will be washed back to a class behind you to repeat the block in which you failed to make passing grades. Upon failing to pass the test after repeating a block, or upon one or more washbacks, you may be considered for elimination in your best interest or in the best interest of the Air Force. Remedial instruction is available to help you avoid the possibility of washback and elimination.

Remedial Instruction

Remedial instruction is provided to give extra help to students in learning course material. If instruction on a particular subject isn't clear you may voluntarily ask your instructor to be placed on remedial instruction. Remedial instruction may also be compulsory should you have failing daily quiz scores or if your instructor thinks you need extra study.

When attending remedial study your instructor will give you two special study assignment forms. A copy of the special study form is presented to your squadron training NCO. The original is kept by you and given to your instructor when remedial instruction is completed.

The classroom instructor will inform you of the time, dates, and location of your remedial instruction. You will be assisted during this study time by an instructor, or instructors so as to improve your daily quiz scores and block grades.

Proficiency Advancement

This is a program to allow you to be tested on any portion of the course in which you have already had training or experience. In other words, it isn't economically sound to take up your time training you in a subject in which you are already proficient. If you should identify a block in the course which contains materials for which you have had good training and for which you feel you can pass the tests, you should apply for proficiency advancement. If you pass all the required tests, you can bypass these materials and graduate ahead of your class.

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MODIFICATIONS

Pages 5-30 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

ELECTRICAL AND ELECTRONIC FUNDAMENTALS

OBJECTIVE

The purpose of this unit of instruction is to help you

1. become familiar with the terms and theories that apply to electrical and electronic fundamentals.

2. understand the causes, effects and applications of magnets and magnetic laws.

3. understand two types of reactance, their causes, and effects.

INTRODUCTION

Electricity has been, and still is, something to be respected. This is probably due to the fact that it cannot be seen and also the possibility of injury or death if proper precautions are not observed when working with it. This is also true of many other things, that are used every day, but the results of carelessness are normally less severe. As you become familiar with this particular form of energy, you should learn to respect it. Properly handled and used, electricity has become one of the greatest benefits in existence to mankind. To properly handle and use electricity, you will first have to understand some of the factors about this form of energy. Some of the factors you will be concerned with are electron theory, magnetism, and reactance. This study guide will help you to understand the factors surrounding this very useful form of energy.

INFORMATION

SECTION NO. 1, ELECTRON THEORY

Remember that this is fundamental, and that your future in this field is based on how much you learn and how many of these basic facts you retain.

Matter and Energy

Material things can be classified under the general classification of matter and energy. Matter can be defined as anything which occupies space and has weight. That is, anything that can be measured in terms of weight or dimension, such as a chair, a book, a human body, gold, silver, air, water, etc. These things are tangible, since they can be seen, felt, or measured.

Energy is intangible; that is, it cannot be seen but is represented by the effects it has on matter. Energy can be defined as "the ability to do work." It can have various forms such as mechanical energy, chemical energy, electrical energy, and heat energy. Any of these forms can be transformed from one to the other.

In the study of electricity it is convenient or desirable many times to approach it from an energy standpoint.

Energy is measured by its effects on matter. These effects usually produce motion. From this viewpoint, the unit of energy is equal to the force necessary to produce motion multiplied by the distance the object is moved--hence, the expression "foot-pounds."

Two types of energy are potential and kinetic. Potential energy is energy stored up or in a restful position. Kinetic energy is energy in motion.

Specific examples of potential or kinetic energy are unused coal, running water, lightning, current flow and voltage source.

Construction of Matter

Matter exists in any one of three states: gas, liquid, or solid. To understand why certain substances act as they do when electrically charged, something must be known about how materials are put together. For example, if we could take the rubber in a rubber ball apart, or take apart the glass in a glass rod, what would we have? What sort of materials are substances made of, and how are these materials put together to make these substances? Scientists call this the "structure of matter." All substances are composed of elements, molecules, or atoms.

ELEMENTS. The ancient Greeks were convinced that all physical things consisted of four elements: air, earth, fire, and water. To them, materials were different because they were composed of varying amounts of these four elements. As time passed and scientific methods were developed, the four Greek elements were broken down into more and more "indivisible" substances, which still retain the same element. More than 100 such elements have been isolated.

An element such as copper, gold, or oxygen, is a substance which cannot be reduced to a simpler substance by ordinary chemical means. All matter consists of elements or combinations of elements. The difference in the various elements is not that they have different type electrons or protons, but it is the number of these particles that make elements different.

COMPOUNDS. A compound is a substance containing more than one element chemically united in definite proportions by weight, and having properties different from those of its original components. For example, water is made up of two parts of hydrogen and one part of oxygen, therefore, water is a compound.

MOLECULE. A molecule is defined as the smallest particle of matter which can exist by itself and still retain all the properties of the original substance. If a drop of water (a compound) is divided until the smallest possible particle is obtained and is still water, that particle is known as a molecule. A water molecule, if divided, would become atoms of hydrogen and oxygen.

ATOM. If you subdivide any element until you had the smallest particle that retains its identity, as a part of that element, then you would have what is called an atom. The atom is also defined as the smallest part of an element that can take part in ordinary chemical changes. (See figure 6)

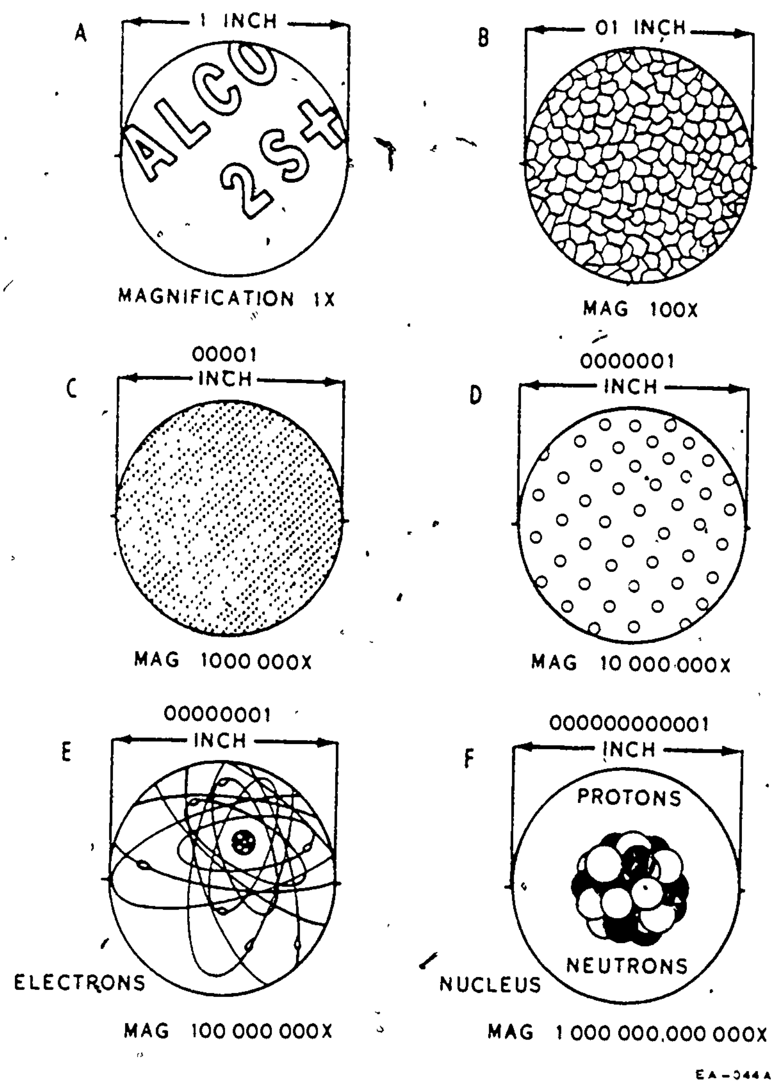


Figure 6. Structure of Aluminum

All the atoms of a particular element have the same mass (or weight) but this mass is different from the mass of the atom of any other element as already mentioned. As previously stated, all matter is a combination of one or more of these atoms just as words are a combination of the letters of our alphabet.

Formerly it was believed that the atom was the smallest particle of matter, but nuclear physicists have proven that the atom is made up of many small particles. Each of these atoms has a nucleus or center around which rotates one or more particles.

The structure of the atom is similar to our solar system with the sun as a nucleus and the planets rotating around the sun, see figure 7.

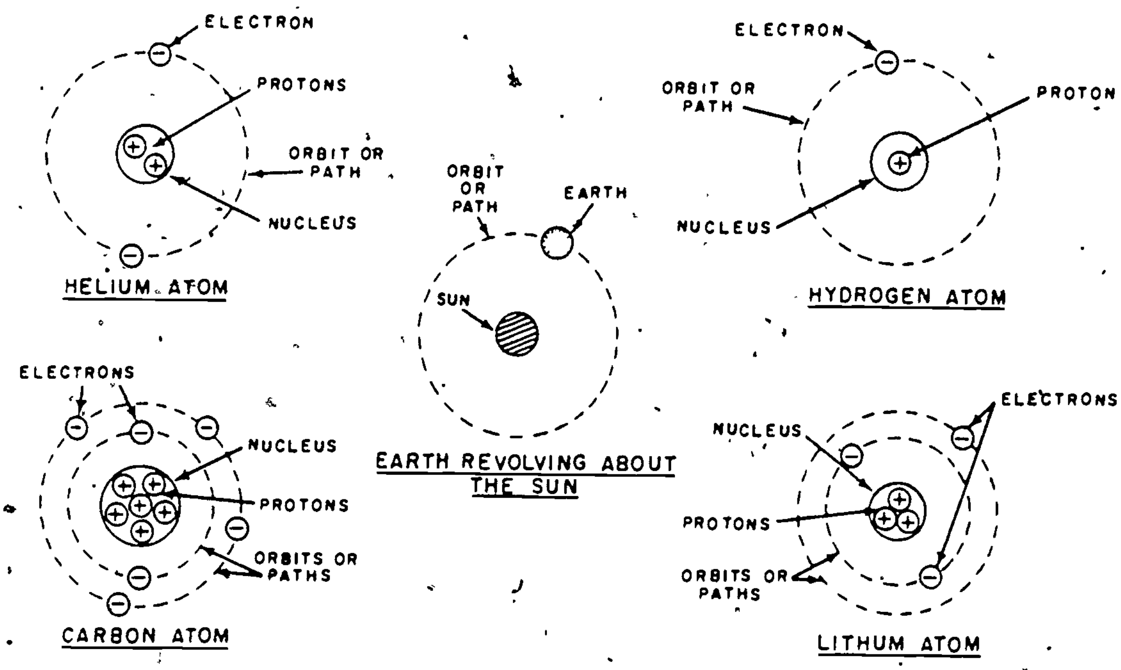


Figure 7. Electron and Proton Arrangements of Four Different Atoms with the Earth Shown Rotating About the Sun for Comparison

The nucleus of any atom contains or is made up of particles called protons, which carry a positive charge of electricity, and neutrons which are neutral in charge or have no charge. Their weight is equivalent to the proton. The symbol for a neutron is N. We will not consider the neutron in our work in this course.

It has been proven that an electron, which orbits the nucleus of the atom, from the atom of any element is the same as an electron from the atom of any other element, and the proton from an atom of any element is the same as the proton from the atom of any other element. The electron has a negative charge.

The weight of the protons plus the weight of the neutrons located in the nucleus make up all of the weight of the atom. The weight of the electron is so light that it is considered insignificant, although it has a larger volume than the proton. The atomic weight of an atom is the weight of the protons plus the weight of the neutrons. Each of these particles is said to have a weight or mass of one. An example would be carbon which has six protons and six neutrons and thus an atomic weight of twelve. Atoms also have atomic numbers and to find this merely add the number of protons. The atomic number for carbon is six. (See figure 8)

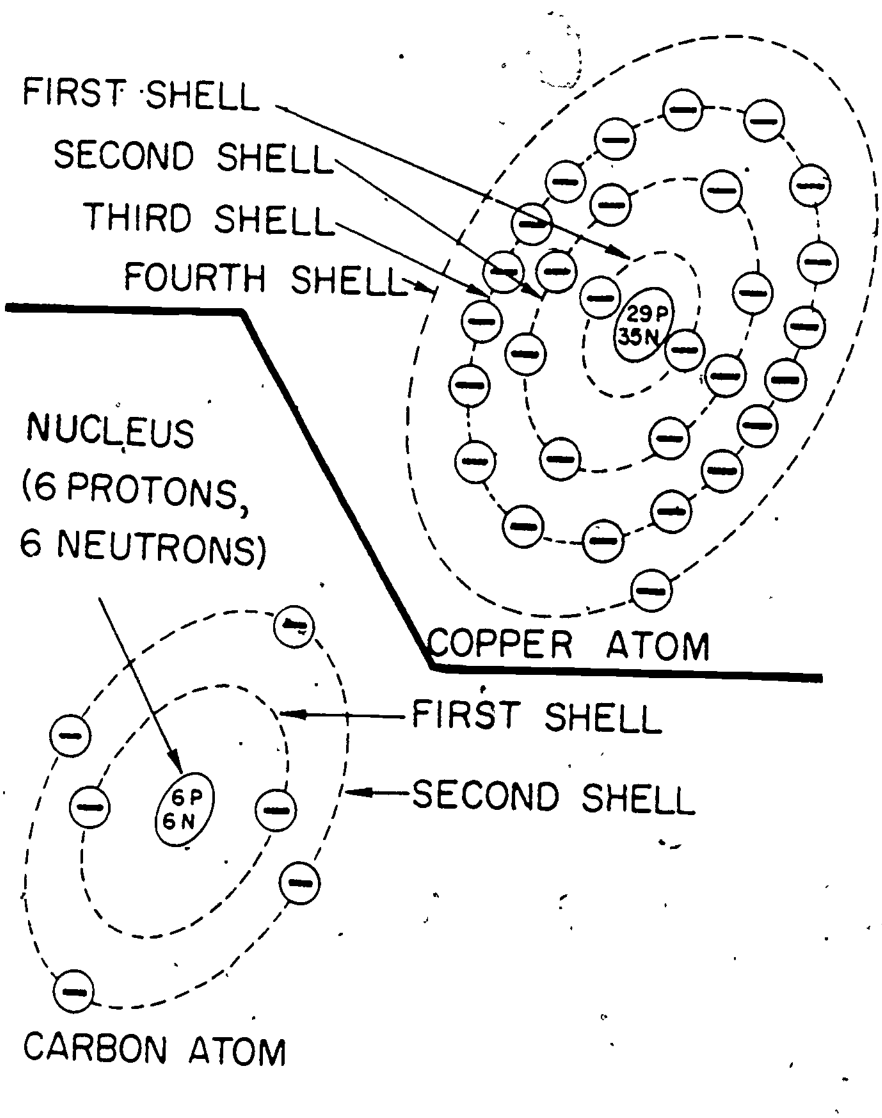


Figure 8. Atomic Structure

An atom in its normal condition has an equal number of electrons and protons. The negative charge of electricity on the electron is equal and opposite to the positive charge of electricity on the proton. The normal atom then is electrically balanced and shows no signs of electricity. The mass (weight) of a proton is something like eighteen hundred and fifty times the mass (weight) of an electron. When there are more than two electrons in an atom, they rotate around the nucleus at different distances from the center of the nucleus in fixed orbits or rings and with a fixed number in each orbit, when they are in their normal state. Each orbit has a maximum number of electrons it can hold. The first orbit contains two electrons with the exception of hydrogen which has only one. The second orbit has eight electrons, the third has 18, the fourth has 32, etc. Of course, all atoms would not have full orbits and would not always contain this number of electrons.

Other atoms have more than four orbital levels.

Previously it was mentioned that the proton was much heavier than the electron. While this is true, the electron has a much larger volume. Also not only do the electrons orbit the nucleus of an atom, but each electron spins on its own axis, similar to the earth rotating in 24 hours. If an atom had eight electrons in its second orbital level and four were spinning clockwise and four counterclockwise, then the atom could not make up a magnetic substance. If over half of these eight electrons were spinning in one direction and the others in the opposite direction, then this atom could become a magnetic substance.

If we accept the above statements as being true, and scientists have proven they are true, then we must conclude that everything on this earth is composed of the same things--electrons and protons with equal charges of positive and negative electricity and in electrical balance.

Why are some things hard and others soft, some brittle and others pliable, some will burn and others will not, some will conduct electricity and others will not? The answer is in the way the individual atoms are constructed. The simplest atom is the hydrogen atom. It has one electron and one proton.

The next is the helium atom with two (2) electrons and two (2) protons, and here is where the other particles in the nucleus begin to appear which are being disregarded because of its neutral charge. There are two (2) neutrons in this nucleus.

Going on up the line of elements there will be one more electron and one more proton added for each individual element added to the list. This will continue in order until you get through the entire list of elements.

If through some force an atom loses or gains an electron, it is then called an ion. If an electron is lost the atom becomes a positive ion, while if an electron is gained the atom becomes a negative ion. The voltage necessary to remove an electron from an atom is called the ionization potential.

Electron Theory of Conduction

It is necessary for you to know the different materials insofar as electricity is concerned as to whether they are conductors, resistors or insulators. The outside orbital level is called the valence orbit. This level contributes all electrical properties to an atom. The positive charged nucleus attracts the electrons in orbit to prevent their escaping into space while their speed enables them to stay in orbit and prevent being pulled into the nucleus. Perhaps you wonder why the protons which all have the same charge can exist in the nucleus without flying apart since like charges repel. Scientists say there is a binding force that holds them together. It is believed that one of the subatomic particles recently discovered causes this binding force.

The ability of a particular object to conduct current is called the conductance, the unit of which is the mho and the symbol of which is G.

VALENCE. Valence is the capacity atoms have to react with one another. The various elements are assigned valence numbers as one, two, three, etc. The valence ring is the outer electron orbit, and it is this orbit that determines the electrical characteristics of an atom.

You will study two types of valences in electrical fundamentals. This study will prove helpful in basic electronics. Electrovalence is the loss or gain of an electron by an atom to reach a more stable electronic condition. An example of electrovalence is sodium combining with chlorine to make common table salt. (See figure 9) Sodium has one electron in its valence ring, while chlorine has seven electrons in its valance ring. Sodium will give up its lone valence electron to chlorine. This makes the next orbit of sodium full and makes the outer valence ring of chlorine full. Thus sodium chlorine (table salt) is formed by the actual exchange of these electrons.

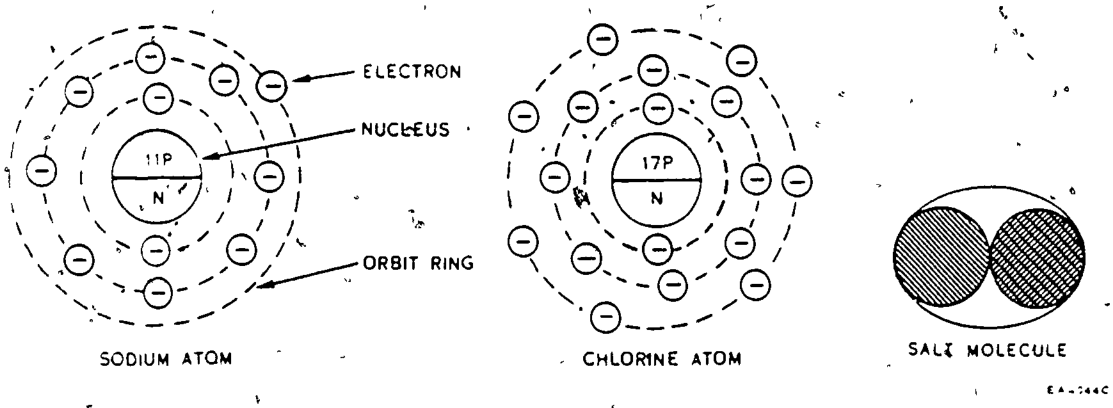
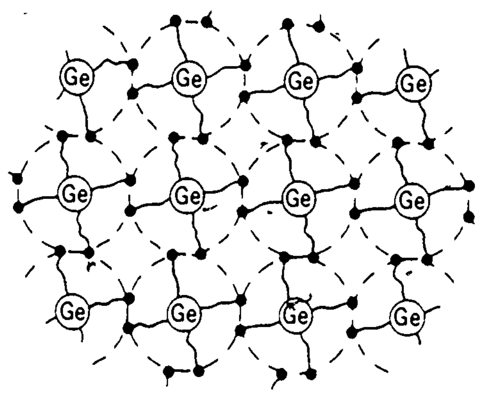


Figure 9. Electrovalence

Covalence is the sharing of electrons to reach a more stable electronic condition. An example of covalence is germanium which has atoms with four valence electrons and this shell needs eight to become more stable. Each two atoms share their four with each other and reach a somewhat more stable arrangement in this manner. (See figure 10).



Crystalline Germanium in Covalent Bonding

Figure 10. Covalent Bonding

CONDUCTION. Note in figures 11 and 12 that the electrons are rotating at different distances from the nucleus. Those in the outer orbit or ring are bound less tightly to the nucleus because of the distance, while those near the nucleus are more tightly bound.

The atoms of the metals such as silver, copper, aluminum, etc. are as a rule closer together and the orbits of the electrons in the outer ring will actually overlap as shown in figures 11 and 12.

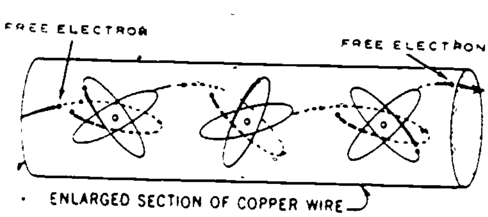


Figure 11. Free Electron

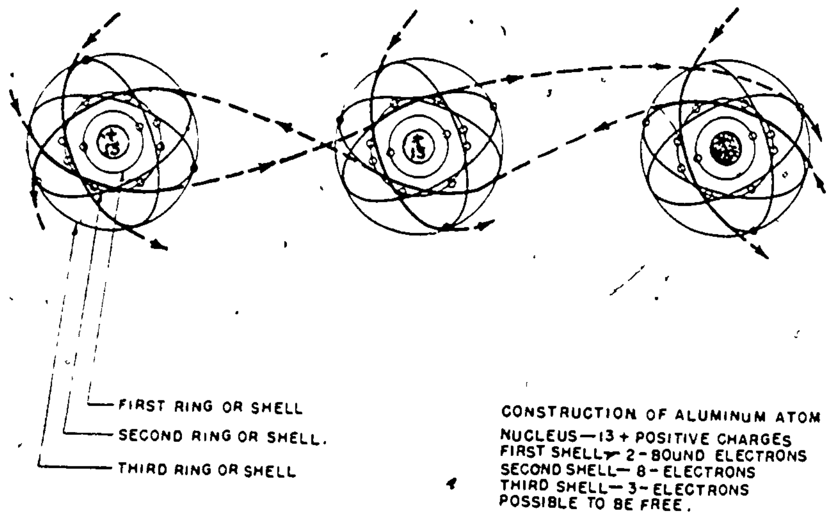


Figure 12. Three Atoms of Aluminum

While the electron of one particular atom is making its rounds, it may get closer to the nucleus of another atom and join onto that atom, while the electron from the second atom joins onto another atom. This gives us another term--free electrons. Free electrons mean that some of the electrons are wandering around aimlessly in most any direction in the metal. These free electrons are easily separated from their atom's nucleus.

Any material with a large number of free electrons is considered a conductor of electricity.

Materials with few free electrons are classed as resistors. Some of the materials commonly used for resistors are: German silver (comprised of copper, nickel and zinc), copper-nickel alloys and nickel-chromium alloys. Carbon is another extensively used resistance material. Another group of materials that are closely related to resistors are the semiconductors. These materials will conduct electron flow under certain conditions and in certain directions. Examples are Rochelle salts, selenium, Germanium crystals and copper oxide.

There are other materials with practically no free electrons. These materials are classed as insulators. Some of the common insulators are porcelain, glass, air, dry wood, mica, oil, and rubber.

There is no sharp dividing line between conductors and resistors or between resistors and insulators. The best conductor will offer resistance to the flow of current and a resistor will conduct current. Any material will conduct current if the pressure is great enough. An insulator will conduct current if enough force is used, but this will distort the insulator.

It is more a matter of ease of conduction. A good conductor should conduct or carry current easily or with little opposition.

A resistor is often used to impede or cut down the flow of current, while an insulator keeps current in its proper path or circuit.

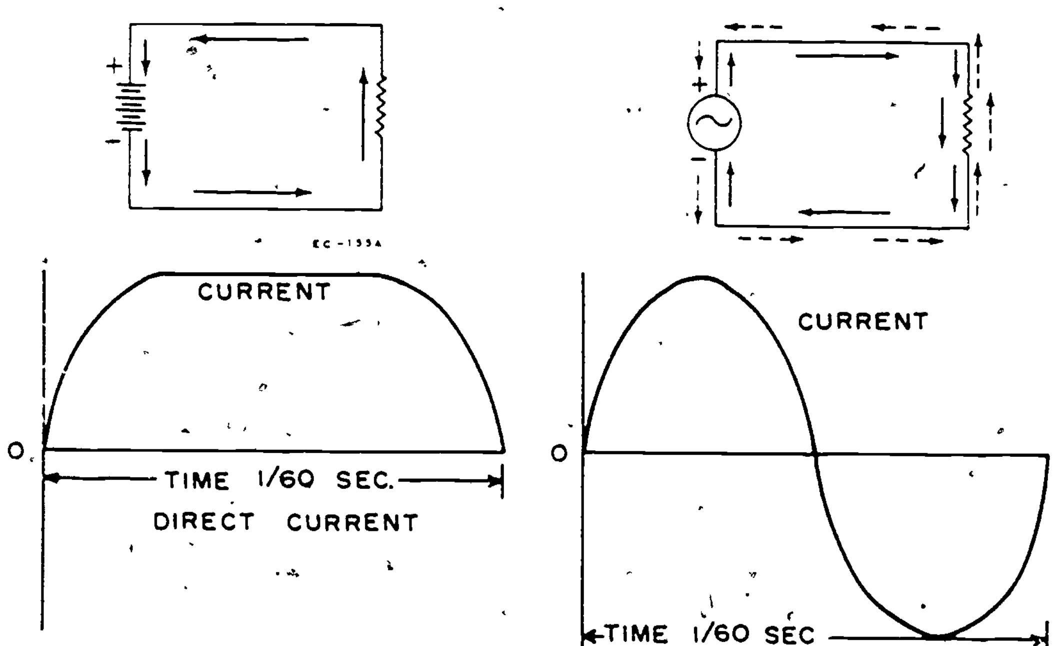
Types of Electricity

Possibly one of the reasons electricity is looked upon with fear and apprehension is because you cannot see electricity. Since electricity cannot be seen, you must develop safe working habits while you are working around it.

DYNAMIC ELECTRICITY. Dynamic electricity (electricity in motion) is simply the uniform movement of free electrons in a conductor. If these electrons move in one direction only, you have direct current (dc). If they move back and forth along a conductor you have alternating current (ac). The discussion will be continued to direct current (dc), at this time. Actually dynamic electricity is the most useful type of electricity and is used to operate our many appliances. Dynamic electricity may be ac, dc, or pulsating dc. (See figures 13A and 13B)

What makes free electrons move in the conductor? Voltage is the answer and you will learn more about that in a short while.

Now return to the movement of the free electrons and see what they do. When these electrons move they may produce four noticeable effects. These are: heat, magnetism, chemical action (as in charging a battery), and they may produce physical shock These are the four effects of current.



Waveform for DC

Waveform for AC

Figure 13A. Circuits with Waveforms

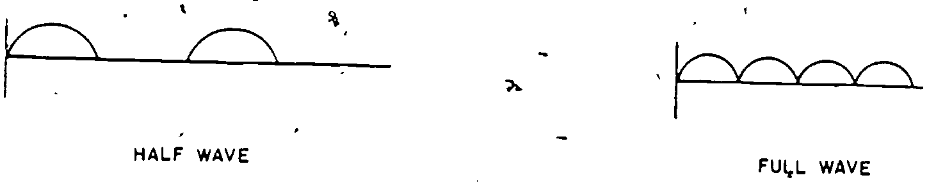


Figure 13B. Pulsating DC

STATIC ELECTRICTY. Static electricity (electricity at rest) is electricity produced by friction. Benjamin Franklin identified a positive charged body as being one with the same charge as left on a glass rod when it was rubbed with silk, and a negative charged body as being the same charge as left on a hard rubber rod when it was rubbed with fur. Of course, the silk rubbed on the glass would have a negative charge while the fur rubbed on the rubber rod would have a positive charge.

Friction between your clothes and the seat covers in your car may cause a difference in potential (voltage), thus causing the presence of static electricity. However, electricity becomes dynamic (in motion) when it jumps from your hand to the handle of your car tending to balance the potential and causing an electron flow. Nature is continually attempting to balance things. It is possible as you slide across the car seat, for you to see the sparks and feel the effects of the electron flow.

The glass rod mentioned above actually released its electrons to the silk. This left the glass rod with a deficiency of electrons and the silk with an excess of electrons. The rubber rod actually accepted some of the electrons from the fur leaving the rod negatively charged and the fur would be left positively charged.

The rubber and glass rods are said to be charged when rubbed with various types of materials. Around all charged bodies there exists an invisible field of force. This field contains imaginary lines of force. The field exists around both a positively charged and a negatively charged object. The force between two charged objects is directly proportional to the amount of charge on each and inversely proportional to their distance. Like charges repel each other; unlike charges attract each other.

An electric charge may be detected by its ability to attract light objects, such as pith balls and bits of paper. A device used for detecting electric charges is called an electroscope. In its simplest form, an electroscope consists of a pith ball hanging on the end of a silk thread. If you touch the pith ball with a glass rod which has been rubbed with silk, you charge it positively. Any other charged body which is brought near the pith ball will repel it if the body is positive, and attract it if the body is negative.

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The distribution of charges on objects varies according to the shape of the object. See figure 14.

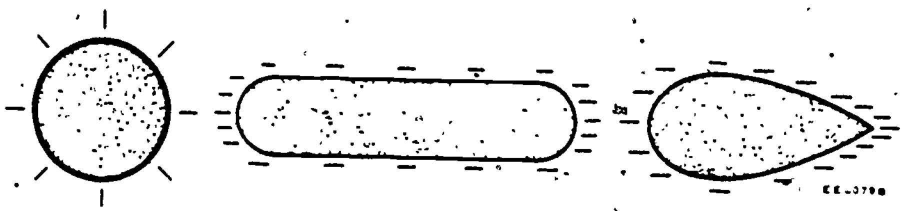

Figure 14. Distribution of Charges

The charge on the outside of a sphere is uniformly distributed. On charged objects, other than spheres, the greatest charge is found on the part which has the greatest curvature. Thus, if a teardrop-shaped object is charged, the intensity of the electric field will be greatest in the regions of the sharp point. Use of this fact is made in the design of lightning rods and of certain spark gaps. Static electricity is usually harmful and serves very few beneficial purposes.

Current

A movement of electrons in a specific direction is defined as current flow. Remember there are billions of electrons in a conductor, and that the electron is the smallest negative charge of electricity, in fact, it is too small to use as a unit of measurement of electricity. The negative charged electron flows toward the positive potentials.

A meter connected directly into the line, so the electrons would flow through it is called an ammeter. This meter will actually count the electrons and tell how many amperes of current are flowing. It is connected in series. The symbol for the ammeter is (A).

The mathematical symbol for current is "I" (representing intensity of current), and the schematic symbol is "A." The unit of measurement is the ampere. Current has four effects as previously mentioned. They are magnetism, heat, chemical action, and physical shock.

Voltage

Voltage is the force that moves the electrons in a conductor. Voltage is nothing more than more electrons at one place than at another. Voltage, potential difference, electromotive force (EMF), electron moving force, and electrical pressure are all used interchangeably and mean the same thing.

Suppose you wanted to energize the outlet on your workbench. There are three principal ways or means by which you can get voltage or difference of potential between these two points. You may use (1) a battery, (2) a generator, or (3) a thermocouple. The thermocouple furnishes very little voltage. There are other sources of voltage but they also furnish small amounts of voltage. Other sources are by friction, compressing certain crystals, and the photoelectric effect. It would take 20 billion candles to produce 100 watts of electrical energy.

BATTERY. In the stable or normal atom, there are as many electrons as protons and an equal balance of electrical charges. The chemical action of a battery removes some of the free electrons from the atoms on one post of the battery and stacks them up on the other post. It takes energy to remove these electrons from their normal position in the atom and stack them up where they do not belong. These electrons which are stacked up on one post are in a position to do work when a circuit is completed between the negative and positive posts as shown in figure 15; therefore, a battery is a device which changes chemical energy to electrical energy.

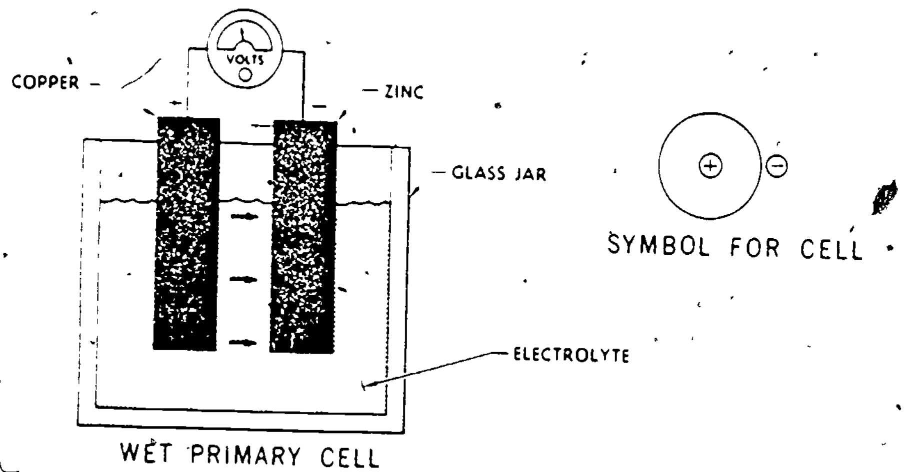

Figure 15. Battery Cell

GENERATOR. The generator takes free electrons from one terminal and stacks them up on the other terminal. In this case mechanical energy is changed to electrical energy as shown in figure 16.

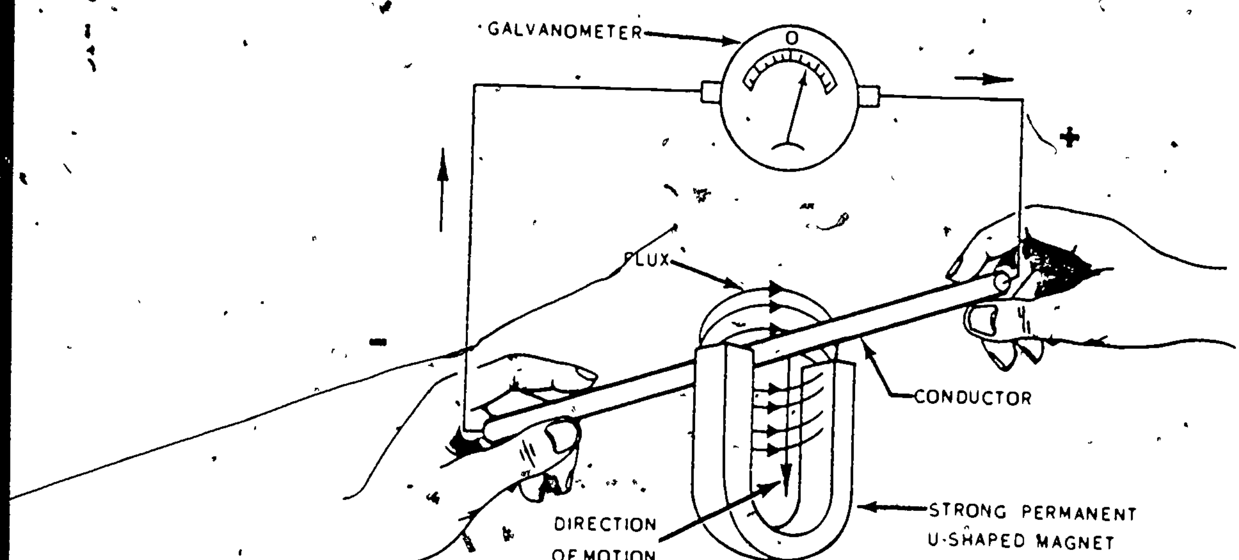

Figure 16. Generator Action

THERMOCOUPLE. A thermocouple is two different metals joined together such as copper and iron wire, or other unlike materials. When this junction is heated, as shown in figure 17, it causes free electrons to stack up on one terminal while the other will have a deficiency of electrons, battery and generator. In this case heat energy is changed into electrical energy.

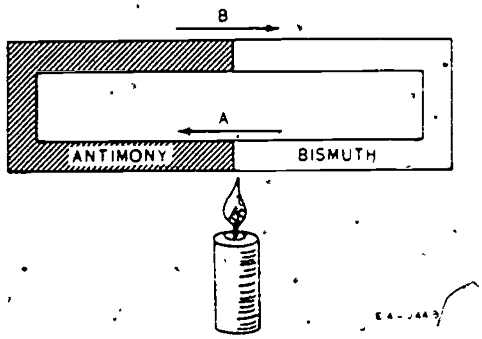

Figure 17. Thermocouple

In each of these three cases energy was used to displace electrons from one post and stack them up on the other. The post or terminal with an excess of electrons is called the negative terminal, and the post or terminal with the deficiency of electrons is called the positive terminal.

This condition is expressed by the term "difference of potential" or voltage which actually means ability to do work due to a state of unbalanced electron condition.

You are possibly familiar with the construction and use of a pile driver. It is a device used for driving posts or piles into the earth for foundations or dams. It consists of a framework and a heavy weight with some means of raising the weight and letting the weight drop on top of the pile or post. Why is this weight lifted? To give the weight potential energy. When the weight is dropped, this potential energy is changed into dynamic energy and forces the pile into the ground.

A similar thing happens in electricity by taking free electrons from their normal position and stacking them up on the negative post. This is like lifting the weight on the pile driver. When the weight is dropped it does useful work. The same things happens in an electric circuit when a switch is closed. The potential energy of these electrons will perform some of the useful effects of current as mentioned before--heat, magnetism, chemical action, and shock.

The mathematical symbol for voltage is "E" and the schematic symbol is "V." The instrument used to measure this potential difference between two points is called the voltmeter. The unit of measurement is the volt. The voltmeter is usually connected in parallel. The symbol is (V).

The volt is actually a measure of the energy expended in displacing a unit charge from one terminal to the other in our sources of voltage, which is the basic unit of electrical energy.

Resistance

The definition of resistance is to oppose or retard. In electricity resistance means the opposition to the movement of free electrons through a circuit or conductor.

Remember there are billions of electrons, protons, and other particles in a conductor. When the free electrons are forced along a conductor they are in continual collision with these particles. These collisions tend to stop the free movement of the electrons and are one of the main retarding forces.

The resistance of a conductor is determined by four factors: length, cross sectional area, kind of material, and temperature. The longer the conductor the more resistance, the larger the cross sectional area the less the resistance, the more free electrons (determined by the kind of material) the less the resistance, and in most cases the higher the temperature the more the resistance. An exception to this rule is carbon which is one of the few materials that has less resistance with an increase in temperature.

When a material increases in resistance with an increase in temperature, it is said to have a positive coefficient. One that decreases in resistance with an increase in temperature is said to have a negative coefficient. Figure 18 illustrates one of the uses of resistors.

The unit used as a measurement of resistance is the ohm. One volt will force one ampere of current through one ohm of resistance. The mathematical symbol for resistance is "R" and omega symbol "Ω" as the schematic representation.

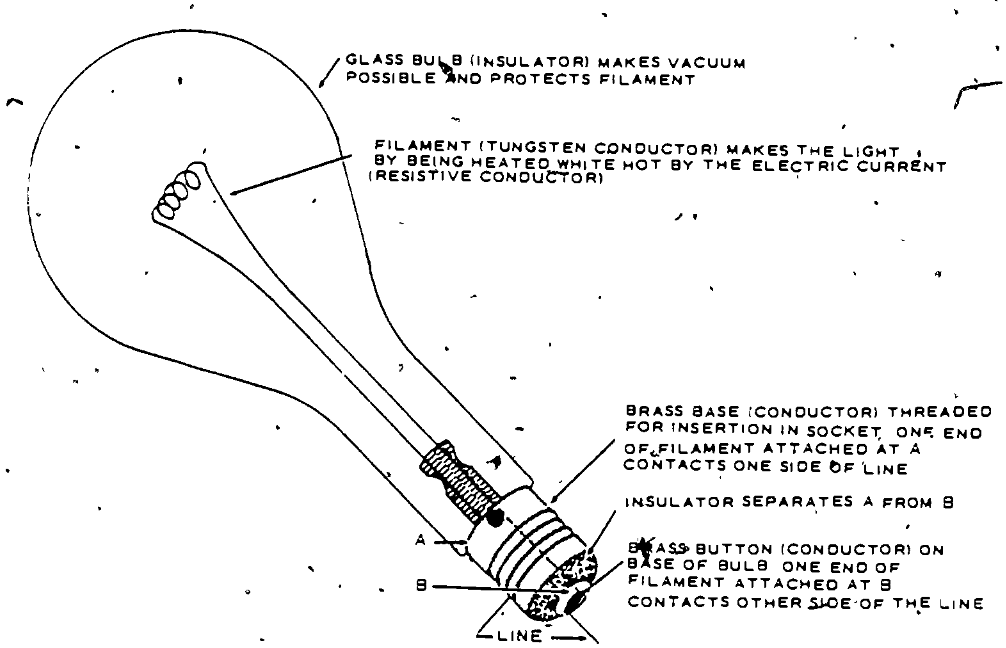

Figure 18. Incandescent Light Bulb Showing Insulators, Conductors and Resistor

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Resistors

Resistors are classified as variable resistors and fixed resistors.

VARIABLE RESISTORS. Variable resistors may be classified as rheostats or potentiometers, depending upon their use, the number of terminals, and how they are connected in the circuit.

A rheostat is a variable resistor which may be used as a control to vary the amount of current which flows in an electric device. The rheostat has two terminals; one terminal is connected to one end of the resistance and the other terminal, to the slider arm contact. A typical circuit in which a rheostat is used is shown in figure 19. Since the rheostat controls the circuit, it serves to vary the intensity of the pilot light, R.

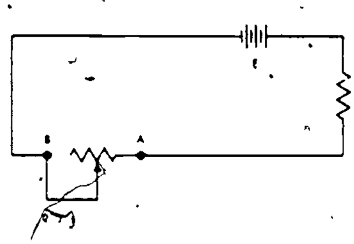

Figure 19. Controlling Current Flow With Rheostat

As the slider arm is moved from A toward B, the amount of rheostat resistance (AB) in the circuit is increased. Since the rheostat resistance and the fixed resistance of the lamp are in series, the total resistance of the circuit also increases. The total current in the circuit therefore decreases. By a similar analysis, you can see that as the slider arm is moved toward A, the total resistance decreases and the current through the lamp increases.

The potentiometer is also a variable resistor. However, the potentiometer has three terminals; the two ends and the slider arm are connected in the circuit. A potentiometer is a control used to vary the amount of voltage to an electrical device.

By omitting the connection to one end of the potentiometer, you may use it as a rheostat. The potentiometer is used to control the volume of your radio and the brightness control of your television receiver. In Figure 20, note how the potentiometer is used as a means of obtaining a variable voltage from a fixed voltage source for an electrical device. The voltage applied across the device is equal to the voltage from B to C because the load is connected in parallel. When the slider arm is moved to point A, the entire voltage is across the load, and when the slider arm is moved to point C, the voltage across the load is zero. The potentiometer makes it possible to apply any voltage within the range between zero and full voltage across the load.

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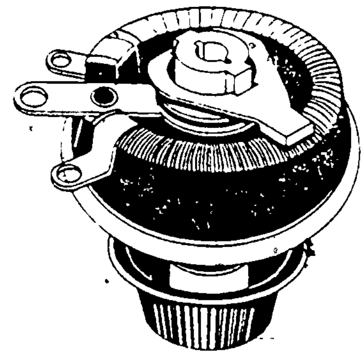

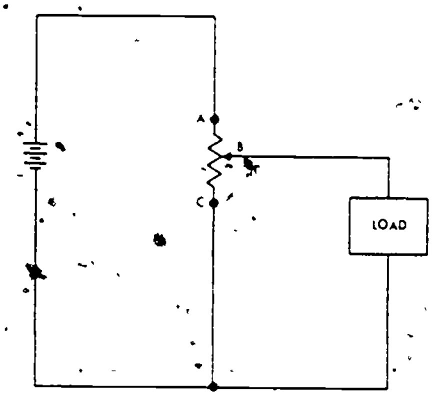

Figure 20. Tapered Control and Varying Voltage with a Potentiometer

FIXED RESISTORS. Resistors are usually made of either carbon or high resistance wire. Most variable resistors are made of wire wound around some sort of form. The larger the physical size of the resistor the more heat (wattage) it can handle safely.

SUMMARY

All material things on this earth are made from atoms. Atoms are constructed from still smaller particles. The center or nucleus of any atom is made up of small particles called protons, which carry a positive charge of electricity. Moving around this nucleus at different distances are other small particles called electrons, which carry a negative charge of electricity. The normal atom has as many electrons as protons and has equal but opposite charges.

Due to the structure of some materials, there are electrons which wander around aimlessly through the material. They are called free electrons. A material with many free electrons is classed as a conductor of electricity. These materials with a few free electrons are classed as resistors. Materials with practically no free electrons are classed as insulators.

It is possible to disturb the normal balance of the atom in some materials by removing some of the free electrons from some atoms and forcing these electrons into other atoms. The atom from which the electrons came has a deficiency of electrons and therefore carries a positive charge. The atoms to which the electrons are added have an excess of electrons and therefore a negative charge. Any time there are more electrons at one place than another, there is a voltage or difference of potential between these two places or points. Other names for voltage are electromotive force and electrical pressure. Three ways of producing a voltage are: generator, battery, and thermocouple.

When voltage is applied to a circuit, it causes free electrons to move along the conductors in a uniform movement. If the electrons move in one direction only, it is called direct current (dc). If the electrons move forward and backward through the circuit, it is called alternating current (ac). Four effects of current are: heat, magnetism, chemical action, and physical shock.

When free electrons move through a conductor, they are continuously colliding with other particles in the conductor. These collisions give opposition to the free movement of the electrons. This opposition is called resistance.

QUESTIONS

1. What is an electron?
2. Define voltage.
3. What are the two most common sources of voltage?
4. What principle does the battery use to produce voltage?
5. What are the two types of electricity?
6. What are protons?
7. What is "static" electricity?
8. Define resistance.
9. Define current.
10. What factors determine the resistance of a conductor?

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Magnets

A magnet is of metal, usually iron or steel that has the characteristic of becoming magnetized. Magnets have certain properties such as the ability to attract other magnetic materials. Studies show that all magnets are governed by certain natural laws.

Types of Magnets

A natural magnet as mentioned is a piece of magnetite, a kind of iron ore. The ancients knew the properties of this ore and called it lodestone, which means "leading stone." The only use found for it was in making magnetic compasses for telling direction. In modern times scientists have discovered more about magnets and the relation of magnetism to electricity.

Artificial magnets are man-made magnets. Scientists have found ways to magnetize certain materials. Magnetic substances such as iron, steel, and nickel, may be magnetized by using magnetic induction. Nonmagnetic materials such as glass, wood, etc., cannot be magnetized by any means.

If the head of an iron nail is placed under a magnet so that its head touches the magnet, the lower end of the nail will hold up several tacks. The nail has been made into a magnet by touching the magnet. We say that the magnetism is induced in the nail. This is commonly called magnetic induction. Curiously enough, the nail does not need to be in contact with the magnet in order for magnetism to be induced. If you will bring the nail directly under the magnet but not touching it, the nail will still hold one or more tacks, showing that magnetism has been induced in it. However, in both cases as soon as the magnet is removed, the nail will lose its magnetism. Thus, the magnetism induced in an iron nail makes it only a temporary magnet, because it loses its magnetism soon after it is removed from a magnetic field.

Magnets that keep their magnetism for a long period of time after being removed from a magnetic field are called permanent magnets. Magnets of this kind are usually made by an electric method. If you put a piece of iron or a piece of steel in a wire coil and pass dc current through the coil magnetizing them, they would both pick up about the same number of tacks while the current is on. But, when the current is turned off and the pieces are taken out of the coil of wire, you will find that the piece of steel will be able to pick up more tacks than the piece of iron. In fact, the iron usually loses most of its magnetism as soon as the current stops flowing through the coil of wire. One of the best permanent magnets made today is called Alnico. This is an alloy or a combination of metals. It is made of aluminum, nickel, iron, and cobalt. Steel is an alloy and, of course, is a good magnetic material.

The induced magnetism that remains in a magnet substance after the magnetizing force has been removed is called residual magnetism. Because steel and certain alloys hold magnetism for a long period of time, they are used to make permanent magnets. Iron, on the other hand, is used to make temporary magnets and is a temporary magnet.

Magnets are made in many shapes, according to their use. Common shapes are the bar and horseshoe magnets. A keeper (a piece of soft iron connecting the poles), should be kept on the magnet to enable it to maintain its strength, (see figure 21) for illustration of keeper. Magnets are usually labeled North or South but if they are not, there are ways of finding the polarity. You could bring it near a magnet of known polarity; it could be suspended from a string and it will point North and South. Also, a compass could be used to find the polarity.

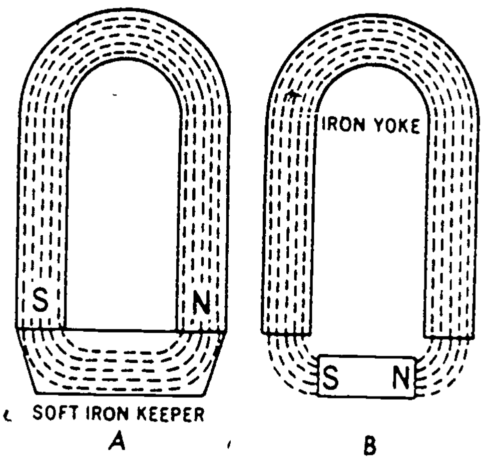


Figure 21

Theory of Magnetism

In the theory of magnetism, it is usually assumed that all matter is made up of small molecules that act as though they were very small magnets. For magnetic materials like iron or steel, these magnets are strong, in all other materials the magnets are weak. In a material not magnetized, the molecules align in no regular position and extend in every direction as shown in figure 22(A). When magnetized, all of the molecules will line up, with their north poles pointing in one direction as in figure 22(B). In soft iron the molecules tend to return to their original position when the magnetizing force is removed, so the magnetism is temporary and the magnet is called a temporary magnet. In hard steel the molecules tend to retain their magnetic position, and the magnet remains magnetized after the magnetism force is removed. The hard steel, therefore, becomes a permanent magnet. The magnetism that remains after the magnetic force is removed is known as RESIDUAL MAGNETISM, as previously mentioned. Heat and shock will destroy magnetism because they give the molecules an opportunity to return to their original position. If a magnet is broken, it will become as many small magnets as there are pieces. All combined will have the strength of the original. (See figure 23)

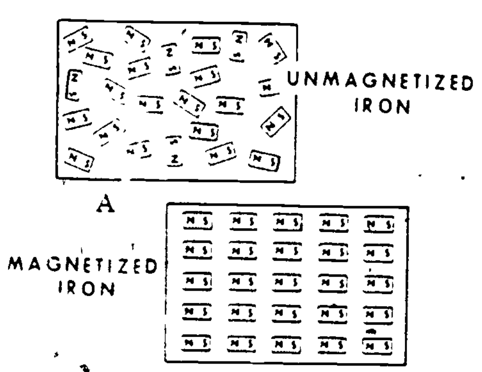


Figure 22

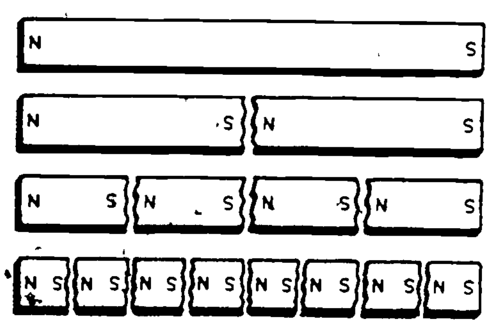


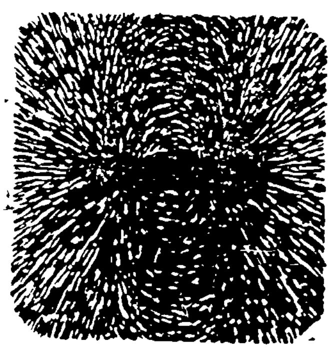
Figure 23. Effects of Breaking a Magnet

Magnetic Fields

When a sheet of paper is placed over a bar magnet and iron filings are scattered over the paper, the filings will arrange themselves in definite paths or lines from one pole around to another. (See figure 24.) This fact shows that magnetism acts as a force and arranges the particles in lines, which indicate the direction of magnetic attraction. These lines along which the magnetic forces act are called lines of magnetic force, lines of flux, or simply lines of force. The space around a magnet through which these forces act, and in which other magnetic material is affected, is called a magnetic field or simply the field of a magnet.

If the bar magnet as shown in figure 24 is held endwise to the paper, the filings will arrange themselves as shown in figure 24. The positions taken by these filings indicate that the lines of force radiate from the north poles in all directions and enter the south pole.

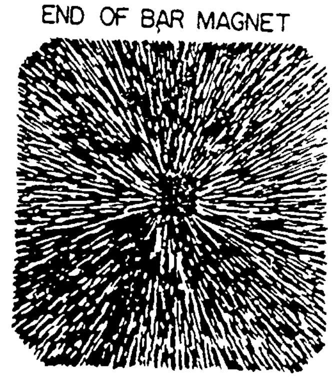
BAR MAGNET



LONGITUDINAL VIEW

Figure 24

END OF BAR MAGNET



CROSS-SECTIONAL VIEW

Figure 25

It should be understood that these lines of force, as shown by the filings are purely imaginary; therefore, it must not be assumed that the magnetic forces act along these lines only and nowhere else, such as between the lines. The strength of the magnetic field at any point decreases as the distance of the point from the magnet or other sources of magnetism increases.

DIRECTION OF LINES OF FORCE. Every line of force of a magnet is assumed to pass out from the north pole, make a complete circuit through the surrounding medium, and return into the south pole; from there it passes through the magnet to the north pole again, as shown in figure 26. The direction of the lines of force is indicated in this way, and the path that they take is called the magnetic circuit. Figure 27 also illustrates the above statement very well.

Although a line of force may apparently leave the end of a magnet and disappear into space as indicated by the arrangement of the iron filings shown in figure 25, it must eventually return to the opposite pole of the same magnet.

The direction of the lines of force in any magnetic field can be traced by several compasses as shown in figure 28. The north pole of the needle will always point in the direction of the lines of force, or in other words, the needle always turns so that its axis is parallel to the lines of force at that place.

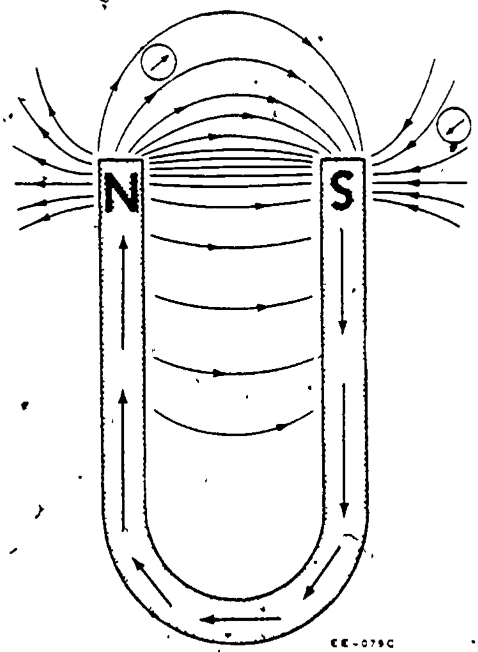


Figure 26

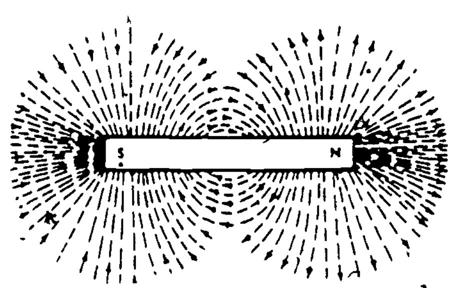


Figure 27

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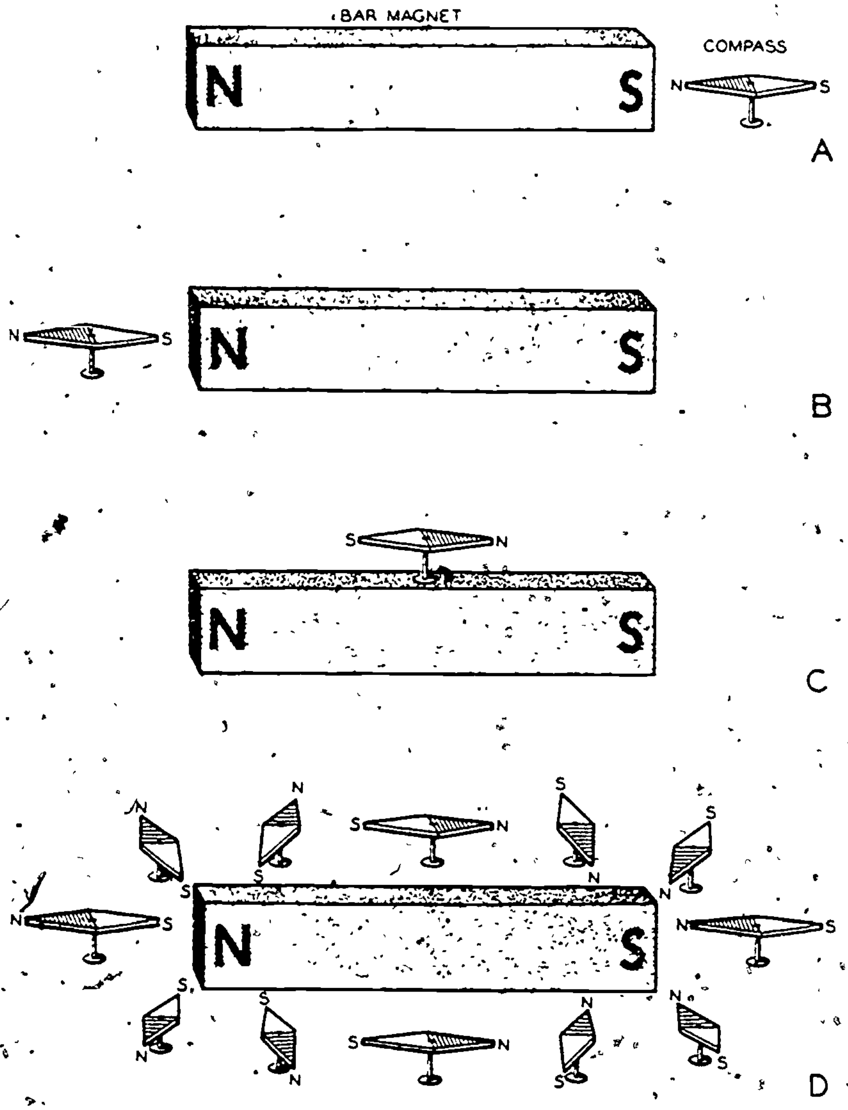

Figure 28. Effects of Magnetic Field on Compass Needle

ATTRACTION AND REPULSION. When a north pole of one magnet is placed near the south pole of another, the magnets will attract each other. The lines of force that come from the north pole of the first magnet move through air to the south pole of the second magnet, as shown by the iron filings in figure 29.

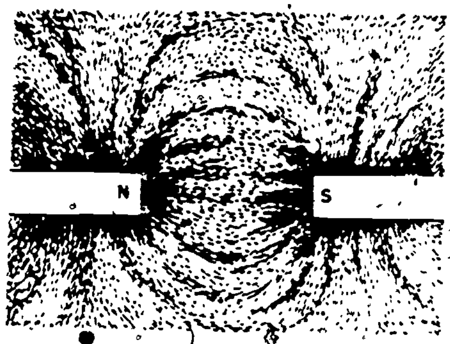

Figure 29

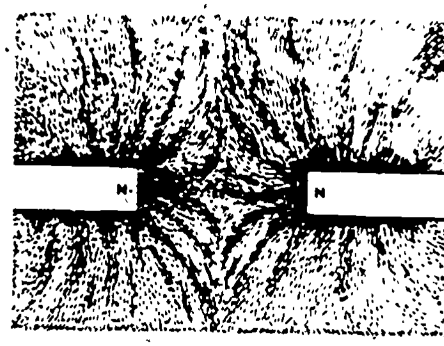

Figure 30

The lines of force continue through the second magnet, pass out to the air, and finally return to the south pole of the first magnet. The lines of force thus pass through both magnets, and the tension in these lines tends to pull the magnets together. The action is similar to that which would be experienced if the lines of force were replaced by stretched rubber bands.

When a north pole of one magnet is placed near the north pole of another, the magnets will repel each other. The lines of force may be represented by the iron filings above the magnets as before, but this time they will appear as shown in figure 30.

There will be a crowding together of these lines of force as indicated, which explains the repelling action. Again these lines of force may be considered as rubber bands which, when crowded into a small space, exert a sidewise pressure on one another, thereby tending to separate the magnets. Note that the lines of force in this diagram do not intersect or the lines of force do not cross each other.

From the facts which have been stated and illustrated, the fundamental law of magnets is established: Like poles repel each other, whereas unlike magnetic poles attract each other.

MAGNETIC INDUCTION. When a magnetic substance such as iron is brought into a magnetic field so that the magnetic lines of force pass through it, the substance immediately becomes magnetic. The lines of force are assumed to crowd together and tend to pass through the magnetic substance as indicated in figure 31 because it is a better conductor for lines of force than the surrounding air.

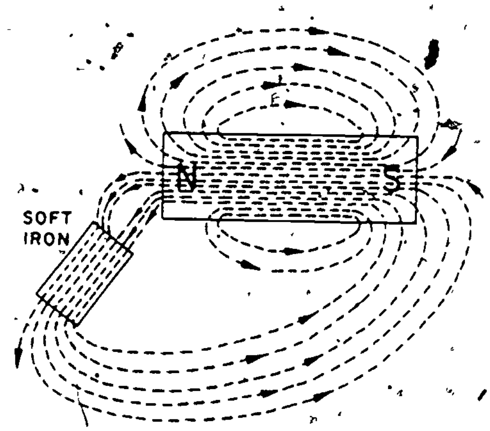

Figure 31

In this illustration a small rectangular piece of iron is placed in the magnetic field of a bar magnet. The substance so magnetized is usually, however, only a temporary magnet. When it is removed from the magnetic field, its magnetism usually disappears. While under the influence of the magnetic field, the substance behaves as does any magnet and has polarity which is so distributed that its south pole is the one where the magnetic lines enter it; whereas its north pole is in that portion of substance where the magnetic lines leave it. This method of producing magnetism in a magnetic substance is called magnetic induction as previously mentioned.

MAGNETIC SCREEN. When a magnetic material such as soft iron is placed near a magnetic field, the lines of force of the field will tend to pass through the iron instead of the surrounding air, as the iron provides an easier path and is said to have high permeability. (See figure 31.) This principle is used in the magnetic screen, which provides a space in the magnetic field that is free from the lines of force as indicated in figure 32. The iron at (A) is rectangular in shape and the air space free from the flux (B) is shown at (C). This condition could not be obtained by surrounding the space by glass, porcelain, copper, or other nonmagnetic material, since the reluctance (opposition) to lines of force of these is about the same as that of air. The magnetic screen is sometimes used to shield delicate measuring instruments from stray fields and thereby increase their efficiency.

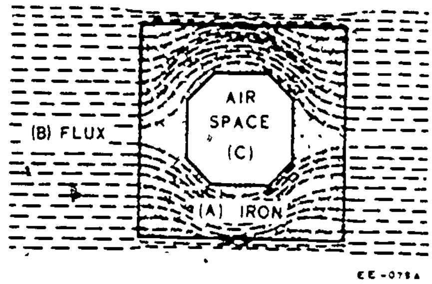

Figure 32.

Electromagnetism

You have studied both electricity and magnetism. Magnetism as a result of electricity and electricity as a result of magnetism.

The production of magnetism is accomplished by the fact that a current carrying conductor is surrounded by a magnetic field. Electricity is generated by a mechanical means (generator) and is created by electromotive induction.

Electromagnets come in all shapes and sizes. Some are so small they will fit in the top of your pen and some are so large they can lift tons of iron. For example, a very powerful electromagnet has been invented. It is the size of a donut and weighs one pound, yet it has 33 times the strength of an old-type electromagnet weighing 20 tons. For every size and shape of electromagnet, there are many jobs such as doorbells, buzzers, relays, solenoids, meters, telephones, generators, motors, transformers, and so forth (see figure 33).

Electromagnets are like permanent magnets in their attraction but unlike in their control. Their attraction may be tremendous. They can, when properly constructed, hold tons of iron, but because these magnets are controlled by an electric current, the magnetism can be turned on and off with the flick of a switch.

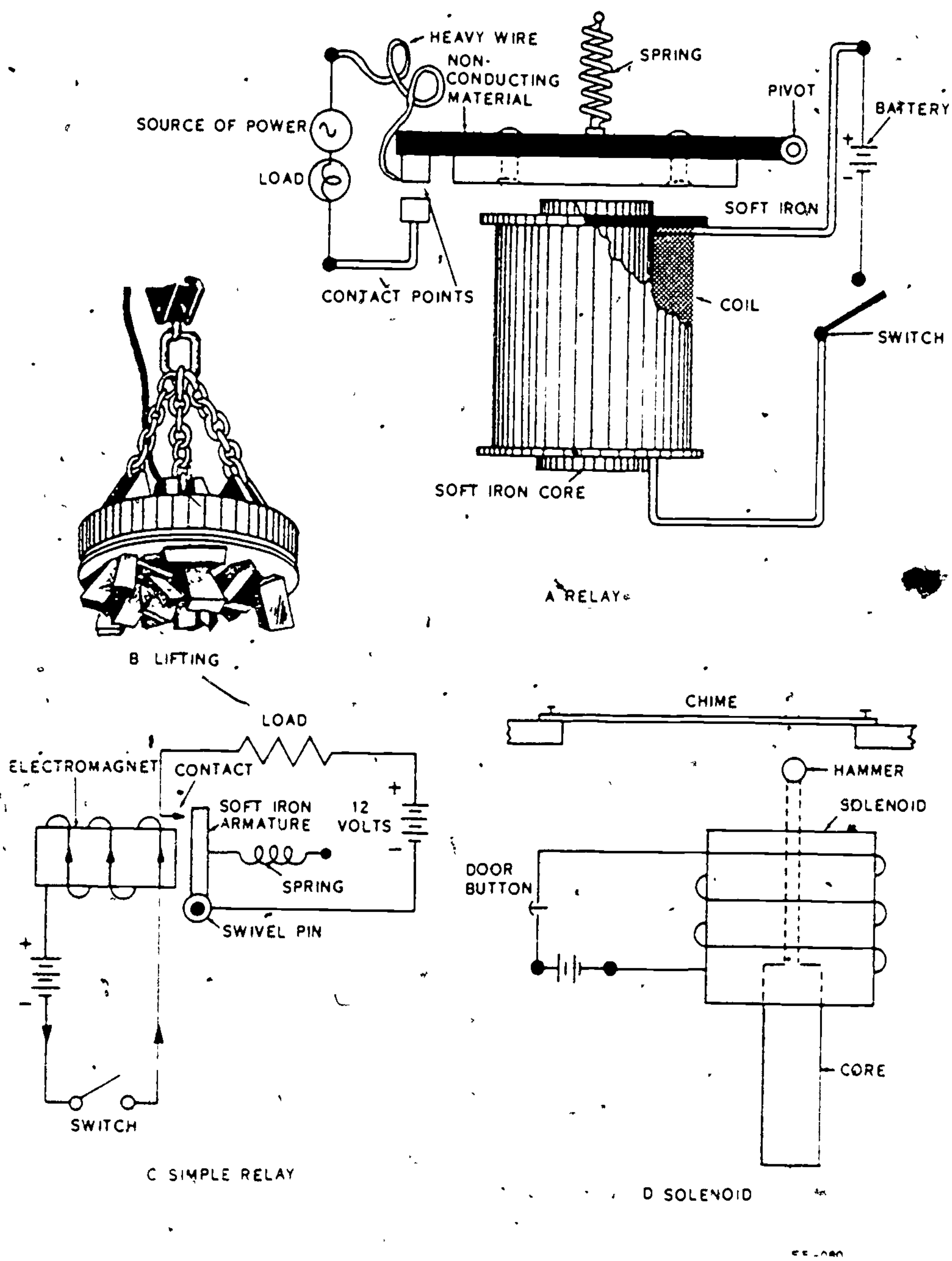

Figure 33. Uses of Electromagnetism

Electromagnets are usually constructed with a coil of wire surrounding a soft iron core. To understand how electromagnetism works you must understand the characteristics of conductors when they are carrying current.

THE MAGNETIC FIELD AROUND A CONDUCTOR. All conductors carrying current are surrounded by a field of flux. This was discovered by Hans C. Oersted in 1820. This can be proven by connecting a wire to a battery and as in figure 34 dip the wire in iron filings. The filings are attracted and held to the wire. Now disconnect the wire--the filings will drop off. This is proof that the FIELD EXISTS ONLY WHEN CURRENT IS FLOWING.

Figure 34. Magnetism Produced by Current

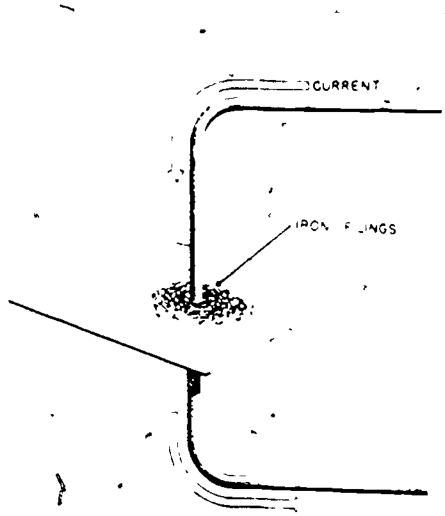

Figure 35A. Magnetic Field Around a Conductor

Visualize passing the conductor through a hole in a piece of cardboard as shown in figure 35A. Connect the wire to a battery and sprinkle iron filings on the cardboard. The filings outline the exact shape of the field.

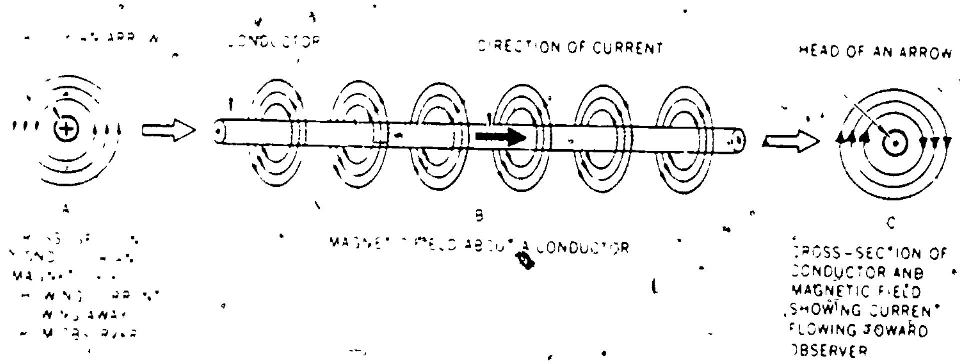

Figure 35B. Magnetic Field About a Conductor

Two characteristics stand out: (1) the field is circular around the conductor and (2) no lines cross.

The magnetic field around a current-carrying conductor surrounds the wire for its entire length. (See figure 35B.) The field is strongest near the conductor and gets weaker the further you get away from the conductor. The magnetic circles around a conductor are in the same direction.

Place compasses around the conductor as shown in figure 36A. The "N" end of all compasses point in the direction of the magnetic lines of force. This shows that the magnetic lines of force are circular around the wire.

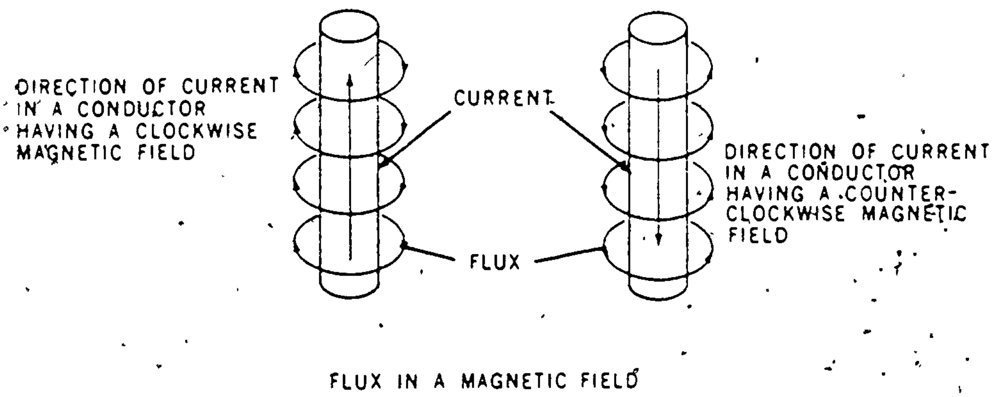

Figure 36A. Direction of Magnetic Field Around a Conductor

Leave the compasses in place and reverse the current direction (switch battery connections). All the compass points now reverse. This shows that the direction of the magnetic lines of force are determined by the direction of current flow. This is commonly called the left-hand rule. (See figures 36A, B, C, and D.) Later you will study the Generator Left-Hand Rule.

If you grasp a current-carrying conductor with the left hand, holding the extended thumb in the direction of current flow, the fingers encircle the wire in the direction of the magnetic field as shown in figure 36B.

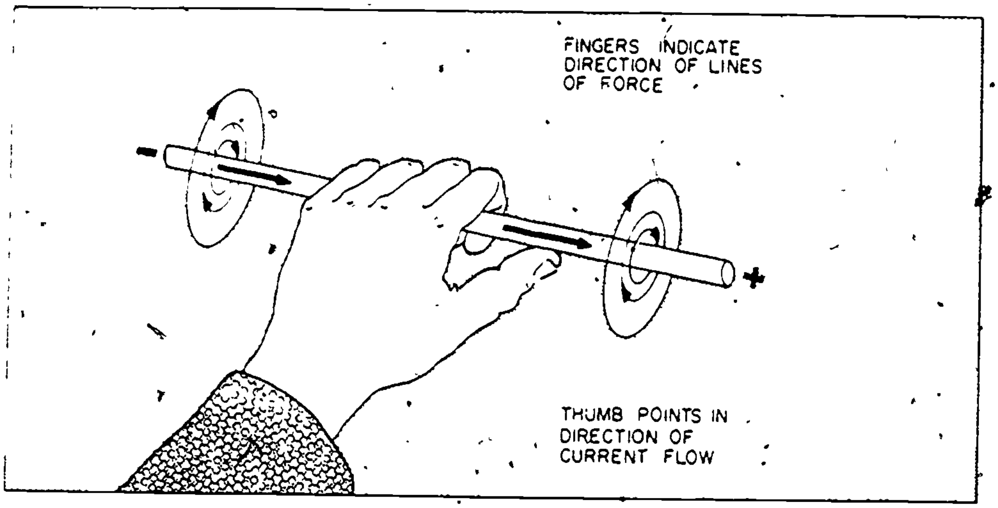

Figure 36B. Determining Direction of Lines of Force

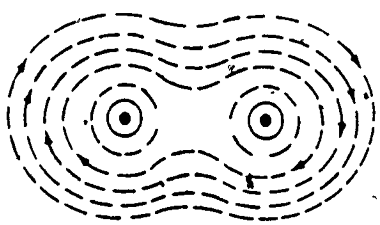

Figure 36C. Magnetic Field Surrounding Parallel Conductors with Current in Same Direction

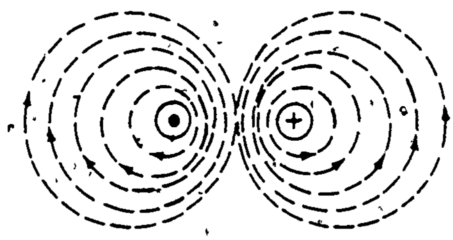

Figure 36D. Surrounding Parallel Conductors with Current in Opposite Direction

The polarity of a coil can also be determined by the left-hand rule. Grasp the coil in the left hand so that the fingers follow the direction in which current is flowing. The thumb will point to the north pole as shown in figures 37A and 37B.

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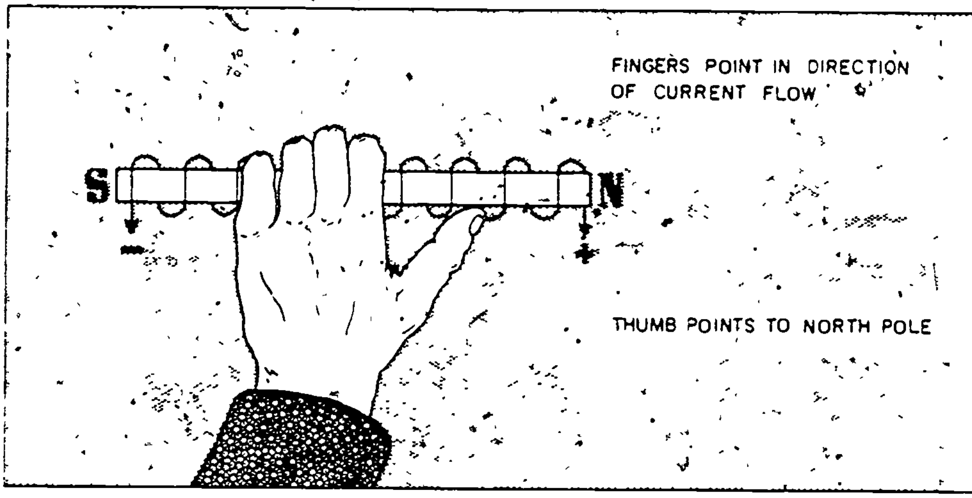


Figure 37A. Determining Polarity of a Coil

The magnetic field around a single conductor is of little use since it is normally too weak to exercise much attraction. If you form a number of loops close together, you can concentrate the strength of the magnetic field and create polarity. It is important to have polarity since these are the points of greatest magnetic concentration.

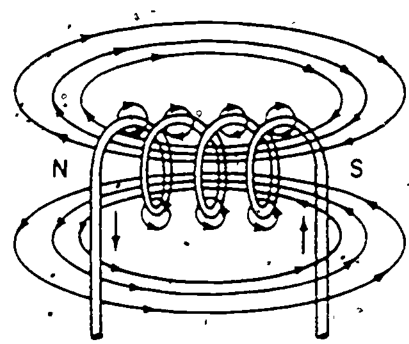


Figure 37B. Conductor Formed Into Loop

The strength of an electromagnet is determined principally by three things: (1) the number of turns in a coil, (2) the amount of current flowing in the conductor, and (3) the type of material in the core.

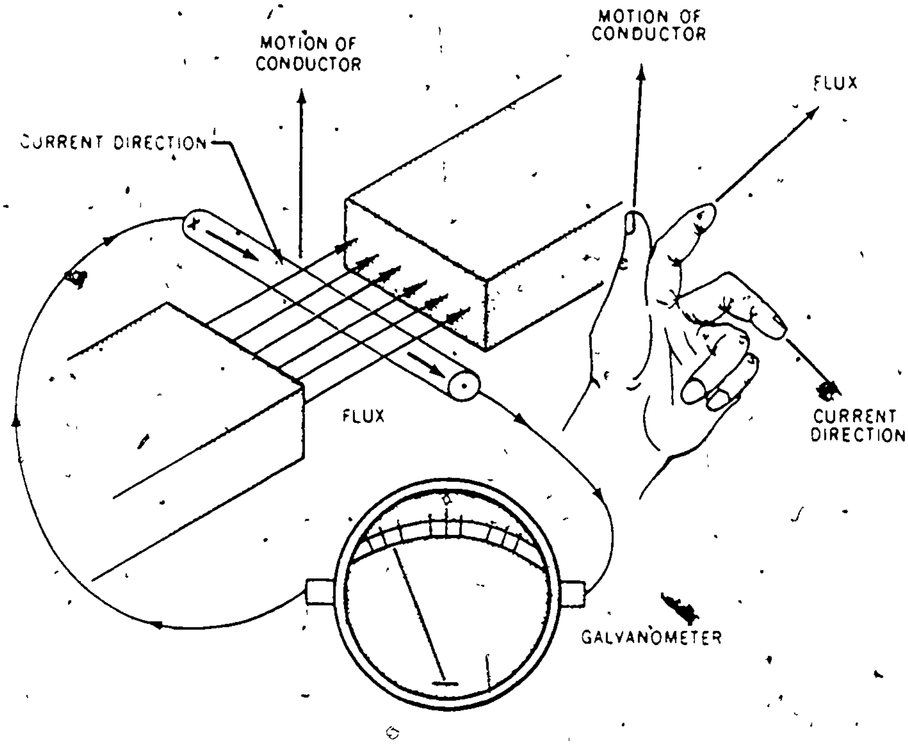


Figure 38

ELECTROMAGNETIC INDUCTION. A magnetic field can be made to create an EMF (electromotive force, voltage), and thereby cause a current to flow in a closed loop. This creaion of an EMF is accomplished by moving a conductor so that it cuts across lines of force, or by moving the lines of force so that they cut across the conductor. The relative motion is illustrated in figure 38.

In figure 38, if the conductor is moved back and forth between the pole faces so that its motion is parallel to the direction of the magnetic lines of force and therefore not cutting them, there will be no deflection on a meter connected to the conductor. This demonstrates that there is no induced voltage. As the angle between the lines of force and the path of the conductor is increased, the deflection on a meter increases until the maximum deflection is reached when the conductor is moving at right angles to the field. It may be stated, therefore, that a conductor moving parallel to magnetic lines of force will have no EMF induced in it, while one moving at right angles to the field will have a maximum EMF induced in it. This action leaves an excess of electrons at one end and a deficiency of electrons at the other end. This is voltage or difference in potential.

Generation of AC Voltage

Previously you learned several ways to generate a voltage. One way was by the use of a generator. A generator is made up of two parts. They are the rotor or rotating part and the stator or stationary part. The three factors necessary to produce a voltage mechanically are conductors, magnetic field and relative motion. In most ac generators the conductors are wound in the stator while the rotor provides the rotating magnetic field. Figure 39 shows a basic ac generator.

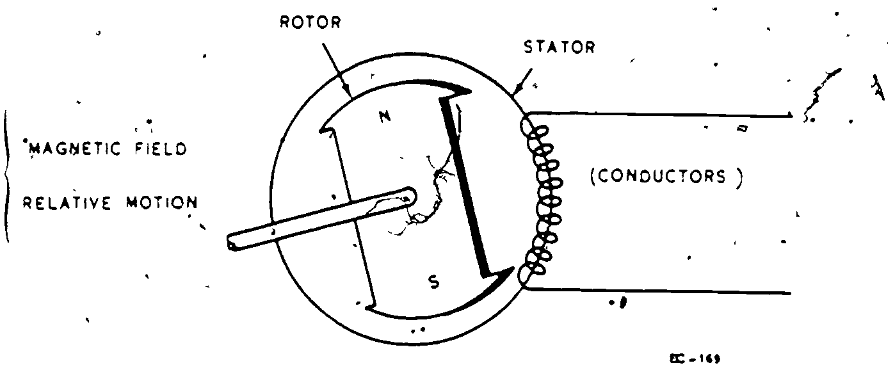


Figure 39. Basic AC Generator

As the magnetic poles are turned past the conductors a voltage of varying amplitude (amount) and direction is generated. Figures 40, a, b, c, d, e, f, g, h, and i will show how this is accomplished.

As you can see each POLE (north or south) of the rotor produced a voltage equal in amount but different in direction. Because these voltages periodically change in direction, the current flow will periodically change in direction with the voltage. THREE-PHASE VOLTAGE. By increasing the number of separate coils you can increase the number of voltages that you generate. These separate and independent from each other. Figure 41 will show the Mechanical and Electrical arrangement of the coils.

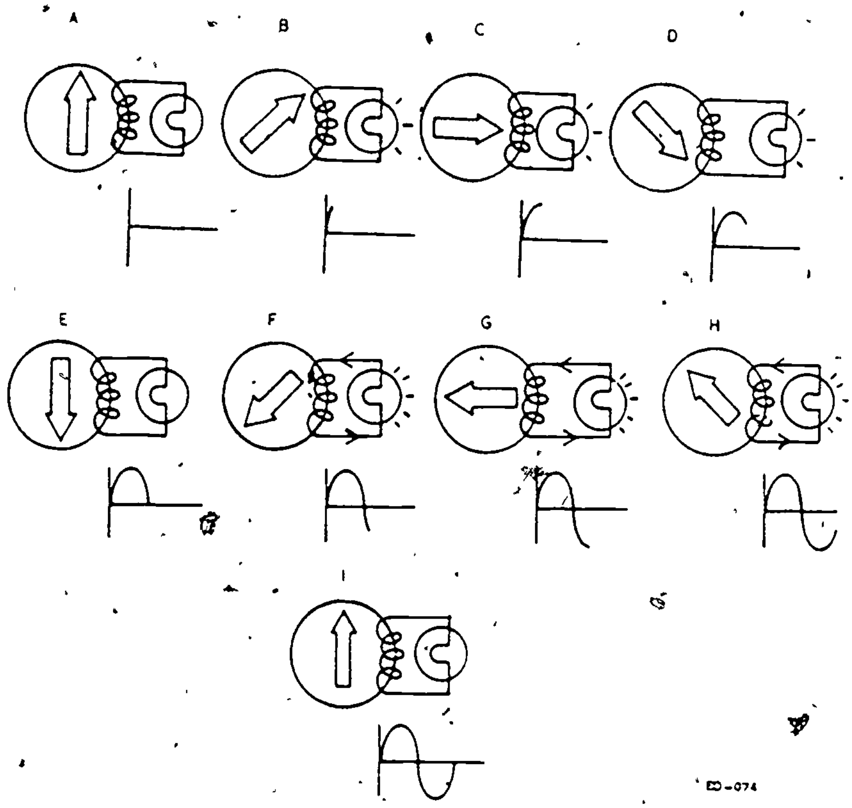


Figure 40. Generation of One Cycle of AC Voltage

Figure 41, the three coils or phases are separated by 120 Mechanical Degrees. It would be impossible for the north pole at the magnet to pass two of these coils equally at the same time. Since a voltage is generated when the north or south pole of a magnet passes a coil of wire and the phases are separated by 120 mechanical degrees the voltages will be 120 electrical degrees apart. To identify these different voltages you identify the different phases by letter.

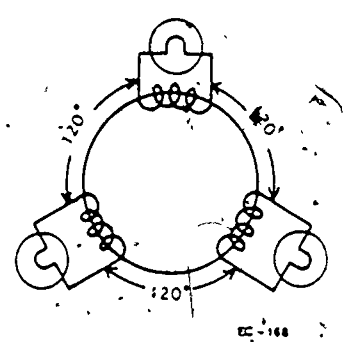


Figure 41. Three Coil (Phase) Stator

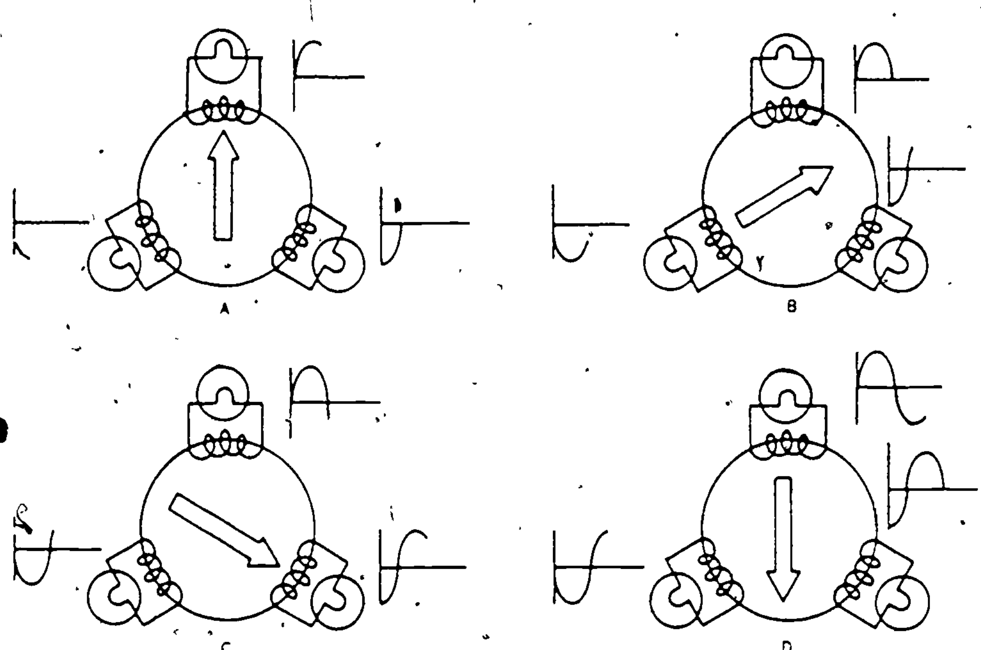


Figure 42. One Alternation (1/2 cycle) Three-Phase Voltage

Figure 42 shows the rotor making one-half revolution. If you continue the rotor in the same direction until it has made one full revolution you have completed two alternations or one cycle. Take all three sine waves from figure 42 and plot them on one picture. You can see what the voltage looks like as to time amount and direction at any point. Figure 43 shows this sine wave.

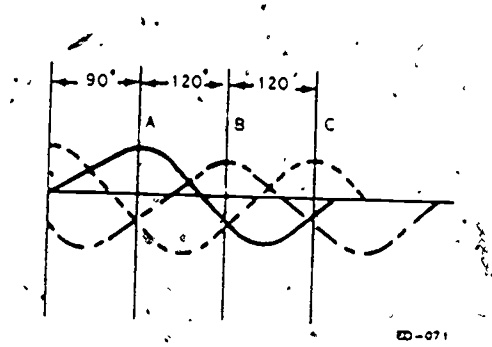


Figure 43. Three-Phase (3 Ø) Sine Wave

Three-Phase Connections

The two types of connections used are wye and delta. They are special connections and apply only to three-phase power and equipment. Figure 44 shows these two connections.

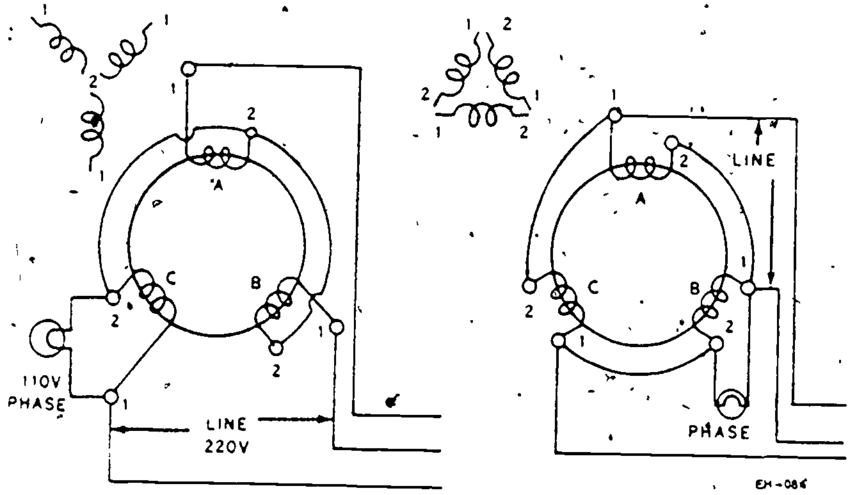


Figure 44. Three-Phase Connections

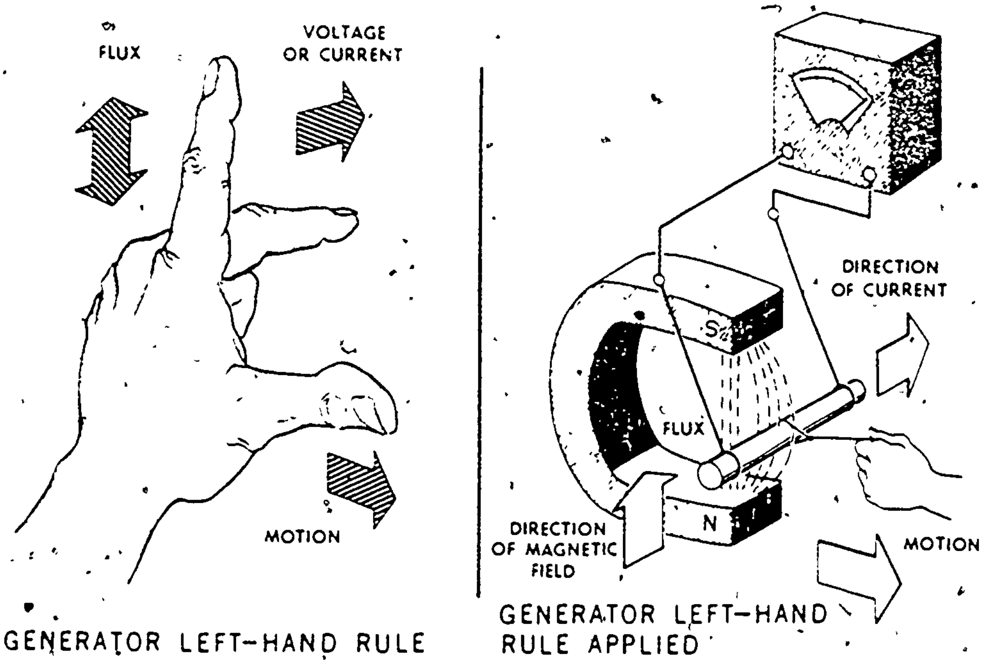


Figure 45. Illustration of Left-Hand Generator Rule

Generator Left-Hand Rule

In the generation of voltage there are many instances when you need to know the direction current flow is established. To determine the direction of current flow you use the generator left-hand rule.

The generator left-hand rule states: "PLACE THE THUMB, FIRST AND MIDDLE FINGERS OF THE LEFT HAND ALL AT RIGHT ANGLES TO EACH OTHER. THE FIRST FINGER SHOULD POINT IN THE DIRECTION OF THE MAGNETIC FIELD (NORTH TO SOUTH OUTSIDE MAGNETS). THE THUMB SHOULD POINT IN THE DIRECTION OF THE MOTION OF THE CONDUCTOR. THE MIDDLE FINGER WILL THEN POINT IN THE DIRECTION THAT THE ELECTRONS WILL MOVE IN THE CONDUCTOR." (See figure 45.)

Terms

LINES OF FORCE. The invisible lines surrounding a magnet of any type.

PERMEABILITY. The ability to conduct lines of force.

SATURATION. Completely filled; as an iron core that will hold no more lines of force.

FLUX DENSITY. Number of magnetic lines of force passing through a given area.

LODESTONE OR MAGNETITE. Mineral consisting chiefly of a magnetic oxide of iron that is found in its natural state in magnetized condition.

MAGNETIC FIELD. Region in which the magnetic force created by a permanent magnet or by a current carrying conductor or coil can be detected.

RELUCTANCE. Opposition that a substance offers to magnetic lines of force.

RESIDUAL MAGNETISM. Magnetism remaining in a substance after removal of the magnetizing force.

RETENTIVITY. Ability of a material to retain its magnetism.

DENSITY. Ratio of the mass of a substance to the volume of the specimen.

ELECTROMAGNETISM. Magnetism developed by a current of electricity.

FLUX. Term used to designate collectively all the electric or magnetic lines of force

MAXIMUM OR PEAK. The term maximum has already been used in the discussion of the simple alternator. The maximum value of an alternating voltage was indicated as being the highest voltage that was reached on the positive or negative alternation. A similar term used to express this value is peak. The peak value is the highest value of voltage or current reached during either the positive or negative alternation.

INSTANTANEOUS. The instantaneous value of voltage or current is the value of voltage or current at one particular instant. This value may be zero if the selected instant is the time during which the polarity of the voltage is changing. It may also be the same as the peak value if the selected instant is the time that the voltage or current stops increasing and starts decreasing. There may be any number of instantaneous values between zero and the peak value.

AVERAGE. The average value is the average of all the instantaneous values during one alternation. Since the voltage increases from zero to peak and decreases back to zero during one alternation, the average value must be some value between two limits.

PHASE. One electrical power unit (Voltage and Current) reduced to a graphics illustration.

PHASE RELATIONSHIP. The mathematical degree of difference between a voltage and its current.

Figures 46 and 47 shows a A/C Sine wave.

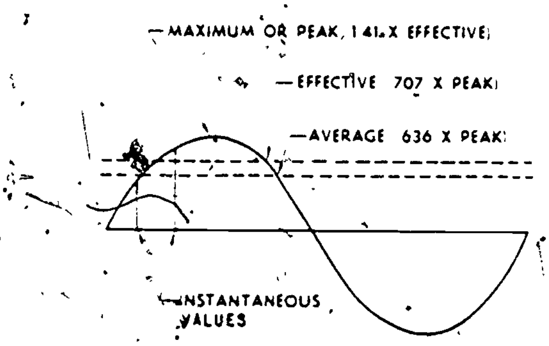


Figure 46

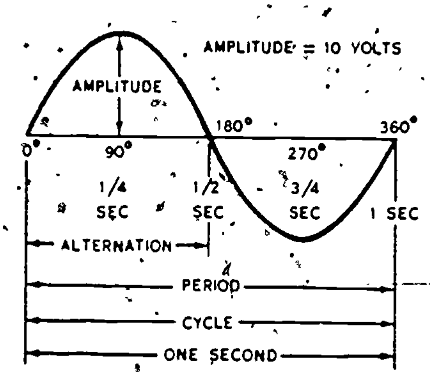
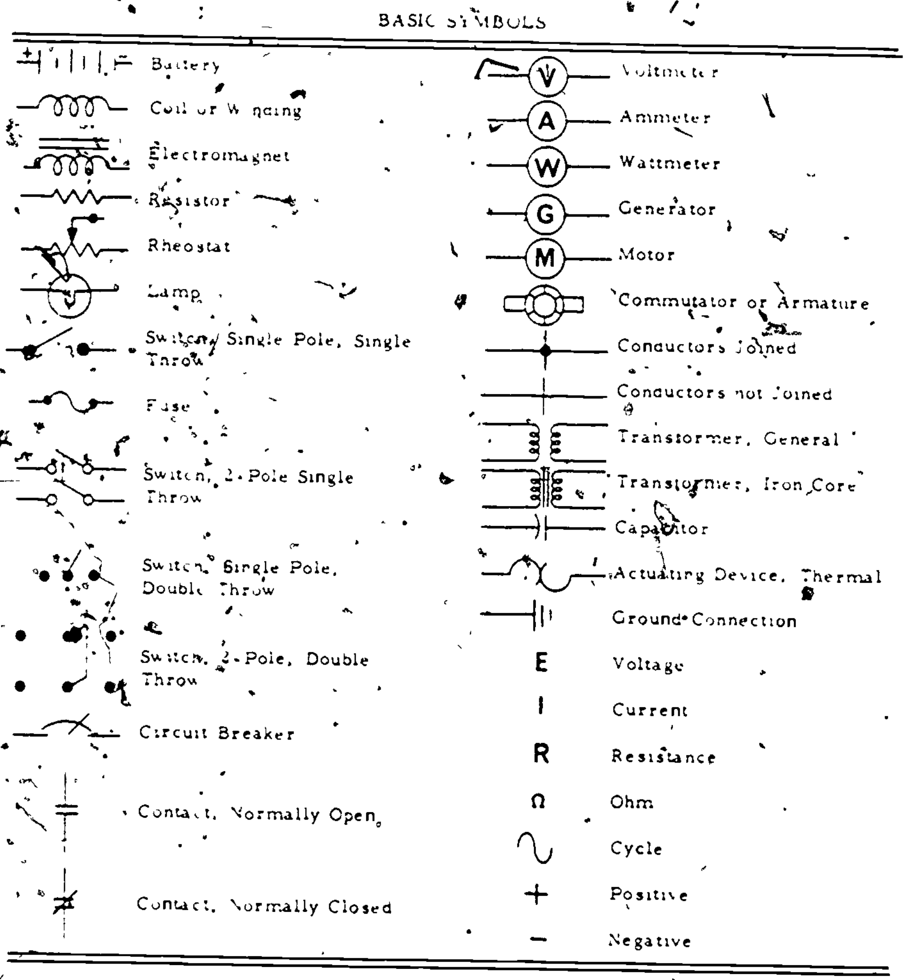


Figure 47



SUMMARY

Metals that possess the property of attracting magnetic substances are called magnets, and those substances that are attracted by a magnet are known as magnetic substances.

The basic idea of the theory of magnetism is that every molecule of a magnetic substance is a tiny magnet with a north and south pole. When the molecules of a magnetic substance are arranged in an irregular arrangement, the substance is not magnetized. When the molecules line up so that their north poles point in one direction and their south poles point in the other direction, then the substance is magnetized.

Some materials are capable of being more strongly magnetized than others. The terms used to describe these qualities of a material are permeability and reluctance.

Permeability is the ease with which magnetic lines of force may be conducted or carried in a substance. Reluctance is the opposition that a substance offers to magnetic lines of force.

A natural magnet is simply a piece of magnetite, a kind of iron ore called lodestone. Artificial magnets are man-made magnets.

Magnets that lose their magnetism soon after they are removed from a magnetic field are called temporary magnets. Magnets that keep their magnetism for a long period after being removed from a magnetic field are called permanent magnets. Magnetism remaining in a magnet after the magnetizing force is removed is called residual magnetism.

Like poles of two magnets repel--unlike poles of two magnets attract each other.

Magnetism caused by current flow in a conductor is known as electromagnetism. The magnetic field around a single conductor is of little use since it is normally too weak to exercise much attraction. Even though they may be weak, they have a definite direction known as the left-hand rule. If you form the conductor in a number of loops together, you can concentrate the strength of the magnetic field and create polarity. The polarity of this coil can be determined also by the left-hand rule.

The strength of an electromagnet is determined by the number of turns in the coil, the amount of current flow, and the kind of material used for the core.

If a conductor is moved across a magnetic field, it will cause the free electrons to move toward one end of the conductor. This leaves one end of the conductor with a deficiency of electrons while the other has an excess of electrons. To determine the direction of current flow in a conductor using the generator left-hand rule, place the thumb, first and middle fingers of the left hand at right angles to each other, with the first finger pointing in the direction of the magnetic field. The thumb indicates the direction of motion in the conductor. The middle finger points in the direction that the electrons move in the conductor.

Generators work on the principle of electromagnetic induction. They are used to produce or generate voltage and are normally single or polyphase in construction.

QUESTIONS

1. What direction do the lines of force travel outside a bar magnet?
2. What is the induced magnetism called that remains in a piece of iron after the magnetizing force is removed?
3. Why is iron better than air for magnetic lines of force to pass through?
4. What action takes place when the south pole of one magnet is placed near the south pole of another?
5. What does the term retentivity mean as it refers to magnetism
6. What surrounds a current-carrying conductor at all times?
7. What are the three main factors that determine the strength of an electromagnet?

8. What is a magnetic material?

9. What is the term for opposition to magnetic lines of force?

10. What term is used to express the relative ease with which lines of rce travel within a material?

11. Name three devices which make use of electromagnetism.

12. Why does heating a magnet weaken it?

13. Why are two parallel conductors carrying current in the same di tion attracted to each other?

14. What is the purpose of a keeper?

REFERENCES

Audel's Practical Electricity, Middleton

AFM 52-8, Electronic Circuit Analysis

Basic Electricity, Volume 2, Van Volkenburgh

SECTION NO. 3, REACTANCE INDUCTANCE

Inductance is the property of an electric circuit that opposes any change in the current through that circuit. That is, if the current increases, a self-induced voltage opposes this change and delays the increase. If current decreases, a self-induced voltage tends to aid, or prolong the current flow, and delays the decrease. Thus, the most noticeable effect of inductance in a circuit is that current can neither increase not decrease as fast in an inductive circuit as it can in a noninductive circuit.

Counter EMF

Current in a conductor always produces a magnetic field surrounding the conductor. When the current changes, the magnetic field also changes, and EMF is induced in the conductor. As the field strenth increases, the lines of force increase in number and expand outward from the center of the conductor. The lines of force cut across the conductor and induce a voltage in such a polarity as to oppose the increase in current. When the field strength decreases, the lines of force contract toward the center of the conductor and induce a voltage in such a polarity as to oppose the decrease in current. It is actually this expansion and contraction of the magnetic field as the current varies which causes an induced EMF, and the effect is known as "inductance." The induced EMF is always in a polarity to oppose the effect that produced it and is called a counter EMF.

Factors Which Affect Inductance

The factors which affect the inductance of a coil are shown in figure 47.

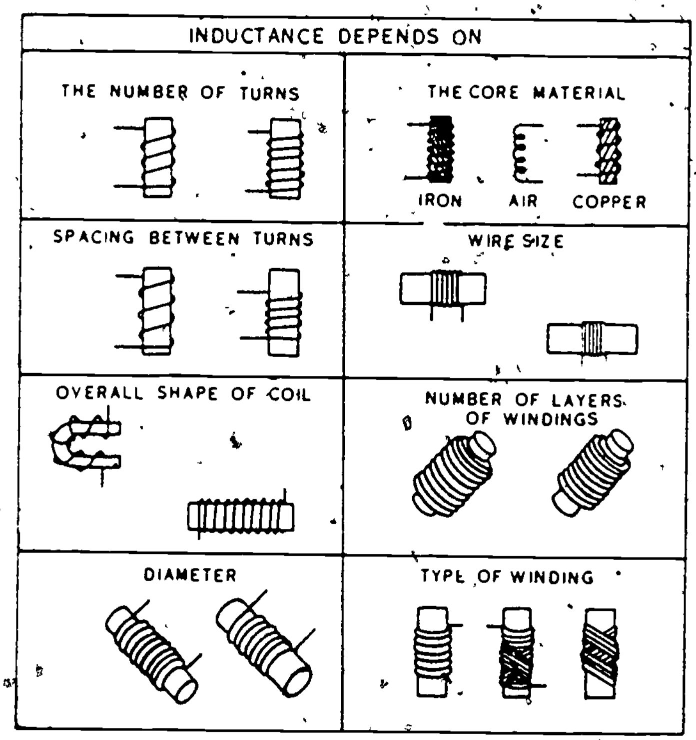


Figure 47. Physical Construction Affects Inductance

Unit of Measure

The basic unit of measure for inductance is the henry. A coil has an inductance of one henry if a current change of one ampere per second causes an induced EMF of one volt. For quantities of inductance smaller than one henry, the millihenry and microhenry are used. A unit larger than the henry is not normally used since inductance normally is of a value which can be expressed in henries or part of a henry. The symbol for inductance is the letter (L).

Inductive Reactance (X_L)

Inductive reactance is the opposition to current flow offered by the inductance of a circuit. Its symbol is X_L, with the X representing reactance and L representing inductance. Inductive reactance is measured in ohms.

PHASE RELATIONSHIP. Inductive reactance not only limits the current flowing in an ac circuit but also tends to retard the building-up and falling-off of current.

RESISTANCE. If an ac circuit has only resistance, the current rises and falls at approximately the same time as the voltage and the two waves are said to be in phase with each other (figure 48).

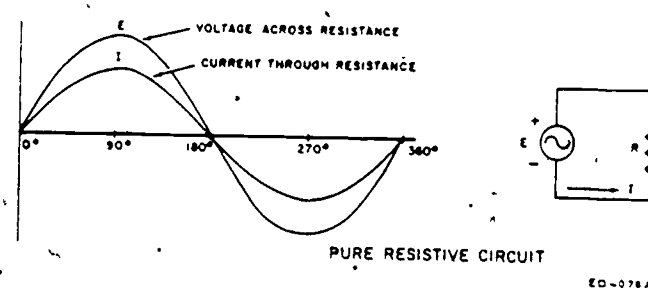


Figure 48. Voltage and Current In-Phase

INDUCTANCE. If an ac circuit has only pure inductance, the current is delayed in building-up and falling-off and lags behind voltage approximately 90° as shown in figure 49.

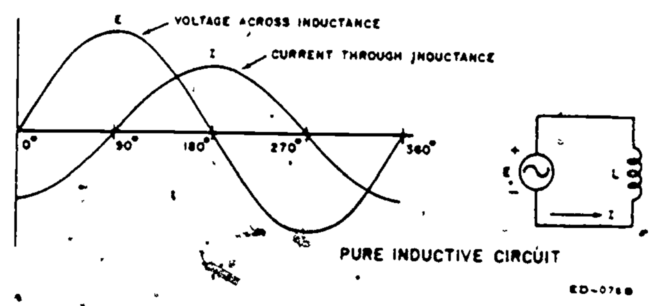


Figure 49. Current Lagging Voltage

INDUCTANCE AND RESISTANCE. In a circuit containing both inductive reactance and resistance, the alternating current sine wave will lag the voltage sine wave by less than 90 degrees (figure 50). The exact amount of lag depends on the ratio of circuit resistance to circuit inductance. The greater the resistance compared to the inductance, the nearer the two waves are to being "in phase," and the lower the resistance compared to the inductance, the nearer the sine waves are to being a full 90 degrees "out of phase."

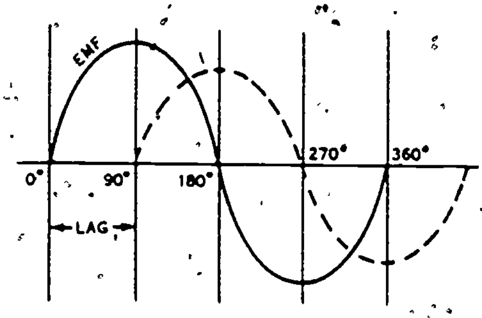


Figure 50. Current Lagging Voltage by 90 Degrees

PHASE ANGLE. When stated in degrees the current lag is called the "phase angle." If the phase angle between the voltage and the current is 45 degrees lagging, it means that the current wave is lagging the voltage sine wave by 45 degrees. Since this is halfway between zero degrees (the phase angle for a resistive circuit) and 90 degrees (the phase angle for an inductive circuit), the resistance and the inductive reactance must be equal, with each having an equal effect on the current flow (figure 57).

The inductive reactance must be added to the resistance in such a manner as to take into account the phase angle between the voltage drop across the resistance and the voltage drop across the inductance to determine the total opposition to current flow. This opposition is called impedance.

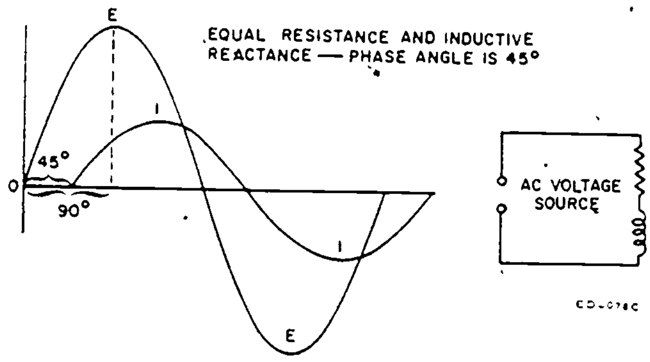


Figure 51. Phase Angle

CAPACITANCE (C)

Capacitance is the property of an electric circuit that opposes any change in the voltage of that circuit (figure 52). That is, if the applied voltage increases, capacitance opposes the change and delays the voltage increase across the circuit. If the applied voltage decreases, capacitance tends to maintain the higher original voltage across the circuit, thus delaying the voltage decrease across the circuit. Consequently, the most noticeable effect of capacitance in an electric circuit is that voltage can neither increase nor decrease as fast in a capacitive circuit as it can in a noncapacitive circuit.

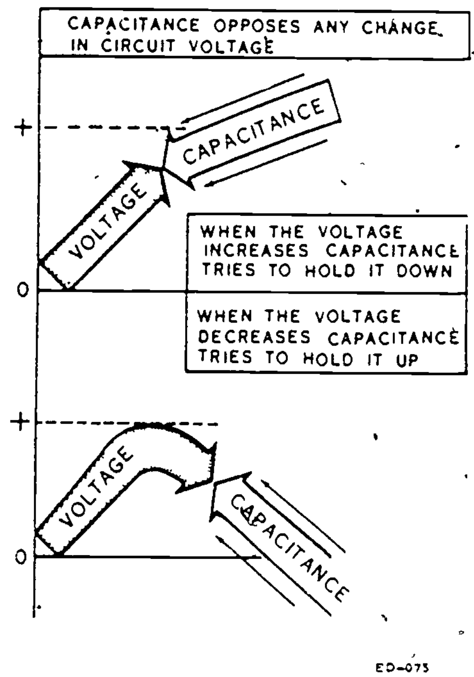


Figure 52. Capacitance

Capacitor

Electrical devices which are used to add capacitance to a circuit are called "capacitors." Another term sometimes used instead of capacitor is "condenser." The words "capacitor" and "condenser" are sometimes used interchangeably because they mean the same thing.

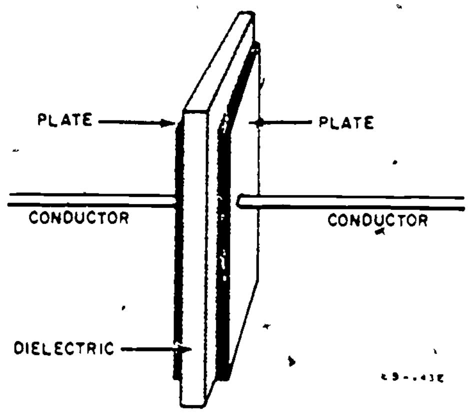


Figure 53. Basic Capacitor

Basically, capacitors consist of two metal plates separated by an insulating material called the "dielectric" (figure 53). While early condensers were made with solid metal plates, newer types of capacitors use metal foil, particularly aluminum foil, for the plates. Dielectric materials commonly used include air, mica and waxed paper.

Storage Action

Capacitance exists in an electric circuit because a capacitor is able to store electric charges (figure 54). Consider two flat metal plates placed parallel to each other, but not touching. These plates can be given either a negative charge or a positive charge. If charged negatively, a plate will have an excess of electrons, but if charged positively it will have too few electrons.

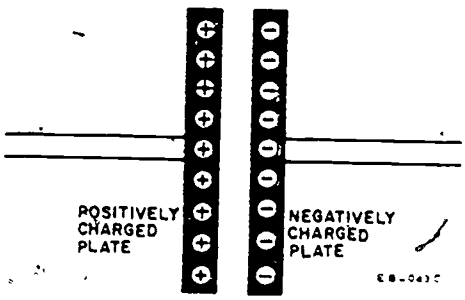


Figure 54. Storage Action

Factors Which Effect Capacitance

Three basic factors which influence the capacity of a capacitor are the area of the plates, the distance between the plates (thickness of the dielectric), and the material used for the dielectric.

1.9

PLATE AREA. Plate area is a very important factor in determining the amount of capacitance, since the capacitance varies directly with the area of the plates. A large plate area has room for more excess electrons than a small area, and thus it can hold a greater charge. Similarly, the large plate area has more electrons to give up and will hold a much larger positive charge than a small plate area. Thus an increase in plate area increases capacitance, and a decrease in plate area decreases capacitance (figure 55).

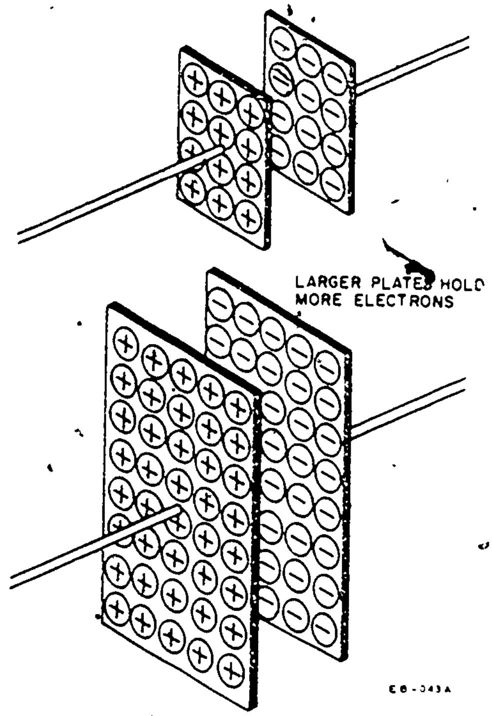


Figure 55. Plate Area Affects Capacitance.

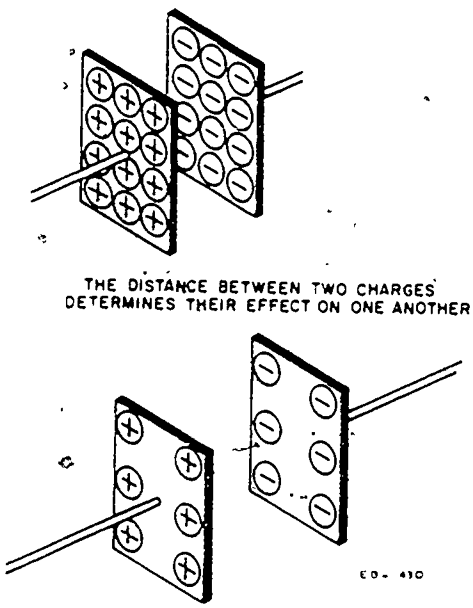


Figure 56. Distance Between the Plates Affects Capacitance

DISTANCE BETWEEN THE PLATES. The effect two charged bodies have on each other depends on the distance between the two. Since the action of capacitance depends on the two plates and the difference in their charges, the amount of capacitance changes when the distance between the plates changes. The capacitance between two plates increases as the plates are brought closer together and decreases as the plates are moved apart (figure 56).

DIELECTRIC MATERIAL (INSULATOR). The material between the two plates of a capacitor is called a dielectric. The material can be either air, liquid or a solid. If there is nothing between the plates but air the capacitor has an air dielectric; if it is mica, it has a mica dielectric; and if it is ceramic it has a ceramic dielectric. The type of dielectric determines the capacity of a capacitor. As a matter of fact, if you slide a piece of mica as shown in figure 57 between the plates of a capacitor so the mica fills up the space, you will find the capacity increases somewhere between 6 and 8 times.

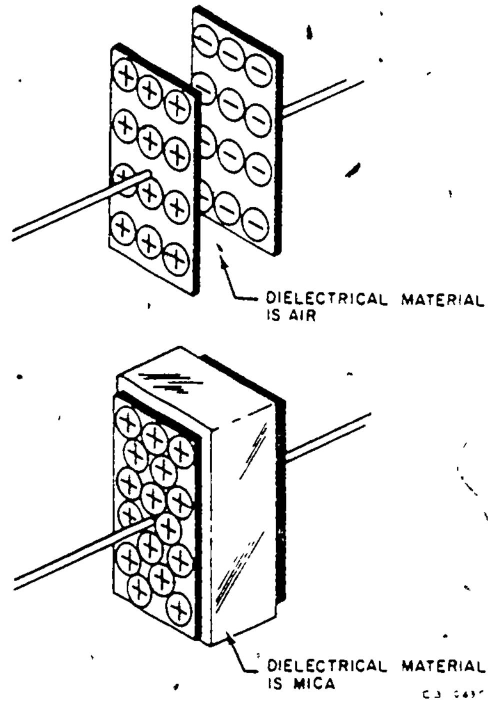


Figure 57. Dielectric Material Affects Capacitance

Unit of Measure

The action of a capacitor in a circuit is to store a charge. This charge varies with the voltage across the capacitor, increasing if the voltage rises, and discharging if the voltage falls. The basic unit of capacitance is the farad. This is a measure of how much of a charge a capacitor can store. The storage capacity of a capacitor rated at one farad is much too great to use in practical electrical circuits. Because of this, the units normally used are the microfarad (equal to one-millionth of a farad) and the micromicrofarad (equal to one-millionth-millionth of a farad). Since electrical formulas use capacitance stated in farads, it is necessary to change the various units to the base unit.

MICROFARADS TO FARADS. Move the decimal point 6 places to the left. Example, 120 microfarads equals 0.000120 farads.

MICROMICROFARADS TO FARADS. Move the decimal point 12 places to the left. Example, 1500 micromicrofarads equals 0.000000001500 farad.

To see how capacitance affects the voltage in a circuit, assume a circuit contains a two-plate capacitor, a knife switch and a dry cell (figure 58).

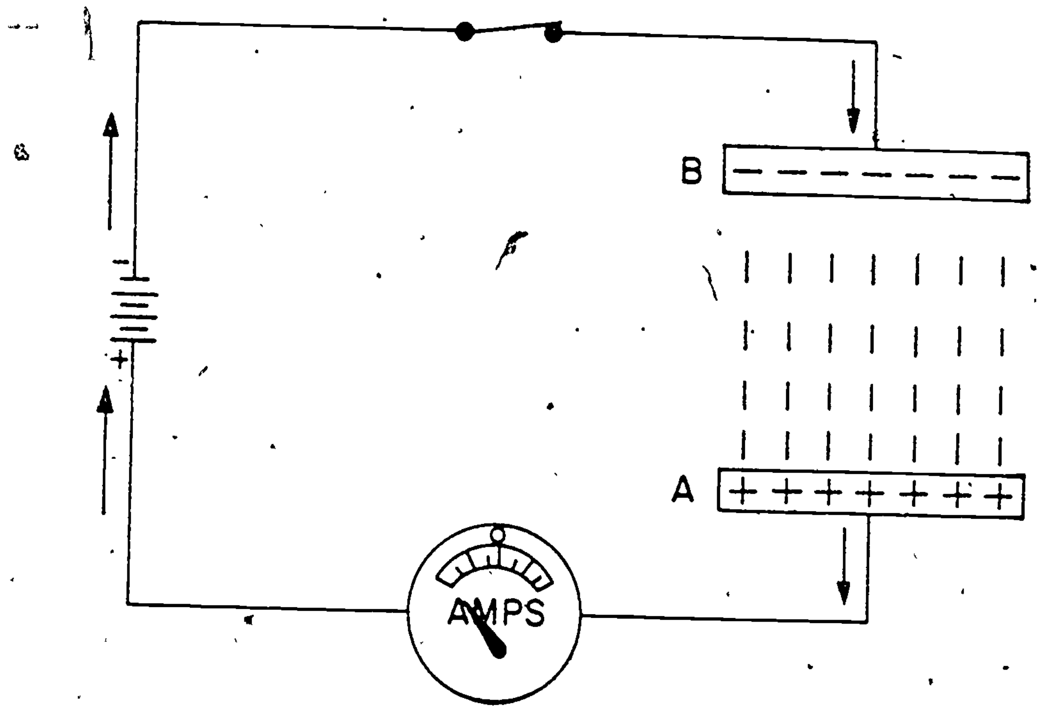


Figure 58. Charging a Capacitor

When the switch is closed, the battery furnishes electrons to the plate connected to the negative terminal and takes electrons away from the plate connected to the positive terminal. The voltage between the two plates should equal the voltage between the battery terminals. However, this does not occur instantly because one plate must lose excess electrons to become positively charged. As electrons move onto the plate attached to the negative terminal of the cell, a negative charge is built up which opposes the movement of more electrons onto the plate. In the same manner, as electrons are taken away from the plate attached to the positive terminal, a positive charge is built up which opposes the removal of more electrons from that plate. This action on the two plates is called "capacitance" and it opposes the change in voltage. It delays the increase in voltage for a limited time but it does not prevent the change.

When the switch is opened, the plates remain charged, since there is no path between the two plates through which they can discharge (figure 59). As long as no discharge path is provided, the voltage between the plates will remain equal to that of the battery and, if the switch is again closed, there will be no effect on the circuit since the capacitor is already charged. In other words, a capacitor will block the flow of direct current after it is fully charged.

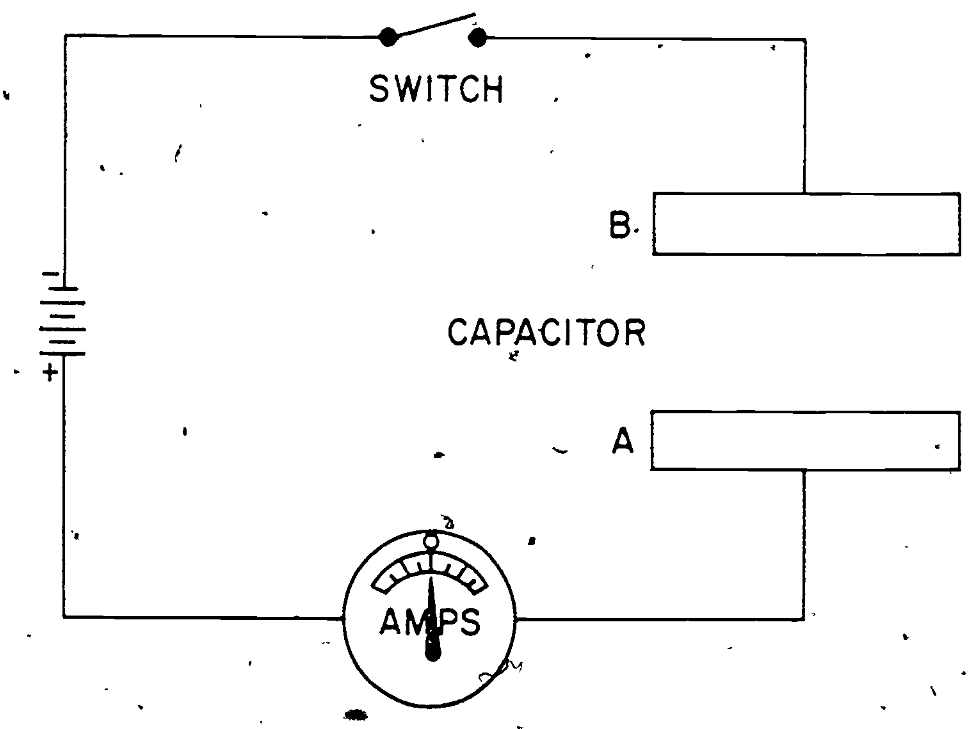


Figure 59. Fully Charged Capacitor

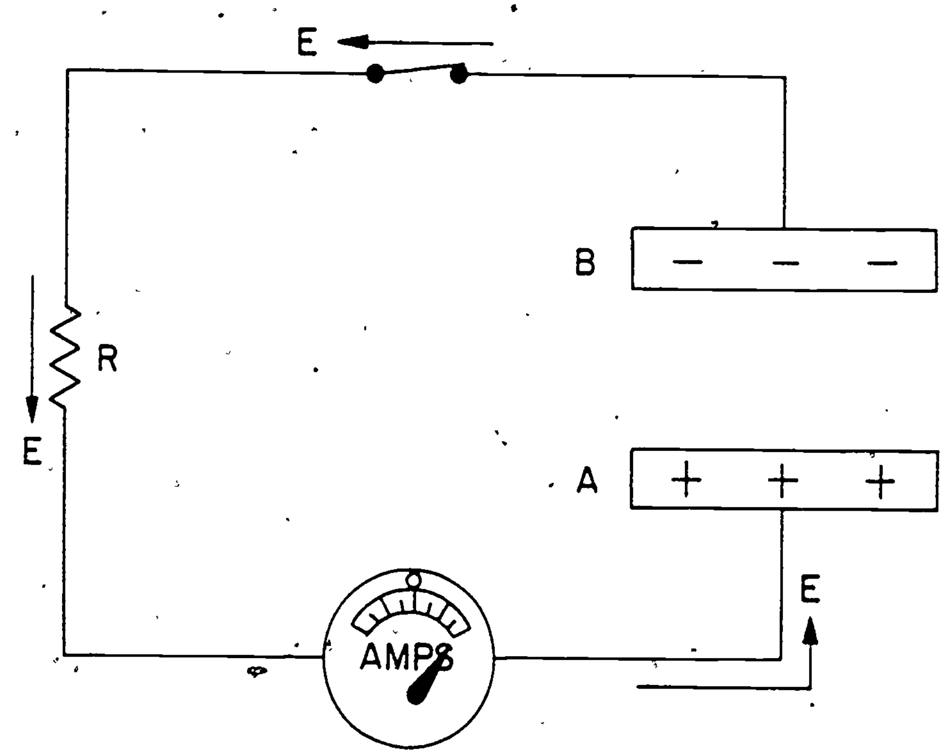


Figure 60. Shorting a Capacitor

CAPACITOR SHORTED. As previously stated, a charged capacitor will hold its charge when the circuit switch is opened (figure 60). If the capacitor terminals are shorted, the capacitor discharges causing a strong arc. Current flow during discharge of the capacitor is in the opposite direction as it was during the charging of the capacitor.

Capacitance in AC Circuits. In an ac circuit the amount of current flowing in the circuit will depend upon the applied voltage and the capacity of the capacitor. Electrons will flow back and forth in the circuit because of the alternating current flow. They will flow first into one side of the capacitor and force electrons out of the other side on which they build up a surplus and into the side on which there was a shortage. Notice the electrons do not flow through the capacitor. Remember the plates of the capacitor are separated by a dielectric and the dielectric is a nonconducting material. However because the capacitor can store a charge there is an effect of current flowing in the circuit.

Capacitive Reactance (Xc)

The capacitor does not allow electrons to move back and forth without offering opposition and the opposition is called capacitive reactance.

The opposition is measured in ohms, just as the inductive reactance of a coil is measured in ohms. However, there is a difference between inductive reactance and capacitive reactance. This is because the voltage leads the current in an inductive circuit and lags the current in a capacitive circuit as shown in figure 61. This means that the capacitor acts opposite to the coil.

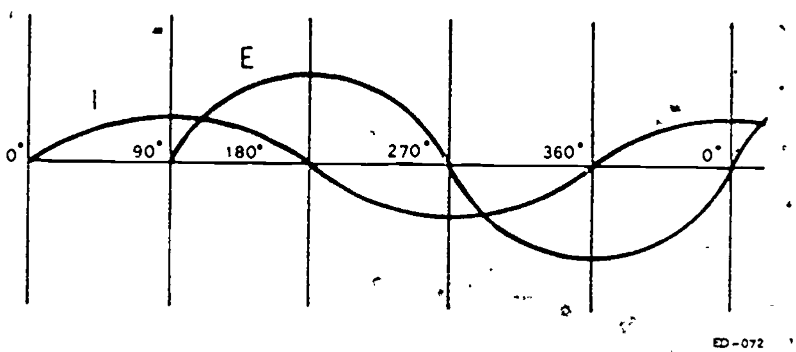


Figure 61. Current Leading the Voltage in a Capacitive Circuit

Impedance

After studying the effects of coils and capacitors it must be apparent that in alternating current circuits there are several different types of opposition to current flow. This is true, since there are actually three forms of opposition. These are inductive reactance caused by the use of coils; capacitive reactance caused by the use of capacitors; and resistance caused by resistive units such as heating elements, lighting, straight wires, etc. It must be understood that while a coil offers opposition in the form of inductive reactance, it also offers resistance, due to the resistance of the wire used in making the coil. Therefore, the total opposition to current flow in an alternating current circuit is a combination of the opposition offered by inductive reactance (X_L), capacitive reactance (X_C), and resistance R or r. This total opposition is known as impedance. The symbol for impedance is Z, and is always measured in ohms. It is not possible to just add the resistance and the reactance and arrive at the impedance. The reason for this is as mentioned previously, the difference in the phase relationship. In the resistive part of the circuit we would have the current and voltage in phase while in the reactive portion they would be out of phase. For this reason formulas must be used to find the circuit values.

SUMMARY

Inductance is that property of a circuit which opposes any change in the rate of current flow. The symbol for inductance is L. and the basic unit of measurement is the henry.

A coil is said to have an inductance of one henry when a change in current of one ampere per second causes an induced back EMF of one volt.

The factors that affect the amount of inductance of a coil of wire are the number of turns, the type of core, the spacing and method used in winding the coil, the diameter of the coil, and the ratio of the diameter to the length.

When the magnetic field of an inductor induces a back EMF in the inductor itself, it is said to possess self-inductance.

The current lags the voltage in an inductive circuit. The opposition of an inductor to the flow of alternating current is called inductive reactance. Since the symbol for reactance is X, the symbol for inductance is L. the symbol for inductive reactance is X_L and is measured in OHMS.

The capacity for storing energy in an electric field is called capacitance. The amount for capacitance of a capacitor depends upon the plate area, distance between plates, and the type of dielectric material used in a particular capacitor. The symbol for capacitance is C, and the basic unit of measurement is the FARAD.

The opposition of a capacitor to alternating current is called capacitive reactance. The current leads the voltage in a capacitive circuit. In ac circuits the opposition to current flow is called impedance. If a resistor is the only component in an ac circuit, the impedance and the resistance of the circuit are the same. The impedance of an ac circuit may also be due to inductors or capacitors, or a combination of inductors, capacitors, and resistors. Impedance is measured in OHMS and its symbol is Z. It is the total opposition of the circuit.

QUESTIONS

1. The property of an electric circuit which tends to prevent a change in current is called ________________.
2. The letter symbol for inductance is ________________.
3. Inductance is measured in ________________.
4. A coil used to add inductance into an ac circuit is called an ________________.
5. The opposition to current flow caused by inductance is called ________________ ________________.
6. Capacitance is that property of an electric circuit that opposes any change in ________________.
7. The letter symbol for capacitance is ________________.
8. Electrical devices which are used to add capacitance to an electric circuit are called ________________ or ________________.
9. Capacitance is measured in ________________.
10. Three factors which affect the value of a capacitor are:
    a. ________________.
    b. ________________.
    c. ________________.
11. The total opposition to current flow is called ________________.
12. The letter symbol for impedance is ________________.

REFERENCES

1. MIL-STD-15-3, Electrical Wiring Symbols for Architectural and Electrical Layout Drawings, Part 3.

2. TO 31-1-141-2, Basic Electronic Technology and Testing Practices, Chapter 3.

3. Basic Electricity, Volume 1, Van Volkenburgh.

METERS

OBJECTIVES

The objective of this study guide is to teach you the operation and use of electrical meters used in your career field.

INTRODUCTION

Meters are used in maintaining, troubleshooting, and repairing electrical equipment. You will find that the proper operation of electrical devices requires that you properly interpret meter readings. The best and most expensive measuring instrument is of no use to the man who does not know what he is measuring or what the readings indicate. You must remember that the function of a meter is to measure quantities. When a meter is inserted into a circuit, it should not change the value of the circuit. This requirement is not easily achieved because most meters require current for their operation and this current must come from the circuit being measured.

All meters are either self-excited or externally-excited. Self-excited meters have their own source of power. Externally-excited meters get their power to operate from the circuit they are used in. Meters also can be classified as indicating or recording. If they give an instant reading and do not leave a record, they are indicating type meters.

In order to teach you how to measure current, resistance and voltage the TS-297/U multimeter, the AN/PSM-1 and AN/PSM-2 and clamp-ammeter are used exclusively throughout this study guide.

INFORMATION

THE MULTIMETER TS-297/U

The multimeter (TS-297/U), is a multirange, alternating-current (ac) and direct current (dc) volt ohmmeter. This meter may be used for measuring voltage, current or resistance within the ranges of the meter. The TS-297/U multimeter is shown in figure 62.

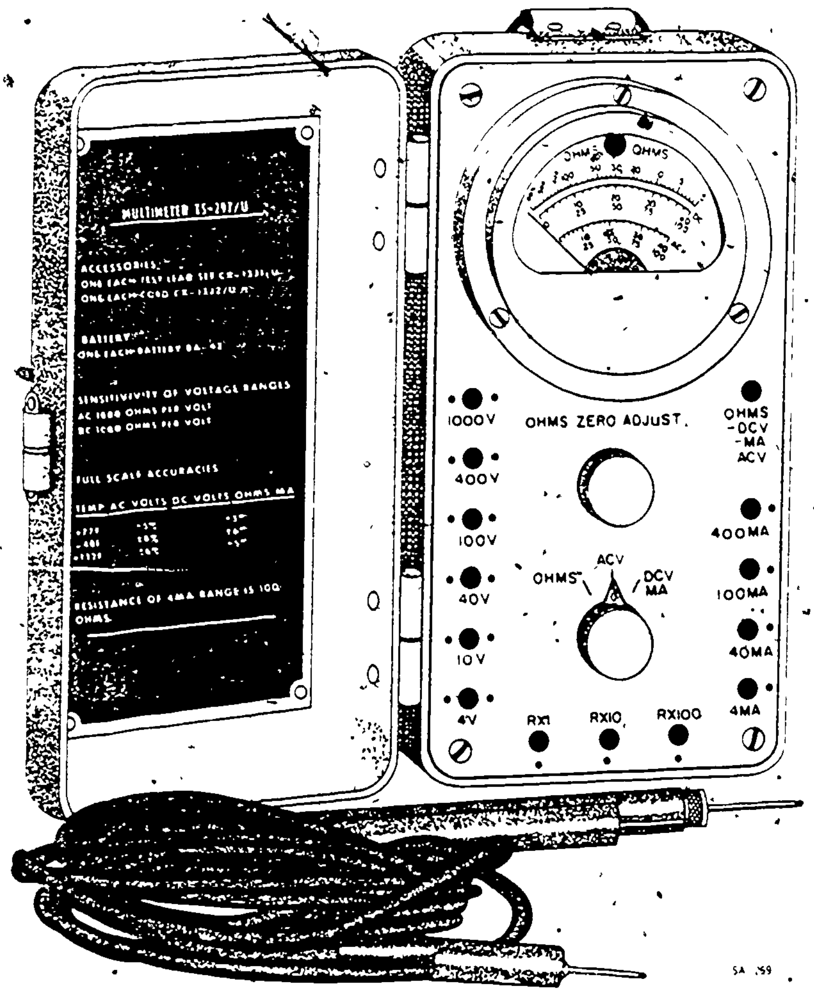


Figure 62. Multimeter TS-297/U With Cord CX-1332/U

Using the Multimeter TS 297/U

Figure 63 shows a multimeter. On the face of this meter you will see two knobs. One is the zero adjust knob for the ohmmeter scale, while the other is called the selector switch. By using this switch you may make this meter into an ohmmeter, ac - voltmeter, dc - voltmeter, and dc - milliammeter. This meter will not read above 400 milliamperes or .4 ampere, but it will read up to 1000 volts.

Two test lead probes are used with this meter when taking measurements. The black test probe always goes in the jack located at the upper right-hand corner. This is called the common jack. The position of the red test probe will depend on what you want to measure. If you are measuring voltage, place selector switch in correct position and the red test probe in one of the jacks on the left side of the meter. If the voltage you are measuring is unknown, use the 1000-volt jack. Once you find the voltage, change to the jack to just above that voltage for greater accuracy. If you want to read milliamperes, place selector switch in correct position and place the red test probe in the jacks on the right. If you need to check continuity or measure resistance, place the test probe (red) in one of the jacks in the manner described previously. When you finish with this meter always turn the selector switch on the ac or dc voltage positions. Since the ohmmeter has a battery, it may discharge if the selector switch is left in the ohm position.

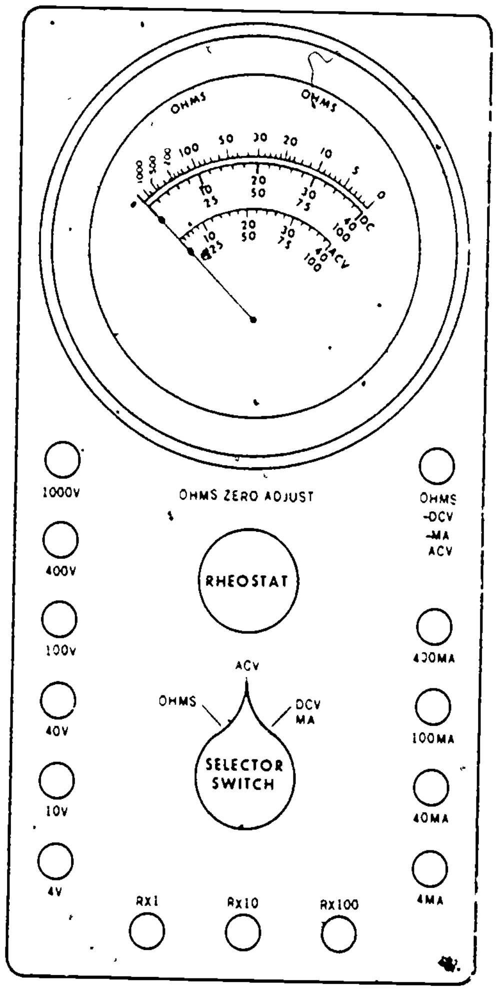


Figure 63. Multimeter

You can readily see that the scales are labeled ac, dc, and ohms. You use the dc scale for dc voltage and milliamperes. Looking at the two ac scales, you can see a 100-volt and a 40-volt scale. If you have your test probe in the 1000-volt jack of the meter, you use the 100-volt scale and add a zero to each figure so that 100 becomes 1000, 75 becomes 750, 50 becomes 500, and 25 becomes 250. If you use the 400-volt jack, you also add a zero to each figure in the 40-volt scale. Should you use the 10-volt jack, you use the 100-volt scale and subtract a zero from each figure on the scale. If you use the 4-volt jack, use the 40-volt scale and subtract a zero from each figure. This scale would then become 0, 1, 2, 3, 4, instead of 0 through 40.

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When using the ohmmeter portion of this multimeter, always touch the two test probes together and use the zero adjust knob to bring the pointer to zero before using it. This takes care of battery loss and internal resistance. When the pointer can no longer be zeroed in, the battery should be replaced. You will notice that the scale reads just backwards of the other scales. At the end of the ohmmeter scale you will notice the symbol for infinity. This means that when the pointer is touching this, the resistance is an infinite amount (too large to measure).

Rx1 means that you take the reading on the scale and multiply it by 1. "R" is the reading on the scale. This reading of 500 ohms would place the pointer into the crowded section of the scale. You could get more accuracy by using the Rx10 terminal. Then the pointer would actually rest on 50 ohms. Fifty ohms times 10 would be 500 ohms. If you did this, your pointer would be on the portion of the scale where the numbers are evenly distributed. For a more accurate reading try to keep the pointer as nearly as possible to the center of the scale.

CAUTION: Never use the ohmmeter on a live circuit as it will damage the meter.

Insulation Test Set AN/PSM-1A and AN/PSM-2A

The ohmmeter AN/PSM-1A is designed to measure insulation resistance from 0 to 100 megohms and the ohmmeter AN/PSM-2A is designed to measure insulation resistance from 0-1000 megohms. The testing voltage of both models is 500-volts dc which is provided by a hand-cranked generator. Turning the crank in either direction until the indicators glow steadily red generates 500-volts dc testing voltage which is available at the binding posts.

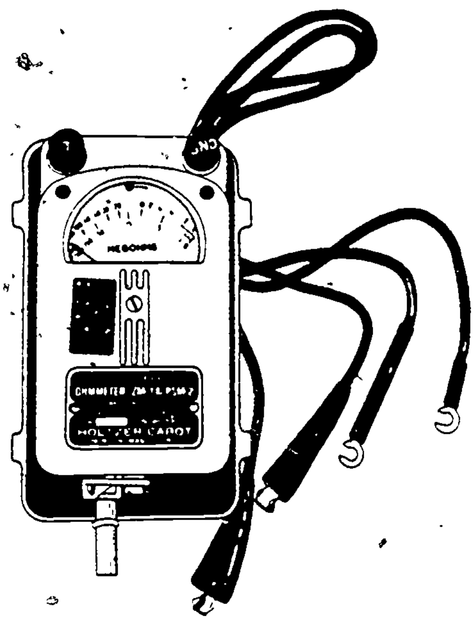

Figure 64. Insulation Test Set AN/PSM-1 and AN/PSM-2A

The Insulation Tester (megohmmeter), figure 64, checks the insulation of coils and windings of motors, generators, and transformers. Considering various machines, the insulation resistance of windings may range to several thousand megohms (million ohms). The megohmmeter is used by connecting one test lead to the conductor and the other lead to ground, and rotating the handcrank just fast enough to keep the indicator lamps glowing. Any current leakage through the insulation will cause the pointer to move up the scale. The pointer will indicate the amount of insulation resistance in megohms. The voltage should be applied for at least 30 seconds and the pointer should stabilize before the reading is taken.

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Clamp-Multimeter

The clamp-multimeter has a 4-range, 0-600 ampere, portable ac ammeter designed for measuring current in power circuits and is so constructed that it may be used without physically breaking the circuit to be measured. It may be used for measuring current in insulated or noninsulated conductors up to 2 inches in diameter provided the current is within the range of the meter. This meter is shown in figure 65.

OPERATING PROCEDURE. Set the range selector switch to the proper position. If the approximate value of current is unknown set the range selector switch to the highest range.

Press the trigger to open the jaws, then hook the curved jaw around one conductor and release trigger.

IMPORTANT. Be sure the clamping jaws encircle only one line and are firmly closed when making the measurement.

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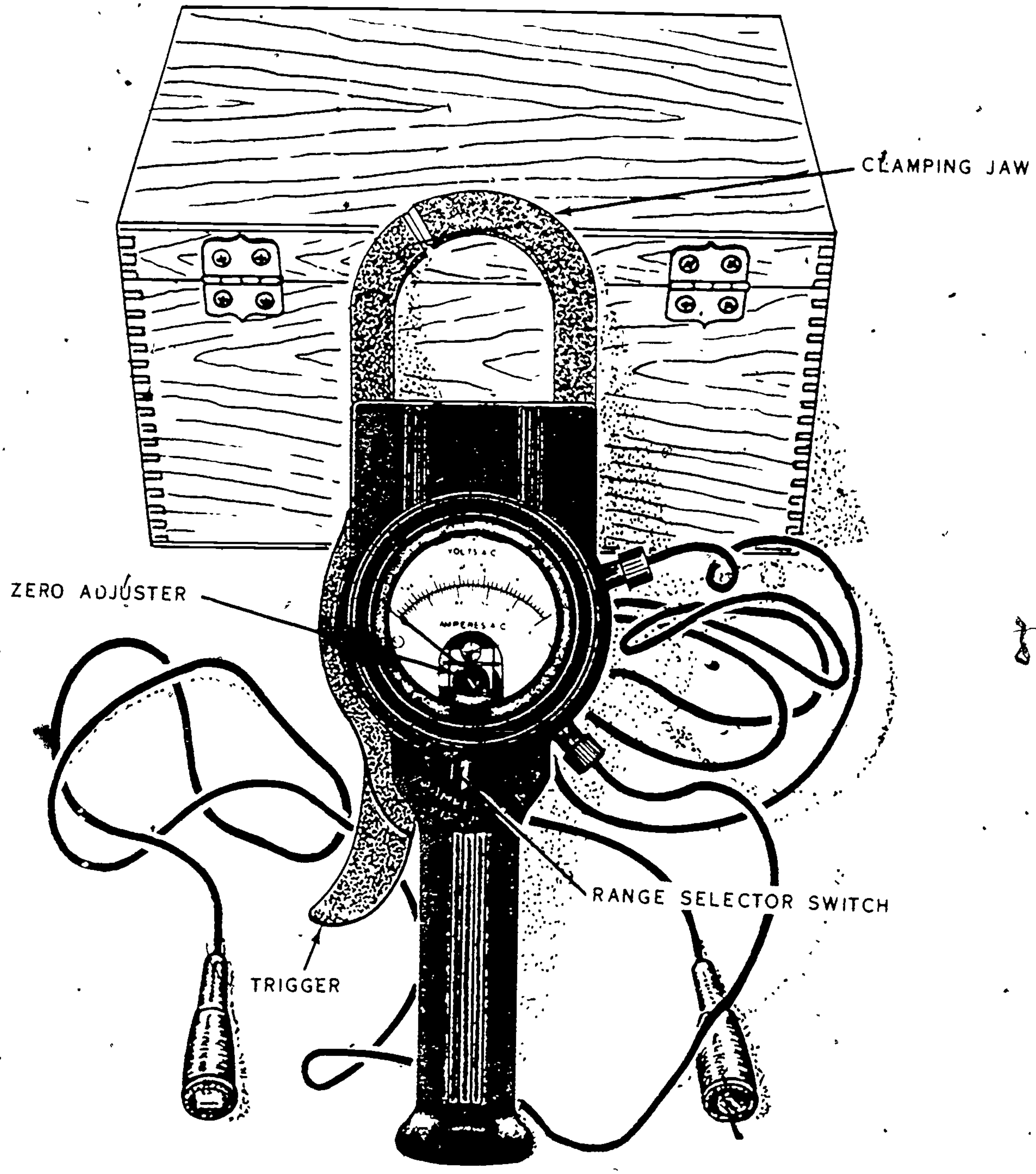

Figure 65. Clamp-Multimeter

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SUMMARY

Meters are used in maintaining, troubleshooting, and repairing electrical equipment. You will find that the proper operation of electrical devices requires that you properly interpret meter readings. The best and most expensive measuring instrument is of no use to the man who does not know what he is measuring or what the readings indicate.

Although scales vary from meter to meter they are all very similar. If you learn to read the scales of a few meters, you will be able to figure out the scale on other meters. Over most of the scale, the numbers are usually evenly distributed. At either end the numbers will be close together in some instances. You will study the reason for this later in your electrical work. When reading the scale, stand directly in front of it. If you are reading it from an angle, your reading is likely to be off. Read the number that the pointer is nearest. Put this number down to whatever accuracy you wish.

Some have their own voltage source while others depend on the circuit voltage. Remember, never use a meter or other measuring device that has its own source of power on an energized circuit. These devices will not give you quantities, but they will indicate trouble in circuits.

Each of the meters discussed consists of a basic meter movement combined with additional devices necessary for its particular purpose. A voltmeter, ohmmeter, and ammeter may be combined in one unit using only one meter movement. Switches, jacks and the necessary additional devices are included to make such a combination volt-ohm-ammeter or multimeter.

QUESTIONS

1. What is the purpose of an ohmmeter?
2. What does the term multimeter mean?
3. Does the ohmmeter have its own source of power?
4. What is the megohmmeter used for?
5. Why must an ohmmeter never be used in a live circuit?
6. What is the purpose of the zero adjust knob on the multimeter?
7. How is a voltmeter connected in a circuit?
8. Why is an ammeter always connected in series in a circuit?
9. What is the source of power in a megommeter?

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REFERENCES

1. TO 33A1-12-48-1
2. TO 33A1-12-126-1
3. TO 33A1-4-5-11

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OHM'S LAW AND SERIES CIRCUITS

OBJECTIVE

The objective of this study guide is to assist you in becoming more familiar with series circuits, Ohm's Law and Power Values.

INTRODUCTION

The relationships of current, voltage and resistance must be considered in every electric circuit. Electrical current will flow only in a closed circuit which provides a continuous conducting path from the negative to the positive terminal of the voltage source. As discussed in this lesson, Ohm's Law shows the relationships of voltage, current, and resistance in electrical circuits.

Work done by electricity is called power and is measured in watts. Watts is a result of multiplying amperage time voltage.

INFORMATION

ELECTRICAL CIRCUITS

All circuits must have at least three parts as shown in figure 66. These parts are;

Source of voltage

Conductors

Unit of resistance

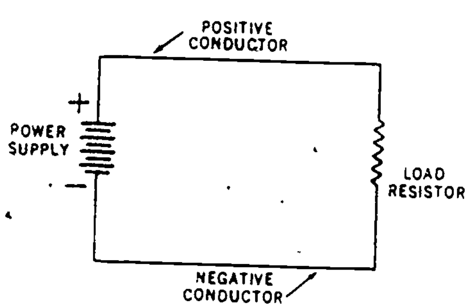

Figure 66. Basic Circuit

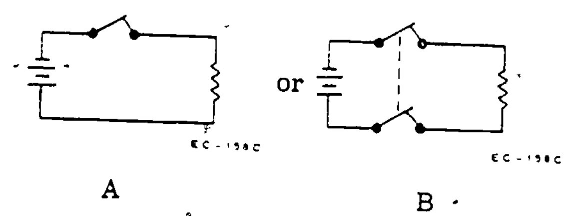

Figure 67. Simple Circuit

A circuit may have other units, but to be properly called a circuit, these three parts must be present. This does not provide much in the way of control. Therefore, a switch should be added to shut off the current flow. Now the circuit will look like figure 67.

Many different types of switches may be used. In figure 67, example B, no current passes through the dotted lines. This merely indicates that the two parts of the switch are connected together physically and not electrically. It is called a double-pole, single-throw switch.

To protect the parts of the circuit and the people working around the circuit, some form of self-protection should be added to the circuit. There are many different types of protection devices that may be added to a circuit. Perhaps the most common are fuses (⁀) and circuit breakers (⁄). Both of these devices protect a circuit from an overload or an excessive amount of current. A fuse operates on the principle that current flowing through a resistance causes heat. The greater the current, the greater is the heat produced. When the current which flows through the low resistance of the fuse becomes excessive, the heat becomes sufficient to melt the fuse and open the circuit. This prevents further current flow and protects the circuit from damage. Fuses are of many different types and sizes. Since fuses are used to protect conductors and equipment from overload, do not replace a fuse with one of a larger rating. A circuit breaker operates on similar principles and does the same job as a fuse. Figure 68 shows how a fuse may be installed to protect a circuit.

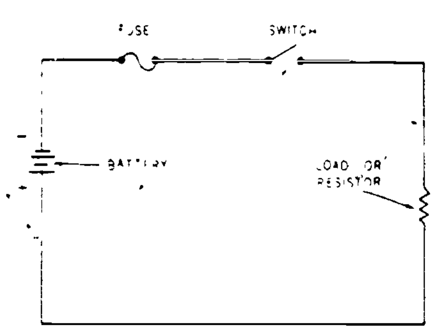

Figure 68. Simple Circuit

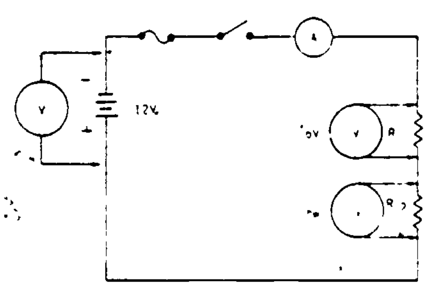

Figure 69. Measuring Current and Voltage

To determine the amount of current flowing in the circuit, an ammeter (Ⓐ) is added to the circuit. An ammeter is always connected in series with the circuit or end-to-end with what you are measuring. See figure 69.

Since you can measure only the difference in pressure between two points, the voltmeter (Ⓥ) is not connected directly into the circuit. It is connected across the resistance, voltage source, or other electrical device. This is referred to as a parallel connection. See figure 69.

Circuits also have other classifications. They are often broken down into simple, series, parallel, and series-parallel or (combination) circuits. These are shown in figure 70.

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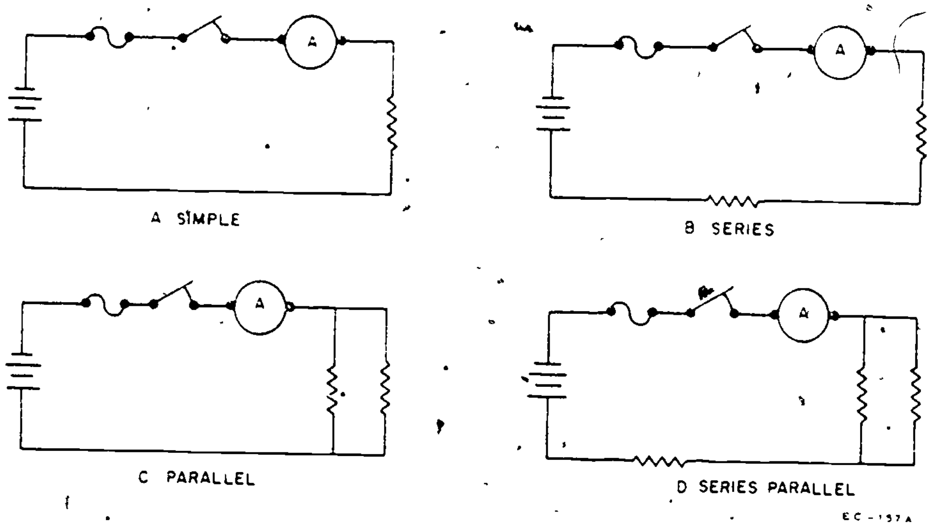


Figure 70. Circuit Classification

Most electricians refer to the simple circuit as a series circuit since its single resistor is connected in series with the fuse, switch, etc.

SERIES CIRCUITS

A series circuit is one in which resistance or electrical devices are connected end-to-end as shown in figure 71. Note that the path of current flow is from the negative side of the battery through lamps L_1, L_2, and L_3, and back to the positive side of the battery. It is apparent that if the filament of any one lamp burns out (opens), the current path is no longer complete and the other lamps must also go out. You have probably seen this happen with Christmas tree lights in series. A series circuit may, therefore, be defined as a circuit in which the current flows in only one path. Each unit of resistance is dependent on the other units.

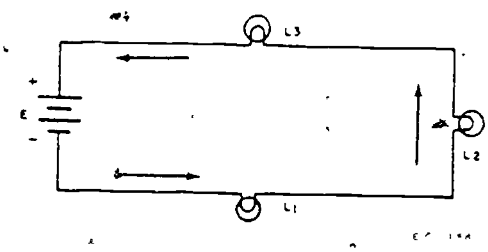


Figure 71. Series Circuit

The characteristics concerning the voltage, current, and resistance of a series circuit are as follows:

Voltage

The sum of the voltage drops equal the total voltage. In other words, if you were to measure the voltage across each resistor with a voltmeter and add these voltages they would equal the total voltage or source voltage. Expressed mathematically, $E_T = E_1 + E_2 + E_3 +$ etc. (See figure 72.)

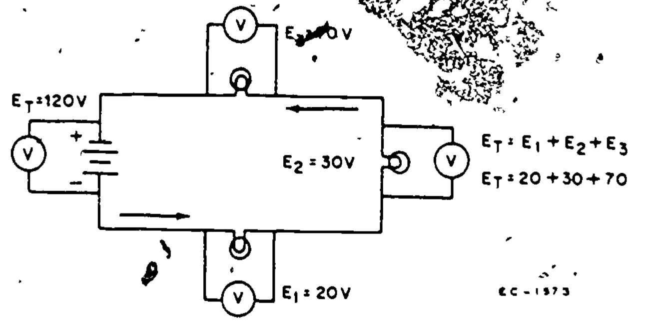


Figure 72. Series Circuit

Current

The current which flows is the same in each part of a series circuit. Expressed mathematically, $I_T = I_1 = I_2 = I_3$, etc. Where I_T is the total current and I_1, I_2, and I_3, respectively. (See figure 73.)

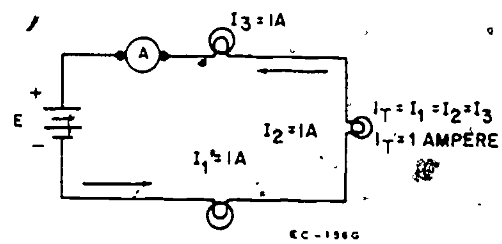
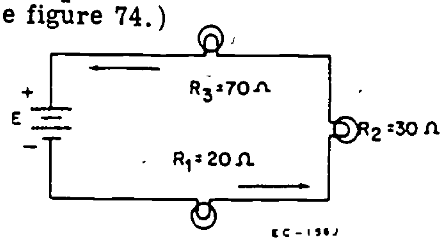


Figure 73. Series Circuit

Resistance

The current which flows in the series circuit meets opposition from each resistor, in turn. If the resistors R_1, R_2, and R_3 were 20, 30, and 70 ohms, respectively, the current in the circuit would meet a total opposition of 120 ohms. The three resistors would then offer the same opposition to the current in the circuit as one resistor of 120 ohms. IN A SERIES CIRCUIT, THE TOTAL RESISTANCE IS EQUAL TO THE SUM OF THE INDIVIDUAL RESISTANCE. Expressed mathematically, $R_T = R_1 + R_2 + R_3$, etc. Where R_T is the total resistance and R_1, and R_2, and R_3 are the resistance in series. (See figure 74.)



$R_T = R_1 + R_2 + R_3$

$R_T = 20 + 30 + 70 = 120$ ohms

Figure 74. Series Circuit

You have seen that an electrical circuit consists of a source of potential connected to an electrical device which has resistance. When the circuit is completed, current flows in a closed path.

In 1827, George Simon Ohm discovered that the amount of current which flows in a circuit increases if the potential (voltage) applied is increased, and decreases if the resistance of the circuit is increased. He also found that the current decreased when he decreased the potential applied, and increased if the resistance were decreased. These findings are known as Ohm's law which states that the current in a circuit is directly proportional to the applied voltage and inversely proportional to the resistance. Often this statement is expressed mathematically by means of the Ohm's Law triangle or circle as shown in figure 75.

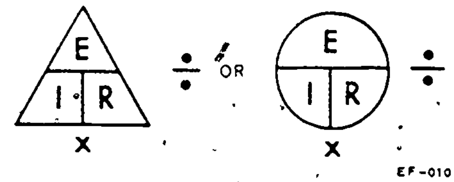


Figure 75. Ohm's Law Triangle and Circle

Where E is the EMF in volts, I is the intensity of the current in amperes, and R is the resistance in ohms. The formulas may be derived from the above:

$$E = I \times R, \quad R = E/I, \text{ and } I = E/R.$$

If you know any two factors, you can always find the third. Put your finger over the factor you want to find in either the triangle or circle and you will have the other two factors to replace with the known values.

Subletters may be used to distinguish between various parts of a circuit. (See figure 76.) E_T, I_T and R_T represent total voltage, current, and resistance, while E_1, I_1, and R_1 represents facts about lamp or resistor 1, and E_2, R_2 and I_2 represent facts about resistor 2.

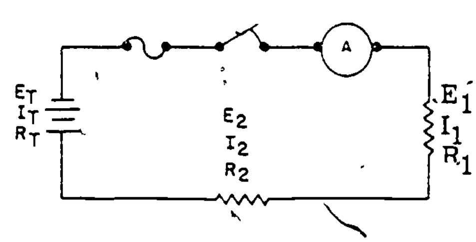


Figure 76. Representing Circuit Parts

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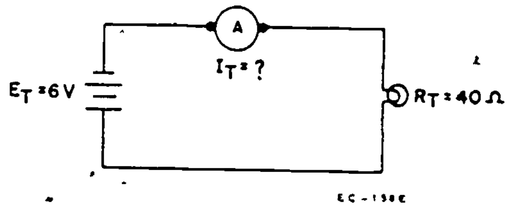
Ohm's law may be used to solve various problems as shown below.

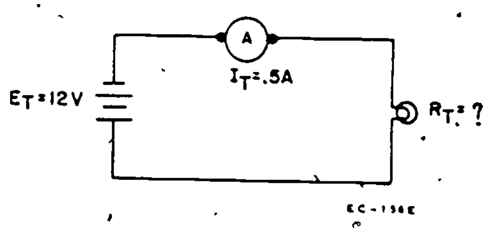
1. A lamp of 40-ohm resistance is connected to a battery of 6 volts. How much current does the lamp draw?

E_T = 6 volts
R_T = 40 ohms
$I_T = E_T/R_T$
I_T = 6 volts/40 ohms
I_T = .15 amperes



Find: I_T

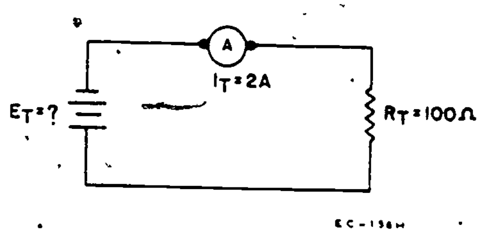
2. What is the resistance of the filament of a light bulb which requires 12 volts and draws .5 amperes?



Given: E_T = 12 volts, I_T = .5 amperes Find: R_T

$R_T = E_T/I_T$, R_T = 12 volts/.5 amperes, R_T = 24 Ω

3. A 100-ohm resistor has 2 amperes of current flowing through it. What is the voltage across the resistor?



Given: R_T = 100 ohms, I_T = 2 amperes Find: E_T

Solution: $E_T = I_T \times R_T$, E_T = 2A x 100, E_T = 200 volts

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POWER VALUES

To assure the circuits you construct or other equipment you install will operate properly and safely, it is necessary to know how much Electrical Power is required. To determine the power, certain other terms must be understood.

Work

Work is the overcoming of opposition through a certain distance. Work requires for its definition two very basic factors--that of force and that of distance. The amount of force is that which causes or tends to cause a change in the motion of bodies. A good example of force is voltage. We define it as the force that moves electrons in a conductor. Voltage does work for us and, of course, we must pay for this work when we pay our electric bill. Work accomplished is found by multiplying the force applied against an object by the distance the object is moved. Technically, even though force is applied, no work is done unless an object is moved at least a little. Distance must be involved. Mathematically expressed:

$W = F \times D$ or Work - Force x Distance
W = Work Done by the Object
F = Force in Pounds Applied to the Object
D = Distance Object is Moved in Feet

Power

Power is the time rate at which work is done, and is measured in foot-pounds per second. Expressed mathematically, Power = Work/Time.

The following example will illustrate the difference between work and power. When a 100-pound bag of sand is dragged 10 feet, 1,000 foot-pounds of work is performed. If this work is performed in 5 seconds, the power required is:

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{1,000 \text{ ft lbs}}{5 \text{ sec}} = 200 \text{ ft lb per second}$$

If the 100-pound bag is dragged 10 feet in 10 seconds, the power required is:

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{1,000 \text{ ft lbs}}{10 \text{ sec}} = 100 \text{ ft lb per second}$$

Mechanical power is usually measured in horsepower (hp). One horsepower equals 550 foot-pounds per second or 33,000 foot-pounds per minute.

Electrical power is measured in watts or kilowatts. A kilowatt is 1,000 watts; it is often used because a watt is such a small unit. Electricity is normally paid for in kilowatt hours. A watt used for an hour is a watt hour or a kilowatt used for an hour is a kilowatt hour. To change 2,200 watts to kilowatt, divide by 1,000. 2,200/1,000 = 2.2. The basic unit is the watt. One horsepower is equal to 746 watts or .746 kilowatt. One watt equals .00134 horsepower and one kilowatt equals 1.34 horsepower. One watt is equal to one ampere moved through a potential difference of one volt. In other words, when an ampere of current flows between two points, the difference of potential of which is 1 volt, 1 watt of power is being expended between these two points. Thus, the power used in any circuit is the product of the voltage and the current flowing in that circuit. Expressed as equations:

$$P = I \times E, \text{ or } E = \frac{P}{I} \text{ or } I = \frac{P}{E}$$

Where P is the power in watts, I is the current, and E is the potential difference in volts, often they are placed in a triangle and the equation formed in the same manner as Ohm's law. See figure 77.

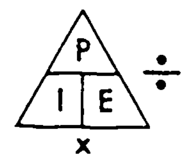


Figure 77. Power Triangle

The power formula is often remembered as watts = Volts x Amperes. Since the watt is a very small unit of power, we commonly use the kilowatt (kw), which is 1,000 watts as mentioned previously.

$$\text{Kilowatt} = \frac{\text{Volts x Amperes}}{1,000}$$

It should be mentioned now that the power formulas that have been given are for dc circuits and ac circuits with only resistors. You must remember that other things must be considered in ac circuits such as inductors and capacitors, in figuring power.

1. If an electric motor requires 10 amperes at 110 volts, what is the power consumed?

   $P = I \times E = 10 \times 110 = 1,100$ watts or 1.1 kilowatt

2. If a battery charger operates at 100 volts and consumes 600 watts, what must be the smallest fuse which will maintain operation?

   $I = P/E = \frac{600}{100} = 6$-Ampere Fuse

3. What voltage will be measured at the terminals of a 500-watt generator when 10 amperes are being drawn?

   $E = P/I = \frac{500}{10} = 50$ Volts

By the use of these power formulas, one of the three quantities of current, power, or voltage can be found if the other two quantities are known.

The electrical load of this building is the power which it consumes. Everything that uses power in this building is the load.

Power may be referred to in terms of E/R X E.

Power	Ohm's Law
P = I x E	I = E/R

If I equals E/R, then substitute E/R in the power formula for I and you have:

$P = E/R \times E$ or $P = E^2/R$

If E equals I x R, then substitute I X R in the power formula for E and you have:

$P - I \times I \times R$ or $P - I^2 R$

Since power is the time rate of doing work, it follows that the greater the length of time the power is consumed, the greater will be the total power consumed. Electric power is purchased commercially in watthours (watts x hours) or kilowatt (kw) hours (watthours / 1,000). A 100-watt lamp requires 100 watts of power for proper operation and consumes 100 watthours of power in 1 hour, 200 watthours in 2 hours, etc. In terms of kilowatt hours, the above lamp uses 100W/1,000 = .1 kilowatt (kw) hour of power 1 hour; in 10 hours, the lamp uses 10 times as much, or 1 kw hour of power.

EXAMPLES

1. If a kw hourmeter reads .09 kw in 10 hours, what is the average rate of consumption?

   .09 kw = 90 watts
   90 watts/10 hours = 9 watts per hour

2. If a 2-hp motor is connected to the powerline and operated for 10 hours continuously, what will be the power consumed in kw hours?

   1 horsepower = 746 watts
   2 horsepower = 2(746) = 1, 492 watts
   Thus, 1.492 watts = 1.492 kw
   1.492 kw x 10 hours = 14.92 kw hours

POWER LOSSES

The most common loss of power in electrical work is that which is dissipated in the form of heat when current flows through a resistance. This power loss is sometimes called the I^2R loss or copper loss and is always present when current is flowing. The heat is usually dissipated into the air and lost, but it can be utilized as in the case of the electric oven, toaster, soldering iron, or filament of a vacuum tube. It may be calculated by the following formula:

$$P = I^2R \text{ or } P = \frac{E^2}{R}$$

Power losses in resistance are more important in communication work than your career field. Resistors are used to reduce the voltage to parts of different tubes. For example, if the 12-volt battery of a car is used to light a 6-volt radio tube which draws .3 ampere of current, a series resistor will be necessary. The value of this resistor may be found as follows: Since the voltage drop necessary is 6 volts, we want to lower the 12 volts to 6 volts. If the current drawn by the tube is .3 ampere, the resistance necessary will be: R - E/I - 6 volts/.3 ampere = 20 ohms. The power rating of this resistor should be: $P = E^2/R = 36/20 = 1.8$ watts or $P = I^2R = .3 \times .3 \times 20 = 1.8$ watts. Therefore, any 20-ohm resistor with a wattage rating of 1.8 watts or greater may be used. If a resistor of smaller wattage is used, it will overheat or burn out and cause an open circuit. This wattage rating indicates the safe wattage that the resistor will radiate in form of heat in free air without becoming damaged.

Electric motors have losses due to friction and resistance of windings. Therefore, the mechanical output can never equal the electrical input. The output of any power-consuming device divided by the input and multiplied by 100 will give it power efficiency in percent. (No machine can be 100 percent efficient.) This true efficiency that a machine has is often referred to as its Power Factor. The power factor is of a great deal of importance in ac circuits. It will always be less than one (1). Thus, when a machine power factor is multiplied by 100 it will be less than 100 percent efficient.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

Problems and Examples

1. If a 1-hp motor draws 6 amperes of current at 220 volts, what is the efficiency of the motor?

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{746 \text{ watts}}{220 \times 6} \times 100$$

$$\frac{74,600}{1,320} = 56.51\%$$

2. An electric iron when operating in a circuit draws 12 amperes of current at 120 volts. What power is dissipated?

$P = I \times E$
$P = 12 \times 120 = 1,440$ watts

POWER IN AC CIRCUITS

In dc circuits, the power was easily found by the various power formulas. In ac circuits, other factors must be considered and used along with the formulas you have studied. Dc circuits had only resistance to consider, while ac circuits have inductors and capacitors to also consider. They act entirely different from resistors. Their components store energy and deliver it back to the circuit at fixed intervals. The power actually used is not the power apparently used. This is normally referred to as true power and apparent power. In dc circuits and ac resistive circuits the true, power and apparent power are the same, but in the ac circuits the true power is normally less than the apparent power. Power factor has been mentioned previously. It must be taken into consideration in some types of ac circuits.

SUMMARY

To analyze and understand circuits, you must learn the various symbols that are employed in electrical schematics. All circuits must have at least three parts. They will always have a source of voltage, conductors and a unit of resistance (or other electrical devices). Of course, they usually have a protection device such as a fuse or circuit breaker and a control device (switch) of some sort.

Ohm's law is the relationship between voltage, current and resistance. The current is directly proportional to the voltage and inversely proportional to the resistance. Mathematically expressed: $E = I \times R$, $R = E/I$, and $I = E/R$. Remember to take values from the same part of the circuit. For example, do not use E_2 with R_1, etc. Studying the information contained in this study guide should prepare you for more complex circuit problems.

Power is the time rate of doing work. Voltage x current = Watts which are units of power expressed mathematically $P = I \times E$.

Figure 78 provides a chart for figuring power values and Ohm's law.

P = Power in Watts
I = Intensity of Current in Amperes
R = Resistance in Ohms
E = Electromotive Force in Volts

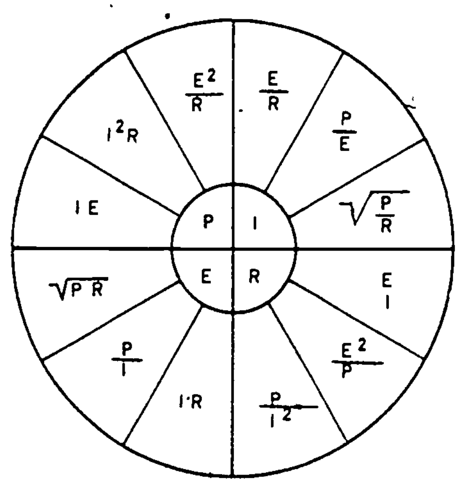


Figure 78 Chart

QUESTIONS

1. What is Ohm's Law formula for finding voltage? ____________

2. What are the essential components of a circuit? ____________

3. How many resistors does a simple circuit have? ____________

4. Is the current directly proportional to the voltage?

5. A series circuit has ____________ path for current flow.

6. The total resistance is the ____________ of the individual resistances.

7. The ____________ of the voltage drops in a series circuit must equal the applied voltage.

8. If one resistor allows 6 amperes to pass, how many amperes can pass the other resistor in series?

9. What is Power?

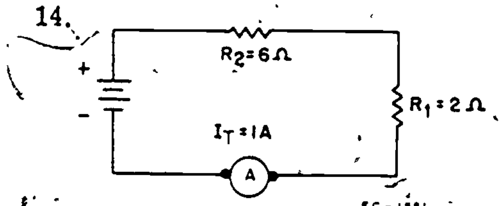
10. What is the formula for work?

11. How many watts are in a horsepower?

12. How many watts are in a kilowatt?

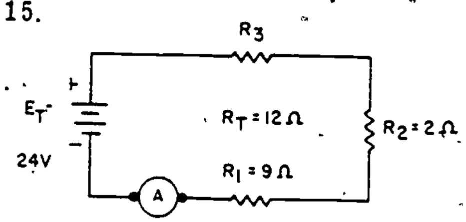
13. What is the power formula?

14.



FIND: I_2 ____________

15.



FIND: R_3 ____________

I_T ____________

E_2 ____________

P_T ____________

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200

REFERENCES

1. TO 31-1-141-2, Basic Electronics Technology and Testing Practices

2. AFP-85-1, Electrical Facilities Safe Practice Handbook

3. Basic Electricity, Volume 2, Van Volkenburgh

PARALLEL CIRCUITS

OBJECTIVE

The objective of this study guide is to help you become familiar with construction features and performance of parallel circuits.

INTRODUCTION

It is often necessary to connect electrical devices so that the entire source of voltage is across each device. A circuit in which two or more resistors are connected across the same source of EMF is a parallel circuit. As in other types of circuits, there are characteristics that pertain only to parallel circuits. Parallel circuits are found in homes, barracks, hangars, etc.

INFORMATION

CIRCUIT CONSTRUCTION FEATURES

Figure 79 is a parallel circuit, it consists of a battery and three electric lamps connected in parallel. Note that the current which leaves one terminal of the battery breaks up into three parts and then returns to the other terminal of the battery. Parallel circuits have more than one current path. (Figure 80 is a series circuit for comparison.)

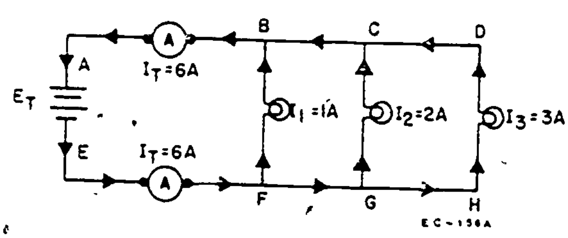


Figure 79. Parallel Circuit

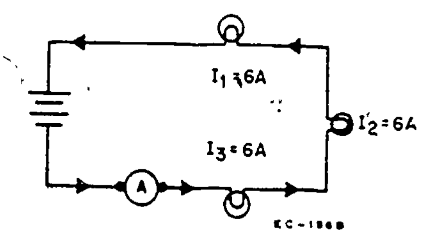


Figure 80. Series Circuit

In the parallel circuit shown in figure 81, note that points A, B, C and D are connected together and are one point electrically. Similarly points E, F, G and H, make up another electrical point. Since the applied voltage appears between points A and E, the same voltage appears between points B and F, between points C and G, as well as between points D and H. Thus, a rule regarding parallel circuits would be that the voltage is equal throughout the circuit. Expressed mathematically, $E_T = E_1 = E_2 = E_3$ where E_T is the applied voltage, E_1 is the voltage across R_1, E_2 is the voltage across R_2, and E_3 is the voltage across R_3. (See figure 81.) The voltage potential across a resistor is commonly referred to as voltage drop.

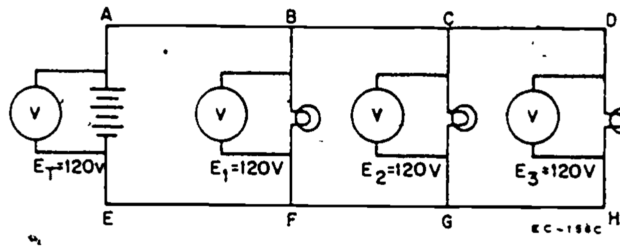


Figure 81. Computing Voltage in a Parallel Circuit

Current

Another characteristic or rule of a parallel circuit is that the current flowing toward a point is equal to the current flowing away from the point. Therefore, $I_T = I_1 + I_2 + I_3$ etc., where I_T is the total current and I_1, I_2, and I_3 are the currents through R_1, R_2, and R_3, respectively.

In other words, the total current in a parallel circuit is équal to the sum of currents passing through each individual branch as shown in figure 82.

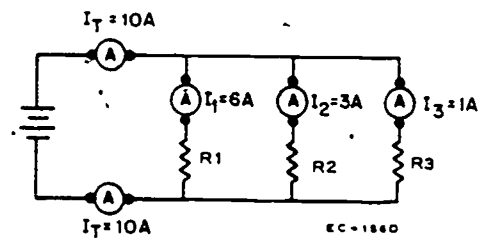


Figure 82. Computing Current in a Parallel Circuit

$I_T = I_1 + I_2 + I_3$

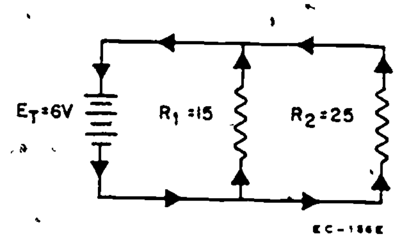
I_T = 6A. + 3A. + 1A. = 10A.

Problem:

Find I_T ______________

Given: E_T = 6v
R_1 = 15 ohm
R_2 = 25 ohm

Solution: $I_1 = E_1/R_1$ = .4A
$I_2 = E_2/R_2$ = .24 A
$I_T = I_1 = I_2$
I_T + .64 A



Resistance

Several formulas are used to find the total resistance in a parallel circuit. Probably the easiest methods to use are the product over the sum method and the formula for equal resistors, but several methods will be given.

There is a basic rule concerning parallel circuits that states "The total resistance in a parallel circuit is always smaller than the smallest branch resistance." In figure 83, the parallel circuit has a 2-ohm, 3-ohm, and a 6-ohm resistor. The total equivalent resistance must be less than 2-ohms since it is the smallest branch resistor. R_T is less than 2-ohms.

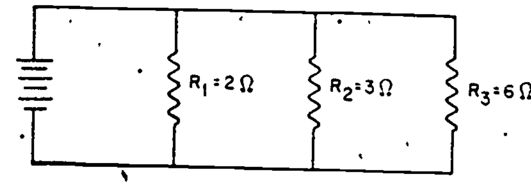
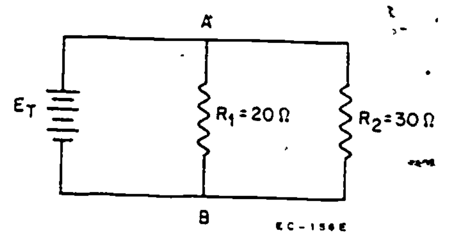


Figure 83. Parallel Circuit

TWO RESISTORS ONLY IN PARALLEL. The equivalent resistance of two resistors in parallel is equal to the product of the two resistors divided by their sum. For example, a 20-ohm resistor and a 30-ohm resistor in parallel are equivalent to a resistor of 12-ohms. (See figure 84 below.) This is found as follows:



$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_T = \frac{20 \times 30}{20 + 30} = \frac{600}{50} = 12\text{-ohms}$$

Figure 84. Two Resistors in Parallel

If you wanted to use this method with a parallel circuit having more than two resistors, as shown in figure 85, you use the product over the sum method on two of the resistors and then take the answer you get and use it with the next resistor. Continue doing this until you have used all of the resistors. Remember, you can take only two at a time. The answer you get using two resistors is the equivalent for both resistors. It doesn't matter the order in which you take the resistors.

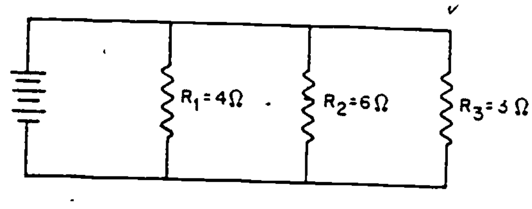


Figure 85. More than Two Resistors in Parallel

Find R_T ____________________

Solution: $R_T = \dfrac{R_1 \times R_2}{R_1 + R_2}$ or $\dfrac{R_2 \times R_3}{R_2 + R_3}$ or $\dfrac{R_1 \times R_3}{R_1 + R_3}$ etc.

$$R_T = \frac{R_2 \times R_3}{R_2 + R_3}$$

(Total equivalent resistance for two of the resistors NOT for the entire circuit)

$$R_T = \frac{6 \times 3}{6 + 3} = \frac{18}{9} = 2 \text{ ohms}$$

$$R_T = \frac{2 \times 4}{2 + 4} = \frac{8}{6} = 1.33 \text{ ohms}$$

(Notice that the total resistance for the entire circuit is less than the smallest branch resistor which is 3 ohms)

EQUAL RESISTORS IN PARALLEL. The total resistance connected in parallel is equal to the resistance of one resistor divided by the number of resistors. (See figure 86.) Expressed mathematically, $R_T = \frac{R}{N}$. R = Value of one resistor and N = Number of like resistors.

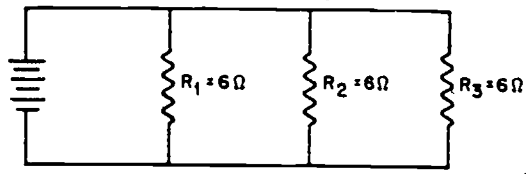


Figure 86. Equal Resistors in Parallel

Find R_T ______________.

Solution: $R_T = R/N = \frac{6}{3} = 2$ ohms

When like resistors are in a parallel circuit along with unlike resistors, as shown in figure 87, use the above method for the like resistors and then take your answer and use it with the product over the sum method to arrive at total resistance.

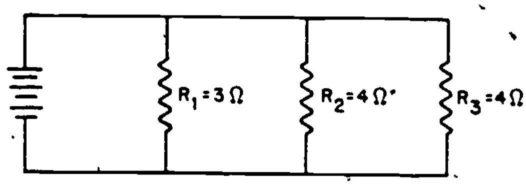


Figure 87. Unlike Resistors in Parallel

Find: R_T ______________

Solution:

$R_T = R/N$ (Value of like Resistors/Number of like resistors)

$$R_T = \frac{4}{2} = 2 \text{ ohms}$$

$$R_T = \frac{2 \times 3}{2 + 3} = \frac{6}{5} = 1.2 \text{ ohms}$$

RECIPROCAL METHOD. The reciprocal method is also used to find total resistance for any number of resistors as shown in figure 88. This method requires more mathematics than the others mentioned. The formulas used for this method are:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \text{ etc.}$$

or

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ etc.}$$

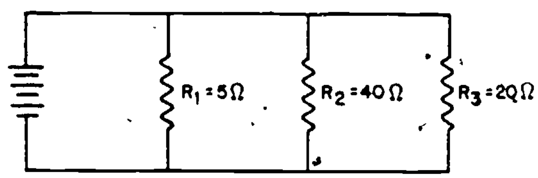


Figure 88. Reciprocal Method

Find R_T ______________________

Solution: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R_T} = \frac{1}{5} + \frac{1}{40} + \frac{1}{20}$

Find least common denominator (smallest number that the lower part of the fraction will divide into equally)

$\frac{1}{R_T} = \frac{8}{40} + \frac{1}{40} + \frac{2}{40}$

$\frac{1}{R_T} = \frac{11}{40} = .275$ ohms

Cross multiply (R_T x 11 and 1 x 40)

$11R_T = 40$

$\frac{11R_T}{11} = \frac{40}{11}$

$R_T = \frac{40}{11} = 3.63$ ohms

Measurement of Circuits Values

It is essential that you know the correct use of meters in a parallel circuit if you hope to understand the characteristics of this circuit. As in all circuits, the voltmeter is connected in parallel while the ammeter is connected in series. (See figure 89.)

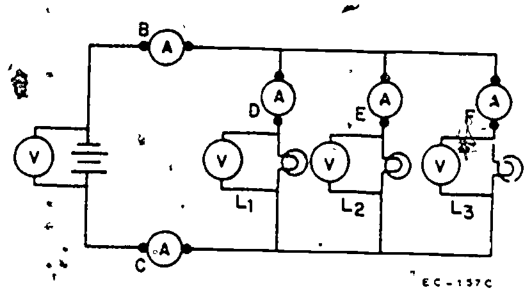


Figure 89. Using Meters in a Parallel Circuit

You can see in the illustration that the voltmeter is connected in parallel or across the component you are measuring. The ammeter is connected in series in all instances. It must be connected end to end with the component you are measuring. Positions B and C place the ammeter in the main line to read total current. Position D has the ammeter measuring current in only lamp 1, while the ammeter at position E is measuring current in lamp 2, and the ammeter at position F is measuring current in lamp 3.

SUMMARY

A parallel circuit has two or more units of resistance, or other electrical devices, connected across the same source of power and the current devices among the various branches. Each unit of resistance can be made independent of the other units. The voltage is equal in a parallel circuit or $E_T = E_1 = E_2$, etc. The total current equals the sum of the current passing through each branch or $I_T = I_1 + I_2$, etc. The total resistance in a parallel circuit is always less than the smallest branch resistance. The total resistance can be found by the product over the sum method,

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

and a number of other methods.

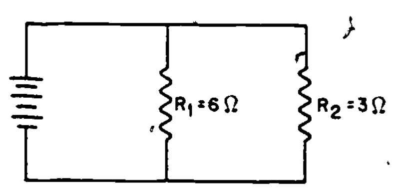
QUESTIONS

1. Why is the voltage drop the same across each unit in parallel?

2. If you have two resistors in parallel and another is added (also in parallel), will the total current increase or decrease?

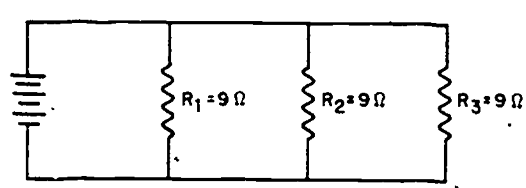
3. Will the total resistance increase or decrease if another unit is added in parallel?

4.



Find: R_T

5.



Find: R_T

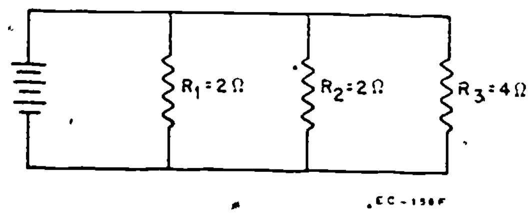
6. Five light bulbs are connected in parallel. If one burns out, what happens to the following?

   a. Total Voltage

   b. Total Current

   c. Total Resistance

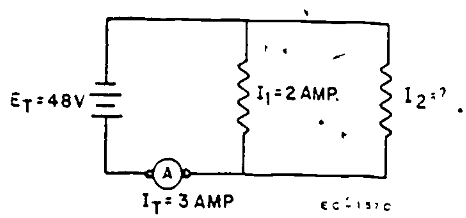
7.



Find: R_T

8. The total current in a parallel circuit is equal to the ______________ of the current in the individual branches.

9.



Find: E_1 ______________

E_2 ______________

I_2 ______________

R_1 ______________

R_2 ______________

R_T ______________

10. In a parallel circuit, the total resistance is always ______________ than the smallest branch resistance.

REFERENCES

1. Basic Electricity, Van Volkenburgh, Vol II

2. TO 31-1-141-2, Basic Electronics Technology and Testing Practices

3. AFP 85-1, Electrical Facilities Safe Practice Handbook

SERIES-PARALLEL CIRCUITS

OBJECTIVE

The objective of this study guide is to help you become familiar with the purpose, construction, and circuit value measurement of series-parallel circuits.

INTRODUCTION

A series-parallel circuit is a combination of a series circuit and a parallel circuit. That is, some parts are in series while others are in parallel. These circuits are quite often called combination circuits.

INFORMATION

USE

Series-parallel circuits are constructed when it is desirable to cause a voltage reduction across a parallel section of a circuit, or to increase the resistance of a parallel circuit.

Series-parallel circuits are not very often used in lighting and power wiring; however, in certain situations, it may be desirable to dim the lights. If so, an adjustable resistor is installed in series with a bank of lights which are wired in parallel. This is an example of a series-parallel circuit.

CONSTRUCTION

A series-parallel circuit is a combination of a group of resistors in parallel with another group of resistors in series.

To construct a series-parallel circuit, first look at figure 90 which has two resistors in series, then refer to figure 91 which has two resistors in parallel. Now, if you combine these two types of circuits into one, as shown in figure 92, you will have a series-parallel circuit.

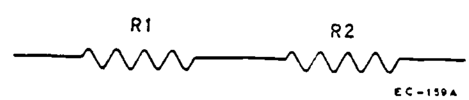


Figure 90. Resistors in Series

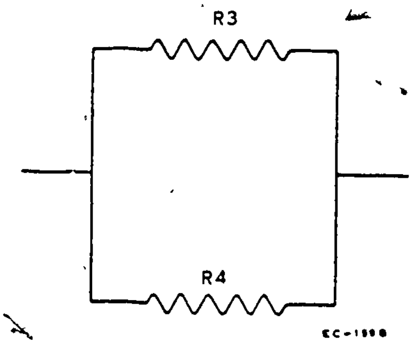


Figure 91. Resistors in Parallel

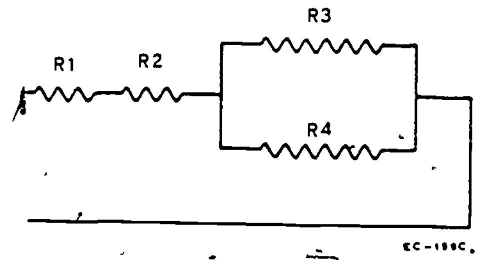


Figure 92. Series-Parallel Circuit

CHARACTERISTICS

The illustrations shown are series-parallel circuits. Note that the current which leaves one terminal of the power source passes through the series resistors then on through the parallel resistors, and then recombines as it returns to the other terminal of the power source. The rules listed pertain to series-parallel circuits containing 3 or 4 resistors connected similar to the circuits shown.

Voltage

The sum of the voltage drops of the series portion, plus the voltage drops across one unit of resistance within the parallel portion, is equal to the applied voltage.

In the schematic diagram of the series-parallel circuit shown in figure 93, the sum of the voltage drops across the series resistors R_1 and R_2, plus the voltage drop across one unit of resistance of the parallel portion R_3 or R_4, equals the total voltage in the circuit. Thus, a rule regarding series parallel circuits expressed mathematically would be:

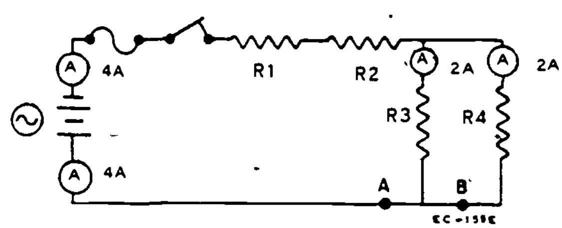


Figure 93. Series-Parallel Circuit

$E_T = E_1 + E_2 + \text{etc}$ (Series Portion)

$+E_3 = E_4 = \text{etc}$ (Parallel Portion)

Current

The sum of the currents in each resistor of the parallel portion is equal to the current in the series portion and also equal to the total current in the circuit.

In the schematic diagram of the series-parallel circuit, shown in figure 94, the sum of the currents flowing through resistors R_3 and R_4 equal the current flowing in the series portion of the circuit R_1 and R_2 and also, the total current flowing in the circuit. Thus, another rule of a series-parallel circuit expressed mathematically is $I_T = I_1 = I_2 =$ etc (Series Portion) $= I_3 + I_4 +$ etc (Parallel Portion).

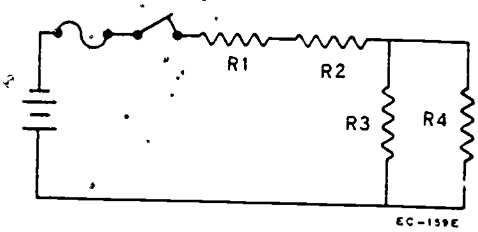


Figure 94. Series-Parallel Circuit

Resistance

The sum of the resistances in the series portion plus the total resistance of the parallel portion equals the total resistance of the circuit.

In the schematic diagram of the series-parallel circuit, shown in figure 95, the sum of the resistors R_1 and R_2 added to the total resistance of R_3 and R_4, in the parallel portion, equals the total resistance in the circuit. Thus, another rule expressed mathematically is $R_T = R_1 + R_2 +$ etc (Series Portion)

$$+ \frac{R_3 \times R_4 \text{ (Product)}}{R_3 + R_4 \text{ (Sum)}}$$

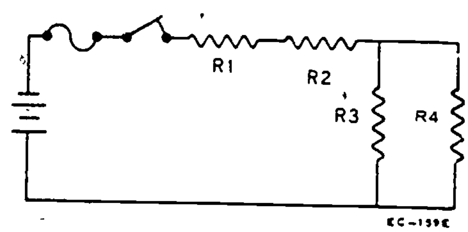


Figure 95. Series-Parallel Circuit

MEASUREMENT OF CIRCUIT VALUES

In figure 96, it is apparent that the combined current which flows through resistors R_2 and R_3 must flow through resistor R_1 to return to its source of power.

The best procedure in solving this problem is first to find the equivalent resistance of R_2 and R_3. Substitute this equivalent resistor for R_2 and R_3 resistors and reduce the circuit to a series circuit, which would draw the same current from the source of power.

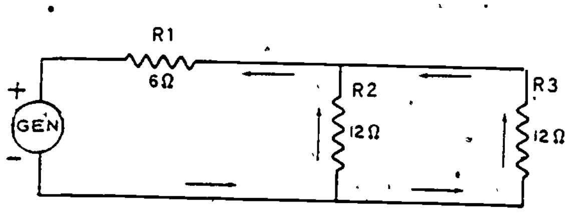


Figure 96. Combined Current in Series-Parallel Circuit

To find an equivalent resistor for resistance R_2 and R_3 apply the "Product over Sum" method for parallel circuit resistors:

$$R_t = \frac{12 \times 12}{12 + 12} = 6 \text{ ohms}$$

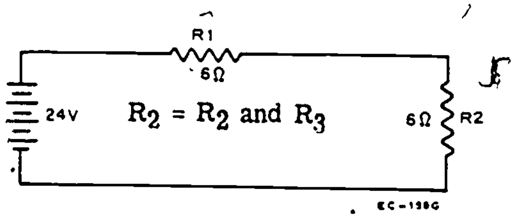


Figure 97. Series Circuit Equivalent to Series-Parallel Circuit

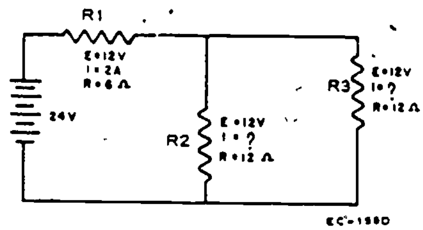


Figure 98. Series-Parallel Circuit with Known Values

A circuit that would draw the same current as the series-parallel circuit shown in figure 98 is shown in figure 97.

Now apply the laws for a series circuit:

$$I_t = \frac{E_t}{R_T} = \frac{24}{6 + 6} = 2 \text{ amperes}$$

The voltage drop across resistor R1 is: $E_1 = I_1 \times R_1 = 2 \times 6 = 12$ volts

The voltage drop across resistor $R_2 + R_3$ must be 12 volts also, because the sum of the voltage drops in a series circuit equals the applied voltage (24 - 12 = 12 volts). Now you have the information shown in figure 98. Applying Ohm's law to the two parallel resistors you find that one ampere of current flows through each resistor R_2 and R_3.

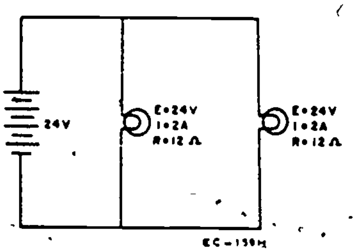


Figure 99. Parallel Circuit

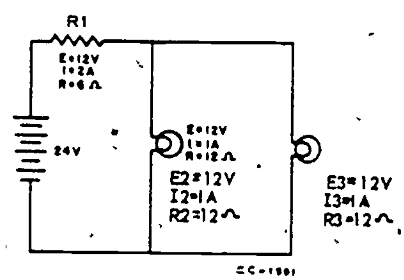


Figure 100. Series-Parallel Circuit with Known Values

As an example of the effects of combining a series circuit and a parallel circuit, replace resistors R_2 and R_3 with lamps and remove the resistor in series. You would see that the lamps would burn bright because each lamp would draw two amperes of current. Figure 99 shows this circuit construction.

By placing a 6-ohm resistor in series with the two lamps as shown in figure 100, the current through each lamp would be reduced to one ampere. The lamps will then glow dimly. (The brilliancy of the lamp is relative to the amount of current passing through the lamp.)

SUMMARY

A series-parallel circuit as the name implies, has the characteristics or effects of both the series and parallel circuits. To solve problems of a series-parallel circuit, it is necessary to find an equivalent resistance for the parallel part of the circuit. A series circuit can then be constructed by using this equivalent resistance in place of the parallel part of the circuit. Solve the series circuit for total current and voltage, then substitute these values in the original problem and solve for current in the parallel part of the original problem.

QUESTIONS

1. Referring to figure 93, if R_1, R_2, R_3 and R_4 are all 10-ohm resistors and the alternator is delivering 100 volts:

   a. How much voltage is dropped across R_1?

   b. How much voltage is dropped across R_2?

   c. How much voltage is dropped across R_3?

2. Referring to figure 93, if the current is 4 amperes at point "A," what will the current be at point "B"?

3. Name some uses of series-parallel circuits.

4. What is a series-parallel circuit?

5. What are the effects of combining resistors into a series-parallel circuit?

6. What is the resistance of a circuit which has one 3-ohm resistor in series and two 6-ohm resistors in parallel?

7. What is the equivalent resistance of a 6-ohm resistor and a 12-ohm resistor connected in parallel?

8. What instrument is used to measure units of electrical pressure?

9. What instrument is used to measure amperes?

10. How does connecting a resistor in series with a parallel circuit affect the total current flow of the circuit?

REFERENCES

1. Basic Electricity, By Van Volkenburgh

2. TQ 31-1-141-2, Basic Electronics Technology and Testing Practices

3. AFP 85-1, Electrical Facilities Safe Practice Handbook

TRANSFORMERS, RECTIFIERS, AND POWER SUPPLIES

OBJECTIVE

This unit of instruction will help you become familiar with the construction, theory, and operation of transformers, rectifiers, power supplies, batteries, and transistors.

INTRODUCTION

In order to supply the correct amount and type of voltage for some equipment it is necessaryto change the voltage that is provided commercially to the using site. To make these changes of voltage certain equipment is required. This equipment is covered in the following section.

INFORMATION

SECTION NO. 1, TRANSFORMER

Transformer Construction

A transformer is composed of two coils, a primary coil and a secondary coil, wrapped around a core, usually made of silicon steel. The two coils are wrapped close together yet electrically insulated, from each other. The coil connected to the power supply is called the primary coil. The coil connected to the load is called the secondary coil. The core provides a way for positioning the coils and a path for magnetic flux lines. Usually the core will be laminated silicon steel to reduce eddy currents and hysteresis in the transformer.

Transformer Theory

You have been taught that an expanding and collapsing magnetic field will induce a voltage within the circuit itself (self-induction) and within nearby circuits (mutual induction). The transformer works on the principle of mutual induction. See figure 101. As ac voltage is applied to the primary coil it causes a current flow that produces a magnetic field. The expanding and collapsing of this field cuts the turns in the secondary coil inducing a voltage in it. The amount of voltage produced in the secondary coil will depend on the applied voltage and the number of turns in the primary compared to the number of turns in the secondary. The amount of voltage available in the secondary will depend on the Power Rating of the transformer. The number of turns in the primary compared to the number of turns in the secondary is called the turns ratio of a transformer.

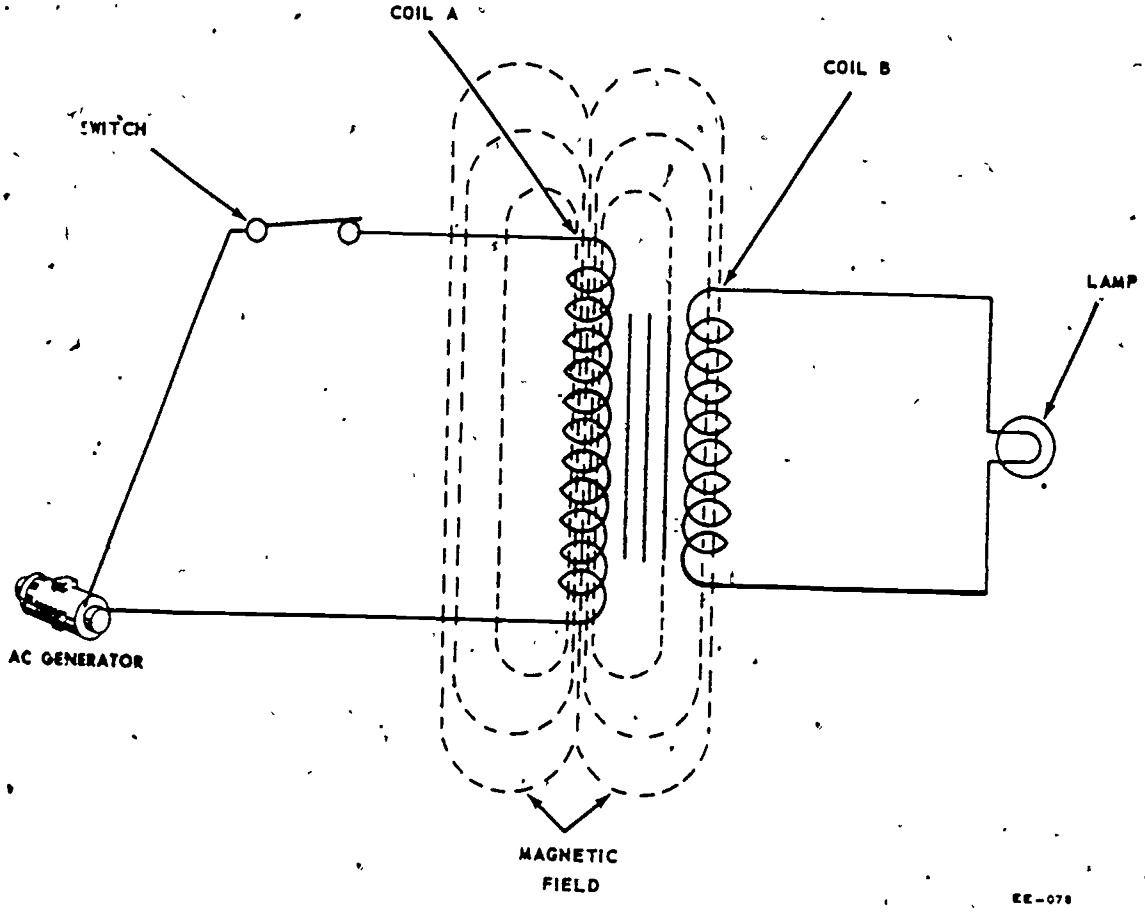


Figure 101. Transformer Action*

Turns Ratio

Assuming that all the magnetic lines of force from the primary cut through all the turns of the secondary, the voltage induced in the secondary will depend on the number of turns in the secondary and the number of turns in the primary. For example, if there are 1000 turns in the secondary and 100 turns in the primary, the voltage induced in the secondary will be 10 times the voltage applied to the primary:

$$\frac{100}{1000} = \frac{1}{10}$$

Since there are more turns in the secondary than there are in the primary, the transformer is called a "step-up transformer." See portion A of Figure 102. If, on the other hand, the secondary has 10 turns and the primary has 100 turns, the voltage induced in the secondary will be one-tenth of the voltage applied to the primary:

$$\frac{100}{10} = \frac{10}{1}$$

Since there are less turns in the secondary than there are in the primary, the transformer is called a "step-down transformer." See portion B of figure 102.

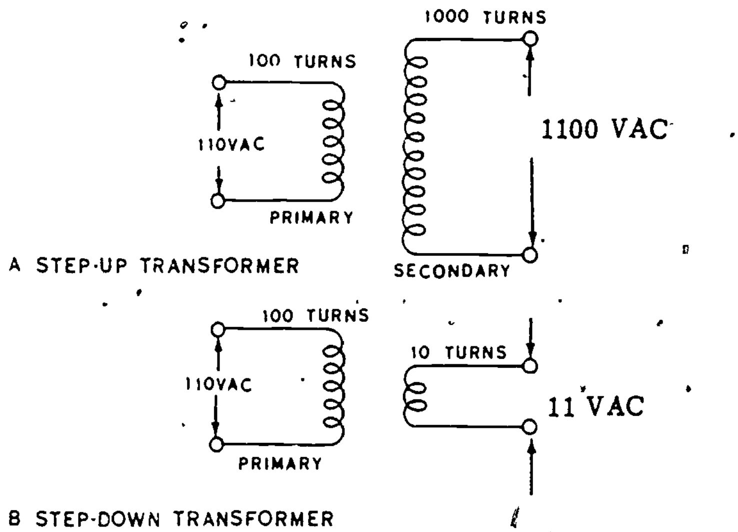


Figure 102. Step-Up and Step-Down Transformers

SUMMARY

The main purpose of a transformer is to increase or decrease voltage. The three parts of a transformer are primary coil, secondary coil and core.

A transformer operates on the principle of MUTUAL INDUCTION.

The amount of voltage induced in the secondary winding of a transformer depends on the ratio of turns between the primary and secondary coils. This ratio is directly proportional. A step-up transformer will increase the voltage, because there are more turns in the secondary winding. A step-down transformer will decrease the voltage because there are fewer turns in the secondary winding.

QUESTIONS

1. Name the three parts of a transformer?
2. Which coil of a transformer is connected to the ac power source?
3. What is the purpose of the core?
4. Which coil is connected to the load?
5. If 120 volts is applied to a 10:1 ratio transformer, what is the output voltage?

6. If the transformer has 5 times as many turns on the secondary as it has on the primary, what type of transformer is it called?

7. A transformer with a 1:10 ratio is what type transformer?

8. The primary of a transformer has 110 volts and 10 amps applied to it. The secondary has 1100 volts. How many amps does the secondary carry?

9. What is the principle of operation of a transformer?

10. Why is the core laminated?

REFERENCES

1. Basic Electricity, By Van Valkenburgh

2. Practical Electrical, H. P. Richter

3. AFM 52-8, Electronic Circuit Analysis

SECTION NO. 2, RECTIFIERS

Purpose of Rectifiers

A rectifier is used to change alternating current to direct current. The direct current that comes from the rectifier will be pulsating current full wave or half wave. See figure 103.

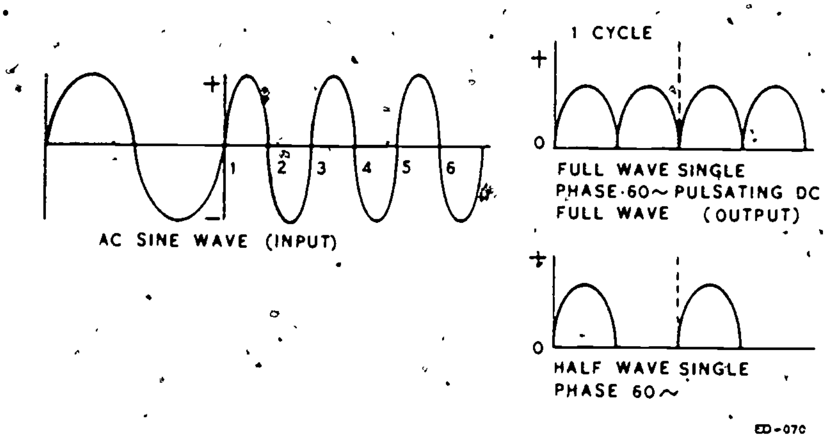


Figure 103

Certain equipment, such as relay coils, will operate more efficiently on direct current. Other equipment, such as electronic equipment, must have direct current to operate. For these reasons, rectifiers were developed and used.

Dry Disc Rectifiers

One of the earlier types of rectifiers developed was the dry disc rectifier. This type of rectifier is limited to the amount of current, voltage and heat that it can withstand. For these reasons, dry disc rectifiers are being used less as improved systems of rectifiers are being developed.

Most dry disc rectifiers are of the selenium iron type, which consist of a prepared film of selenium on a metallic substance such as iron. See figure 104 This allows current to flow more readily in one direction. A full wave dry disc rectifier will have four terminals. Two terminals are for ac input. It does not matter which ac lead is connected to the ac terminals because the current will periodically reverse. You should identify the dc terminals in order to maintain the proper polarity to the unit. A dc voltmeter can be used for this purpose.

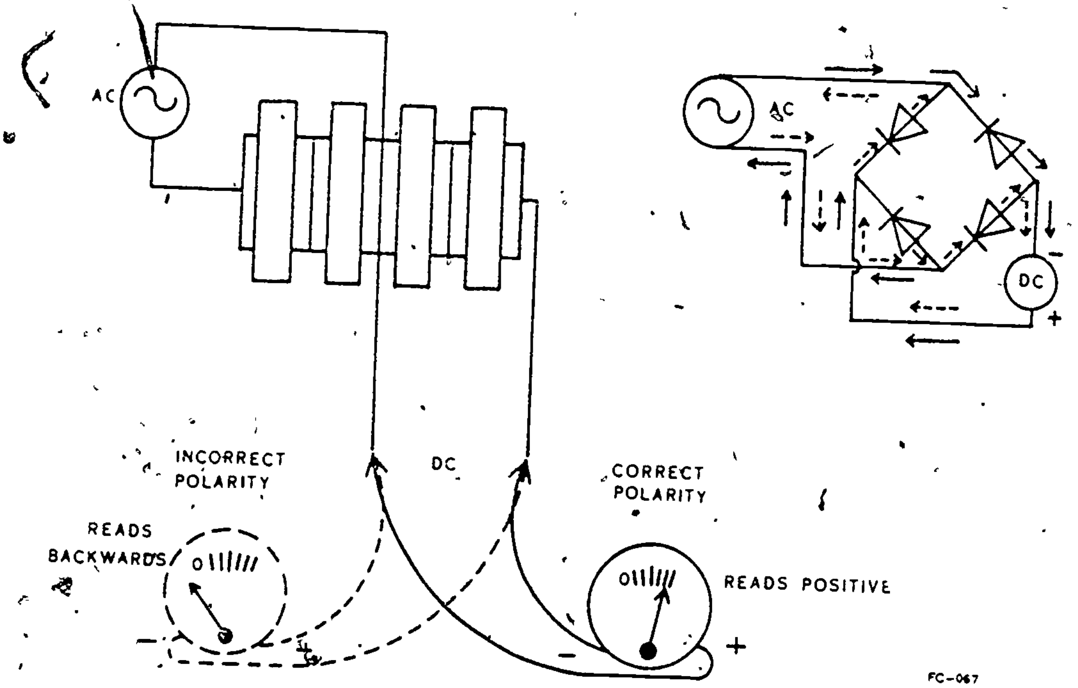


Figure 104. Full Wave Dry Disc Rectifier

The sumbol of a half wave rectifier is drawn like this  . In this course current flow will be traced against the point of the arrow, in some commercial drawings current flow is traced with the arrow. Be careful when using drawings containing rectifiers. See figure 105

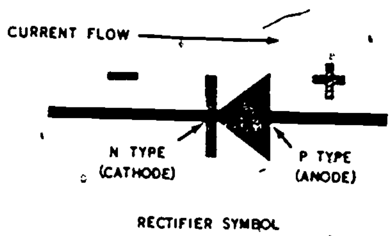


Figure 105

Vacuum Tube Rectifiers

In the beginning of radio communication the receivers were quite large and bulky, primarily because the power supplies had three separate batteries. Batteries were being used because dc power was required. In order to reduce the weight, size and inconvenience of batteries, a power supply was developed that could rectify available alternating current to direct current. This power supply made use of a vacuum tube diode to accomplish the rectification. Figure 106 shows a typical example of this type of power supply.

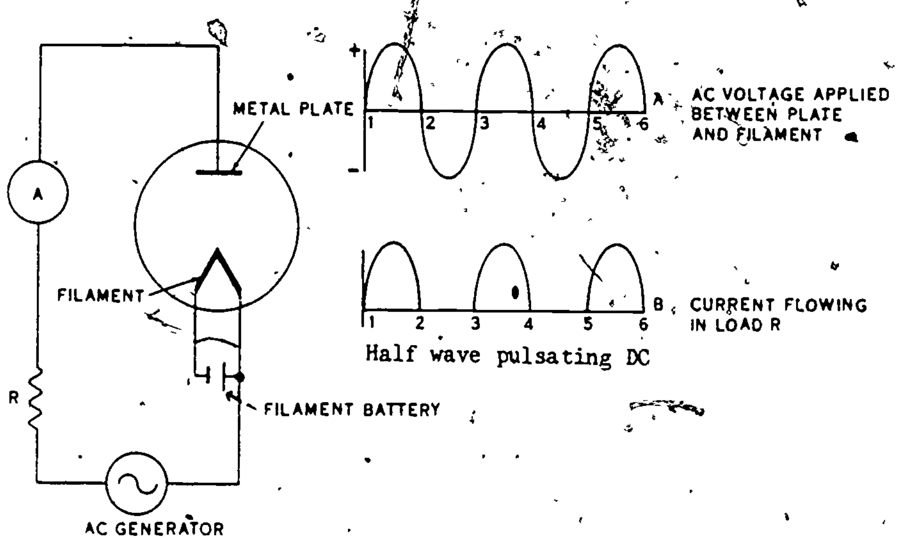


Figure 106

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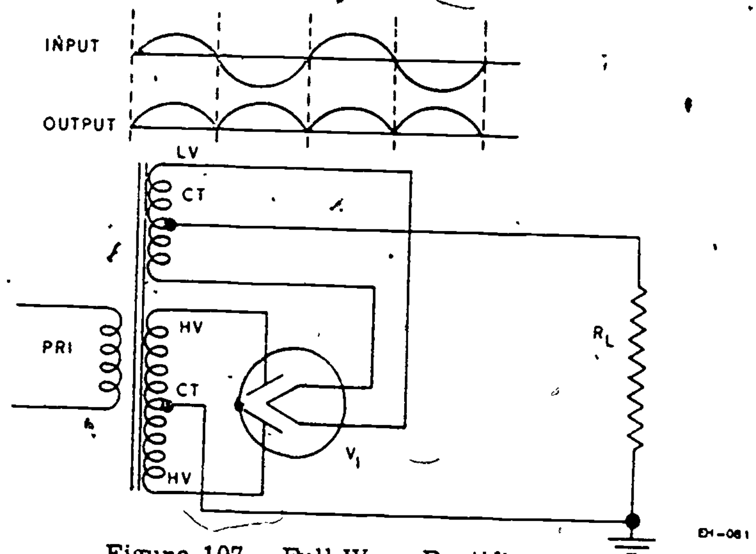

Figure 107. Full Wave Rectifier

The system in figure 107 uses two diodes in one glass container called a duodiode. It provides full wave pulsating direct current. Filter systems, such as the one shown in figure 108 are added to the circuit to smooth out the pulsations and provide a smooth direct current (dc).

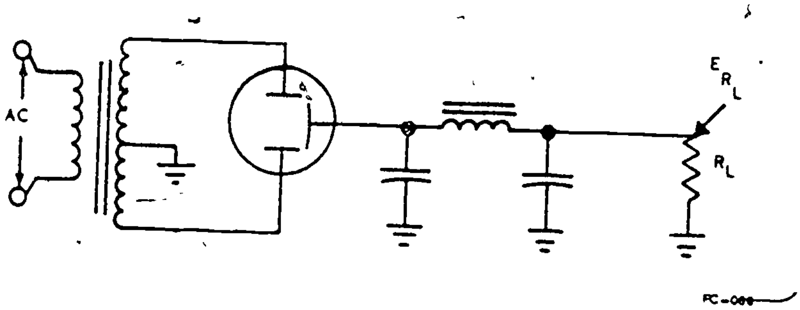

Figure 108. Rectifier Circuit With Filter

While the vacuum tube system provided a high voltage dc supply, the current that could be sent through this type of rectifier was quite low. Large amounts of space were required for cooling the tubes and transformers and the size of the equipment was a consideration.

Crystal Rectifiers

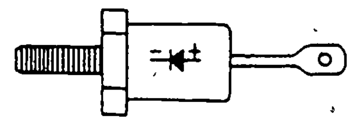

Figure 109. Crystal Rectifier Physical Appearance

A smaller, cheaper, and more efficient substitute was needed for the vacuum tube. Near the end of World War II such a device was developed. This device was called the transistor. It is a small crystal which impurities have been added and is called a semiconductor. They have the advantages of small size, solid state construction and can withstand high voltages and currents. Figure 109 shows an example of a crystal rectifier.

The principle of operation of the crystal rectifier (diode) is that current will flow more readily in one direction than in the other.

SUMMARY

A rectifier is used to change alternating current to pulsating direct current. Types of rectifiers are dry disc (selenium-iron), vacuum tube, diodes, and crystal diodes. The symbol for a rectifier is

and the current flow of the circuit is traced toward the arrow point.

QUESTIONS

1. What type voltage does a rectifier circuit produce?
2. Why is direct current required?
3. What materials are required for a dry disc rectifier?
4. What limitations does a dry disc rectifier have?
5. What is the purpose of a rectifier?
6. Name two advantages of a crystal rectifier.

REFERENCES

1. Basic Electricity, By Van Volkenburgh
2. Practical Electrical, H. P. Richter
3. AFM 52-8, Electronic Circuit Analysis

There are two basic types of batteries and both of them produce electricity from chemical action. They are made up with primary cells or secondary cells. A primary cell is not rechargeable and is discharged when its chemical action stops producing voltage. The dry cell flashlight battery is a good example of the primary cell. Even though primary cells may be used for many applications, when a large current flow is necessary he storage battery or secondary cell is essential.

The secondary cell works in a similar manner to the primary cell. The major difference is that in the secondary type the chemical action is reversible. The lead-acid storage battery is the most common one used in the Air Force. Take a look at its construction, figure 110 shows a cutaway view of a 6-volt lead-acid battery.

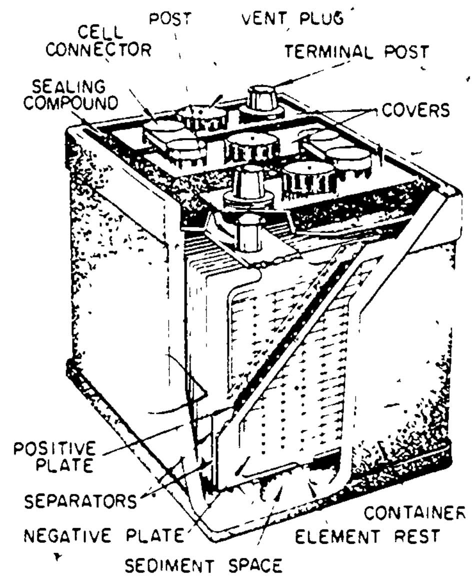

Figure 110. Lead Acid Battery

The positive plates in this battery are made of lead peroxide. The negative plates are made of sponge lead. All of the plates are separated from each other by some insulating material, such as glass which is called a separator. These plates are connected together and placed in a container with a separate compartment for each cell. This container is called the battery case. Three cells are connected in series to make a 6-volt battery. A mixture of sulphuric acid and water is then added to the case. The mixture is commonly called the electrolyte. During discharge: that is, while electrical power is being taken from the battery. the sulphuric acid combines chemically with the plates to release electrical energy.

Since the acid is combined with the plates during discharge, the condition of the battery or state of charge can be measured by measuring the amount of acid in the solution. This measurement is made by using a hydrometer. (See figure 111.)

Battery Banks

There are times when batteries must be connected together. This is called banking. Banking may become necessary for different situations. One is when it is necessary to charge more than one battery at a time. When this situation arises the batteries are usually banked in series. By this, the positive post of the first battery is connected to the negative post of the second. This leaves a positive and a negative post to be connected to the charger. If more than two batteries need to be banked in series for charging they may be connected in the same way. A situation which requires batteries to be banked in series is where more voltage than can be delivered by one battery is required. For example, if a motor crane required a 24-volt battery and none were available, two 12-volt batteries can be banked in series, and the crane can be operated until the specific battery needed can be obtained. You can see that the voltage of batteries connected in series is equal to the sum of the voltages of the batteries.

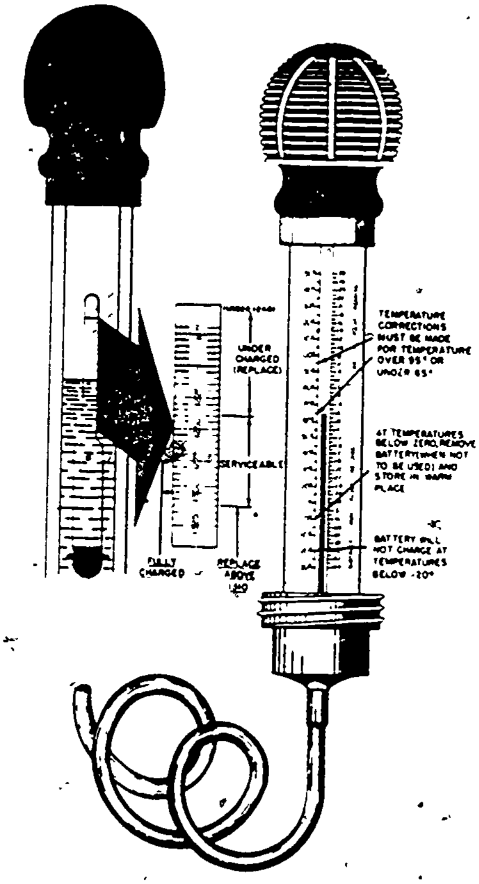

Figure 111. Hydrometer

Series is only one way in which batteries may be banked. While they are banked in series for charging or when higher voltage is needed, they may also be banked in parallel. Figure 112 hows two 6-volt batteries banked in series and two banked in parallel.

Parallel banking of batteries is used when there is a requirement for more amperage than can be furnished by one battery, but no increase in voltage is desired. A good example of this is the jumper cables so many people use in starting their cars in the winter. By the use of the jumper cables, the batteries of two cars are connected in parallel without having to disconnect the batteries in either car. They must not be connected in series, because the voltages of the two batteries would add and you would damage some electrical unit on the car. Remember, that to increase voltage, you bank batteries in series, but to increase amperage without increasing voltage, bank the batteries in parallel.

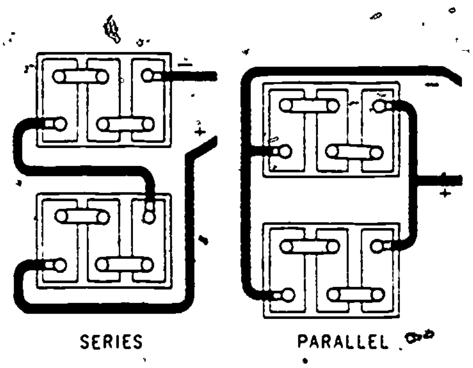

Figure 112. Battery Banking

Battery Chargers

When a lead-acid battery is discharged it should be recharged. There are two types of chargers which may be used. The motor-generator type, and the ac - to - dc rectifier type. The motor-generator is used by telephone exchanges and powerplants in their equipment rooms. The ac - to - dc rectifier is the type used on Air Force installation.

Operation by forcing direct current through the battery in the opposite direction from which the current flows during discharge, the acid is driven back into the water solution thus restoring the electrical energy as chemical energy. Most chargers have leads marked positive and negative. The one which is marked positive connects to the positive post of the battery, and the one marked negative connects to the negative post of the battery. Thus you can see that current coming from the charger is forced through the battery in the opposite direction providing the voltage of the charger is higher than that of the battery. During the charging period a constant check should be kept on the specific gravity, so that the battery can be removed when it has reached full charge. Figure 113 shows an ac to dc battery charger.

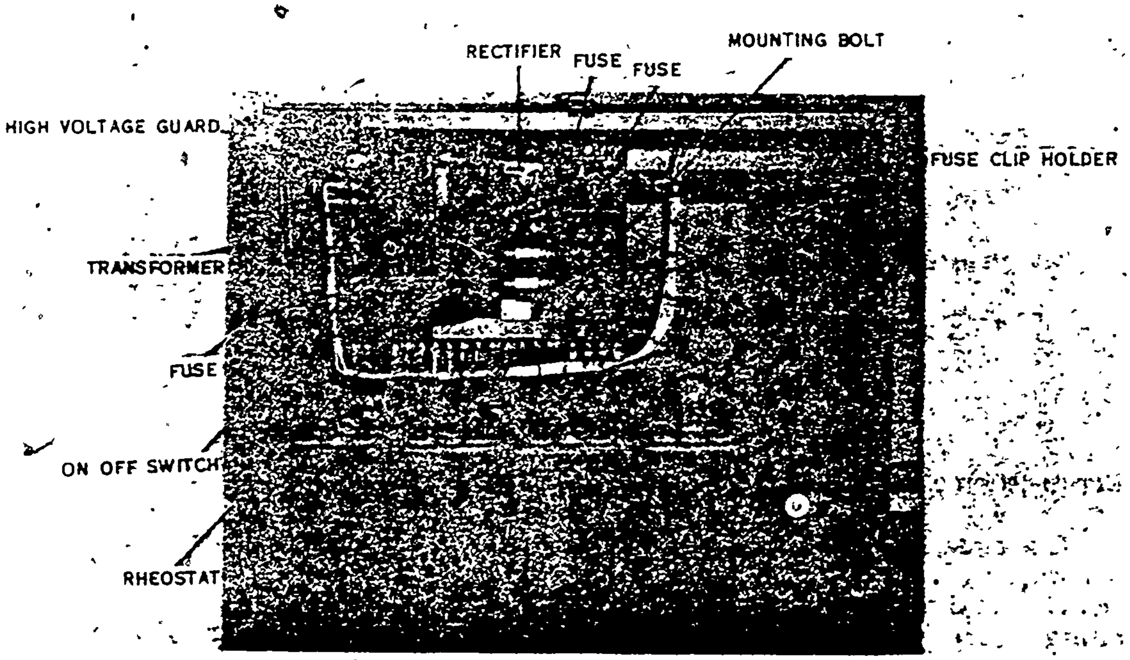

Figure 113. AC to DC Battery Charger

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When a battery is being charged, a portion of the energy is dissipated in the electrolysis of the water in the electrolyte. The water is broken down, and hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on the charger, the charging rate is too high. If the rate is not too high, steady gassing, which develops as the charging proceeds, indicates that the battery is nearing a fully charged condition. Because of this gassing you should keep a close check on the water-acid solution, adding distilled water as necessary. CAUTION: A mixture of hydrogen and oxygen is dangerously explosive. Positively no smoking, electric sparks, or open flames are permitted near batteries being charged.

QUESTIONS

1. How are the cells connected in a lead-acid battery?
2. What is used to measure the amount of acid in the electrolyte of a lead-acid battery?
3. Name two ways to connect batteries in a battery bank.
4. What is the purpose of a battery bank?
5. What is the most common type of a battery charger used in the Air Force?
6. Why is it dangerous to smoke around a battery being charged?
7. What types of gases are released at the negative and positive plates when a battery is being charged?

REFERENCES

1. Basic Electricity, Van Volkenburgh
2. Practical Electrical, H. P. Richter
3 AFM 52-8, Electronic Circuit Analysis

MAGNETIC AMPLIFIERS

Construction of Magnetic Amplifiers

The magnetic amplifier consists of three essential units, the control winding, the load winding, and a core. The control winding usually has many turns of fine wire wound around an iron or silicon steel core. The load winding consists of a few turns of heavy wire wound around the core. These windings are not electrically connected to each other but are magnetically linked together since they are wound on the same core. (See figure 114.)

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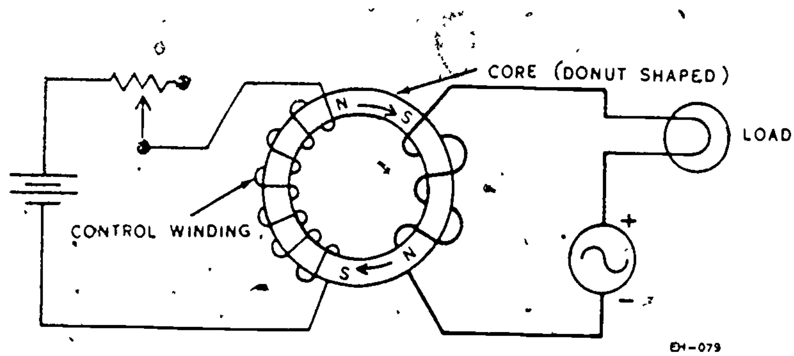

Figure 114. Magnetic Amplifier

In some magnetic amplifiers a rectifier is connected in the load winding and a choke coil is placed in the control winding.

Magnetic amplifiers are made in many shapes and sizes but they all operate on the same principles. They may have square, round or three-legged cores. They are sometimes added together to give higher amplification.

Theory of Operation

In figure 115 direct current flows through the control winding setting up a dc flux (in one direction) in the core.

An ac source is connected to the load, alternating current flows through the load winding building a magnetic field. Since the current is alternating the flux set up in the core is constantly changing in magnitude and direction.

Within the core exists two types of flux: (1) dc, the flux created by the direct current which is constant in magnitude and direction; (1) ac, the flux created by alternating current which is changing in magnitude and direction.

The ac flux tends to saturate the core (fill the core completely with lines of force which causes it to act as though the core was removed) and then desaturate the core because of its changing direction. This results in a changing inductive reactance in the load winding. This changing inductive reactance allows us to lower or raise the power to the load. The dc flux aids or opposes the ac flux as the ac flux reverses direction.

The load windings are composed of a few turns of heavy wire. A small number of turns are used to lower reactance and large conductors are used to handle a large current.

The control winding has many turns of fine wire, reactance does not have to be considered since it is connected to dc. The large number of turns builds a strong ac magnetic field in the core which is used to control the output of the load. In many instances dc in milliamps is used to control in amperes.

On one-half of the ac cycle the ac flux is aiding the dc flux and on the other half cycle the ac flux is opposing the dc flux. To prevent the ac flux from opposing the dc flux on half of the cycle, a rectifier is placed in the load winding. Since it is almost impossible to keep all the ac flux out of the control winding a choke coil is installed. The choke will not hinder the dc in the control winding but will try to keep the changing ac flux from inducing an alternating current in the control winding.

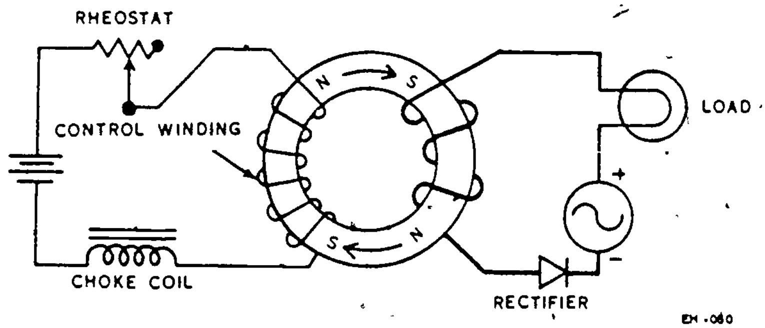

Figure 115. Magnetic Amplifier with a Choke Coil and a Rectifier

SUMMARY

There are two basic types of batteries (1) primary and (2) secondary cells. The most common rechargeable type used in the Air Force is the lead-acid type. The ac to dc rectifier battery charger is generally used on Air Force installations for recharging lead acid batteries. Batteries can be banked together in series to increase voltage and connected in parallel to increase current.

The main parts of a magnetic amplifier consists of a control winding, a load winding and a core. Although the windings are not electrically connected they are magnetically linked together since they are wound on the same core. Magnetic amplifiers are used to control a large current in the load circuit with a small current in the control circuit.

They are rugged in construction and have many advantages over the vacuum tube.

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QUESTIONS

1. What is the main purpose of the magnetic amplifier?
2. Name the three primary parts of the magnetic amplifier?
3. What type current is used in the control winding?
4. What winding is the choke coil connected to?
5. What is meant by saturation of the core?

REFERENCES

1. Basic Electricity, Van Volkenburgh
2. Practical Electrical, H. P. Richter
3. AFM 52-8, Electronic Circuit Analysis

TRANSISTORS

Basically, the transistor is a valve which controls the flow of current (electrical charges in motion) through it.

The transistor is constructed in two different ways from a semiconducting substance. The two main substances in the transistor construction are germanium and silicon. Relatively, few free electrons exist in pure semiconductor material. The material displays a relatively high resistance to current, but not quite enough to be classified as an insulator. In the pure form, such material is not useful for diodes or transistors. By blending in with the semiconductor material a small amount of a suitable impurity, the resistance of the semiconductor is lowered to better fit our electronic requirements.

Two basic types of materials are created when these impurities are added to the semiconductors. They are known as N and P type semiconductors.

In an N type, antimony is added to the pure semiconductor. This causes additional free electrons in the semiconductor material, thereby lowering its resistance. The resulting material is described as N type because of the free electrons which carry a negative charge. Refer to figure 116.

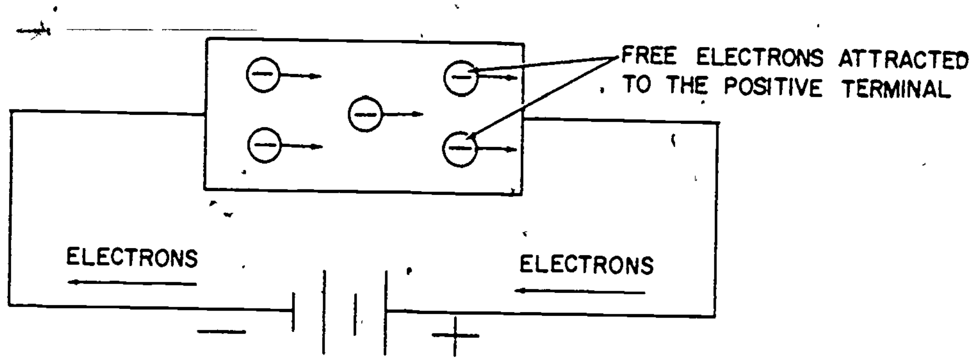
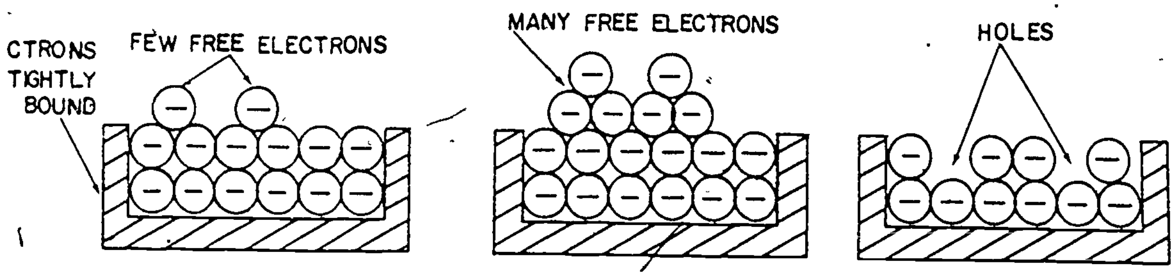


Figure 116. Electron Flow in N-type Crystal

Note that the current in the N-type semiconductor is entirely due to the flow of the free electrons introduced into the pure semiconductor. The N type is also called the donor type, since it donates electrons.

P-Type Crystal

A different kind of substance can be blended to produce the opposite effect. In this case, the material that is added will substitute holes for electrons. These holes can be treated as positive charges within the material, since the hole is the lack of a negative charge. This kind of semiconductor is called a P-type semiconductor, because conduction is by means of these positive charges. Figure 117A, illustrates how electrons are arranged in a pure semiconductor. Most of the electrons are like balls in a box--tightly packed and unable to move. Only a few electrons are on the top layer and free to move about. Figure 117B shows the N-type semiconductor with many more free electrons, and figure 117C shows the P-type semiconductor with holes where the tightly bound electrons have been removed.



(A) Pure semiconductor (B) N-type semiconductor (C) P-type semiconductor

Figure 117. Electrons in Semiconductor Material

Since a P-type semiconductor has holes, it can conduct current. Figure 118 shows how the electrons and holes can move in a P-type semiconductor. As an electron of the material moves to the right to fill a hole, it creates another hole in the place it left. The electron moved to the right and the hole moved to the left. Since the hole always moves in the direction opposite to that of the electron that created it, it acts as if it were a positive charge in the material. The current which flows in a P-type semiconductor does not depend on free electrons as in the case of the N type, but is due entirely to the tightly bound electrons moving in and out of the holes in the material--or the holes moving through the tightly bound electrons. That is, conduction is by the movement of positively charged holes.

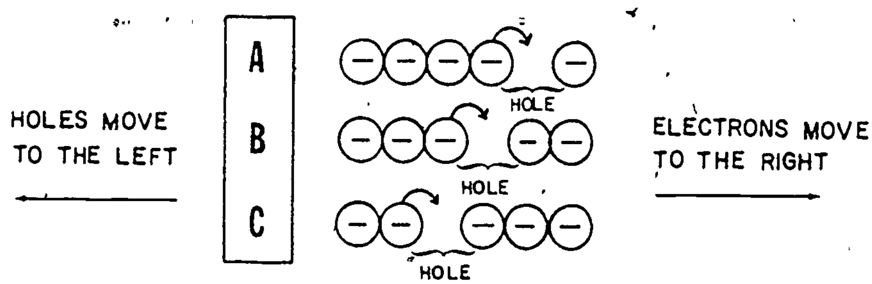


Figure 118. As an electron moves to the right to fill a hole, the hole moves to the left.

Figure 119 illustrates a P-type crystal with a potential across it. It is important that you recognize two things about hole current: 1. Hole current flows only in the semiconductor material. 2. The direction of hole current is toward the negative terminal of the voltage supply (since unlike charges attract).

Notice the current denoted by the arrows in the terminals of figure 119. The number of electrons involved in this current is equal to the number of holes involved in the whole current. Moving holes in one direction (such as from right to left in figure 119) is equivalent to moving electrons in the opposite direction. The P-type crystal is also called the acceptor type crystal, since it readily accepts electrons.

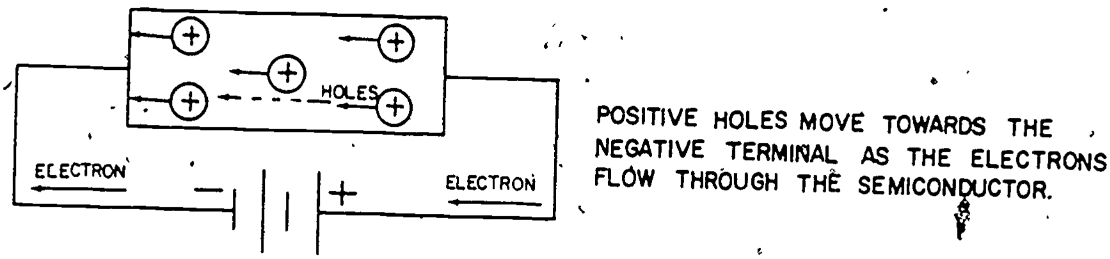


Figure 119. Hole Current Flow in P-type Crystal

Transistors

In many respects, the transistor is similar to the electron tube. Both tubes and transistors are able to amplify signal, voltages, and power. The transistor is composed of three regions of semiconductor material. The two outside regions consist of the same type of crystal, while the middle region is the opposite type of crystal. This means that there are two transistor types, as shown in figure 120. When the two outside regions are N type, the middle region is the P type, and we have the NPN transistor.

When the two outside regions are P-type crystal and the middle region is the N type, the transistor is the PNP type. Both transistor types are common. A lead is attached to each of the regions as shown in figure 120. The base lead is connected to the middle region; the emitter lead is connected to the bottom region; and the collector lead is connected to the top region.

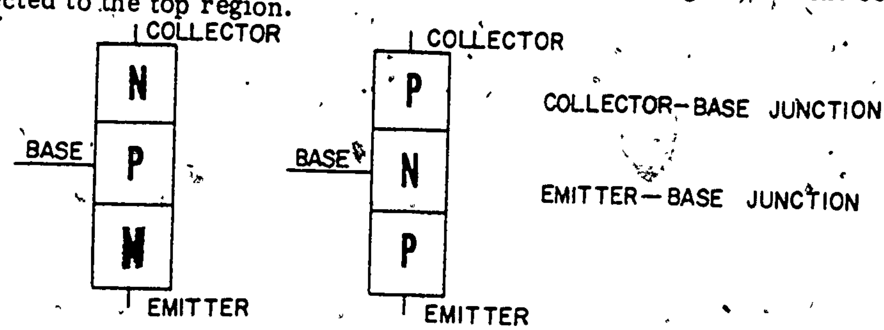


Figure 120. The Two Transistor Types

Transistor Operation

The main current flow in an electron tube is from cathode to plate. In a junction transistor, the main current flow is from the emitter to collector. The current in the electron tube is controlled by the resistance of the control grid. In the transistor the current passes through the base. The base is the controlling factor of the transistor. Regardless of the type of transistor (NPN or PNP), an increase in base current reduces the resistance of the transistor, resulting in a larger value of collector current. A reduction in base current increases the transistor resistance and a smaller value of collector current will flow.

The life of the transistor should exceed that of the vacuum tube because the transistor does not use a heated filament or cathode. Symbols for transistors are shown in figure 121 and the physical appearance of typical transistors is shown in figure 122.

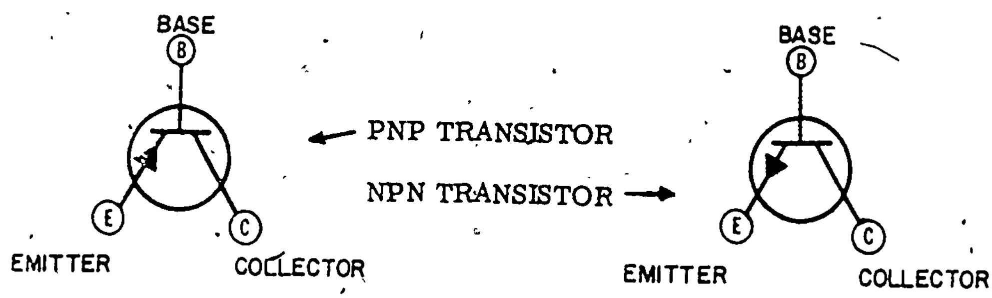


Figure 121. Correct Symbols of the Two Types of Transistors

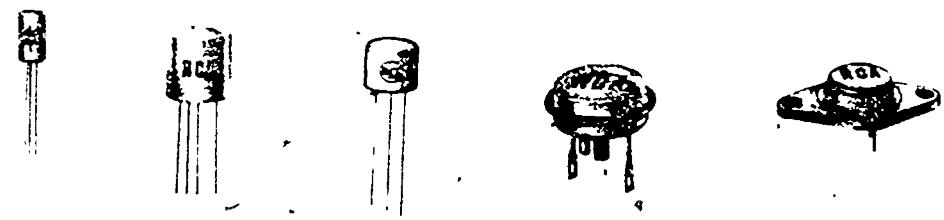


Figure 122. Transistor's Physical Appearance

SUMMARY

The transistor is constructed of two types of semiconductors, N type which has an excess of electrons and the P type that has holes. There are two types of transistors--NPN type and PNP type. The transistor has three main parts: 1. the base, 2. the collector, and 3. the emitter.

QUESTIONS

1. What are the two types of semiconductor materials?
2. What is added to the semiconductor to give it better conductability?
3. What causes current flow in the P-type semiconductor?
4. What causes current to flow in a transistor?
5. Where is the output of a transistor?

REFERENCES

1. Cleveland Institute of Electronics Programmed Lesson, How Tubes and Transistors Amplify: Angelo C. Gillie

2. Electronics in Industry: George M. Chute

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Department of Civil Engineering Training

Electrician

ELECTRICAL FUNDAMENTALS

July 1975

SHEPPARD AIR FORCE BASE

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MODIFICATIONS

Pages 1-12 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

ELECTRICAL AND ELECTRONIC FUNDAMENTALS

Exercise 1. ELECTRON THEORY

OBJECTIVES

Given information on the electron theory of electricity and a list of applicable terms and definitions; match each term with the correct definition.

Given information on the electron theory of electrical current flow, complete statements pertaining to current flow in conductors.

After observing examples of electrical current and voltage waveforms, draw a diagram for AC, DC, and pulsating DC waveforms.

EQUIPMENT

	Basis of Issue
SG 3ABR54230-1-I-1--10	1/student
Oscilloscope	1/10 student
Trainer, Missile System Electronic Circuitry	1/10 student

PROCEDURES

Project 1

1. Below you will find various terms and definitions. In the blank beside the electrical term place the letter that represents the correct definition.

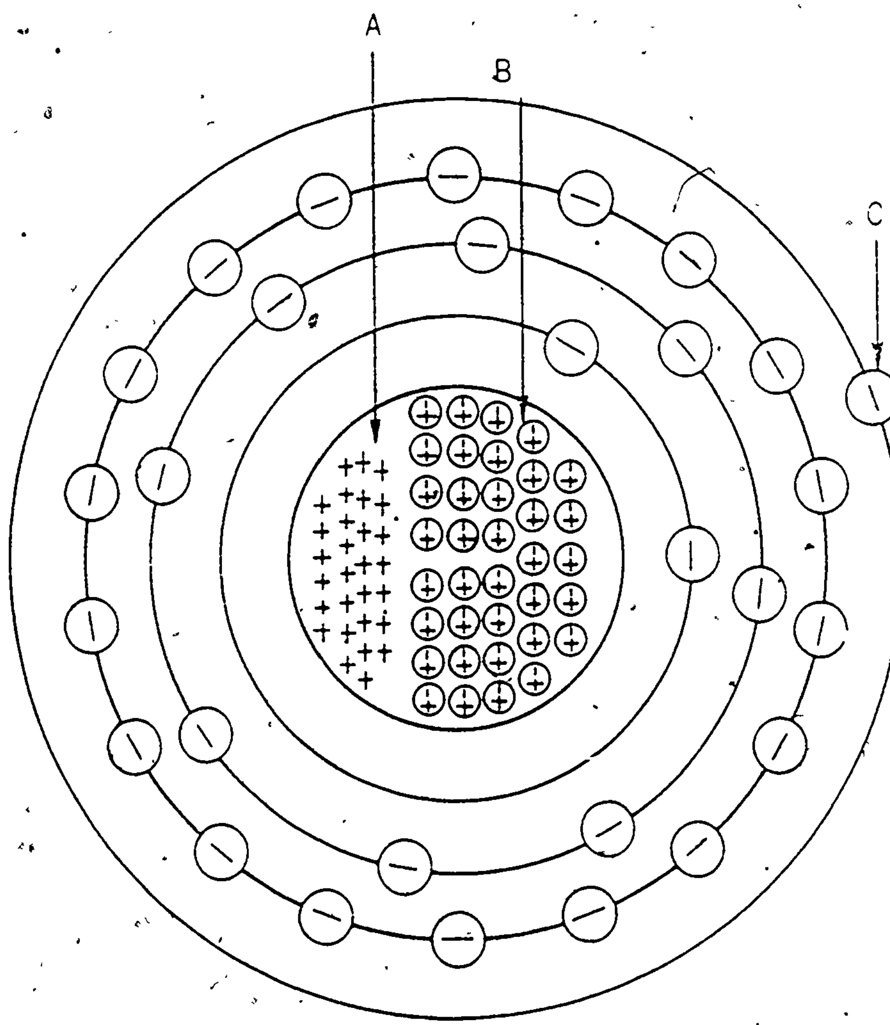
______	(1) Compound	a. Negative particle of an atom
______	(2) Mixtures	b. Substance that can't be decomposed any further by ordinary chemical action.
______	(3) Elements	c. An atom that has lost an electron
______	(4) Atom	d. Protons plus the neutrons
______	(5) Proton	e. A material with electrons easily freed
______	(6) Neutron	f. Positive particle of an atom
______	(7) Electron	g. Two or more elements combined chemically
______	(8) Positive ion	h. Stored energy
______	(9) Negative ion	i. Uniform movement of electrons in a conductor
______	(10) Atomic weight	
______	(11) Atomic number	

________ (12) Conductor	j.	Electricity in motion
________ (13) Resistor	k	An atom that has gained an electron
________ (14) Insulator	l.	Two or more substances combined but no chemical change
________ (15) Potential Energy	m.	Smallest part of an element which can participate in ordinary chemical change
________ (16) Kinetic Energy	n.	Particle of an atom with no charge
________ (17) Static Electricity	o.	Material normally having no free electrons
________ (18) Dynamic Electricity	p.	Opposition to current flow
________ (19) Induction (Electromagnetic)	q.	The number of protons or number of electrons
________ (20) Conduction	r.	Substance having few free electrons
________ (21) Potential difference	s.	Energy in motion
________ (22) Current	t.	Electricity at rest
________ (23) Resistance	u.	Ability of a material to conduct an electric current
	v.	The force that moves electrons in a conductor
	w.	The process of producing voltage by the relative motion of a magnetic field across a conductor

2. List the three major groups of matter: (a) ________

(b) ________ (c) ________

3. Correctly label the subatomic particles of a copper atom



4. Electron flow in a circuit is from ________________ to ________________.

5. List the four most common forms of energy:

a. ____________________________.

b. ____________________________.

c. ____________________________.

d. ____________________________.

6. Like charges ________________________________ each other.

7. Unlike charges ________________________________ each other.

Project 2

Answer the following questions.

1. What is the structural difference between conducting materials and insulating materials? ________________________________

____

____

____

2. What are the laws of attraction and repulsion between two charged bodies?

____

____

____

3. If an irregularly-shaped conducting body is charged, the charge will concentrate on the parts of the body which have the ________________________

________________________________ curvature.

4. List the practical unit of:

a. Current ____________________

b. Potential difference ____________________

c. Resistance ____________________

5. Give the symbol or symbols used to indicate the following practical units

   a. Volt ______________________

   b. Ampere ______________________

   c. Ohm ______________________

6. Define the ampere: ______________________

   ____

7. The OHM may be defined as the resistance which will limit the current to one ampere when the electrical pressure is: ______________________

   ____

8. List three factors other than temperature which determine the resistance of a wire:

   a. ______________________

   b. ______________________

   c. ______________________

9. A wire 12-feet long has a resistance of 8 OHMS. What is the resistance of 36 feet of the same wire?

   ____

10. Underscore the correct statement or statements:

    A good conductor: (a) has few free electrons; (b) is called a dielectric;

    (c) has a high conductance; (d) has a low temperature coefficient.

Project 3

1. Draw the waveforms for AC, DC, and pulsating DC and the symbols for AC and DC generators.

Waveforms	Symbols
AC (a)	DC Generator
DC (b)	AC Generator (Alternator)
Pulsating DC (c)	

Exercise II. MAGNETISM

OBJECTIVES

Given information on the theory and application of magnetism and a list of terms and definitions, match each term with the correct definition.

Given information on the theory and application of magnetism, complete statements pertaining to the application of magnetism.

Using previously given information on the theory of magnetism, a galvanometer, magnet, soft iron bar, and a length of copper wire, perform an experiment to produce an electrical current.

EQUIPMENT	Basis of Issue
SG 3ABR54230-1-I-1--10	1/student
Trainer, Electrical Fundamentals	1/10 student

PROCEDURES

Project 1

1. Place the number of the definition beside the term it represents.

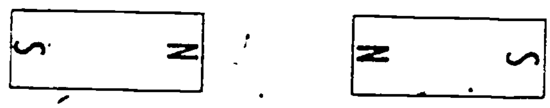
Term	Definition
________a. Reluctance	1. The ability to easily conduct lines of force
________b. Residual Magnetism	2. A device that protects delicate instruments from magnetic lines of force
________c. Permeability	3. Opposition to lines of force
________d. Magnetic Screen	4. The magnetism that remains in an object after the magnetizing force has been removed
________e. Magnetic Induction	5. Action of producing magnetism in iron or steel by the action of lines of force or a magnetic field
________f. Lines of Force	6. Imaginary lines used for convenience to designate the direction in which magnetic forces are acting
________g. Magnet	7. Area where lines of force enter and leave a magnet
________h. Retentivity	8. Metal which has the property of attracting and repelling other pieces of magnetic metal

________ i. Magnetic Poles — 9. Complete path of magnetic lines of force

________ j. Magnetic Circuit — 10. Ability of a material to retain magnetism

Project 2

1. Place two magnets end-to-end so the two north poles are opposite to each other as shown below:



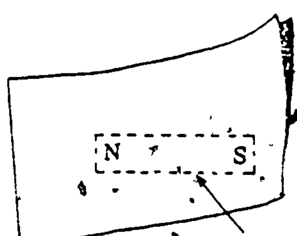
2. Slowly move the magnets together. Notice if they tend to attract or repel each other. Answer the following questions:

   a. This experiment shows that LIKE POLES ________________ EACH OTHER.

   b. If one magnet was turned so a north pole was opposite a south pole, the magnets would ________________

   Why? ________________

3. Place a sheet of paper on top of a magnet as shown below. Then shake some iron filings on the paper in the area above the magnet.



Sheet of Paper

Magnet Under Paper

Sheet of Paper

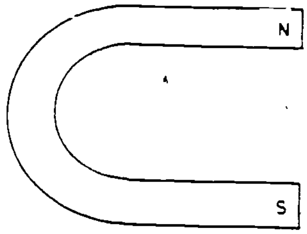
Magnet Under Paper

4. Tap the paper slightly, notice the formation of the iron filings. Answer the following questions:

   a. Where did most of the iron filings form? ________________

   Why? ________________

5. Draw the magnetic lines of force and indicate by arrows the magnetic direction of flow. Use the figure below and show lines of force within and outside the magnet. (Also use compass.)



6. Answer the following questions:

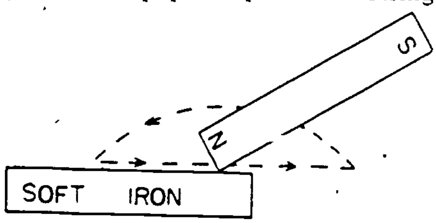
a. Magnetic lines of force will not ______________________ each other.

b. The direction of magnetic lines of force is always ______________ to ______________________ outside of a magnet.

c. A magnet field can be bent by a ______________________.

d. Magnetic lines of force (can, cannot) be insulated. (Mark out one.)

7. Take a bar magnet and stroke it against a piece of soft iron as shown below. After several strokes, see if the iron will pick up a small paperclip or iron filings.



8. Answer the following questions:

a. The magnetism which stayed in the soft iron is called ______________________

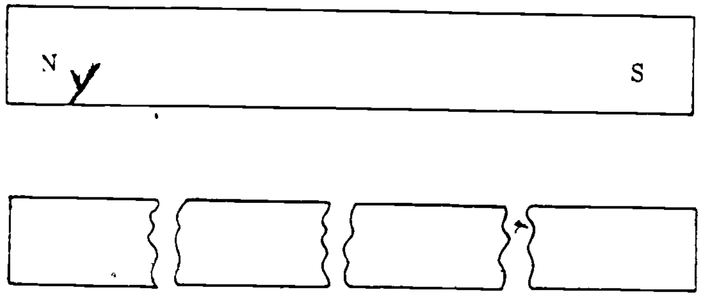
____

b. The magnet will make iron filings magnetic, by magnetic ______________

____

c. Two things which will cause magnets to lose their magnetism are ______________ ______________________ and ______________________

9. Mark the pole of each piece of the magnet that has been broken into smaller parts in the following figure.



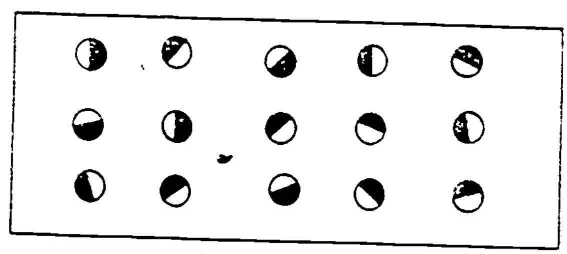
10. What is meant by magnetic poles? ____

____

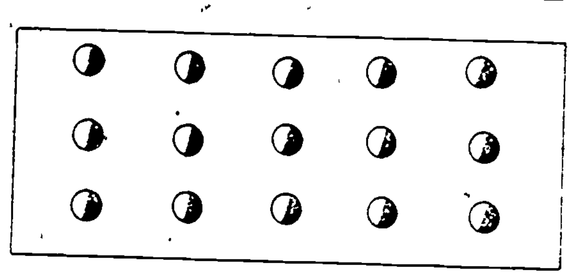
____

11. Based on the molecular theory of magnetism, determine which material represented below is magnetized, and which is not, by writing magnetized and nonmagnetized in the spaces provided.

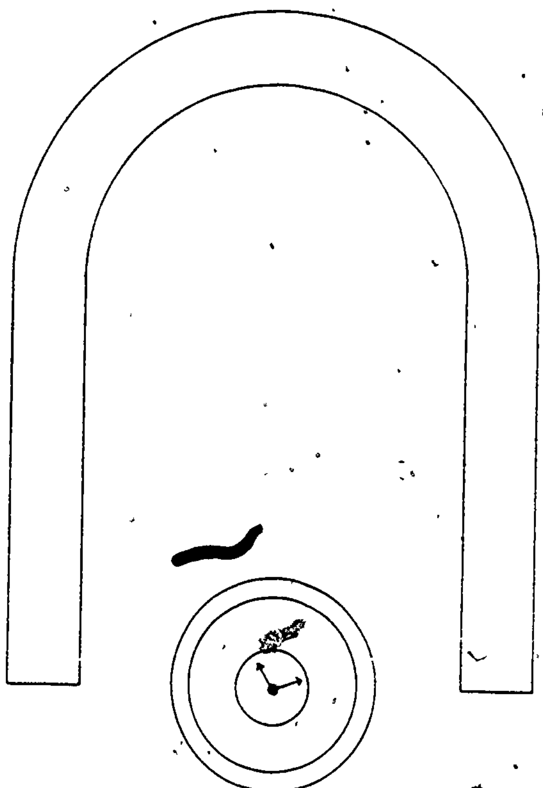
a. ______________________



b. ______________________



12. Using a drawing containing a magnetic screen located between the poles of a U-shaped magnet, indicate by dotted lines and arrows the path and direction taken by one line of force.



Project 3

1. Using a galvanometer, two lengths of copper wire, and a soft iron bar, arrange these components to make a circuit similar to the drawing shown in figure 4.

2. Move the iron bar from the north pole to the south pole. Notice any indication of movement of the galvanometer pointer.

a. Did the galvanometer pointer move? ____________________

b. If not, then how could you cause the galvanometer pointer to move? ______

____

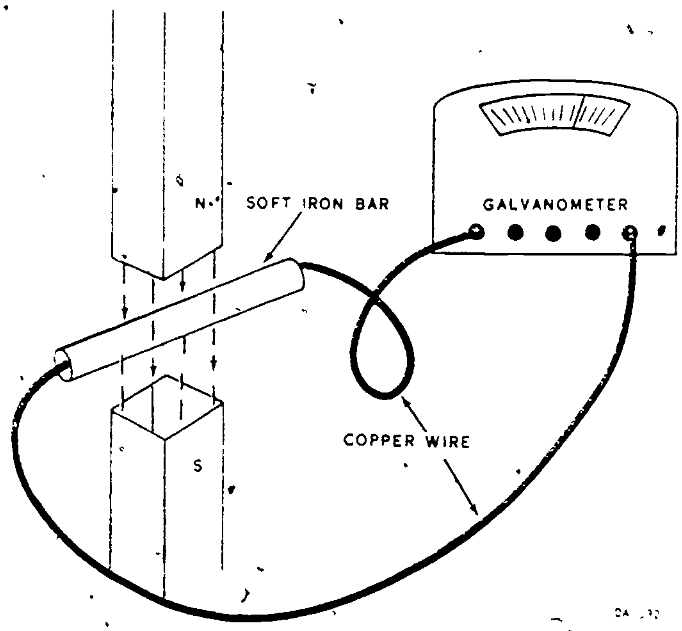


Figure 4. Simple Generator

3. With the same iron bar used in figure 4, move it at right angles to the magnetic field between the north and south pole. Notice the galvanometer pointer movement.

a. Did the meter pointer movement increase? ______________

b. Why? ____

____

c. Did the voltage change direction as the iron bar was moved back through the magnetic field? ____

____

4. Demonstrate to the instructor how the current flow direction may be determined with the use of the generator left-hand rule.

5. Answer the following questions:

a. The process of getting a meter indication when an iron bar is moved through a magnetic field is called ______________________________

b. To get the maximum voltage, a conductor must move at what angle to a magnetic field ______________________________

Why? ______________________________

c. When using the generator left-hand rule the first finger will point to ______________________________

d. How may the voltage be increased using the same generator? ______________________________

e. Name the three things necessary to produce a voltage:

(1) ______________________________

(2) ______________________________

(3) ______________________________

f. Define electromagnetic induction. ______________________________

6. The direction of the magnetic field around a current carrying conductor depends on the ______________ of the ______________ in the conductor.

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7. In figure 5 detect if the current is flowing toward you by placing a dot (.) in the center of the appropriate drawing and a plus (+) in the drawing with current going away from you.

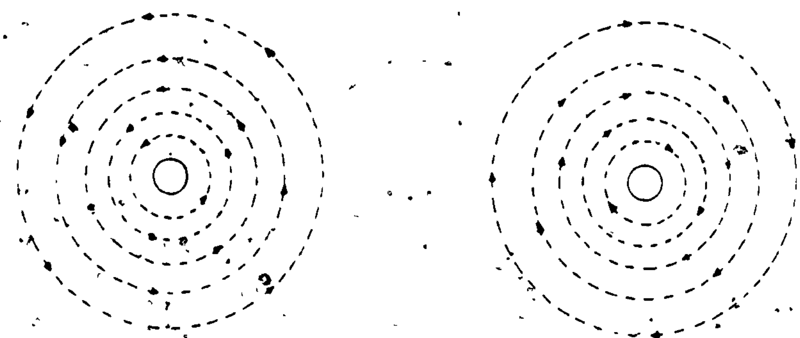

Figure 5. Determining Direction of Current Flow in a Conductor

8.) Indicate the direction of current through the coil in figure 6 in order to establish flux in a clockwise direction through the iron core.

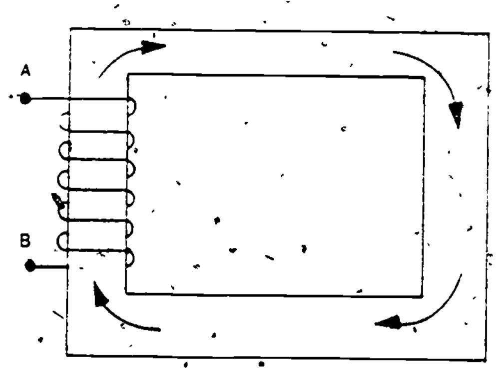

Figure 6. Determining Current Flow in a Coil

9. Show by means of arrows the flux in the iron core when current in the coil flows from A to B in the drawing in figure 7.

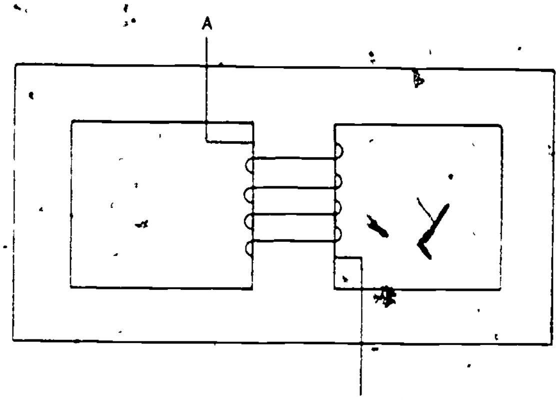

Figure 7. Determining Direction of Flux in Iron Core

10. In figure 8 below determine and mark the polarity of the iron cores and show the path and direction of the flux by means of arrows and lines.

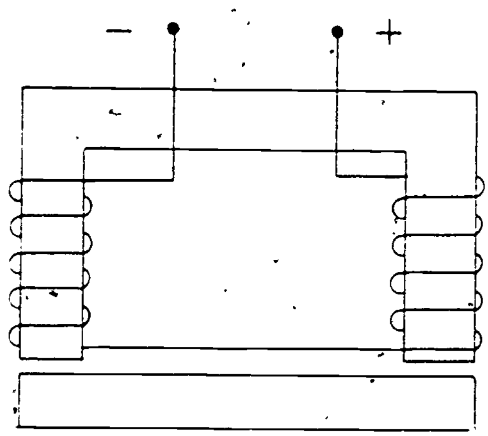

Figure 8. Determining Polarity

11. Figure 9 shows a coil winding that will produce the magnetic polarity in the core.

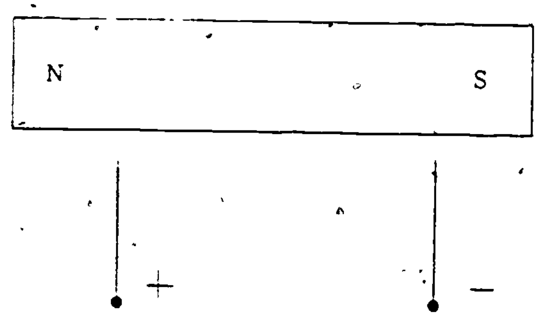

Figure 9. Determining Polarity

12. The instructor will demonstrate three (3) types of waveforms on an oscilloscope. Draw and label each of these three demonstrations.

a. ______________________________

b. ______________________________

c. ______________________________

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13. Place the number of the definition beside the term it represents.

_______ a. Frequency	1.	360° electrical degrees.
_______ b. Sine Wave	2.	Average of all the instantaneous values during one alternation.
_______ c. Cycle	3.	The value of voltage or current at one particular instant.
_______ d. Period	4.	The highest voltage reached on the positive or negative alternation.
_______ e. Amplitude	5.	The number of cycles per second.
_______ f. Average	6.	A graphic illustration of electrical forces.
_______ g. Instantaneous	7.	The distance from zero to the maximum value.
_______ h. Peak	8.	The time in seconds or fractions of a second, required to generate one cycle of alternating voltage.

Exercise III. REACTANCE

OBJECTIVES

- Given information on reactance in AC circuits, complete statements pertaining to inductive and capacitive reactance.

- Using the information given on reactance and a list of terms and definitions, match each term with the correct definition.

- Given a programmed text, identify symbols used in electrical and electronic fundamentals.

EQUIPMENT	Basis of Issue
SG 3ABR54230-1-I-1--10	1 student
2TPT-3100-01-Introduction to Electrical Symbols	1 student
Trainer, Reactance comparison	1/10 student

PROCEDURES

Project 1

1. Answer the following questions pertaining to Inductance and Capacitives.

   a. What are three factors that affect inductance?

      1. ________________

      2. ________________

      3. ________________

   b. What type of Phase relationship does an inductive circuit produce?

      ____

   c. What are the three factors which effect capacitance?

      1. ________________

      2. ________________

      3. ________________

   d. What type of Phase relationship does a capacitive circuit produce?

      ____

e. What are the three parts of a capacitor?

1. ______________________________

2. ______________________________

3. ______________________________

Project 2

1. Place the number of the definition beside the term it represents.

________	a. Inductance	1. The direction of induced current is always such that its magnetic field opposes the motion that produced it.
________	b. Capacitance	2. That property of a circuit which opposes any change in the rate of current flow.
________	c. Reactance	3. Unit of measurement for inductance.
________	d. Current Leads Voltage	4. Basic unit of capacitance.
________	e. Impedance	5. One-millionth farad.
________	f. Counter EMF	6. Capacitive circuit.
________	g. Inductive Reactance	7. Ability to store electrical energy.
________	h. Capacitive Reactance	8. Electrical characteristic, outside of resistance, which impedes the flow of alternating current in a circuit.
________	i. Voltage Leads Current	9. Inductive circuit.
________	j. Henry	10. All of the opposition in a circuit.
________	k. Farad	11. It is measured in ohms and its symbol is X_L.
________	l. Microfarad	12. It is measured in ohms and its symbol is X_C.

2. Complete this project by placing the number of the symbol beside the term it represents.

______________	a. Inductive reactance	1. X
______________	b. Inductance	2. MFD
______________	c. Capacitance	3. C
______________	d. Capacitive reactance	4. X_C
______________	e. Impedance	5. Z
______________	f. Reactance	6. X_L
______________	g. Microfarads	7. L

Project 3

1. Read and complete the program text, 2TPT-3100-01, Introduction to Electrical Symbols, you have been issued.

WB 3ABR54230-1-6
July 1975

METERS

OBJECTIVES

Given information on multimeters, complete statements on the selection, use and care of electrical test instruments.

Using a multimeter and conductor trainer, measure and record readings pertinent to resistance and voltage.

EQUIPMENT

EQUIPMENT	Basis of Issue
SG 3ABR54230-1-I-1--10	1/student
Trainer, Conductor	1/student
Trainer, Multimeter	1/10 student
Multimeter, TS 297V	1 student
Ohmmeter, AN PSM2A	1/10 student
Multimeter, Clamp-on type AN USM-33	1/10 student

Project 1

1. Answer the following questions pertaining to meters.

a. When measuring an unknown voltage, what voltage scale should you use when using a voltmeter? ____________________

____

b. What is the purpose of the megonmmeter (insulation tester)?

____

c. Why should you never use an ohmmeter on a live circuit?

____

d. What is the maximum current a clamp-multimeter will read?

____

e. What is the maximum size conductor the clamp-multimeter can handle provided the current is within the range of the meter?

____

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Project 2

1. Using a multimeter type TS-297 /U, a testboard, and the drawings of the multimeter listed on the following pages, complete the following statements or questions.

a. Set your multimeter to read resistance. Have your instructor check your meter. ____________________

b. Check wire number 1. The ohms reading is __________

What does this reading mean? ____________________

c. Check wire number 2. The meter reading is __________

What does this reading mean? ____________________

d. Check wire number 3. The meter reading is __________

What does this reading mean? ____________________

e. Check wire number 4. How much resistance is in this circuit? __________

f. Check wire number 5. The meter reading is __________

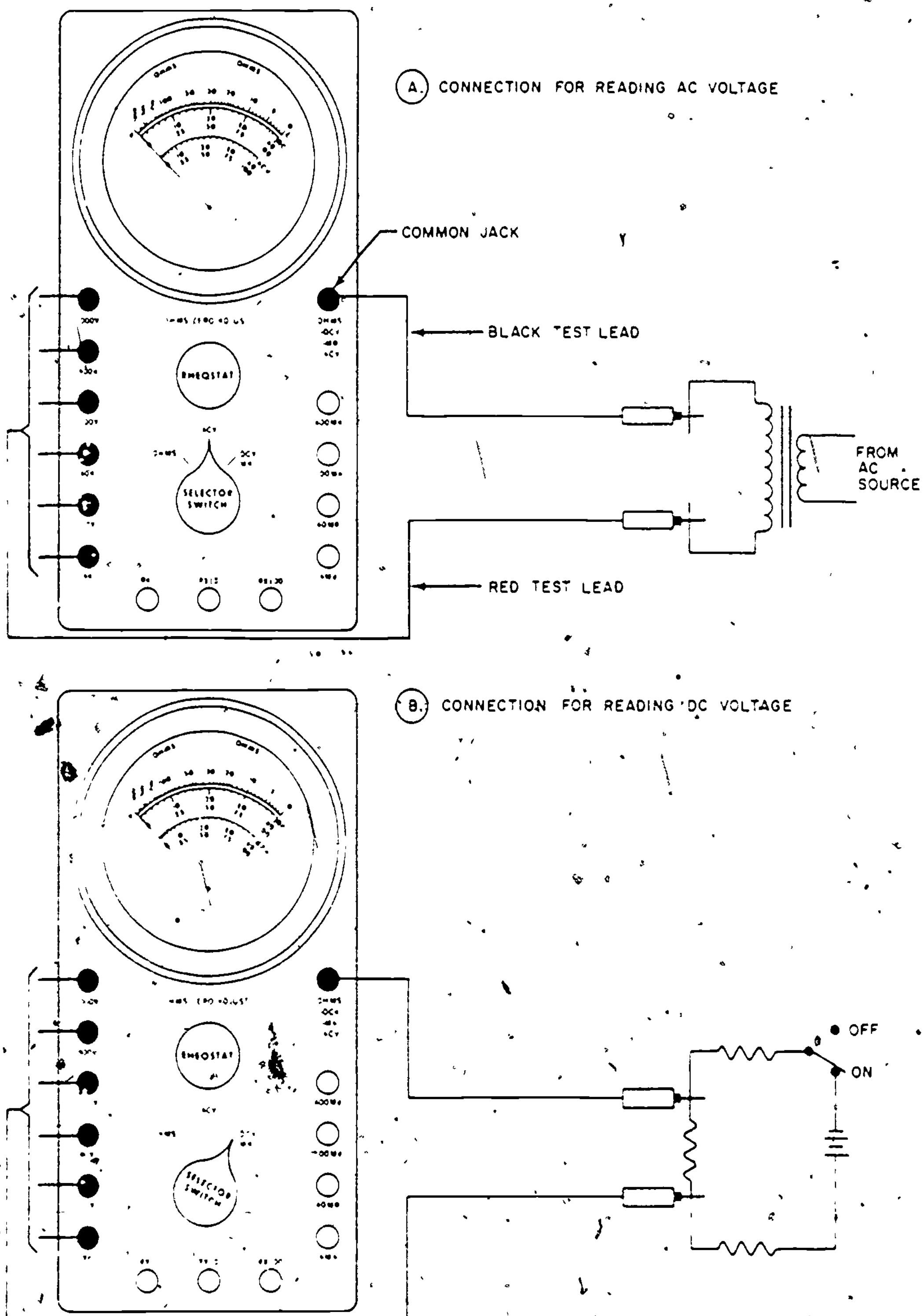
g. Using the meter and wire number 6 explain what role a switch plays in a circuit. ____________________

CAUTION. DO NOT USE THE METER TO TEST VOLTAGE UNTIL INSTRUCTOR TELLS YOU TO DO SO.

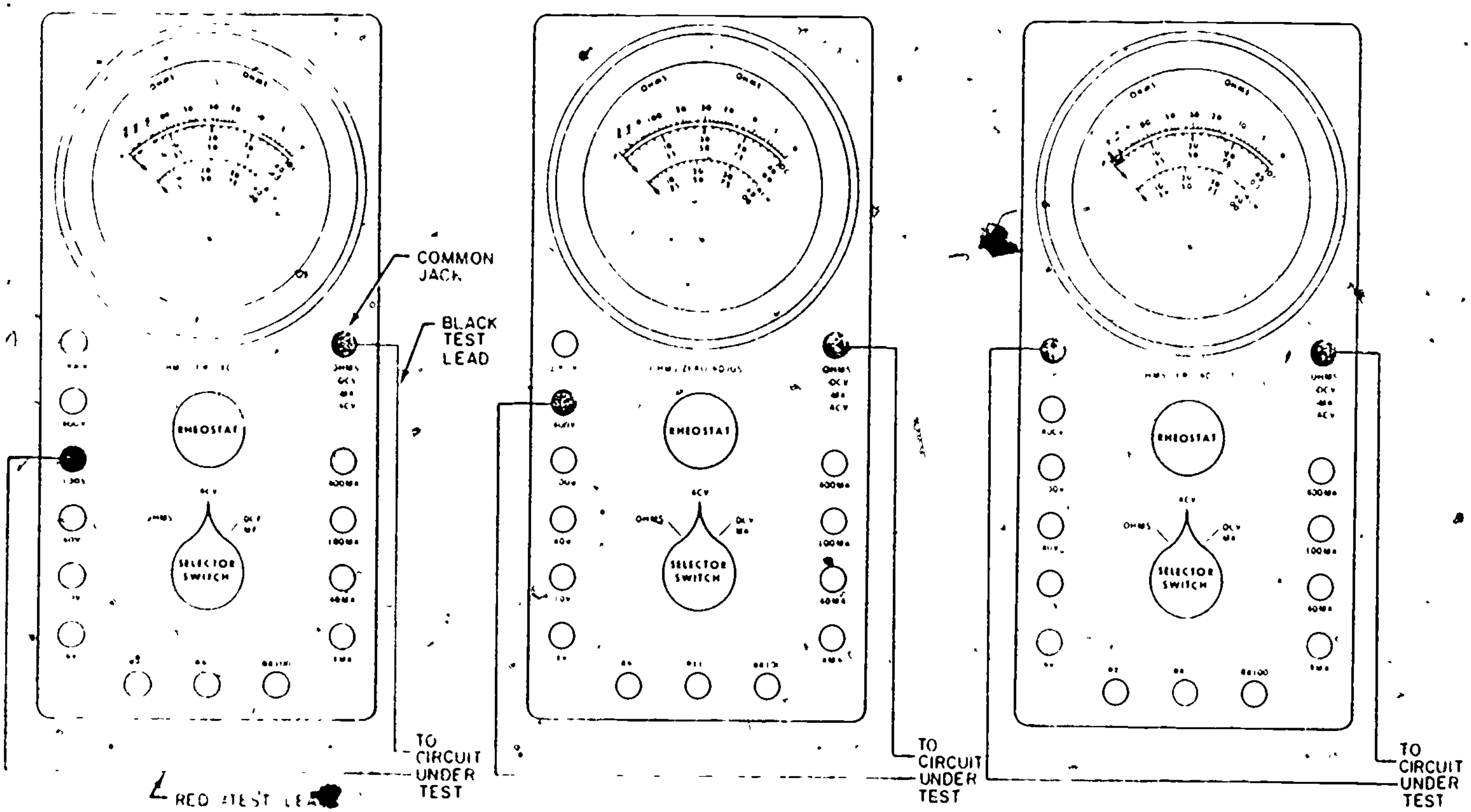
h. Select an electrical outlet located on the wall in the classroom and check the amount of voltage available.

What was the voltage reading? ______________________

i. Return the board and meter to your instructor.

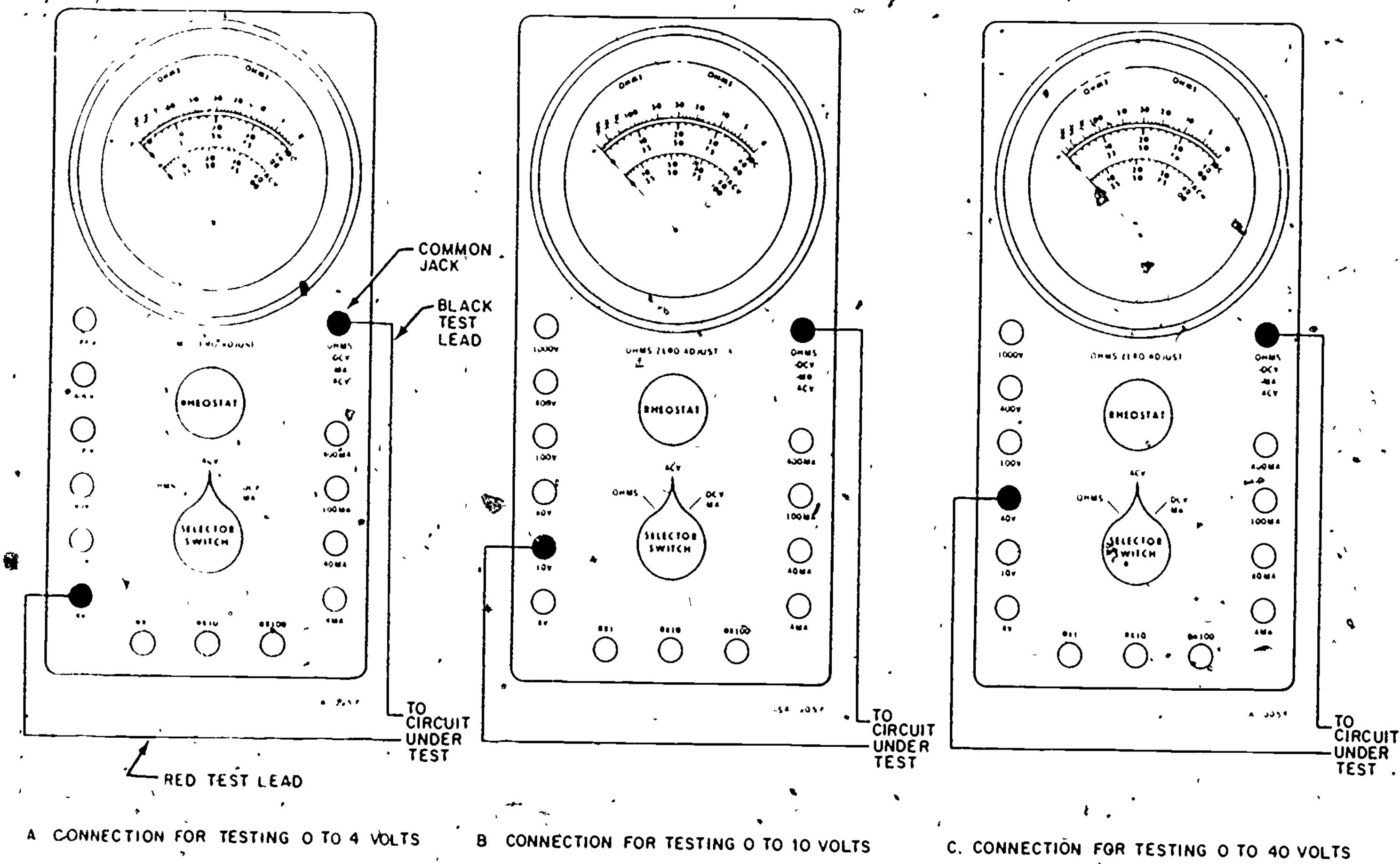


Connection of Multimeter When Measuring AC and DC Voltages



A CONNECTION FOR TESTING 0 TO 100 VOLTS B CONNECTION FOR TESTING 0 TO 400 VOLTS C CONNECTION FOR TESTING 0 TO 1000 VOLTS

Connection of Multimeter for Testing AC Voltages of 0 to 100 volts, 0 to 400 volts, and 0 to 1,000 volts



Connection of Multimeter for Testing AC Voltages of 0 to 4 volts, 0 to 10 volts, and 0 to 40 volts

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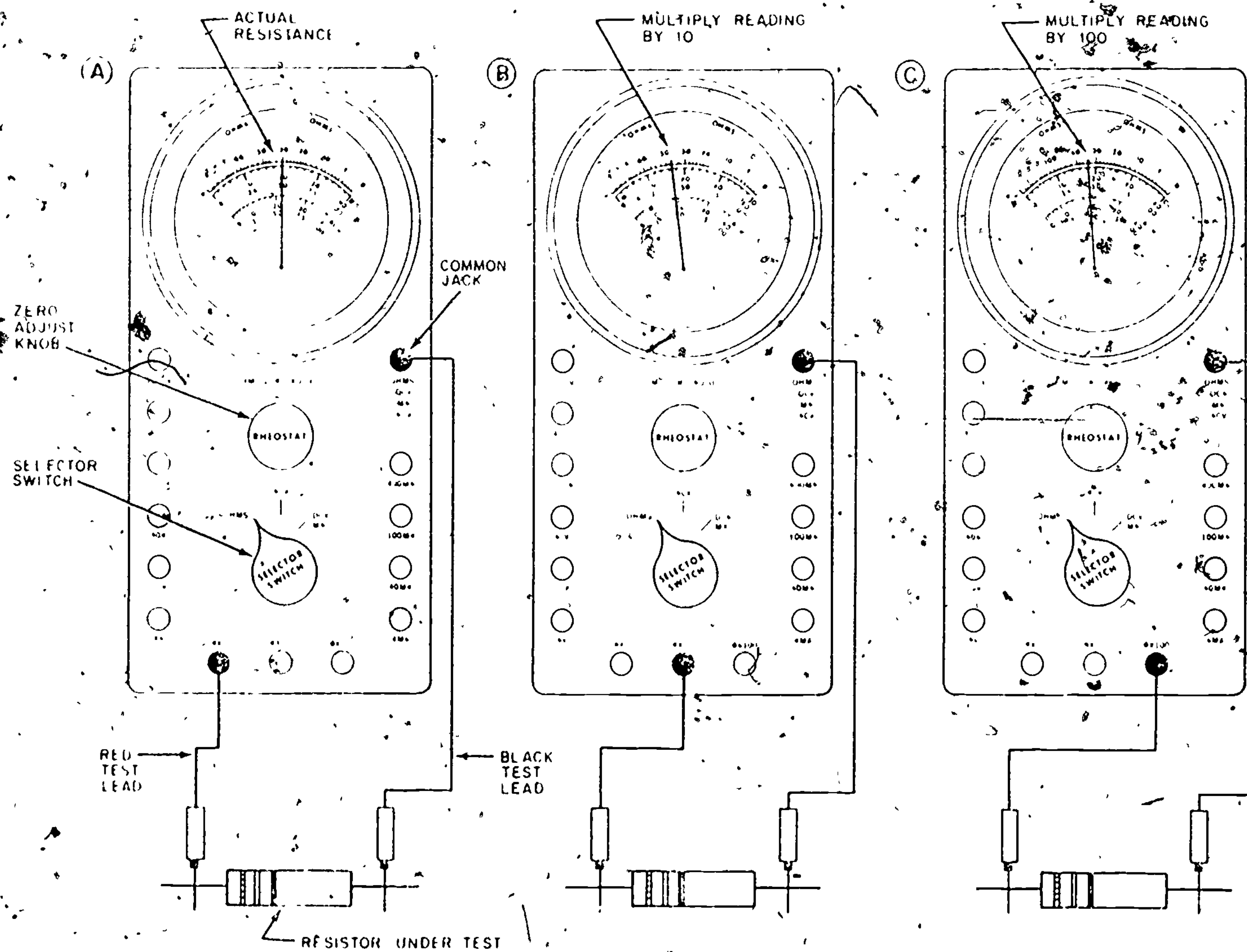

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Connection of Meter for Reading Resistance

WB 3ABR54230-1-I-7
July 1975

OHM'S LAW AND SERIES CIRCUITS

OBJECTIVES

Given ohm's law formula and two known values, solve for the unknown.

Given instructions on a series circuit, use the conductor trainer to construct a series circuit.

Using previously constructed series circuit, measure and record voltage and current, then apply Ohm's law to calculate resistance and power.

Given series circuit problems, use Ohm's law to solve for unknown values.

EQUIPMENT

	Basis of Issue
SG 3ABR54230-1-I-1--10	1/Student
Trainer, Conductor	1/Student
Trainer, Electrical Fundamentals	1/10 Student

PROCEDURES

PROJECT 1

1. Complete the following questions pertaining to ohm's Law.

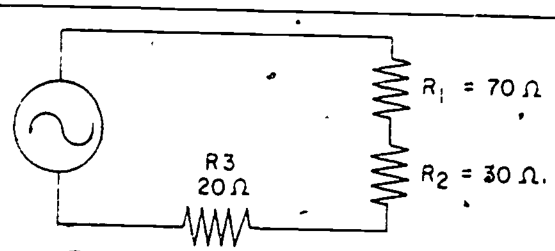
   a. Given a voltage of 12 volts and current of 2 amps, find the Power.

   ____

   b. Given a wattage of 200 watts and a current 5 amps, find the voltage.

   ____

   c.



   R_t = ______________

   d. Given a voltage of 60 volts and a resistance of 20 ohms, find the current

   ____

2. Complete the following by filling in the blank spaces.

a. What are the three essential components of all electrical circuits?

________________, ________________, ________________

b. A simple circuit contains a ________________, a ________________, and a ________________.

c. Voltage and current are ________________ proportional to each other.

d. Current and resistance are ________________ proportional to each other.

e. A series circuit contains a ________________, a ________________, and a ________________.

f. Ohm's Law equations are:

a. E=

b. I=

c. R=

g. The characteristics of a series circuit are:

a. E_t =

b. I_t =

c. R_t =

h. The sum of the voltage drops in a series circuit is ________________ to the applied voltage.

i. The current in any portion of a series circuit is ________________ to the total current.

j. The sum of resistance in a series circuit is ________________ to the total of resistance.

k. Power = ________________ times ________________.

l. A unit of Power is called a ________________.

Project 2

1. Using the correct symbols, draw a simple circuit containing a single-pole, single-throw (SPST) Switch, fuse and lamp socket with a 100-watt lamp, an ammeter, and an alternator as a power supply. Draw the circuit in the block below.

CAUTION Before proceeding to the next step, remove your jewelry. Before wiring a circuit, make sure that all safety and disconnect switches are in the OFF position. Have your instructor check your work before turning switches ON.

2. Have the instructor check your diagram, then wire the circuit on your trainer. Place a 100-watt lamp in the lamp socket. Have instructor check your wiring before you apply power to the circuit.

3. Plug in power lead and close the switch. Take the measurement of the following and record the readings in the space below.

a. Applied voltage (E_t)= ________________ volts.

b. Voltage drop across lamp (E_1)= ________________ volts.

c. Current in the circuit (I_t)= ________________ amps.

4. Disconnect power from the circuit; the using OHM's law and power formula, determine the resistance and wattage of the lamp.

Resistance = ________________ ohms.

Power = ________________ watts.

5. If voltage is increased, would the current flow through the circuit decrease, increase, or remain the same?

____

6. Using the correct symbols, draw a series circuit containing a fuse, (SPST) Switch, and two lamp sockets with a 100-watt and 150-watt lamp, and an ammeter. Place the ammeter to read the total current flow through the circuit. An alternator is used as a power supply. Draw circuit in the block below.

7. Wire the circuit on the trainer according to your drawing and have your instructor check your work.

This circuit has ____________ path(s) of current flow.

8. Plug in the power to the circuit. Measure the following and record the indications.

a. Applied Voltage (E_t) = ____________ volts

b. Voltage drop across Lamp 1 (E_1) = ____________ volts

c. Voltage drop across Lamp 2 (E_2) = ____________ volts

d. Current in the circuit (I_t) = ____________ amperes

9. Using the information obtained from Step 3, Ohm's law and power formula, find the answers for the following:

LAMP 1	LAMP 2	TOTALS
E_1 ____________	E_2 ____________	E_t ____________
I_1 ____________	I_2 ____________	I_t ____________
R_1 ____________	R_2 ____________	R_t ____________
P_1 ____________	P_2 ____________	P_t ____________

a. The ________ of the resistors equals the total resistance.

b. The ________ of the voltage drop equals the applied voltage.

c. The current is ____________ in all parts of the circuit.

10. Add a third lamp socket with a 200-watt lamp to the series circuit. Have your instructor check your circuit. Draw circuit in the box below.

Will the lamps burn dimmer or brighter? ____________________

Why? ____________________

11. Plug in power to the circuit. Measure the following and record the meter indications.

a. Applied voltage (E_t) = ____________ volts

b. Voltage drop across Lamp 1 (E_1) = ____________ volts

c. Voltage drop across Lamp 2 (E_2) = ____________ volts

d. Voltage drop across Lamp 3 (E_3) = ____________ volts

e. Current in the circuit is ____________ amperes

12. Using the preceding information from Ohm's law and power formula, find the answer for the following:

LAMP 1	LAMP 2	LAMP 3	TOTALS
E_1 ________	E_2 ________	E_3 ________	E_t ________
I_1 ________	I_2 ________	I_3 ________	I_t ________
R_1 ________	R_2 ________	R_3 ________	R_t ________
P_1 ________	P_2 ________	P_3 ________	P_t ________

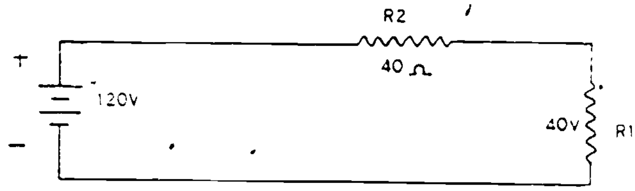
13. Is there more current in this circuit than in the preceding circuit? ________

Why? ____________________

(4) How much current flows through I_1 ________, I_2 ________, I_3 ________, I_4 ________, and I_5 ________.

(5) What is the total current in the circuit? I_t = ________.

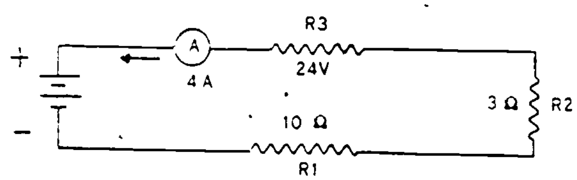
b. Referring to the diagram below, calculate the following



(1) E_1 ________, I_1 ________, R_2 ________, P_1 ________,
P_2 ________, Rt ________, Pt ________.

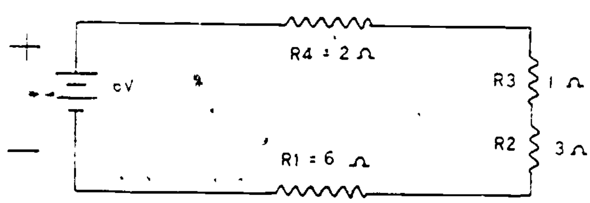
(2) What is the current flow in the circuit? ________________
____

c. Calculate the following after analyzing the diagram below.



R_1 ________, I_2 ________, E_t ________, E_3 ________,
P_t ________, P_2 ________, P_3 ________

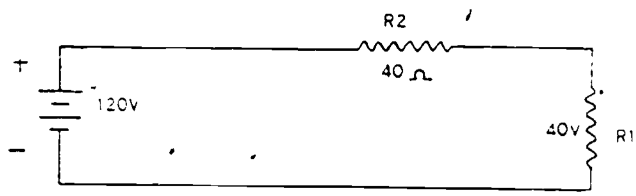
d. Using the diagram below, calculate the following information.



(4) How much current flows through I_1 ________, I_2 ________, I_3 ________, I_4 ________, and I_5 ________?

(5) What is the total current in the circuit? I_t = ________.

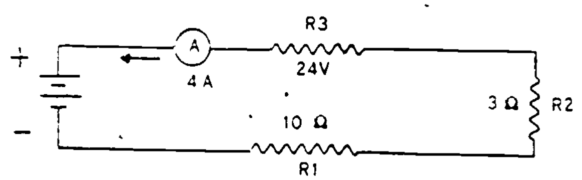
b. Referring to the diagram below, calculate the following



(1) E_1 ________, I_1 ________, R_2 ________, P_1 ________, P_2 ________, Rt ________, Pt ________.

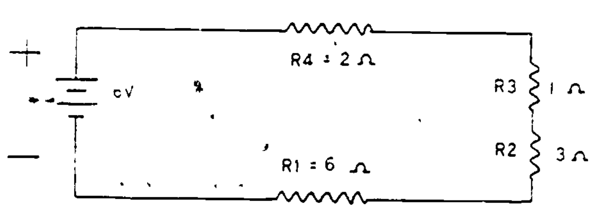
(2) What is the current flow in the circuit? ____

c. Calculate the following after analyzing the diagram below.



R_1 ________, I_2 ________, E_t ________, E_3 ________, P_t ________, P_2 ________, P_3 ________

d. Using the diagram below, calculate the following information.



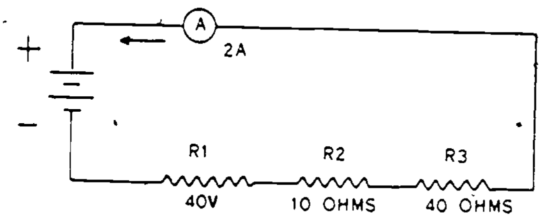
(1) Voltage drop across each resistor.

E_1 ______________, E_3 ______________, E_2 ______________,

E_4 ______________

(2) Total current flow in the circuit. ______________________

e. Using the diagram below, calculate the following:



(1) R_1 = __________ R_2 = __________ R_t = __________

(2) E_2 = __________ E_3 = __________ E_t = __________

(3) P_1 = __________ P_3 = __________ P_t = __________

(4) I_t = __________

Take this worksheet to your instructor and have him check your work.

Checked by ____________________
Instructor

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PARALLEL CIRCUITS

OBJECTIVES

Given instructions on a parallel circuit, use the conductor trainer to construct a parallel circuit.

Using the previously constructed parallel circuit, record meter readings of voltage and current and calculate resistance and power.

Given parallel circuit problems, use Ohm's law to solve for unknown values.

EQUIPMENT

	Basis of Issue
SG 3ABR54230-1-I-1--10	1/Student
Trainer, Conductor	1/Student

PROCEDURE

Project 1

Complete the following projects. Read the instructions carefully and be sure to have the instructor check where indicated.

CAUTION: REMOVE ALL JEWELRY.

Be sure there are no short circuits and all connections are tight.

1. Construct a simple circuit containing a fuse, (SPST) switch, one lamp socket with a 100-watt lamp, and an ammeter. Draw the circuit in the block below.

2. Wire the circuit with the equipment given to you by your instructor. Have the instructor check your wiring.

3. Apply power to the circuit. Measure the following and record the indications below:

   a. Applied voltage (E_t) ______________ volts

   b. Voltage drop across the lamp (E_t) ______________ volts

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c. Current in the circuit (I_t) = ____________________ amperes

4. Using the information obtained from question 3, Ohm's law and the power formula, determine the answers to the following:

LAMP		TOTALS	
E_1 = ____________	volt	E_t = ____________	volts
I_1 = ____________	amperes	I_t = ____________	amperes
R_1 = ____________	ohms	R_t = ____________	ohms
P_1 = ____________	watts	P_t = ____________	watts

5. Using the correct symbols, draw a diagram of a parallel circuit containing a fuse, single-pole single-throw switch, and two lamp sockets with a 100-watt and 150-watt lamp, and an ammeter to measure total current. Label the lamp nearest the source of power L_1 and the other L_2. Draw the circuit in the block below.

6. Using the above diagram, wire the circuit on a trainer. Have an instructor check your wiring.

7. Apply power to the circuit. Measure the following and record the indications below:

a. Applied voltage (E_t) = ____________________ volts.

b. Voltage drop across Lamp 1 (E_1) = ____________________ volts.

c. Voltage drop across Lamp 2 (E_2) = ____________________ volts.

d. Current in the circuit (I_t) = ____________________ amperes.

(1) Did the total current increase when L_2 was added to the circuit? _____

____

Why? ______________________________________

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(2) Did the total resistance of the circuit increase or decrease? ________

____

Why? ________________________________

8. Disconnect the power. Move the ammeter to measure the current in L_1 circuit. Then move it to measure the current in L_2 circuit. Record your answers below:

a. Current in L_1 (I_1), ________________________ amperes.

b. Current in L_2 (I_2), ________________________ amperes.

c. Does the sum of the current through L_1 and L_2 equal the indication given by the main line ammeter? ________________________

Why? ________________________________

9. With the information you have obtained above and the use of Ohm's law and the power formula find the answer for the following:

LAMP 1	LAMP 2	TOTALS
E_1 ________	E_2 ________	E_t ________
I_1 ________	I_2 ________	I_t ________
R_1 ________	R_2 ________	R_t ________
P_1 ________	P_2 ________	P_t ________

a. Is the voltage drop across each branch equal to the applied voltage?

____

Why? ________________________________

b. What formula did you use to find the total resistance? ________

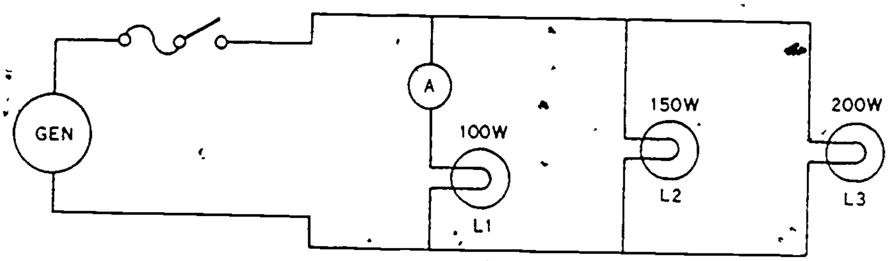
____

c. Is the current the same in each branch circuit? ________

____

Why? ________________________________

10. Use the diagram below and wire the circuit with the equipment given to you by your instructor. Have an instructor check your wiring.



11. Apply power to the circuit. Measure the following and record the indications below:

a. Applied voltage (E_t) ________________ volts.

b. Voltage drop across L_1 (E_1) ________________ volts.

c. Voltage drop across L_2 (E_2) ________________ volts.

d. Voltage drop across L_3 (E_3) ________________ volts.

12. Place an ammeter in each branch circuit and measure the following:

a. Current in Lamp 1 (I_1) = ________________ amperes.

b. Current in Lamp 2 (I_2) = ________________ amperes.

c. Current in Lamp 3 (I_3) = ________________ amperes.

13. With the information you have obtained and the use of Ohm's law and the power formula, find the answers for the following:

LAMP 1	LAMP 2	LAMP 3	TOTALS
E_1 ________	E_2 ________	E_3 ________	E_t ________
I_1 ________	I_2 ________	I_3 ________	I_t ________
R_1 ________	R_2 ________	R_3 ________	R_t ________
P_1 ________	P_2 ________	P_3 ________	P_t ________

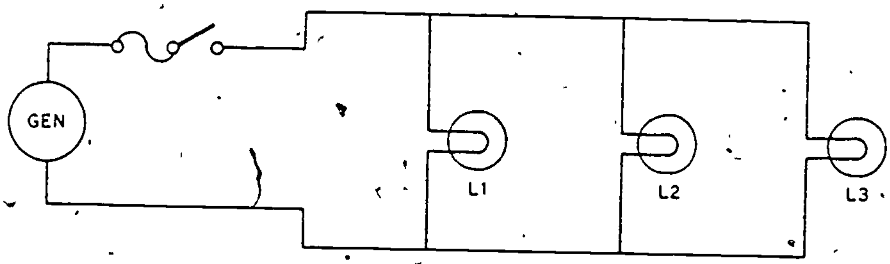
a. The voltage drop across each parallel branch equals the ________________ voltage.

b. The total current is the ________________ of the current in all the parallel branches.

c. The total resistance is always ______________ than the smallest branch resistance.

d. As the current increases (voltage remaining the same) the total resistance must increase, decrease, remain the same. (Circle one.)

14. Apply the principles of Ohm's law to the circuit below and record your answers in the blanks below. Do not construct circuit.



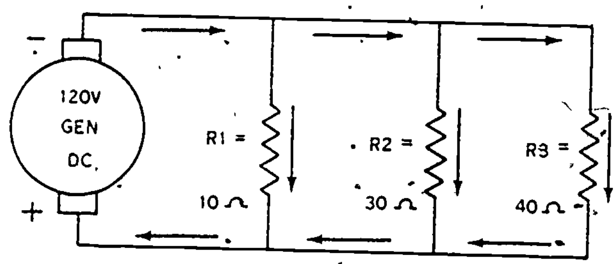
LAMP 1	LAMP 2	LAMP 3	TOTALS
E ______	E ______	E ______	E 12 volts
I ______	I ______	I ______	I ______
R 4 ohms	R 6 ohms	R 3 ohms	R ______

Disassemble and store trainer

Project 2

1. Observing all rules of parallel circuits, apply Ohm's law and the power formula to determine the following information from the circuits below:

a.

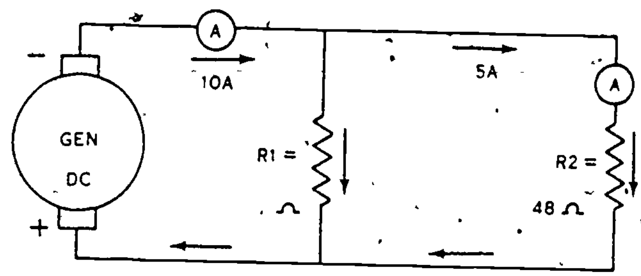


(1) E_1 ______ E_2 ______ E_3 ______ R_t ______

(2) I_t ______ I_1 ______ I_2 ______ I_3 ______

(3) P_t ______ P_1 ______ P_2 ______ P_3 ______

b.



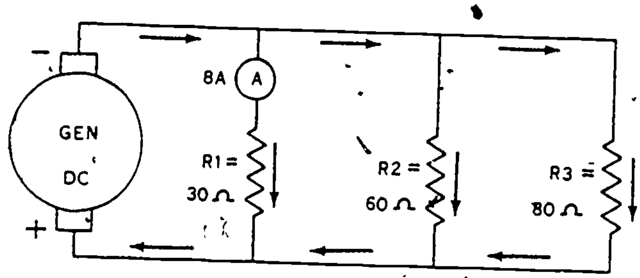
(1) I_1 ____________

(2) E_t ____________, E_1 ____________, E_2 ____________

(3) R_t ____________, R_1 ____________, I_2 ____________

(4) P_t ____________, P_1 ____________, P_2 ____________

c.



(1) E_t ____________, E_1 ____________, E_3 ____________

(2) I_t ____________, I_2 ____________, I_3 ____________

(3) R_t ____________

(4) P_t ____________

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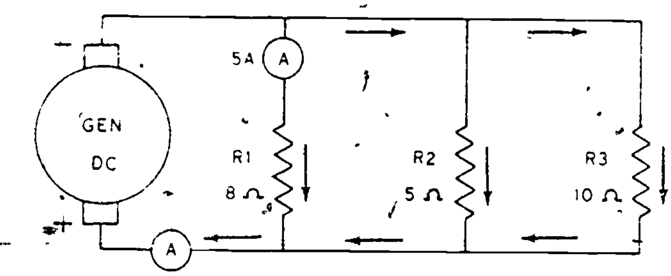
d.



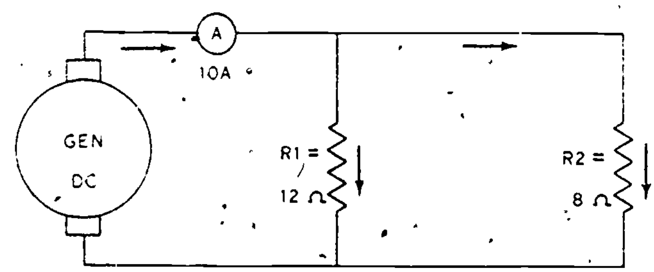
(1) R_3 __________, R_t __________

(2) I_2 __________, I_3 __________

I_t __________

(3) P_1 ______, P_2 ______, P_3 ______, P_t ______

e.

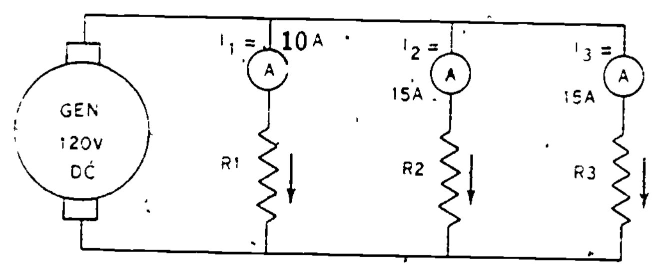


(1) I_1 __________, I_2 __________

(2) P_t __________, P_1 __________,

P_2 __________

f.



(1) I_t = __________ (2) R_t = __________

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2. A resistor of 120 ohms is connected across a 120-volt supply. How much resistance must be added in parallel to increase the total current to two (2) amps? ______

______

3. Three equal resistors connected in parallel have a total resistance of 25 ohms.

Find: R_1 = ______, R_2 = ______, R_3 = ______

4. Three equal resistors that are connected in series have a total resistance of 45 ohms. What would be the total resistance if they were connected in parallel?

R_t = ______

Take this worksheet to your instructor. He will check your work.

Checked by ______
Instructor

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SERIES-PARALLEL CIRCUITS

OBJECTIVES

Given instructions on a series-parallel circuit, use the conductor trainer to construct a series-parallel circuit.

Using the previously constructed series-parallel circuit, record meter readings of voltage and current to calculate resistance and power.

Given series-parallel circuit problems, use ohm's law to solve for unknown values.

EQUIPMENT

	Basis of Issue
SG 3ABR54230-1-I-1--10	1/Student
Trainer, Conductor	1/Student

PROCEDURES

Project 1

Complete the following projects. Read the instructions carefully and be sure to have the instructor check where indicated.

CAUTION: Remove all Jewelry.

Be sure there are no short circuits and all connections are tight.

1. Draw a diagram and construct a parallel circuit containing a fuse, SPST switch, two 100-watt lamps. Have the instructor check your wiring. Draw the diagram in the block below.

2. Apply power to the circuit. Measure the following and record the indications below:

LAMP	TOTALS
E_1 = ________ volts	E_t = ________ volts

E_2 = ______________ volts

I_1 = ______________ amperes I_t = ______________ amperes

I_2 = ______________ amperes

3. Using the information obtained from step 2 Ohm's law and the power formula determine the answers to the following:

R_1 = ______________ ohms R_t = ______________ ohms R_2 = ____ ohms

P_1 = ______________ watts P_t = ______________ watts P_2 = ____ watts

4. Using the diagram that was drawn for the parallel circuit in project 1, add a 150-watt lamp (L_3) in series with L_1 and L_2. After completing this diagram, construct the circuit. Have the instructor check your wiring before applying power. Draw the circuit in the block below.

5: Apply power to the circuit. Measure the following and record the indications below:

a. Applied voltage (E_t) ______________ volts.

b. Voltage drop across lamp 1 (E_1) = ______________ volts.

c. Voltage drop across lamp 2 (E_2) = ______________ volts.

d. Voltage drop across lamp 3 (E_3) = ______________ volts.

e. Current in the circuit (I_t) = ______________ amperes.

(1) Did the total current increase when L_3 was added to the circuit? ______

______________ Why? ______________

(2) Did the total resistance of the circuit increase or decrease? ______

______________ Why? ______________

6. Disconnect the power. Move the ammeter to measure the current in L_3 circuit. Then move it to measure the current in L_1 and L_2. Record your answers below.

a. Current in L_3 (I_3) ______________________ amperes.

b. Current in L_1 (I_1) ______________________ amperes.

c. Current in L_2 (I_2) ______________________ amperes.

d. Does the sum of the current passing through L_1 and L_2 equal the current passing through series resistor L_3 and also the total current?

______________ Why? ______________

7. With the information you have obtained above and the use of Ohm's law and the power formula find the answer for the following:

LAMP 1	LAMP 2	LAMP 3	TOTALS
E_1 ________	E_2 ________	E_3 ________	E_t ________
I_1 ________	I_2 ________	I_3 ________	I_t ________
R_1 ________	R_2 ________	R_3 ________	R_t ________
P_1 ________	P_2 ________	P_3 ________	P_t ________

a. Is the voltage drop across one branch of the parallel portion of the circuit plus the voltage drop across the series resistor equal to the applied voltage?

______________ Why? ______________

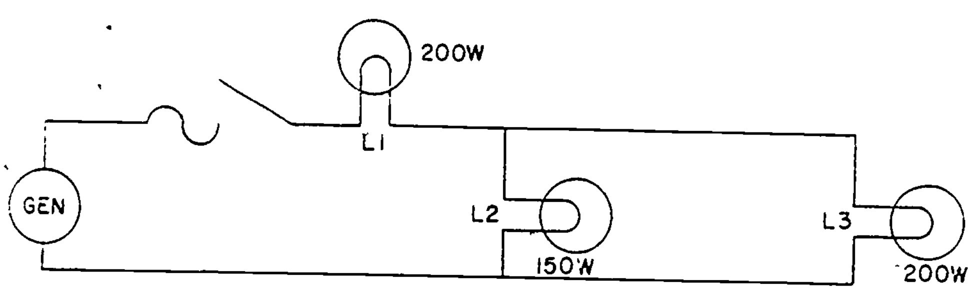
b. What formula did you use to find the total resistance? ______________

____

c. Is the current the same in each branch of the parallel portion of the circuit?

______________ Why? ______________

8. Use the following diagram and wire the circuit with the equipment given to you by your instructor. Have an instructor check your wiring.



9. Apply power to the circuit. Measure the following and record the indications below:

a. Applied voltage (E_t) ______________________ volts

b. Voltage drop across L_1 (E_1) = ______________________ volts

c. Voltage drop across L_2 (E_2) = ______________________ volts

d. Voltage drop across L_3 (E_3) = ______________________ volts

e. Current in Lamp 1 (I_1) ______________________ amperes

f. Current in Lamp 2 (I_2) ______________________ amperes

g. Current in Lamp 3 (I_3) ______________________ amperes

10. With the information you have obtained and the use of Ohm's law and the power formula, find the answers for the following:

LAMP 1	LAMP 2	LAMP 3	TOTALS
E_1 ________	E_2 ________	E_3 ________	E_t ________
I_1 ________	I_2 ________	I_3 ________	I_t ________
R_1 ________	R_2 ________	R_3 ________	R_t ________
P_1 ________	P_2 ________	P_3 ________	P_t ________

a. The voltage drop across one parallel branch plus the voltage drop of the series resistor equals the

____

b. The total current is the ______________________ of the current in all the parallel branches.

c. The total resistance of the parallel portion of the circuit plus the total resistance of the series portion of the circuit equals the

____

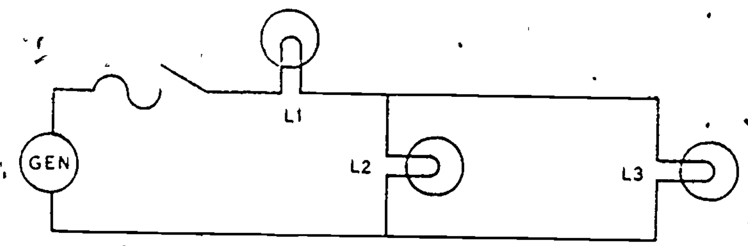
d. As the current increases (voltage remaining the same) the total resistance must, increase, decrease, remain the same, (Circle one)

Disassemble and store your trainer board.

Project 2

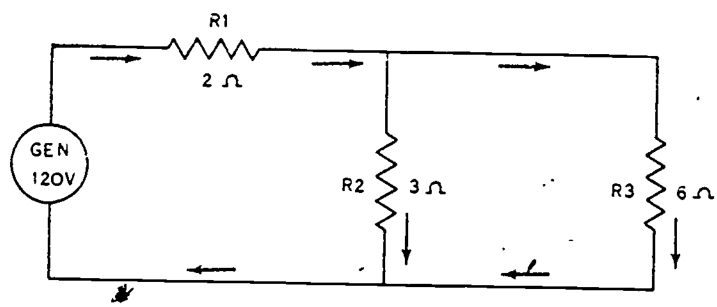
1. Apply the characteristics pertaining to series-parallel circuits and the principles of Ohm's law and the power formula to the following circuits and record your answers in the blanks provided. Do not construct the circuits.

a.



LAMP 1	LAMP 2	LAMP 3	TOTALS
E ______	E ______	E ______	E_t 120 volts
I ______	I ______	I ______	I_t ______
R 2 ohms	R 8 ohms	R 24 ohms	R_t ______
P ______	P ______	P ______	P_t ______

b.

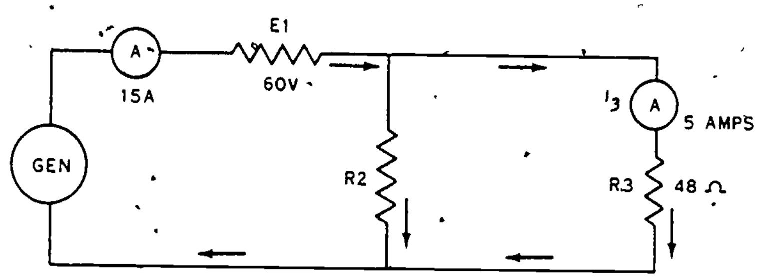


E_1 ______ E_2 ______ E_3 ______ R_t ______

I_t ______ I_1 ______ I_2 ______ I_3 ______

P_1 ______ P_2 ______ P_3 ______ P_t ______

c.



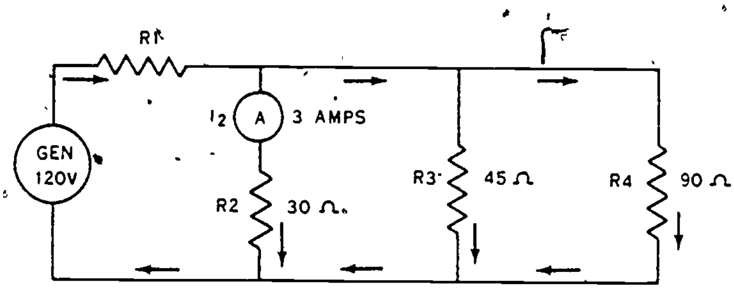
I_1 ______ I_2 ______

E_t ______ E_2 ______ E_3 ______

R_t ______ R_2 ______

P_t ______ P_1 ______ P_2 ______

d.



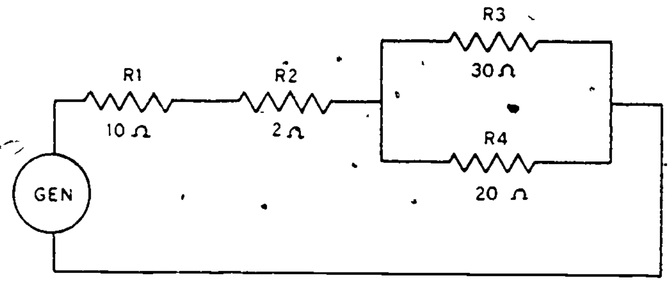
I_1 ______ I_2 ______ I_3 ______ I_4 ______

E_1 ______ E_2 ______ E_3 ______ E_4 ______

R_1 ______

R_t ______ I_t ______ P_t ______ P_1 ______

e.



I_1 ______ I_2 ______ I_3 ______ I_4 ______

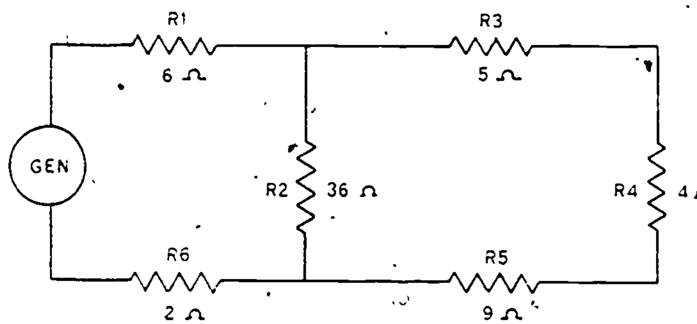
E_1 ______ E_2 ______ E_3 ______ E_4 ______

R_t ______

E_t 120 V I_t ______ P_2 ______

P_t ______ P_1 ______ P_3 ______ P_4 ______

f.



I_1 ______ I_2 ______ I_3 ______

I_4 ______ I_5 ______ I_6 ______

E_1 ______ E_2 ______ E_3 ______

E_4 ______ E_5 ______ E_6 ______

P_t ______

I_t ______

E_t 120 volts P_t ______

Take this worksheet to your instructor. He will check your work.

Checked by ______________
(Instructor)

WB 3ABR54230-1-I-10
July 1975

TRANSFORMERS, RECTIFIERS, AND POWER SUPPLIES

Exercise I. Transformers

OBJECTIVES

Using a schematic and nomenclature pertaining to transformers, label the three main parts.

Given an incomplete schematic and required information, draw the secondary windings of a transformer, including the output voltage value.

Given a drawing of a transformer showing the number of primary and secondary turns and the applied voltage and current, use the turns ratio formula to determine the secondary voltage and current.

Given a list of statements, a schematic and required information, complete statements pertinent to use of transformers in electronic circuits.

EQUIPMENT

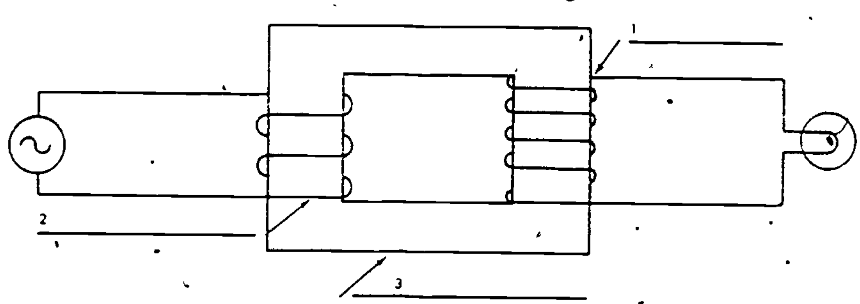
	Basis of Issue
SG 3ABR54230-1-I-10	1/Student
Trainer, Electrical Fundamentals	1/10 Student

PROCEDURES

Project 1

Answer the questions and complete the drawings in this project.

1. Name the three parts of a transformer by filling the blanks:



2. Is this a step-up ________________ or a step-down ________________ ?

3. What is its turns ratio? ____________________________

4. If 10 volts is applied to the primary coil what will be the output voltage? ____________________________

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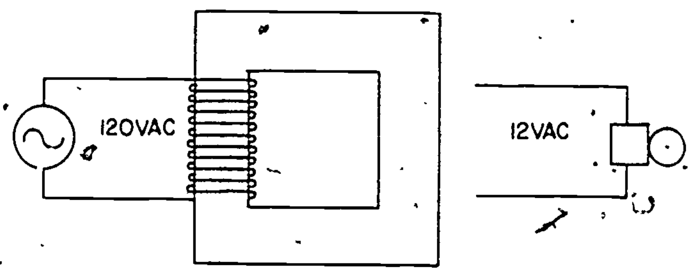
5. If the current is 2 amps in the primary what is the current in the secondary?

Project 2

Complete the drawing and answer the questions.

1. The transformer below is a step-down doorbell transformer. Draw the correct number of windings on the secondary side.



2. What is the ratio of this transformer? ____________________

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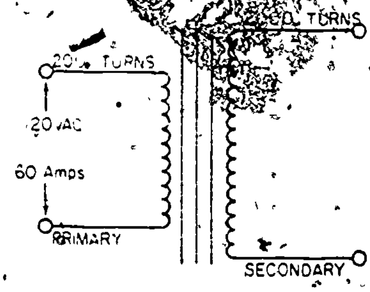
Project 3

1. Complete the drawing and answer the questions.

a.



(1) Find the Secondary Voltage.

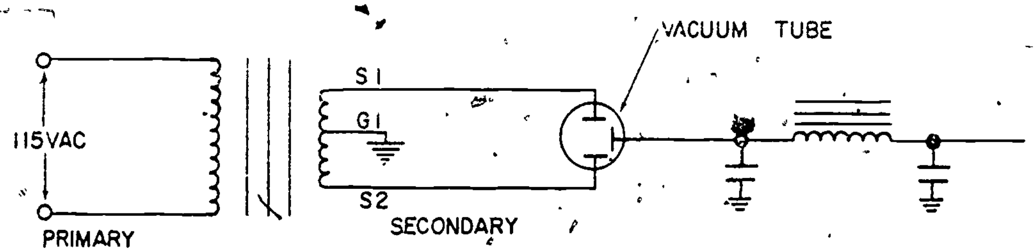
SE ____________________

(2) Find the Secondary Current.

SC ____________________

Project 4

1. Complete the following statements pertinent to the use of transformers in electronic circuits.



(1) Rectifier circuit with filter.

(2) Step-down transformer.

a. What is the purpose of the center tap G_1 of the secondary of the transformer? ____________________

b. Will the current flow be more or less than the primary current? ____________________

c. Are all transformer cones made out of silicon steel? ____________________

Exercise II. Rectifiers

OBJECTIVES

Give a schematic and nomenclature pertaining to rectifiers; label the main parts.

Using the schematic of a rectifier circuit, trace one alternation of current through the circuit by using arrows to indicate direction of current flow.

EQUIPMENT	Basis of Issue
SG 3ABR54230-1-I-1--10	1/Student
Trainer, Missile System Electronic Circuitry	1/10 Student
Oscilloscope	1/10 Student

PROCEDURE

Project 1

1. Complete this project by labeling the main parts of the rectifier.

a.

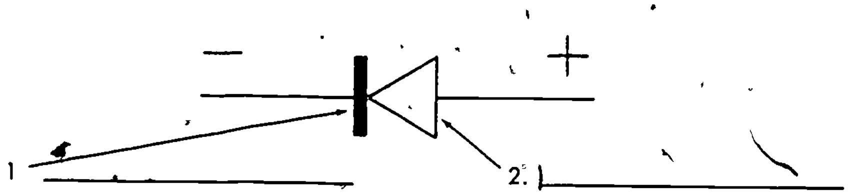


Figure 10. Rectifier symbol

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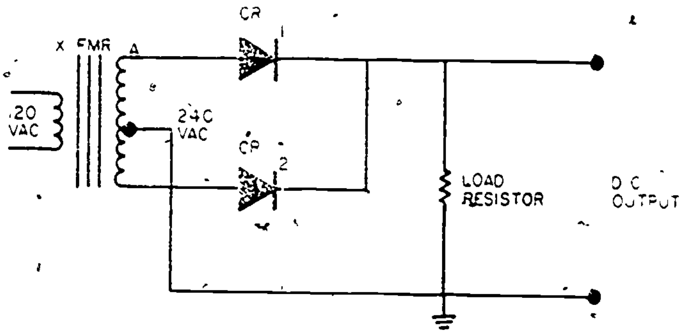
Project 2

Complete this project by tracing the circuits required and filing in the blanks.

1. The output waveform of a half wave rectifier circuit is ______________.

2. To smooth out pulsating direct current use a ______________.

3. Trace one alternation of current through the resistor circuit in diagram below.



4. What will determine the voltage output of the circuit above?

5. Mark the negative terminal with a minus (-) and the positive terminal with a plus (+) of the resistor above.

Exercise III. Power Supplies

OBJECTIVE

Given a list of incomplete statements and required information, complete statements pertaining to batteries.

Given a list of questions pertaining to electrical and electronic power supplies and required information, answer questions on use of power supplies.

Given a drawing of a magnetic amplifier label the three main parts.

EQUIPMENT	Basis of Issue
SG 3ABR54230-1-I-1--10	1/Student
Trainer, Battery Charger	1/10 Student

PEOCEDURE

Project 1

1. Complete the following statement pertaining to batteries:

   a. What do you do to the voltage when you connect batteries in parallel? ____________

   ____

   b. What is used to check the specific gravity of a lead-acid battery? ____________

   ____

   c. What are the two types of battery chargers that may be used?

   (1) ____

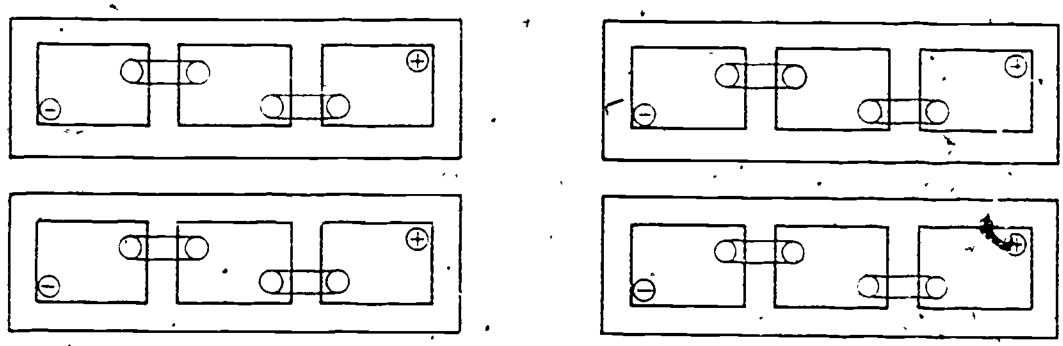
   (2) ____

   d. Why should you not smoke around a battery being charged? ____________

   ____

2. Answer the questions and complete the drawings in this project.

a. Connect the batteries in series and parallel banks by drawing lines to the proper terminals.



(A) Parallel (B) Series

Figure 11

b. Which battery bank will deliver more voltage? (A) __________

(B) __________

c. Connect the battery charger to the battery by drawing lines to the proper terminals.

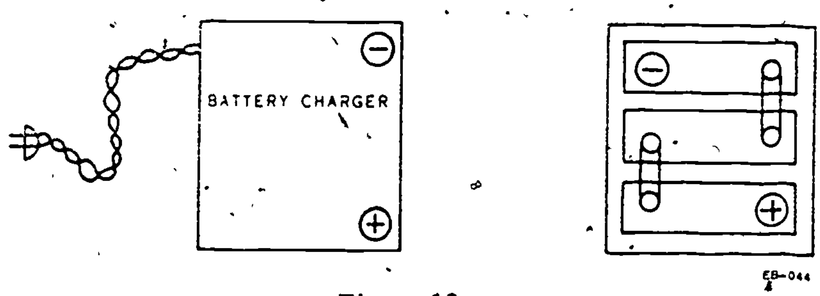


Figure 12

Project 2

1. Complete the following statements.

a. What is the material called that transistors are constructed from? ______

____

b. What are the two basic materials created when impurities are added to the semiconductors?

(1) ____________________ (2) ____________________

c. An N-Type crystal has ______________________ electrons.

d. The transistor has three main parts. Name them:

(1) ______________________

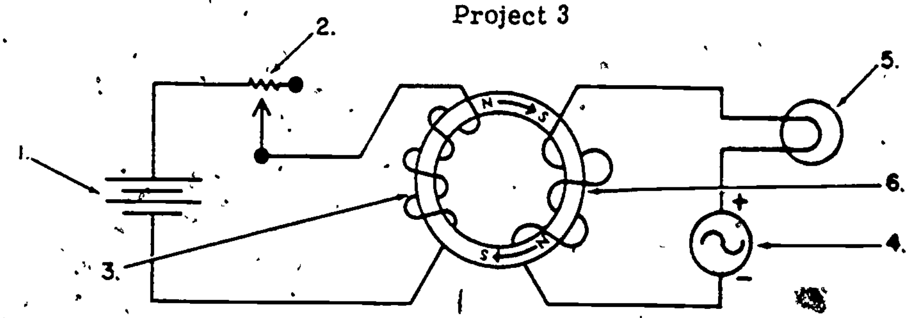
(2) ______________________

(3) ______________________

e. Draw the correct symbols for an NPN and a PNP transistor.

(1) NPN ______________ (2) PNP ______________

Project 3



1. Label each part of this magnetic amplifier.

(1) ______________________

(2) ______________________

(3) ______________________

(4) ______________________

(5) ______________________

(6) ______________________

STUDY GUIDES
3ABR54230-1-II-1 thru 7

Technical Training

Electrician

NONMETALLIC SHEATHED CABLE

August 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

Designed For ATC Course Use

DO NOT USE ON THE JOB

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Electrician

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This supersedes SG 3ABR54230-1-II-1 thru 7, July 1973
(Copies of the superseded publication may be used until the supply is exhausted.)

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SG 3ABR54230-1-II-1
August 1975

NATIONAL ELECTRICAL CODE, ELECTRICAL TERMINOLOGY AND BLUEPRINT READING

OBJECTIVE

Upon completion of this unit of instruction you will be able to:

1. Locate specific facts pertaining to wiring in accordance with the National Electrical Code.

2. Recognize terminology common to the electrical field.

3. Recognize symbols and parts of blueprints.

INTRODUCTION

This study guide is directed to aid you in understanding the language used in the electrical trade. In order to understand any trade, you must first understand the rules, terminology, and symbols of that trade.

INFORMATION

NATIONAL ELECTRICAL CODE

The National Electrical Code (NEC) is a commercial publication that sets the minimum safety standard for electrical work. The Occupational Safety and Health Act (OSHA) has made the NEC a mandatory federal standard, binding under force of legal sanctions. Its use will help insure safe, accurate work. Since this book will be your major guide in all electrical work, you should fully understand and use the book as it is intended. Prior to returning to class tomorrow read Articles 90 and 110. As you study the NEC you will notice the layout of the book; Chapters, Articles, Paragraphs, and Subparagraphs. There is a table of contents in the front of the book and an alphabetical index in the back. You may find it easier to use the alphabetical index at first or until you become familiar with the code.

SUMMARY

The National Electrical Code (NEC) is a commercial publication used by the Air Force to insure minimum safety standards for electrical installation. Your understanding and knowledge of the code will insure your safety as well as the safety of those that live and work around the electrical systems you install.

QUESTIONS

1. Mandatory rules in the National Electrical Code are characterized by the word
______________________.

2. Identified as used in the National Electrical Code means ______________
____
____

3. The National Electrical Code is divided into ______________ chapters.

4. Where is the best place to start to locate information in the N.E.C.?__________
____

5. The N.E.C. contains provisions considered necessary for ______________

6. The conductors and equipment for delivering energy from the electrical supply system to the wiring system of the premises served is called a ______________.

7. Definitions are located in what article in the N.E.C.? ______________

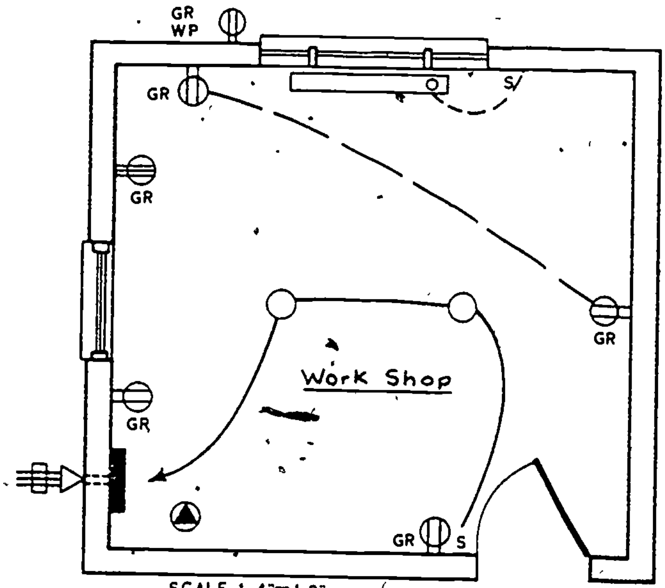
8. Tables and examples are located in what chapter of the N.E.C.? __________

BLUEPRINT READING AND ELECTRICAL TERMINOLOGY

A picture is worth a thousand words. Man has used pictures to convey his meanings for centuries. It would be difficult for an engineer or inventor to describe the exact size, weight, texture and height of an object without a drawing of some type. It would be difficult for a machinist to build a simple object from a word description. A drawing can convey, to the person who is to fabricate the object, the size, shape, or location of holes. Whether the drawing is freehand or made with mechanical aids, it is needed to convey the necessary information to the people who will fabricate or assemble the object.

Lines

To include all necessary information on a drawing in a manner that is usable, lines of different types and thickness are used. The meaning of a line with certain characteristics has been standardized. See figure 1.



SCALE 1 4"=1-0"

NOTES:
1 FLUORESCENT FIXTURE IS A 2-40 WATT TUBE FIXTURE
2 SPECIAL PURPOSE OUTLET IS FOR AN ELECTRIC SAW 240 VOLTS 50 AMPS

LEGEND

S	SINGLE POLE SWITCH		SPECIAL PURPOSE OUTLET 240 VOLT 50 AMP
	GR DUPLEX OUTLET GROUNDED		GR WEATHER PROOF WP DUPLEX OUTLET GROUNDED
	PANEL BOARD		INCOMING SERVICE LINES
	LIGHTING OUTLET CEILING		FLUORESCENT FIXTURE
	GR 240 VOLT 30 AMP AIR CONDITIONER OUTLET		HOME RUN TO PANEL
	CIRCUIT CONCEALED IN FLOOR		EXPOSED CIRCUIT
	CIRCUIT CONCEALED IN CEILING		

CED-045

Figure 1

As you have observed from the drawing, three different types of lines are used to indicate conductors in this one room. The ceiling lights conductors are concealed in the ceiling as indicated by the solid line with one arrowhead on it. The arrowhead indicates this wire is a home run or is connected to the panel. The long dashed lines between the receptacles indicate that this circuit is concealed under the floor. The short dashed line from the fluorescent fixture to the switch indicates that this conductor is exposed. This information shows not only where the wire goes but helps determine when it will be installed.

Legend

The legend will show what symbols are used to identify specific components in the construction of the facility. Review the symbols used in figure 1 and see if all symbols used in the drawing are shown in the legend.

Notes

Special information required in the construction is indicated in the notes section. As you can see in figure 1, a special purpose outlet necessary to handle an electric saw has been included. From this, the exact type outlet can be determined.

Parts of a Blueprint

What you have seen so far is only one part of a complete blueprint. The other parts that will be in the total plan are; site plan, which indicates the location of the facility under construction in the overall location of the area, the plot plan locating the facility in the specific space it will occupy in a confined area, and utilities available such as gas, water, and electricity.

The foundation plan will include exact overall dimensions and concrete design. The floor plan will include lengths, thicknesses, and characteristics of building walls, location of window and door openings, length and character of partitions, number and arrangement of rooms, and the type and location of utility installations. The framing plans show the size, number, and location of the structural members that form the building framework.

The section and detail plans are very close to the same thing. A detail will always be an enlarged scale drawing to show construction features more clearly.

Additional plans for electrical, heating, air conditioning, and plumbing are produced to aid the individual tradesman in his completion of a specific part of the structure.

Specifications

To insure that the structure will be constructed exactly as prescribed, a set of specifications will accompany the blueprints. Each tradesman will have a section of the specifications that is peculiar to him. Specific information as to size, type, and quality desired of standard parts will be listed.

For the electrician, these parts may be further identified by manufacturer's name and catalog number. Since it may not be possible to obtain the specific item, "or equivalent" is usually added after the manufacturer's name and catalog number. The specifications will also identify all items, along with their types, sizes, and amounts, required for the job. This will greatly assist in making an accurate cost estimate of the job.

TERMINOLOGY AND SYMBOLS

Each group has its own language or slang that allows one member of the group to communicate with another member in a form of spoken shorthand. The electrical trade has its own terminology and symbols.

Electrical Terminology

Several terms that are used by electricians and other building trades are listed. It is important that you become familiar with these terms and their meaning. Many more terms are listed in the National Electrical Code - Article 100.

ACCESSIBLE: (As applied to wiring methods) Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building.

ACCESSIBLE: (As applied to equipment) Admitting close approach because not guarded by locked doors, elevation, or other effective means:

AMPACITY: Current-carrying capacity of electric conductors expressed in amperes.

APPROVED: Acceptable to the authority having jurisdiction.

BONDING: The permanent joining of metallic parts to form an electrically conductive path which will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

BRANCH CIRCUIT: The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

BUILDING: A structure which stands alone or which is cut off from adjoining structures by firewalls with all openings therein protected by approved fire doors.

CIRCUIT BREAKER: A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermired overcurrent without injury to itself when properly applied within its rating.

CONCEALED: Rendered inaccessible by the structure or finish of the building. Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them.

DEVICE: A unit of an electrical system which is intended to carry but not utilize electrical energy.

DISCONNECTING MEANS: A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

EQUIPMENT: A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with, an electrical installation.

FEEDER: All circuit conductors between the service equipment or the generator switchboard of an isolated plant, and the final branch-circuit overcurrent device.

FITTING:	An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function.
GROUND:	A conducting connection whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.
GROUNDED:	Connected to earth or to some conducting body that serves in place of the earth.
GROUNDED CONDUCTOR:	A system or circuit conductor that is intentionally grounded.
IDENTIFIED:	Identified, as used in the Code in reference to a conductor or its terminal, means that such conductor or terminal is to be recognized as grounded, see Article 200.
OUTLET:	A point on the wiring system at which current is taken to supply utilization equipment.
PANELBOARD:	A single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.
QUALIFIED PERSON:	One familiar with the construction and operation of the apparatus and the hazards involved.
RACEWAY:	Any channel for holding wires, cables, or busbars that is designed expressly for, and used solely for, this purpose.
RECEPTACLE:	A receptacle is a contact device installed at the outlet for the connection of a single attachment plug.
RECEPTACLE OUTLET:	An outlet where one or more receptacles are installed.
SERVICE:	The conductors and equipment for delivering energy from the electrical supply system to the wiring system of the premises served.
SERVICE DROP:	The overhead service conductors from the last pole or other aerial support to and including the splices, if any, connecting to the service-entrance conductors at the building or other structure.
SERVICE-ENTRANCE CONDUCTORS:	The service conductors between the terminals of the service equipment and a point usually outside the building clear of building walls, where joined by tap or splices to the service drop.
SERVICE EQUIPMENT:	The necessary equipment, usually consisting of a circuit breaker or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply.

UTILIZATION EQUIPMENT: Equipment which utilizes electric energy for mechanical, chemical, heating, lighting, or similar purposes.

FUSES: An overcurrent protective device with a circuit opening fusibile part that is heated and severed by the passage of overcurrent through it.

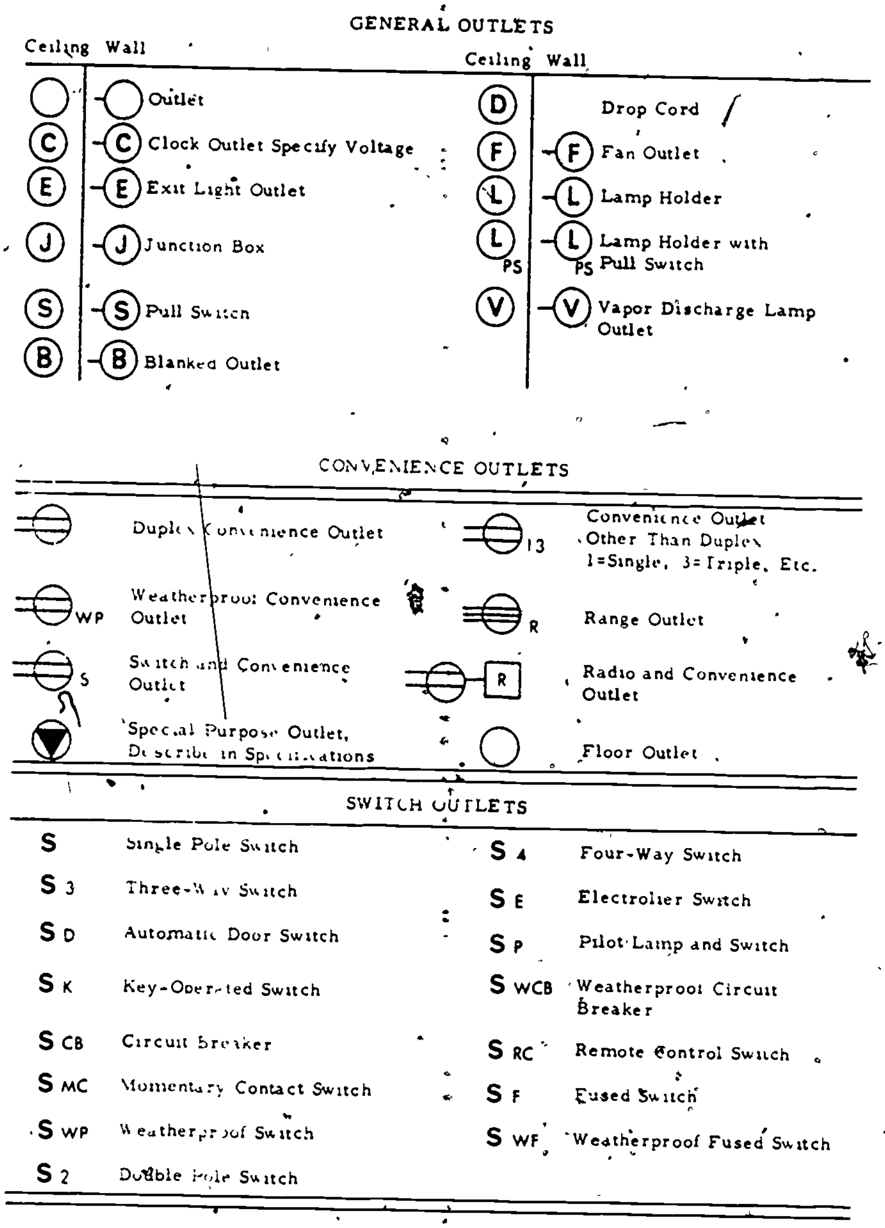


Figure 2

PANELS AND CIRCUITS

Lighting Panel	Power Panel
Feeders - Use Heavy Lines and Show by Number Same as in Feeder Schedule	Branch Circuit Concealed in Ceiling or Wall
Branch Circuit Concealed in Floor	Branch Circuit Exposed
Home Run to Panel Board Number of Circuits Indicated by Number of Arrows	
Any Circuit Without Further Designation Indicates a Two-Wire Circuit. A greater Number of Wires is Indicated Thus	(3 Wires) or (4 Wires)

MISCELLANEOUS SYMBOLS

Pushbutton	Buzzer	Bell
Electric Door Opener	Fire Alarm Station	Fire Alarm Bell
Controller	Horn	Nurse's Signal Plug
Isolating Switch	Radio Outlet	Bell Ringing Transformer
Annunciator		

Figure 2 (cont).

Symbols

It is obvious that a complete illustration of all electrical units on a blueprint or schematic would make the drawing confusing and cluttered. For this reason very simple standardized symbols are used in electrical drawings to indicate units, conductors, and equipment. The symbols listed in figure 2 are the symbols normally found on DEPARTMENT OF DEFENSE drawings.

SUMMARY

Blueprints provide a complete graphic explanation of the proposed construction. Blueprints are made up of standardized symbols and terminology common to the persons using them. They are composed of several plans and will include specifications sheets. Symbols are standardized pictures of building components. Terminology that is common to the tradesman is the language used by people who perform the work involved.

QUESTIONS

1. What information can you obtain from the legend of a blueprint?
2. Outlet is defined as ____________________
____
____
3. What is the symbol for a duplex convenience outlet? ____________
4. What is the symbol for a range outlet? ____________
5. What are two purposes of specifications? ____________
____

REFERENCES

1. National Electrical Code
2. Blueprint Reading by Kenneth Gebert

CONDUCTORS AND OVERCURRENT PROTECTIVE DEVICES

OBJECTIVE

The purpose of this unit of instruction is to develop your knowledge of

1. the types and sizes of conductors.

2. the types, sizes, and testing procedures of overcurrent protective devices.

INTRODUCTION

Have you ever started to use a Skilsaw and noticed that the blade did not have its usual cutting power? The blade may even stall while cutting. The conductor from the power source to the saw may become very warm. Have you wondered why? As you read this study guide, you will be able to determine the reasons for these troubles as well as many others.

Current flowing through a conductor causes heat which could start a fire. Overload devices are installed at different points to prevent overheating of conductors and devices. Not all circuits carry the same amount of current; therefore, many types and sizes of overload devices have been designed.

INFORMATION

CONDUCTORS

A conductor is a path capable of carrying an electrical current. It is usually a copper wire. There are two basic types of metal conductors: the solid and the stranded. The solid insulated wire is used for general-purpose wiring. Where flexibility is needed, the stranded conductor is used. A stranded conductor consists of many strands of smaller wire twisted together to form a larger conductor.

Current flowing through a wire causes heat: the amount of heat varies as to the square of the amperage. There is a limit to the degree of heat that various types of insulation will withstand. Wires most commonly used are insulated with thermoplastic insulation.

The general construction of a solid, thermoplastic insulated conductor is shown in figure 3.

The conductor shown in figure 3 may consist of a copper or aluminum alloy conductor with a thermoplastic insulation. The thickness of the thermoplastic insulation varies with the size and voltage of the conductor.

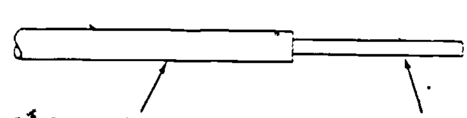


Figure 3. Thermoplastic Covered Solid Conductor

Conductors have many different types of insulation. The type of insulation is determined by use of the conductor; for example, asbestos covered conductors are used for wiring heating appliances.

The type of insulation is coded normally by the first letter of the material used or condition factors. These may be combined as shown in the table below.

Insulation	Code	Use
Rubber	R	Dry locations; general use
Thermoplastic	T	Dry locations; in conduit, house wiring or motor connections
Varnish	V	Dry locations only; motors or transformers
Asbestos	A	Dry locations only; heating appliances
Heat Resistant	H	Dry locations; general use
Moisture Resistant	W	Dry and wet locations; general use
Moisture Resistant Thermoplastic	TW	Wet or dry locations

Conductor Sizes

Conductors are insulated with rubber, asebestos, lead sheath, cambric and paper. Single conductors and cables are color coded. Conductors used for a neutral line will be color coded white or natural gray. The power lead is either black, blue, red, yellow or brown or a combination of several. Green is used for equipment grounds only.

The amount of heat a conductor will withstand depends on its size as well as its insulation. To work with the different sizes of conductors, it is necessary to understand something about the scheme used in wire numbering. Instead of referring to common sizes of conductors by their area, sizes or numbers have been assigned to them. The gage commonly used to determine the size of a conductor is the American Wire Gage (AWG). This gage is not the same as used for fence wire or any nonelectrical purpose wire. Number 14 electrical wire has a conductor 0.064 inches in diameter. The actual sizes (AWG) and the gage numbers for various wire sizes are shown in figure 4. The larger the number, the smaller the wire.

Figure 4. Conductor Size Without Insulation

The highest AWG number is 0000 or more simply written 4/0. Beyond this size, the conductor size is determined by its cross-sectional area in circular mils. A circular mil (cm) is the area of a circle one mil in diameter. A mil is one one-thousandth of an inch (0.001"). Thus a wire or conductor that is 0.002 inches or 2 mils in diameter is said to have a cross-sectional area of 4 cm. Normally, you will see the wire size shown as MCM rather than CM. The first M is the Roman number 1 thousand so MCM stands for thousand circular mils.

In figure 5 the gage for measuring conductor sizes is illustrated. The wire is measured by the slot into which it will fit, not by the hole behind the slot.

Two or more conductors insulated from each other and grouped together are referred to as a cable. One of the more common cables is nonmetallic-sheathed cable (NMC) and consists of two or more insulated conductors grouped together and covered with either braid, rubber or plastic. A small flexible cable used to wire small appliances and lamps is called a cord.

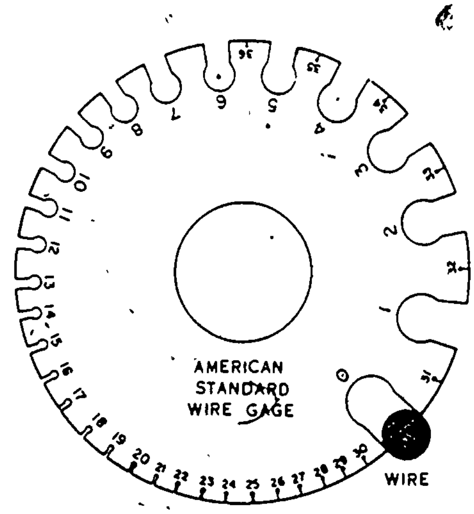


Figure 5. American Wire Gage

A cable that contains two #14 wires is known as 14/2, if it contains three #12 wires it is known as 12/3, etc.

NOTE: See article 310 and table 8, chapter 9, in the National Electrical Code for additional information.

Current Carrying Capacity

The four factors that determine the current carrying capacity of a conductor are the size, type of insulation, composition, and location of the conductor.

For any given combination of volts and amperes, it is necessary to select a size of wire that not only prevents the development of dangerous high temperatures, but also avoids wasted power in the form of voltage drop. To determine the voltage drop of a circuit caused by the conductor used, apply Ohm's law:

$$E = I \times R$$, or Voltage drop = Amperes X Ohms

For example, assume that a 500-watt floodlight is to be operated at a point 500 ft from the power panel, which will require 1000 ft of conductor. At 115 volts, 500 watts is equal to about 4.3 amperes. Using a no. 14 conductor which has a resistance of 2.475 ohms per 1000 ft, multiply 4.3 amperes times 2.475 ohms. The voltage drop would be 11 volts. This would give a power loss of about 47 watts in the circuit in the form of heat which is of no value to the consumer. You can decrease this power loss by increasing the conductor size.

NOTE: See article 310 of the National Electrical Code for additional information.

SUMMARY

Conductors are used to transmit electrical energy from the source of power to the using equipment. Most conductors are made of a copper alloy because of its low cost and high conductivity. The more common types of insulating materials are thermoplastic and rubber.

QUESTIONS

1. What are two types of conductors? ______________________

2. What type of insulation is most commonly used? ______________________

3. How is voltage drop of a conductor determined? ______________________

4. A green insulated conductor is used for what purpose? ______________________

5. Which is larger, number 12 or number 6 conductors? ______________________

OVERLOAD DEVICES

It is impossible for an electric current to flow through a conductor without heating the wire. As the temperature of the conductor increases, the insulation may become overheated and lead to an ultimate insulation breakdown. Overheating of conductors may become a serious fire hazard. To protect conductors against too much amperage, an overload device is installed. Any device that limits the current in a conductor to a predetermined amperage is termed an "overload device."

There are a great many different types of overload devices. The two common overload devices are fuses and circuit breakers.

FUSES

Plug Fuses

There are several different types of fuses. The most common type fuse is called a "plug fuse." A plug fuse consists of a fusible link enclosed within a housing which is screwed into a socket similar to a lamp socket. The fusible link is a short length of metal ribbon or wire made to carry a predetermined amperage, but melts quickly when the current is too high. There is a window through which you can see if the fuse is melted or "blown."

Plug type fuses range from 1 to 30 amperes. The code requires that plug fuses less than 15 ampere or less have a window of a hexagonal form, those above 15 ampere have a round window.

Plug types will not be used in circuits with over 125 volts and shall be used as replacement items only.

Fuses that are not interchangeable with higher rated fuses because of a special adapter are called nontamperable plug fuses (figure 6).

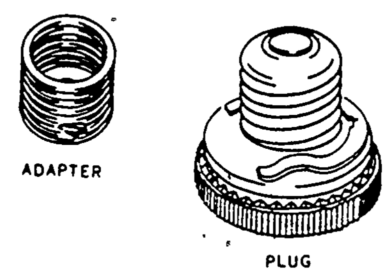


Figure 6. Plug Fuse with Tamper-Resisting Base

The adapters fit into ordinary fuse holders but are so designed that once installed, they cannot be removed. The adapter has an ampere rating the same as a fuse, and a 15 ampere adapter will permit only 15 ampere or smaller fuses to be inserted into it, a 25 amp adapter permits only 25 amp fuses; and so on.

Most nontamperable plug type fuses are the time delay type as shown in figure 7. These fuses are designed to carry an overload for a few seconds. After a time lapse, they will blow like an ordinary fuse, but they act the same as any fuse if the overload is continuous.

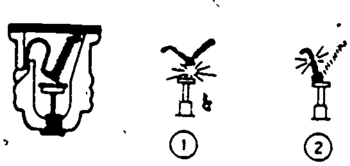
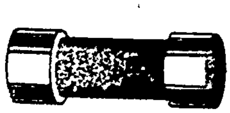


Figure 7. Plug Fuse with Time Lag

The cartridge fuse is not commonly used in the home because of the high current rating. Most cartridge fuses are used in industrial areas and are the only type that can be used when current of more than 30 amperes is involved. These fuses are shown in figure 8.



Cartridge fuse with ferrule contacts

Cartridge fuse with knife-blade contacts

Figure 8. Cartridge Fuses

Cartridge fuses are divided into two types, the ferrule type and the knife-blade type. The ferrule type is used only on fuses rated from 1 - 60 amperes. The knife-blade type is used for 1 to 6000 amperes. Physically, cartridge fuses of different ampere and voltage ratings are of 12 different sizes as noted in the following table: Notice that cartridge fuses of the same amperage rating but different voltage will vary in length; the higher the voltage, the longer the fuse.

Fuse Rating Amperes	Overall Length, Inches	
	250-Volt Type	600-Volt Type
0 - 30	2	5
31 - 60	3	5 1/2
61 - 100	5 7/8	7 7/8
101 - 200	7 1/8	9 5/8
201 - 400	8 5/8	11 5/8
401 - 600	10 3/8	13 3 8

Cartridge fuses are further divided into renewable and nonrenewable types. Since only the fusible link is destroyed when a fuse blows, renewable fuse links are available for replacement. The nonrenewable types, once blown, are of no further value, and the entire cartridge is replaced.

Cartridge fuses with a renewable and nonrenewable links are shown in figure 9.

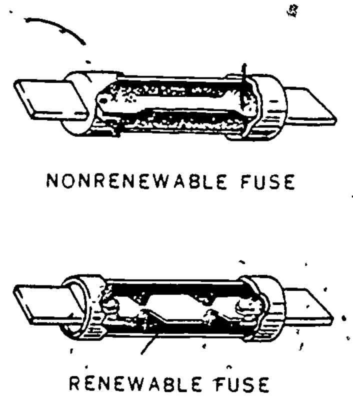


Figure 9. Cartridge Fuses

Time delay fuses of the cartridge type as shown in figure 10 serve the same purpose as the plug type with a time delay except that they will handle a larger overload.

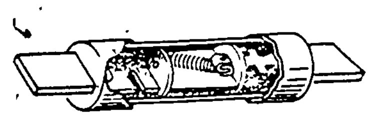


Figure 10. Cartridge Fuse with Time-Lag Feature

Circuit Breakers

Circuit breakers are overload devices designed to automatically trip or open the circuit on a predetermined overload without injury to itself. When it opens a circuit, moving a handle, pushing a button, etc., closes the circuit again--there is nothing to replace. An internal view of one of the most common types is shown in figure 11.

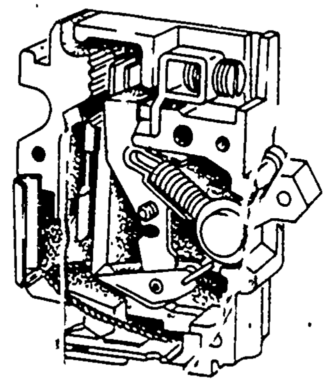


Figure 11. Internal View of a Common Type of Circuit Breaker

A circuit breaker may be of the instantaneous type. That is, it will trip as soon as a predetermined overload exists. This type of circuit breaker normally employs a magnetic trip device. It is more or less a special purpose type and is seldom used except to protect circuits supplying critical equipment.

Another type of circuit breaker is a thermal type. It employs a bimetallic strip as its trip device. This circuit breaker is the time delay type. The bimetallic strip is precision calibrated to respond to heat. As current flows through this strip or is heated indirectly by fcurrent flowing in a heater coil, the bimetallic strip bends. When the strip bends, it releases a catch allowing a spring-activated mechanical device to operate. As the mechanical device actuates, it opens a set of contacts and stops current flow. The circuit breaker will now have to be reset to reclose the contacts and allow current to flow. For example, the bimetallic strip in a twenty (20) amp circuit breaker is calibrated so it will carry 20 amps of current without heating enough to bend. If twenty-one amps of current should flow through the strip, it would begin to heat and slowly bend and thus release the catch. The larger the overcurrent through the bimetallic strip the faster it heats and bends to release the catch.

A circuit breaker is installed in a circuit to limit the amount of current flow in that circuit.

A third and more commonly used type of circuit breaker is a thermal magnetic. This circuit breaker has a thermal and a magnetic trip device. The thermal portion of this circuit breaker functions the same as in a thermal type circuit breaker. The magnetic trip device was added to provide short circuit or large instantaneous current protection. Should a large amount of current (such as caused by a short circuit) flow through the circuit breaker, the magnetic trip would actuate the circuit breaker instantaneously. The magnetic trip device is simply an electromagnet which will increase in strength as current increases. When a large amount of current passes through the circuit breaker, the electromagnet will attract the release catch allowing the circuit breaker to actuate. This circuit breaker offer both time-delay features and instantaneous short circuit protection. Note: See Article no. 240 of the National Electrical Code for additional information.

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Ground-Fault Interrupters

With the establishment of the Occupational Safety and Health Act (OSHA) more and more attention has been put on the protection of personnel. Because of this, the National Electrical Code requirement as of January 1973 specifies that all newly installed outlets in certain areas must be protected by a ground-fault circuit interrupter.

The ground fault interrupter (GFI) is constructed with three main parts: (1) Interrupting device, 120v, (2) Differential transformer, (3) Solid-state sensing and test circuit.

The main point in the operation of a ground-fault interrupter depends on an imbalance in the circuit. Current leaking on the load side of the circuit produces a charge of flux in the magnetic core of the interrupter differential current transformer. This induces voltage in the transformer's secondary winding that quickly actuates the solid-state circuitry causing the circuit to open before any bodily harm can occur. In many cases the leakage can be as little as 0.005 amps.

The National Electrical Code contains two rules on the use of ground-fault circuit interrupters on branch circuits:

(1) Section 210-8(b) calls for personnel ground-fault circuit protection for all 120 volt, single-phase, 15 and 20 amp receptacle outlets installed on construction sites.

(2) Section 210-8(a) requires personnel ground-fault circuit protection for all 120 volt, single-phase, 15- and 20-amp receptacles in outdoors and in bathrooms of residential occupancies.

NOTE: See page 19 of the National Electrical Code Blueprint Reading by Kenneth Gebert for additional information on ground-fault circuit interrupters.

CIRCUIT BREAKER TESTING

Protective devices are too often taken for granted until they fail to protect life or property. This study guide establishes procedures necessary to perform effective testing of single pole molded case circuit breakers.

Model MS-1A Test Unit

The Model MS-1A Test Unit is designed to test current-actuated protective devices, such as, small circuit breakers, fuse links, meters, etc. The tester is housed in a plastic suitcase-type enclosure with storage space provided for the necessary test leads. The unit is light in weight and portable.

The unit consists of an ammeter, an eight-position ammeter selector switch, a variable current adjust reheostat, timer, current transformer, and various switches and connecting terminals for testing purposes.

The input to the unit is 110/120 volt, 60-cycle, single-phase while the output circuit consists of a multitapped transformer providing a wide variety of output taps, ranging from 0 to 140 volts and from 4.5 to 200 amps. However the unit may provide higher amperage at lower voltages, such as, when drawing 400 amperes from tap c, the maximum voltage is 2.2 volts.

SUMMARY

Circuit breakers are adjusted to interrupt the current upon the occurrence of an overload of a definite amount. Testing circuit breakers to meet manufacturer's requirements is the only way to determine if the circuit breaker is operating properly. Testing the circuit breaker with actual operating conditions using MS-1A Testing electrically exercises the breaker and helps them to operate properly.

QUESTIONS

1. How many current ranges do you have on the MS-1A Tester?
2. What is the main purpose of fuses and circuit breakers?
3. What is the highest voltage obtained on the MS-1A Tester?
4. What is the purpose of the MS-1A tester?
5. Name the major parts of the MS-1A Tester.
6. What kind of overload device is used in circuits over 125 volts?
7. What determines the size of an overload device used in a circuit?
8. What are two types of cartridge fuses?

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REFERENCES

1. Instruction Manual for MS-1A Tester by Multi-Amp Corporation
2. National Electrical Code
3. AFM 85-17, Maintenance and Operation of Electrical Plants and Systems
4. AFM 91-17, Electrical - Interior Facilities
5. Electrical Code Diagrams B. Z. Segall, Vols. 1 and 2
6. NFPA Handbook of the NEC, Frank Stetka
7. Practical Electrical Wiring, H. P. Richter
8. Blueprint Reading, Kenneth Gebert

HANDTOOLS

OBJECTIVE

This unit of instruction is to aid you in identifying, using and maintaining basic electrician handtools.

INTRODUCTION

A tool enables you to accomplish a job better, quicker, or easier. From the time the first caveman picked up the first rock to use as a tool, man has developed and used other tools. Tools are made to be used. To provide the most use, tools should be kept in the best condition, and their function understood. As an electrician, you will use the basic tools discussed here.

INFORMATION

HANDTOOLS

The most common tools used by the electrician are pliers, screwdrivers, electrician's knife, rules, cable strippers, fuse pullers, hammers, and wrenches.

Pliers

There are several types of pliers used by the electrician. The most widely used are the lineman's, diagonal cutting (dykes), long nose, and water pump.

The lineman's pliers shown in figure 12 are side cutting pliers with a blunt jaw and a scored gripping surface at the front. In addition to cutting wire, these pliers are used for holding wire while bending or twisting and are often used to strip the insulation from the conductors. The most common sizes are the 6" and the 8".

Figure 12. Lineman's Pliers

Diagonal pliers, as shown in figure 13, have cutting jaws set at an angle of approximately 15° with the handle and are used principally for cutting wires. The most common sizes are the 5" and the 6".

Figure 13. Diagonal Pliers

Long nose pliers, as shown in figure 14, come in either a straight or curved nose. The most common sizes are the 5" and the 6". These pliers are used mainly for bending a loop on the end of the wire to fasten it under a terminal screw.

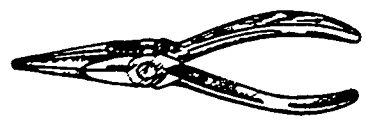

Figure 14. Long Nose Pliers

Water pump pliers, as shown in figure 15, are convenient to use to hold locknuts and/or round objects. They should never be used on nuts or bolts that are designed for use with a screwdriver or wrench.

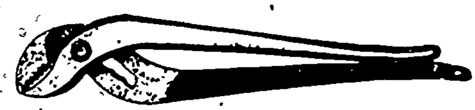

Figure 15. Water Pump Pliers

Keep pliers clean and well oiled at the pivot points. If the pliers are to be stored for any length of time, they should be wiped clean, especially of fingerprints and coated with a thin coat of oil. The pivot pins should be kept tight for efficient operation. Some of the pins are provided with a nut that can be tightened with a wrench while others must be tightened by laying the pliers on an anvil and striking the pivot lightly with a hammer.

Screwdrivers

Screwdrivers are tools used for driving or removing screws. There are several types of screwdrivers, but the most common are the general purpose, cabinet, and the crosspoint. The electrician uses a screwdriver to fasten devices to boxes, boxes to walls, and wires to terminals.

The general purpose screwdriver or common screwdriver is perhaps the one used mainly by the electrician. When using the screwdriver, as shown in figure 16, it is important that the blade be held firmly in the screw slot. This will prevent damage to the screw and possible injury to you if it should slip. These screwdrivers are available in many lengths of blade. The most commonly used by the electrician is the 4" or 6" length blade.

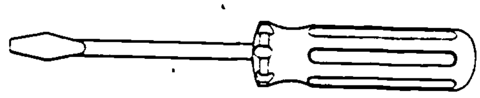

Figure 16. General Purpose Screwdriver

The crosspoint screwdriver, shown in figure 17, is used on special type screws. Never use any other type of screwdriver in the slots as they will round out the screw head and render them unusable. Like the general purpose screwdriver, size is determined by length of the blade.

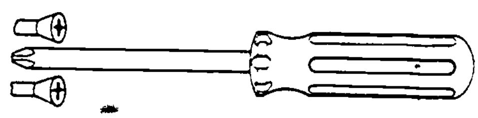

Figure 17. Crosspoint Screwdriver

The cabinet screwdriver, shown in figure 18, has a long slim blade and is used frequently around motors and hard to reach places. The most common size are from 6- to 12-inch blade, but shorter lengths are available.

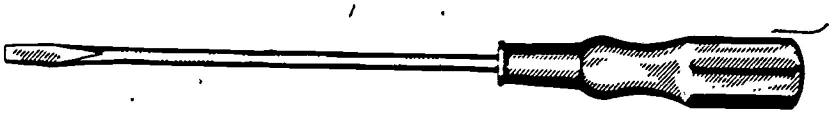

Figure 18. Cabinet Screwdriver

The screwdriver blade must have sharp corners and fit the screw slot closely. The tip of the blade of the screwdriver is made hard to hold its shape and resist the shearing action of the screw slot. The shank of the screwdriver is softer and tougher than the tip so that it can absorb the twisting strain.

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When the tip becomes rounded or broken, you can usually restore its original shape with a file or bench grinder as shown in figure 19.

To remove the nicks and square the tip of the screwdriver, adjust the bench grinder rest to hold the screwdriver at right angles to the grinding surface of the abrasive wheel as shown in figure 19A and grind the tip square. Next, adjust the rest as shown in figure 19B to hold the screwdriver against the wheel. Proper grinding gives the desired point shapes as shown in figure 20.

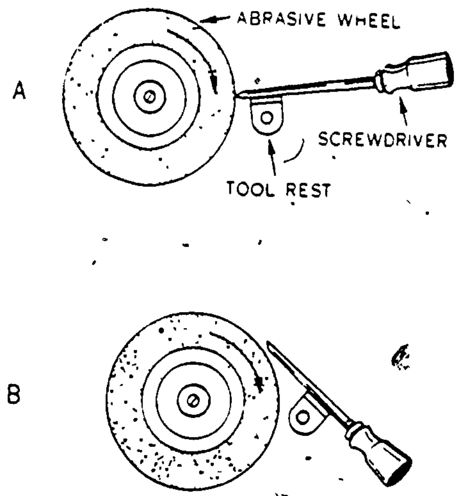

Figure 19. Sharpening a Screwdriver

When using a screwdriver, NEVER hold work in the hand while tightening or loosening a screw. If the blade should slip, it can cause serious injury to the hand. NEVER use a screwdriver as a chisel or pry bar. Such usage is likely to crack the handle, bend the blade, or chip the point. Use of pliers or wrenches to increase leverage can cause the blade to bend or may break the point. Apply only the pressure that can be exerted on the handle by hand.

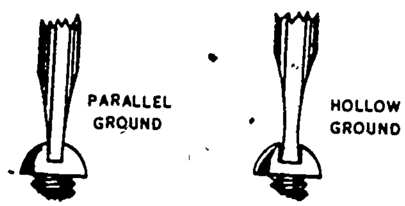

Figure 20. Correct Tip Shape

Electrician's Knife

The electrician's knife, as shown in figure 21, is used to strip and remove the insulation from the wire to enable you to splice or fasten the end to a terminal. Always cut with the sharp edge of the blade away from you. The squared blade can be used for cleaning crevices and scraping wire.

A knife blade is sharpened on an oilstone, holding it flat and pushing it away from you, edge first.

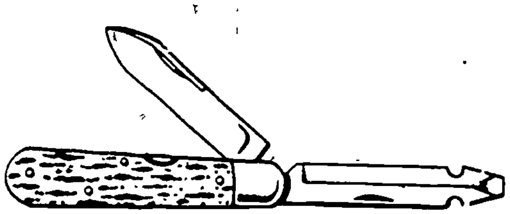
Figure 21. Electrician's Knife

The six-foot folding rule, that is shown in figure 22 is used by electricians. The rule is constructed of sections which are hinged together so that they can be folded into a compact unit and carried in the pocket. The rule must be unfolded carefully to prevent the breaking of the sections. If the joints become hard to operate, drop a few drops of oil in the joint. Keep the rule clean.

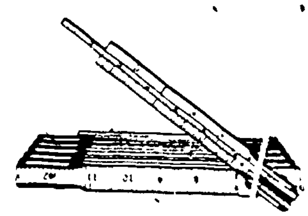

Figure 22. Six-Foot F lding Rule

Steel tapes <u>should not</u> be used by electricians while working aroun energized circuits, but a linen tape may be used safely.

Wire Stripper

The wire stripper, shown in figure 23 is used to strip the insulation from wires to make splices or to attach the conductor to a terminal screw. The stripper should be kept clean and very light lubricating oil may be used on the moving parts.

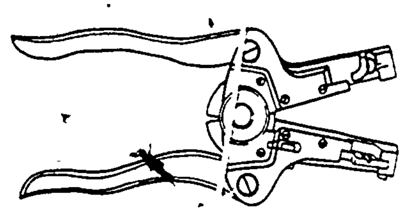

Figure 23. Wire Stripper

Fuse Puller

The fuse puller, shown in figure 24, is constructed of laminated fiber which possesses high dielectric qualities. It can withstand exceptionally high atmospheric conditions. It is available in sizes 5 to 20 inches long. The large size puller is constructed of more laminations and has a large slot in the jaws to accommodate a larger fuse. The fuse puller eliminates danger of pulling and replacing cartridge fuse by hand and bending the fuse clips.

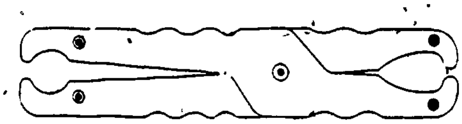

Figure 24. Fuse Puller

Hammers

There are two general types of hammers used by electricians: they are the claw and the ball peen hammers shown in figure 25. The claw hammer is used to drive nails. Although it has claws, it should not be used to pull large nails as it will loosen the handle or break it if too much leverage is applied. The weight of the head designates the size of the hammer. Heads vary in weight from 7 to 22 ounces and should be selected as to its intended use.

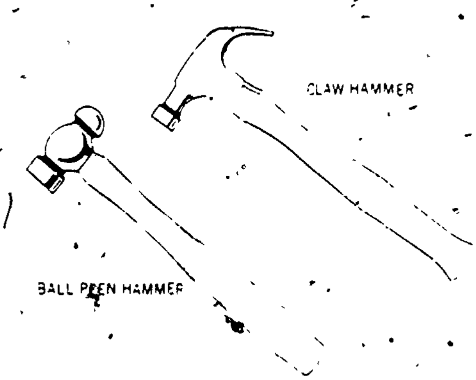

Figure 25. Types of Hammers

When using the hammer, hold it near the end of the handle. A grip just tight enough to control the stroke and keep the handle from slipping out of the hand is best. The blow should be delivered with wrist action.

The ball peen hammer is used to drive chisels or punches. The rounded portion is used to shape metal, flatten rivets, etc.

Hammers should be inspected before use to prevent injury to surrounding equipment and personnel. If the face is damaged or the handle loose, cracked, or broken, it should not be used. The face can sometimes be reshaped on a grinder.

While grinding, the head must be dipped in water occasionally to prevent drawing the temper out of the hammer face. If the handle becomes cracked or it cannot be tightened by driving the wedges into the handle, replace it or cut the handle off so as to prevent someone else from using it and possibly receiving injury.

Wrenches

There are many types of wrenches and each has its own application. The wrenches most commonly used by electricians are the adjustable open-end and the pipe wrench.

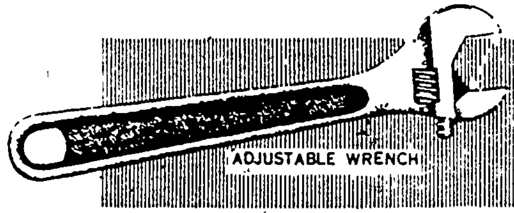

Figure 26. Adjustable Open-End Wrench

The adjustable open-end wrench, shown in figure 26, is made so that the jaws can be adjusted to fit square stock or the flat surface of a bolt head or nut.

The wrench must be adjusted to fit the nut or bolt head snugly, and the pull must be exerted in the direction shown in figure 27. If they are not used in this manner, undue strain is placed on the movable jaws and may break it; the wrench may slip off the nut or bolt head and round off the corners or skin the user's knuckles.

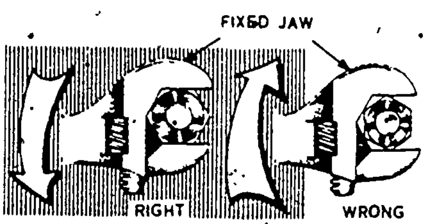

Figure 27. Using Open-End Wrenches

The pipe wrench, shown in figure 28, is used by the electrician to fit rigid conduit together. The conduit should not be allowed to "bottom" in the jaw opening because the wrench will "kick off" and could cause injury to the user. Keep the wrench wiped clean and be sure the jaws are sharp and clean of dirt and grease so that they will not slip.

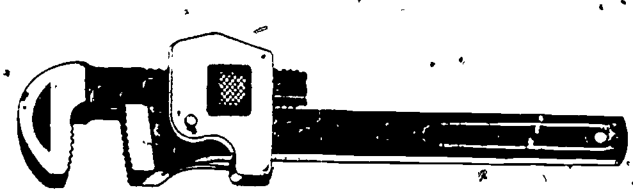

Figure 28. Pipe Wrench

Cable Stripper

The cable stripper, shown in figure 29 is made of flat steel stock and is used to cut the outer sheath of sheathed cable. Holes are drilled to identify conductor size. Most cable strippers have lines on the side in inches. In most cases the cutting blades are fixed and nonrenewable, and the entire stripper must be replaced when the blade becomes too dull to cut the sheath.

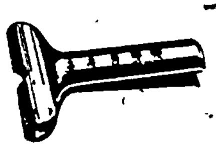

Figure 29. Cable Stripper

Brace and Bits

The tools shown in figure 30 are called a brace and bit. The brace holds the bit in a hand-tightened chuck, usually of two jaws, and provide leverage and control for turning the bit into the work. The bits are interchangeable, usually with spiral flutes to carry the chips out of the hole being bored. They will have a square tang to fit into the chuck and a screw tip to pull the bit into the work. Bits are sharpened with a file or stone.

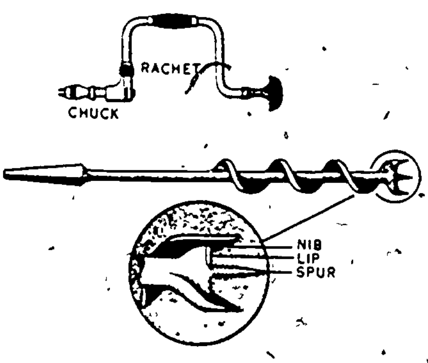

Figure 30. Brace and Bit

SUMMARY

The quality of tools available to do a job is important. The right tool for the job can make the job quicker, easier and safer. The knowledge of how to use and maintain tools is even more important to your career as an electrician.

1. What type pliers are used most by an electrician? ____________
2. What type pliers are used to make terminal loops? ____________
3. What type measuring device should not by used by an electrician? ____________
4. What tool is used to remove and replace fuses? ____________
5. How is the size of a hammer determined? ____________
6. What tool should be used when installing rigid conduit? ____________

REFERENCE

TO 32-1-101

SINGLE-PHASE SERVICE ENTRANCES AND PANELBOARDS

OBJECTIVE

This unit of instruction is to give you experience in the purpose, installation requirements, and installation procedures for service entrances and panelboards.

INTRODUCTION

Since it is not practical to put a generating plant at each home or other point of electrical use, a common source of power in the form of a distribution system will deliver power to the areas needed. This distribution system is the pole line network that you see along your streets. How this voltage is reduced to a usable level, brought from the pole to your house, protected coming into the house, and put into wiring system in your house is what this lesson will cover.

DISTRIBUTION

A basic electrical system will consist of the following parts: generation, transmission, substations, and distribution as shown in figure 31.

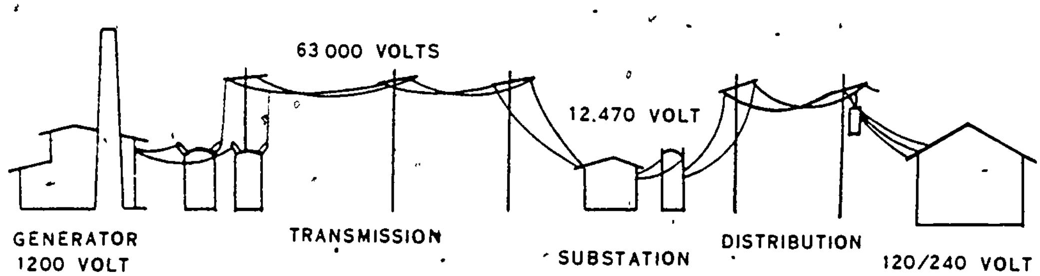

Figure 31. Distribution

The distribution transformer is usually mounted on a pole near the using point. This will be a step-down transformer to lower the distribution voltage to a usable voltage. Since we are concerned here with single-phase voltage, only one transformer will be considered. See figure 32. Knowing the single-phase voltages available at the distribution point will help you understand more about the service entrance requirements.

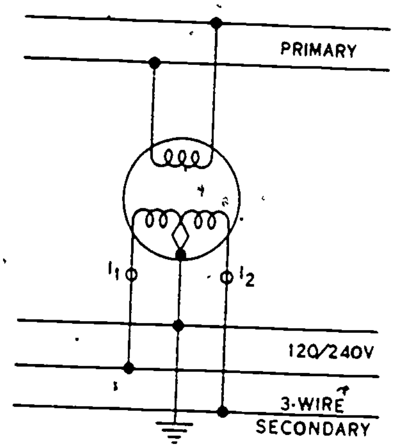

Figure 32.

TERMS AND DEFINITIONS

To understand the purposes and installation of a service entrance, you must become familiar with the terms and definitions of the service, service drop, service entrance, and service equipment. (See Article 100, NEC.)

Service

The conductors and equipment for delivery of energy from the electrical supply system to the wiring system of the premises served.

Service Drop

The overhead service conductors from the last pole or other aerial support to and including the splice, if any, connecting to the service-entrance conductors at the building or other structure.

Service Entrance

Service entrance is the service conductors between the terminals of the service equipment and a point usually outside the building, clear of building walls, where joined by tap or splice to the service drop. A typical, single-phase service entrance using S. E. cable is shown in figure 33.

Service Equipment

The necessary equipment, usually consisting of a circuit breaker or switch and fuses and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply.

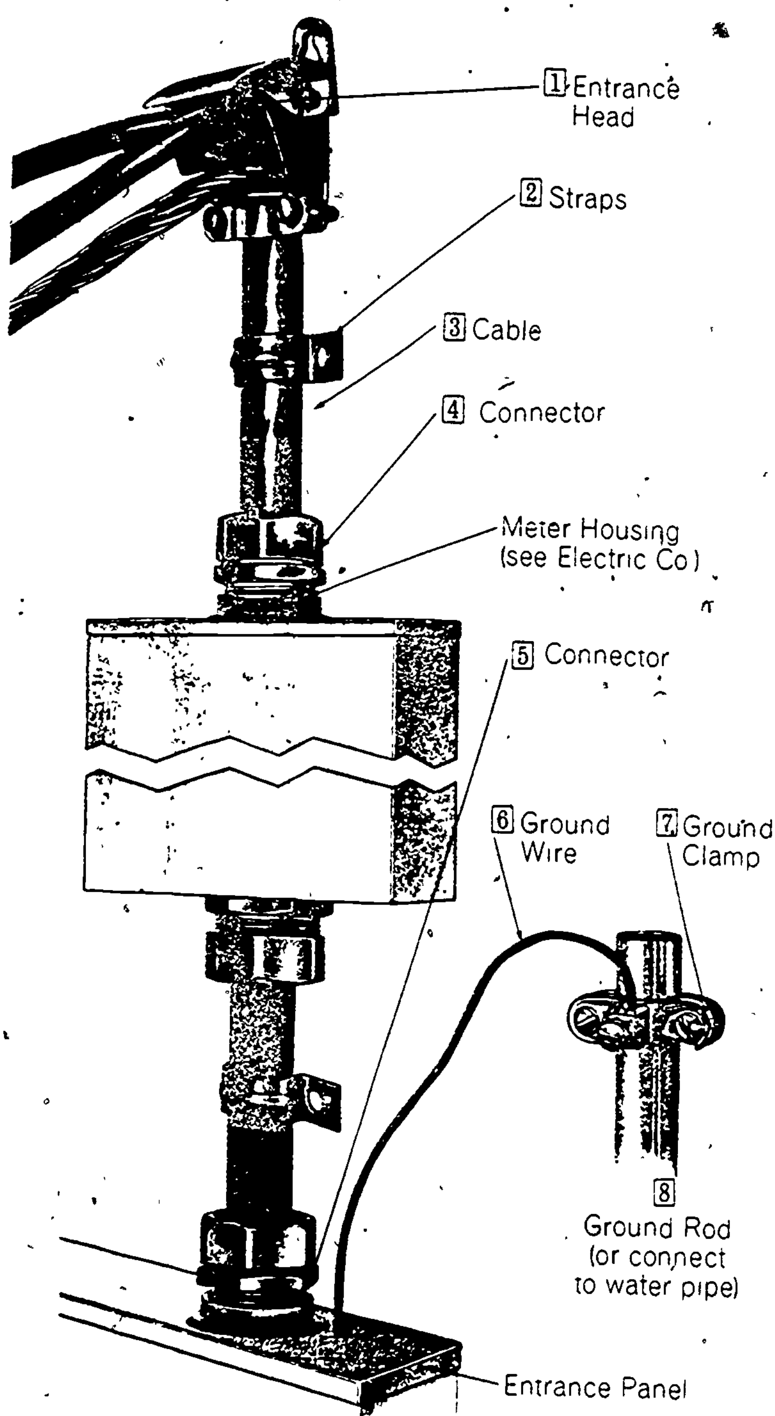

Figure 33. Service Entrance Installation

ELECTRICAL POWER SYSTEMS

The service entrance is attached to the service drop and consists of a weatherhead (entrance head) and conductors which are connected to the service equipment.

The service equipment can be in a panel by itself or it can be included in a panelboard containing the branch circuit protective devices. The service equipment is provided to connect or disconnect the power supplied to the fuses or breakers and the branch circuits. The fuses or breakers are included in the system to protect the equipment and circuit from damage in case of an overload or short, in accordance with NEC Article 240, figure 34.

Branch circuits extend from the protective devices and provide power in the different rooms or areas of the building. It is best to hold current flow to a minimum on the identified or neutral conductor. To do this, the unidentified or hot conductors should carry the same amount of current flow. This is referred to as balancing circuits.

INSTALLATION OF THE SERVICE ENTRANCE

The service entrance will be of the overhead or underground type. In most modern construction the service entrance will be made in conduit. Service-entrance cable (SE) is another method of installing a service.

In some cases the design engineer provides all the necessary information for installation of the service entrance; however, if this information is not provided, you may locate it in Article 230 of the NEC. The service to the building should be centrally located. This will help prevent low voltage at the ends of the building caused by long conductor runs. The service entrance that you install will be in service-entrance cable. Figure 33 identifies the parts of a service entrance.

Weatherhead (Entrance head)

The weatherhead is made up of a ceramic or a bakelite separator-washer and a metal cover. It is attached to a building above the point of attachment to the service drop conductors. Exception: Where it is impracticable to locate the weatherhead (entrance head) above the point of attachment, the weatherhead location shall be permitted not farther than 24 inches from the point of attachment.

Service Entrance Cable

Service entrance cable has several advantages (1) low installation cost, (2) it can be installed around corners where conduit might be difficult to handle, and (3) low material cost.

Service entrance cable shall be of the approved protected type or protected by conduit, EMT, or other approved means, where the cable is liable to contact awnings, shutters, swinging signs, or installed in exposed places in driveways or near coal chutes or otherwise exposed to physical damage.

Service Entrance Cable Supports

Service entrance cable shall be supported by straps or other approved means within 12 inches of every weatherhead (entrance head), connection to a raceway or enclosure, and at intervals not exceeding 4-1/2 inches.

Conductors (Service entrance cable)

The conductors shall be of sufficient size to provide the correct amperage to the building. They must be long enough to extend from the panelboard through the weatherhead plus enough to form a drip loop without splices. (Refer to the NEC for additional information.)

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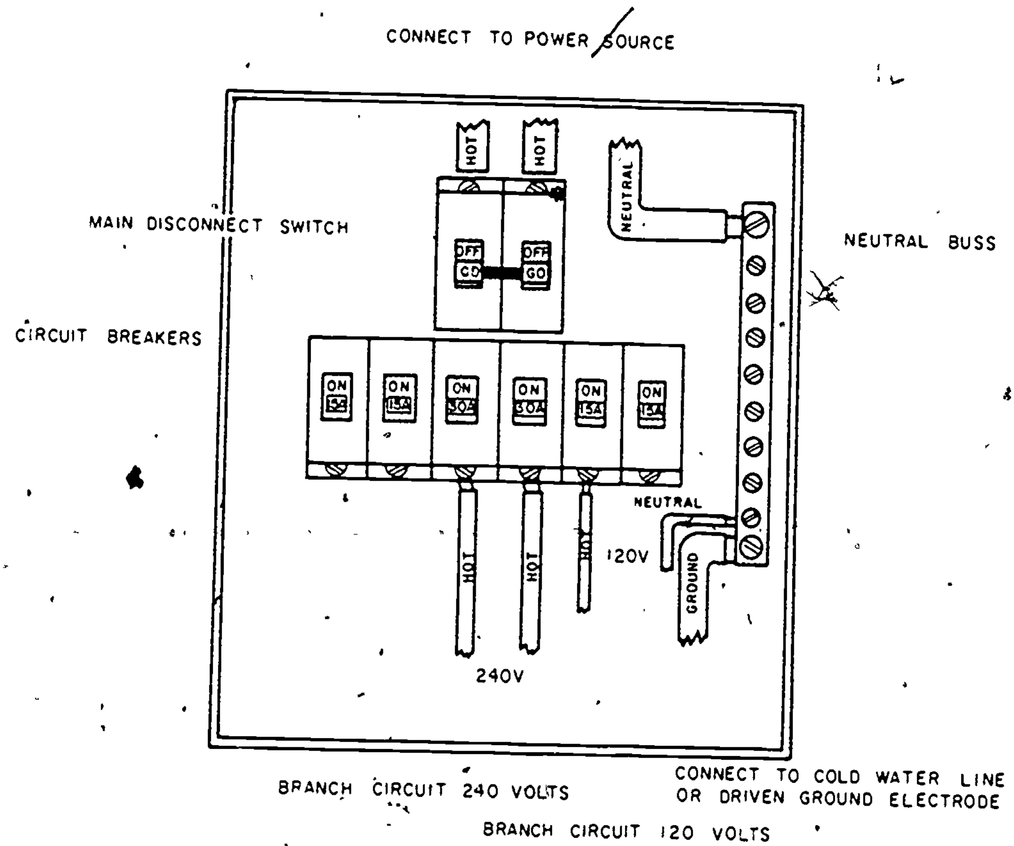

Figure 34. Panelboard

Grounding

The ground clamp should be made of the same material as that to which it is attached. If an iron water pape is used for ground, then use an iron clamp; if copper is used, use a copper clamp. This is done to hold down electrolytic action which can deteriorate the ground or ground wire. The loss of a ground would result in the system becoming very dangerous. Article 250 in the NEC concerns grounding and should be consulted at all times.

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PANELBOARDS

There are several types of panelboards available. Panelboards will differ in buss design, circuit breaker holder design, cover and case design, in voltage and ampacity rating. Review the definition of a panelboard in your NEC. After you have reviewed this definition, refer back to figure 34 and see if this drawing fulfills the definition as written in the NEC.

NEC Articles

The following listed articles pertain to the installation of service entrances and panelboards and should be studied from your code book.

230-2	One service drop per building.
230-23	Size of service drop.
230-24	Clearance of service drops.
230-29	Supports over buildings.
230-26	Point of attachment.
230-41	Size of service entrance.
230-70	Service Equipment. Disconnecting Means (General)
230-81	Connections to terminals.
230-82	Connections ahead of disconnecting means.
250-5	Location of system ground connection.
250-54	Common use of grounding conductor.
250-81	Water pipe.
250-84	Resistance of grounds.
250-112	Grounding electrodes.
250-115	Ground clamps.
384	Switchboards and panelboards.

SUMMARY

Power is supplied to the building from a power distribution system through a stepdown transformer to the service drop attached to the building. The service entrances may consist of a weatherhead, conduit mast, condulet, nipple, panelboard, locknuts, bushings, grounding system, and conductors, or service entrance cables and associated equipment. Panelboards are used to provide protection for the wiring system and to disconnect the inside wiring system from the outside power system.

QUESTIONS

1. What is the purpose of the stepdown distribution transformer located in the system near the facility?

2. The conductors and equipment used for delivering energy from the electrical supply system to the wiring system of the premises served is called?

3. Weatherheads are used on service entrances for what purpose?

4. Should ground conductors normally be fused?

5. What part of a service goes from the pole to the house?

REFERENCES

1. National Electr... Code

2. Blueprint Reading by Kenneth Gebert

3. Electrical Code Diagrams, Volumes I and II

NONMETALLIC-SHEATHED CABLE

OBJECTIVE

The objective of this unit of instructions is to develop your understanding of:

1. The types, uses, specifications, installations procedures, and purposes of nonmetallic-sheathed cable and its application.

2. Procedures for making electrical connections and splices.

3. Branch circuits and how to install them in nonmetallic sheath cable.

4. The construction features, operating principles and wiring requirements for three and four-way switches.

INTRODUCTION

With the rapid expansion of construction and the increased demands for electricity to operate more appliances and equipment, a faster and easier to install and trouble-free system of wiring was needed. The older systems, such as knob and tube, were excellent systems if installed properly but were very expensive to install because of the vast amount of labor involved. For these reasons nonmetallic-sheathed cable was developed. This study guide was developed to aid you in understanding the installation of this type of wiring.

INFORMATION

TYPES AND USES OF NONMETALLIC-SHEATHED CABLE

Nonmetallic-sheathed cable is an assembly of two or more insulated conductors having an outer sheath of moisture resistant, flame retardant, nonmetallic material. It is available in type NM and NMC in sizes No 14 to 2 AWG inclusive. In addition to the insulated conductors, the cable may have an insulated or bare conductor for grounding purposes only.

Type NM

NM nonmetallic-sheathed cable, as shown in figure 35, may be used for both exposed and concealed work in normally dry locations. It may be run or fished into air voids in masonry, block, or tile walls where such walls are not exposed or subject to excessive moisture or dampness. Do not use this type where it will be exposed to corrosive fumes or vapors and never imbed it in masonry, concrete, fill, or plaster. It should never be run in shallow chase in masonry or concrete and covered with plaster or similar finish.

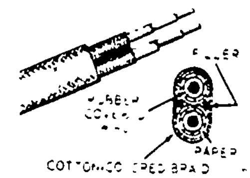

Figure 35. Type NM, Nonmetallic-Sheathed Cable

Type NMC

NMC nonmetallic-sheathed cable, as shown in figure 36, may be used for both exposed and concealed work in dry, moist, damp, or corrosive locations, and in outside and inside walls of masonry, block, or tile. If imbedded in plaster or run in shallow chase in masonry walls and covered with plaster within two inches of the finished surfaces, it should be protected against damage from nails by a cover of corrosion resistant, coated steel, at least 1/16 inch in thickness and 3/4 inch wide.

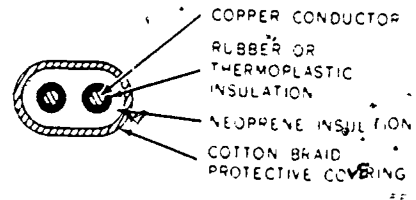

Figure 36. NMC Nonmetallic-Sheathed Cable

SPECIFICATIONS AND INSTALLATION PROCEDURE

Normally, nonmetallic-sheathed cable is not used for imbedded installation in masonry, concrete, fill, or plaster. It should not be installed in potentially dangerous areas where wire damage may occur, such as commercial garages, theaters, storage battery rooms, and hoistways. Also, it may not be used in wet areas such as ice plants or cold storage warehouses.

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The local codes in some areas require the addition of a bare uninsulated conductor type of nonmetallic cable, as shown in figure 37. This bare wire provides an equipment ground at outlet boxes. The bare wire is attached to the outlet box by use of a grounding clip.

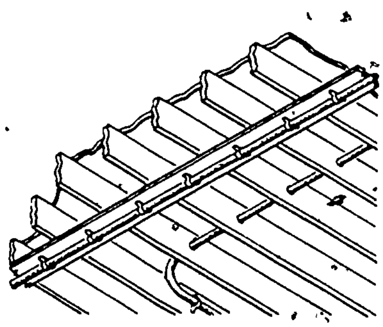
For exposed work, nonmetallic sheathed cable is generally mounted on wooden building members with one or two hole straps, staples or similar fittings designed and installed so as not to injure the cable. Typical staples and straps are shown in figure 38.

Secure the cable at intervals not exceeding 4 1/2 feet and within 12 inches of every outlet or fitting. If the cable is exposed, it must follow the contour of the house finish or running boards. If it is necessary to protect the cable, use guard strips or other suitable means.

If the cable passes through a floor, it should be enclosed in rigid conduit or pipe extending at least 6 inches above the floor. Nonmetallic sheathed cable can be run through holes bored in studs, joists, or similar wood members without any additional protection as shown in figure 39. Bore holes slightly larger than the cable, near the center of the timber. If the cable is run at angles with joists, in unfinished basements, secure conductors (two No 6 or three No 8) directly to lower edges of the joists. Smaller conductors should be run through holes bored in the joists. When cables are run in parallel to joists, they should be secured to their sides or faces.

Figure 37. Nonmetallic Sheathed Cable with Ground Wire

Figure 38. Staples and Straps



WHEN CABLE RUNS CROSSWISE TO JOISTS CABLE MAY BE ATTACHED TO RUNNING BOARD OR CABLE MAY BE DRAWN THRU HOLES DRILLED IN JOISTS

Figure 39. Installing Nonmetallic Sheathed Cable

If the cable is run across the top of floor joists or across the face of rafters or studding within 7 feet of the floor or floor joists of accessible attics, protect the cable with a guard strip the height of the cable. If the attic is not permanently accessible, protect the cable 6 feet within the edge of the attic entrance. Guard strips or running boards are not required if the cable is run along the sides of rafters, stands, or floor joists.

Where cable is run at angles with joists, it shall be run through bored holes or on running boards. See figure 39.

All splices and joints must be made in outlet or junction boxes; therefore, at least 6 to 8 inches of wire must be left for making connections in junction and outlet boxes. Bends in nonmetallic-sheathed cable should not be made with a radius of less than five times the diameter of the cable. Every precaution should be made not to injure the protective covering of the cable.

Outlet and junction boxes are made in round, square, octagon and oblong shapes and vary in depth for different purposes. It is very important to use the proper type box for each wiring job. Outlet boxes are installed in various ways, depending on the type of building construction and whether they are to be installed in new or old work.

Ceiling outlet boxes are generally supported by hanger bars. Hanger bars come in many types. Figure 40 shows the most common types of metal hangers and their installation. Boxes are fastened to the hanger bars by means of bolts or by fixture studs. The hanger bar is fastened to the joists by means of nails or screws. Some electricians prefer to use wooden strips to mount the outlet box as shown in figure 41. Wall boxes are installed to support switches, duplex receptacles, clocks, wall lights and numerous other devices. Outlet boxes are supported by many different devices manufactured for this purpose.

Junction boxes are usually mounted in the attic on running boards, or directly to the ceiling joist.

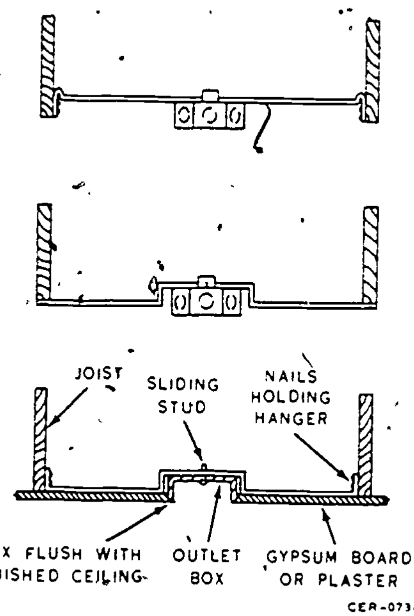


Figure 40. Mounting Ceiling Outlet Boxes

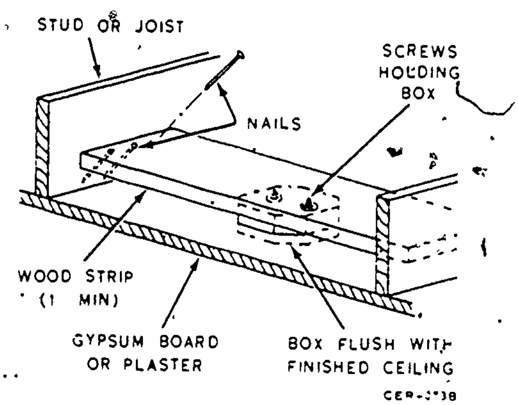


Figure 41. Wood Strip Mounting

Wall outlet boxes may also be supported by wood strips as shown in figure 43. Other popular methods of mounting are shown in figure 42. The type of structure, material available and the type of wall covering usually determine the type of mounting.

Switch and outlet boxes are sometimes mounted as shown in figure 43. The strip must be at least 1 inch thick and so mounted that the front edge of the box will be flush with the plaster or sheetrock. To install an outlet in a lath and plaster wall do not cut away two laths. Cut one and notch the other two as shown in figure 44. To mount an outlet box in a sheetrock wall after the sheetrock is in place, metal box supports as shown in figure 45 may be used. When a house is of brick or tile construction, a considerable amount of labor is involved in the mounting boxes, as the boxes must be flush with the plaster when it is applied. A space must be chiseled into the masonry to receive the box.

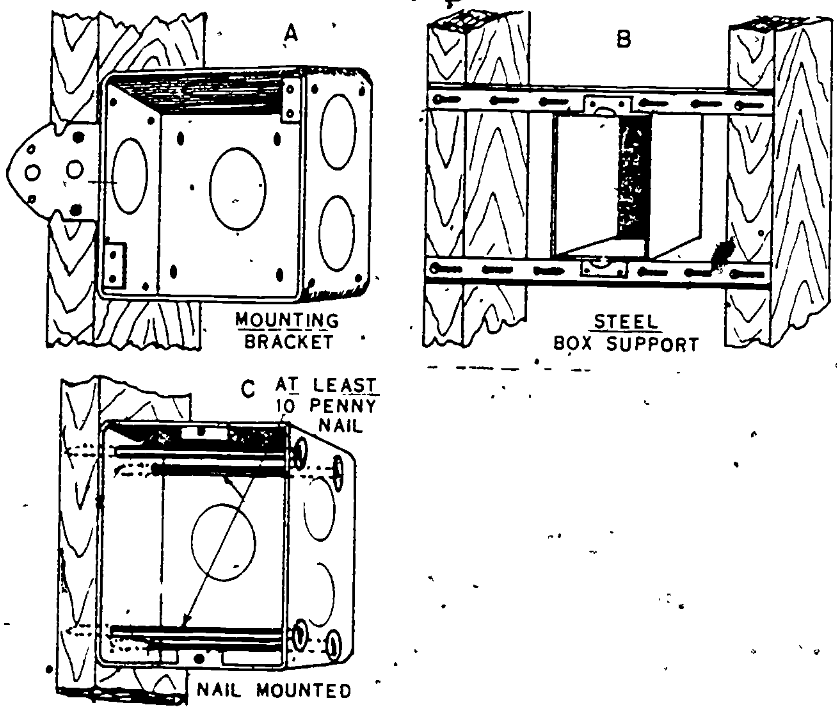


Figure 42. Mounting Boxes with Brackets, Nails or Screws

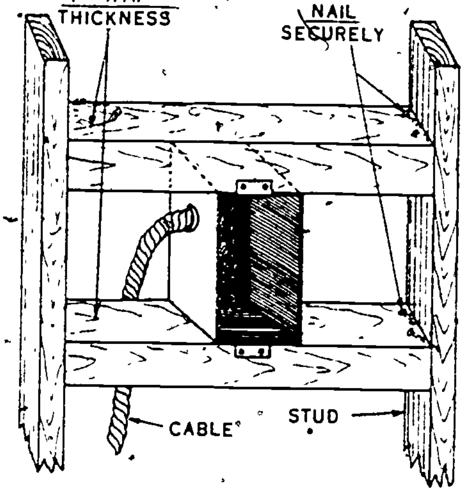


Figure 43. Mounting Switch Boxes on Wooden Strips

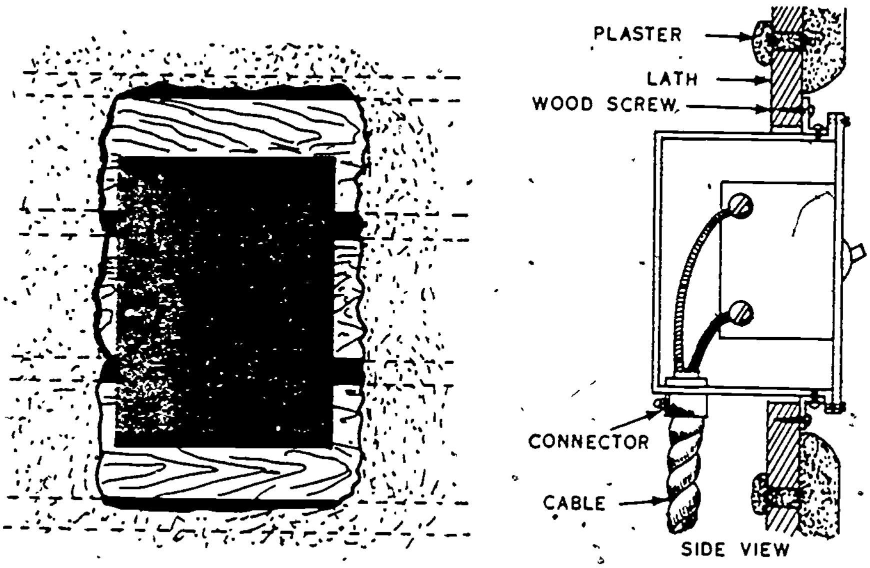


Figure 44. Mounting a Box in a Lath and Plaster Wall.

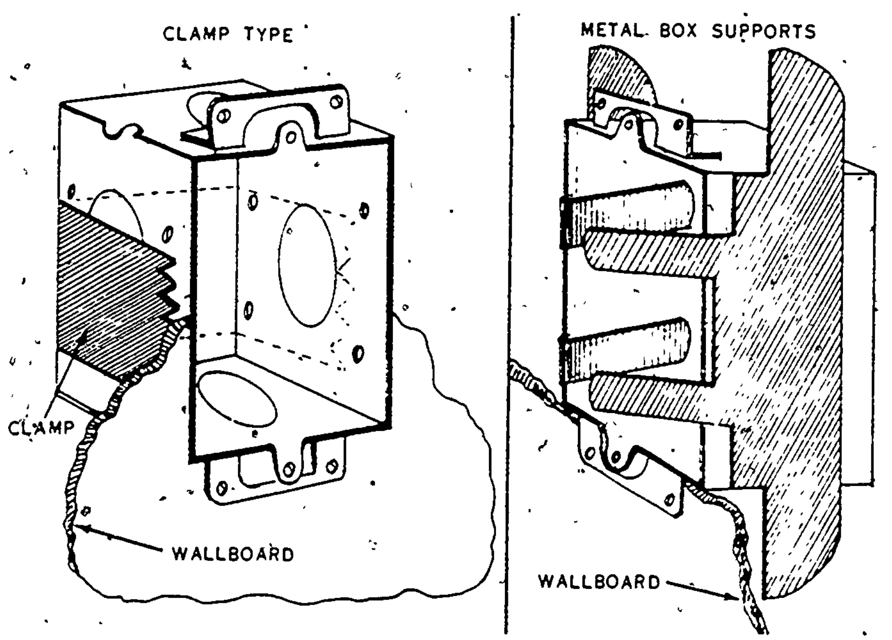


Figure 45. Mounting an Outlet Box in Wallboard

Usually, 4-inch square boxes are used together with covers of the type shown in figure 46. These are available in various depths; so that, if the ordinary 1/2-inch type does not bring the cover flush with the plaster, one of a greater depth will be suitable. The box cannot be secured to the brick directly with screws, consequently it is necessary to use one of the many types of plugs or anchors available for the purpose. To mount a box on a masonry wall, it is necessary to drill holes using a star drill as shown in figure 47. You may also use a power bit. The drill is used by simply pounding on its head with a hammer, rotating the drill after each blow. The anchor is then placed into the hole and expanded as shown in figure 48. The National Electric Code prohibits the use of wooden plugs. If the mounting is over hollow areas, use toggle bolts as shown in figure 49. The bolts are slipped through the opening in the wall, and a spring opens the wings which provide anchorage for the bolt.

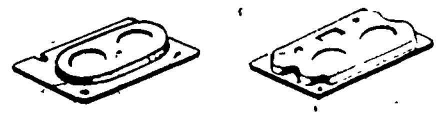


Figure 46. Typical Raised Covers for 4" Square Boxes

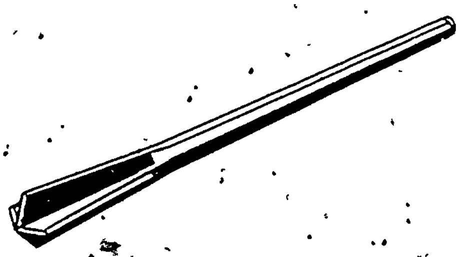


Figure 47. Star Drill

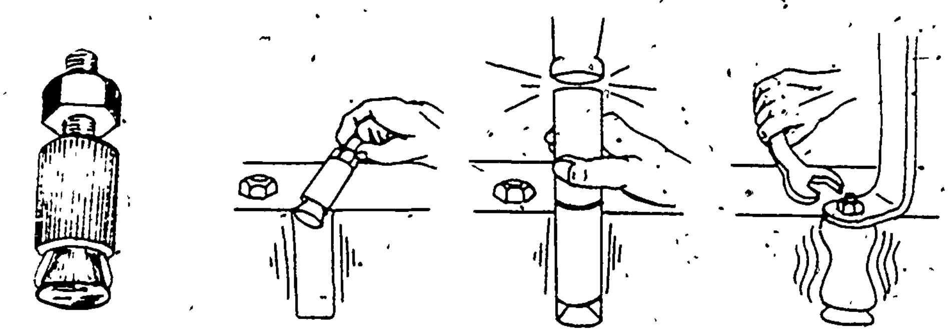


Figure 48. Lead Expansion Anchor

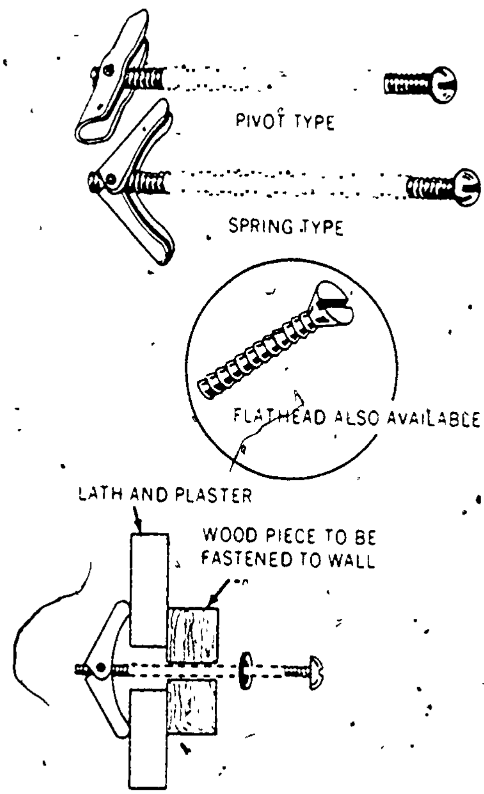


Figure 49. Using Toggle Bolts

ELECTRICAL CONNECTIONS AND SPLICES

To install wiring and make repairs on appliances, motors, generators, and other electrical equipment, it is necessary for you to make various types of connections and splices. Normally, screw terminals or connectors of some sort are provided for connecting wires to switches, receptacles, appliances, and so on. However, for connecting wires together in junction boxes and outlet boxes, you make various kinds of splices. Splices are made by twisting the ends of two or more wires together. Splices may also be made by using various mechanical devices to hold wire ends together.

Before a wire or cable can be attached to a device or spliced, the insulation must be removed at the point of connection. Just enough insulation is removed to make the connection. As you gain experience, the removal of the proper amount of insulation for each connection and splice will become automatic. The electrician's knife is most generally used to remove insulation. However, for small size wire, a wire-stripping tool may be used. When you remove insulation with a knife, be careful that you do not cut into the wire itself. A nick may cause the wire to break after it is installed. A deep nick or scratch reduces the current-carrying capacity of the wire. After the insulation is removed, burnish (scrape) the wire end with your knife or fine sandpaper. This removes any bits of insulation and oxidation remaining on the wire.

For connecting wire to screw terminals, use your long nose pliers to form a loop or eye in the bare end of the wire. Such a loop is shown in figure 50. Notice how the loop is placed around the screw. As the screw is tightened, it tends to close the loop. If the wire is not placed on the screw in this manner, the loop tends to open when the screw is tightened. When making this type connection, the insulation must cover the wire close to the terminal screw. When too much insulation is removed, the bare wire is exposed for too great a distance from the screw. Notice in figure 50 how the insulation is removed to form a "cone" at the end. When you remove insulation with a knife, always leave the end cone-shaped. When a wire stripper is used to remove insulation, the end is left at a right angle to the wire.

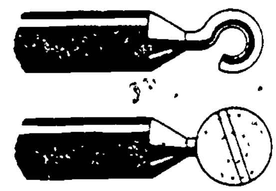


Figure 50. Terminal Loop Eye

Where large wire (generally No 6 or larger) must be connected to switches or other devices, a mechanical connector is provided. Figure 51 shows one type of mechanical connector (sometimes called solderless connector). To use this type connector, you simply place the bare end of the wire in the connector and tighten the screw. As on the loop connection for smaller wire, the insulation must extend up close to the connector.

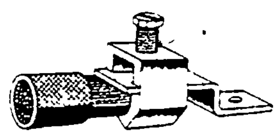


Figure 51. Screw Terminal Connector

Wire splices must be mechanically and electrically secure. That is, the splice must be as strong as a continuous wire, and must conduct electricity as easily as a continuous wire. When you must join two or more small wires together in a junction or outlet box, use the pigtail splice. Figure 52 shows two wires joined together by a pigtail splice. The pigtail splice is also commonly used to splice together the individual coils in motor and generator stator windings. Notice that figure 52 shows two solid wires spliced together. A good example where you are required to splice a solid wire to a stranded wire is in the replacement of motor and generator terminal leads. Terminal leads are stranded and are spliced to the ends of the motor and generator windings. Windings are made of solid copper wire, commonly known as magnet wire.

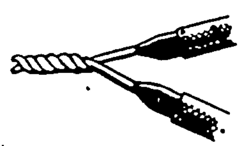


Figure 52. Pigtail Splice

To make the pigtail splice, you remove the insulation from the wire ends, clean them, and then twist the ends together. Use pliers for twisting the ends together. This insures that the ends are twisted tightly together. After the wires are twisted, clip off the free ends. You are now ready to solder the splice and apply insulating tape. Instead of soldering the splice, insulated solderless connectors (wire nuts) may be used. The wire nut screws on the splice and holds it firmly. It also provides the required insulation for the splice.

You sometimes find it necessary to connect one wire to another continuous wire. This may be done with a tap splice. Tap splices may be used with solid or stranded wire, or a combination of both. To make the tap splice with solid wire, remove about 1/2 inch of insulation from the continuous wire and about 3 inches of insulation from the tap wire. Lay the bare end of the tap wire over the continuous wire. Make one wrap around the continuous wire with the free end of the tap wire. Bring the free end of the tap wire across the standing part of the tap wire as shown in figure 53. With the remainder of the free end, make five close turns around the continuous wire. Cut off the excess free end of the tap wire. You are now ready to solder and tape the splice.

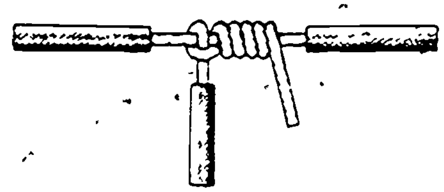


Figure 53. Tap Splice

To tap stranded wires, separate the strands of the continuous wire and thread the tap wire through the separated strands. Separate the tap wire strands and wrap them in opposite directions around the continuous wire as shown in figure 54. After the splice is made, you then solder and tape the splice.

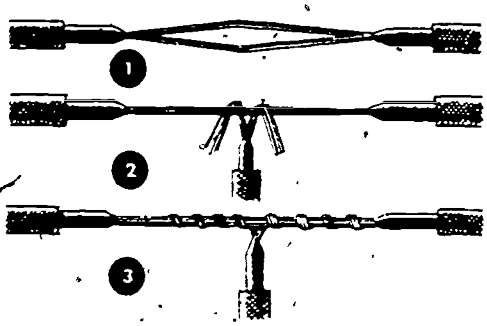


Figure 54. Stranded Wire Splice

Soldering

Soldering is the process of joining metals by adding another metal to bond them together. Electrical work requires solder composed of 60% lead and 40% tin with a resin core. The resin is used as a flux to clean the metal as it is joined. Resin should be used as flux in electrical work as other types of flux will cause corrosion. Heat is supplied to the joint to be soldered by either a soldering gun or a soldering iron. A soldering gun is usually used for light work and small wires; while a soldering iron works better for large, heavy work. Figure 55 shows examples of soldering guns and irons.

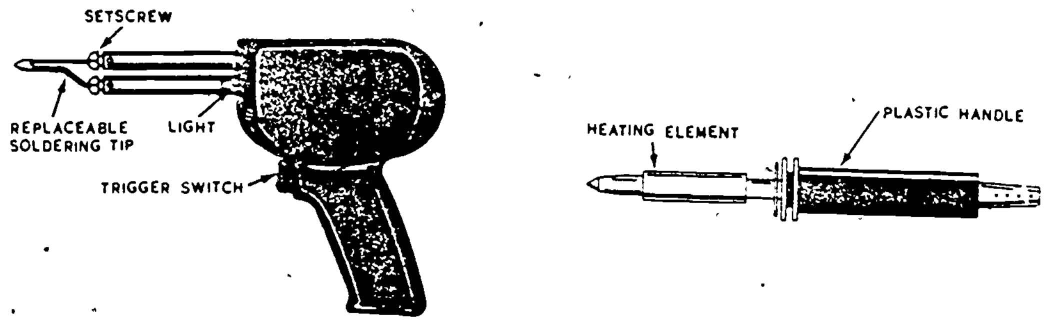


Figure 55. Soldering Iron and Soldering Gun

To prepare the soldering iron, it should be cleaned and tinned. Tinning the copper end means to heat the copper and then apply a thin film of solder to it. This tinning will help transfer heat from the copper to the work being soldered. When soldering, place the heat against the bottom of the work, allow the work to heat and then apply the solder to the heated work. The solder should melt and be drawn into all the open areas of the work. See figure 56.

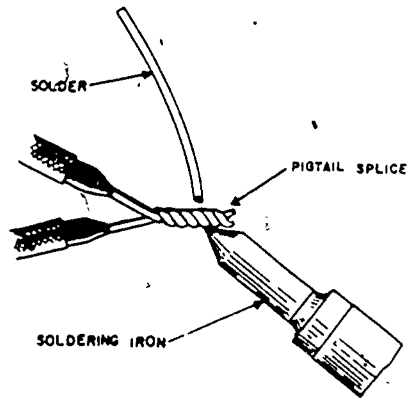


Figure 56. Soldering a Splice

Remove the soldering iron and allow the work to cool until the solder has changed from silver to a dull white. CAUTION: Hot soldering equipment and solder can cause painful burns. Care in using and storing them should be exercised.

Soldering is a relatively safe occupational task that is performed by many people. It is almost always done as a secondary task to some primary job such as making an electrical connection or making a leakproof joint in metal tubing. When soldering, some of the hazards you should be careful of are given in the following papagraphs.

BURN HAZARDS. The most common injury from soldering is burns. Burns, in most cases, are caused by inattention or carelessness. The heated soldering iron is allowed to touch the body or the hot soldered object is picked up before it has cooled. Solder can also cause burns if the molten solder is allowed to drip on any part of the body.

EXPLOSION HAZARDS. Another hazard associated with soldering is the danger of fire or explosion. Soldering irons must not be laid on or allowed to contact combustible materials. An open flame used as a source of heat for soldering is even more hazardous.

TOXIC HAZARDS. A third hazard of soldering, and one not generally recognized, is the toxicity of some materials involved. Soft solder (ordinary solder) is composed of lead and tin. Heating soft solder, particularly with an open flame, generates lead fumes. Inhaling these fumes causes a buildup of lead in the body. Lead tends to accumulate in the body instead of being expelled. Consequently, frequent exposure to lead fumes may eventually lead to lead poisoning.

Soldering requires the use of flux to remove oxides from the metal surfaces being soldered to insure a tight bond. Fluxes are either corrosive or noncorrosive. Rosin (noncorrosive) flux does not produce poisonous fumes when heated. Muriatic (hydrochloric) acid, zinc chloride, ammonium chloride, and sal ammoniac (corrosive fluxes) produce toxic fumes such as hydrogen chloride. These vapors cause burning and irritation of exposed tissue. They also cause violent coughing and difficult breathing. Acid fluxes may seep from cored solder. The acid may cause burns and damage to clothing. During the soldering process, the acid may splatter and get in eyes unless protective goggles are worn. If you do get acid in your eyes, flush them thoroughly with water and get prompt medical attention.

Silver soldering or silver brazing (sometimes referred to as hard soldering) usually does not produce toxic fumes. However, the specifications of the silver brazing alloy used should be carefully checked. If it contains cadmium, toxic fumes are generated during the brazing process. Cadmium fumes are very poisonous and must not be inhaled or permitted to contact the eyes or skin.

VENTILATION REQUIREMENTS. All soldering operations should be performed in an area where there is plenty of ventilation. Never breathe the fumes from soldering. If exhaust hoods are available, do your soldering under the hood. Downdraft, grill-top tables are suitable for soldering small parts where the point of soldering it not more than six inches above the grill top. These grills should have an airflow of 160 to 250 cubic feet per minute per square foot.

Normally, a large open area provides adequate ventilation for soldering. However, if the air is stagnant and the fumes do not dissipate readily, an electric fan can be used to move the air. Place the fan so that it blows the fumes away from you.

PROTECTIVE EQUIPMENT REQUIREMENTS. Soldering done in a confined space such as a closet or tank results in an excessive accumulation of fumes. An approved respirator suitable for protection against metal fumes must be worn for soldering in a confined area where adequate ventilation is not provided. If an open flame torch is used, a deficiency in oxygen may occur. A protective mask connected to an outside air supply is required to prevent suffocation whenever an oxygen deficient atmosphere may be created.

Remember, soldering can be hazardous. Use protective goggles if there is danger of splattering acid. Solder only in a well ventilated area and do not breathe the fumes. Check silver solder for a cadmium content. Use respirators or externally supplied breathing masks for soldering in confined areas. Ignoring these simple precautions may result in illness, injury, or death.

Taping

Once a splice has been made, it must be taped to prevent the bare splice from touching the metal box and causing electrical trouble. Generally the tape used on interior electrical work will be plastic. The tape should be applied in smooth, half lap layers sufficient to provide the same amount of electrical insulation as the insulation on the remainder of the wire.

SUMMARY

Nonmetallic-sheathed cable consists of 2 or 3 rubber or thermoplastic insulated wires bound together and covered with an outer sheath. Type NM is to be used in normally dry locations. Type NMC is more versatile and can be used in dry, damp or moist locations.

Normally, nonmetallic sheathed cable is not used for imbedded installation in masonry, concrete, or used in potentially dangerous places.

Local codes in many areas require a third wire which is bare and uninsulated. This bare wire provides an equipment ground at the outlet boxes.

Nonmetallic-sheathed cable is generally installed on wooden members. If a run is necessary across rafters or joists, a running board should be provided if the installation is in an accessible attic. Nonmetallic cable can be run through holes bored in studs, joists or rafters without any additional protection. This type cable is secured at intervals not exceeding 4 1/2 feet and not more than 1 foot from every outlet box or fitting. All splices and taps must be made in outlet or junction boxes. Cables must be secured to boxes with approved clamps and fittings.

Outlet boxes are installed in many different ways. Ceiling outlets are generally installed with the aid of hanger bars or with wooden strips. Wall boxes are usually installed by using wooden strips or simply by driving 10 penny nails through holes provided in the sides of the box or by screws through the back of the box.

Often it is necesary to mount boxes on masonry surfaces. A star drill or power bit is used to drill holes in masonry for lead anchors. If the mounting is over a hollow area, toggle bolts should be used to hold the box.

Splices must be made mechanically and electrically secure. Always use a resin type soldering flux when soldering splices since other types of flux will cause corrosion. Enough tape must be applied to a splice so that the insulating quality is equal to the insulation that you removed.

NOTE: See Articles 110, 200, 300, 334-13, 336, and 370 in the National Electrical Code for additional information.

QUESTIONS

1. What are the two types of nonmetallic-sheathed cable?
2. Can type NM nonmetallic-sheathed cable be used in concealed work?

3. When using a wooden strip to mount a box the wooden strip must be at least

_______________ thick.

4. What type of flux is used when soldering electrical wires?

5. What is the purpose for tinning a soldering iron?

6. What is the purpose of a running board?

BRANCH CIRCUITS

Branch circuits may be of two types. A general-purpose branch circuit will supply a number of outlets or lighting fixtures or appliances. An individual or special branch circuit will supply only one piece of equipment. See Article 100 of the NEC.

Parts of Branch Circuits

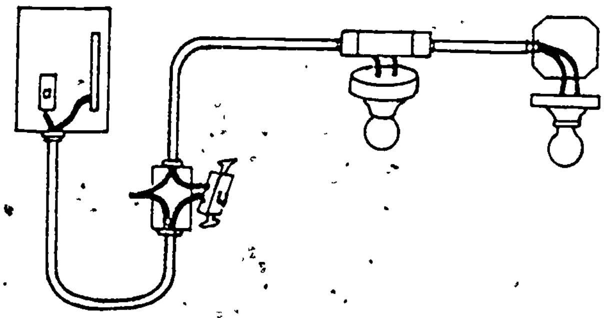
As in Block I, you will still be concerned with power, conductors, and resistances. The panelboard contains overcurrent protection in the form of a circuit breaker. From the panelboard, power is carried on the conductors through the control device (switch) to the power using equipment such as lights or appliances. Figure 57 shows the relationship of these parts in three different configurations.

NEC REQUIREMENTS

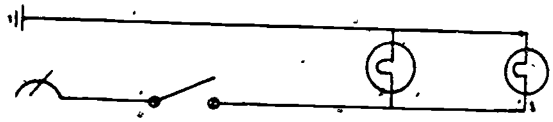
According to Article 210-19c the minimum size conductor you should use when wiring is a 14 AWG.

The current-carrying capacity of the different size conductors can be found in Table 310-16 through Table 310-19.

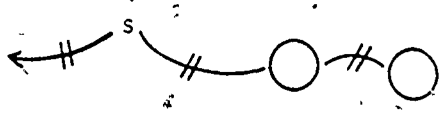
When planning a branch circuit, design the system so that it has a minimum of voltage drop.



Pictorial Drawing



Schematic Drawing



Blueprint--Single-Line Drawing

Figure 57. Circuit Representation

Branch Circuit Voltage Drop

The size of the conductors for branch circuits as defined in Article 100 should be such that the voltage drop would not exceed 3 percent to the furthest outlet for power, heating, lighting, or combinations thereof. Providing further that the maximum total voltage drop for feeders and branch circuits should not exceed 5 percent overall.

To determine how much voltage drop you have, measure the amount of voltage at the service entrance panel, or load center and then measure the voltage drop at the load. Example: Your voltmeter indicates you have 120 volts at the service entrance switch and 105 volts at the load. This means you have a 15-volt drop between the load and the service panel. To find the percentage of voltage drop, use the following formula.

$$\frac{\text{voltage drop}}{\text{voltage at panel}} \times \frac{100}{1} = \frac{15}{120} \times \frac{100}{1} = 12.5 \text{ percent}$$

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This circuit is above the recommended voltage drop. One of the ways to remedy a voltage drop problem is to increase the size of the conductor. A larger conductor will offer less resistance. Chapter 9, Table 8 of the NEC gives the resistance of different sizes of conductors.

Before going into the actual installation procedures of nonmetallic sheathed cable there are a few articles in the National Electrical Code which you should be aware of:

-Boxes shall be securely fastened in place (Article 300-11).

-You should have at least 6 inches of free conductor at every outlet, switch and junction box (Article 300-14).

-All switch, outlets, and splices shall be placed in a box (Article 300-15).

-All unused openings shall be effectively closed (Article 370-8).

-All boxes shall have a cover (Article 370-18c).

-Junction, pull and outlet boxes shall be rendered accessible without removing any part of the building (Article 370-19).

-All splices shall be mechanically and electrically secure and covered with an insulation equivalent to that of the conductor (Article 110-14(b))

-The identified conductor when connected to a lamp holder shall be connected at the screw-shell (Article 200-10(c)).

-When cables are installed through bored holes in studs, joists or similar wood members, hol[illegible] shall be bored at the approximate centers of the wood members, or at least two [illegible]hes from the nearest edge where practical (Article 300-4).

-You can notch the wood members to install cable but you must put a metal plate over the cable to protect it from nails (Article 300-4).

-When mounting a box on a wooden brace, it should be at least 1-inch thick (Article 370-13).

-The identif[illegible]ion of terminals to which a grounded conductor is to be connected shall be by [illegible]ans of a metallic plated coating substantially white in color (Article 20[illegible]b).

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BRANCH CIRCUIT CALCULATION

When figuring how many branch circuits and how much lighting will be required for different situations, refer to Article 220 of the NEC which will give the basic minimum requirement.

General Lighting

Two things to take into consideration when figuring the lighting load are: how large is the area and what will the area be used for?

In determining the load on the "watts per square foot" basis, the floor area shall be computed from the outside dimensions of the building, apartment or area involved and the number of floors, not including open porches, garages in connection with dwelling occupancies, nor unfinished spaces and unused spaces in dwellings unless adaptable for future use. For general illumination in dwelling occupancies you should have one branch circuit for each 800 square feet of floor area for a 20 amp, 2-wire, 120-volt circuit and 600 square feet of floor area for a 15 amp, 2-wire, 120-volt circuit. This is a code minimum and works out to be a capacity of 3 watts per square foot. Table 220-2(b).

Table 220-2(b) "General Lighting Loads by Occupancies," tells you the minimum amount of watts for general lighting according to what the area will be used for.

Receptacle Outlet Circuits

In a dwelling type occupancy you should have at least two receptacle circuits to feed the small appliance load in the kitchen, pantry, family room, dining room and breakfast room. There should be at least one receptacle branch circuit to the laundry room. Each of the above circuits will consume about 1,500 watts each (Article 220-16(a) & (b)).

Most appliances manufactured today have a 6-foot cord on them. You should be able to take an appliance or lamp and put it anywhere along the wall to reach a duplex outlet (Article 210-25(b)).

All receptacle outlets that you install shall be of the grounding type (Article 410-58).

To calculate the demand load of a single family dwelling, you are referred to Article 220.

NONMETALLIC CABLE INSTALLATION

Nonmetallic sheathed cable can be used for concealed or exposed work in normally dry locations (Article 336-3(a)).

There are certain situations where you cannot use NM cable. As service entrance cable, in commercial garages, in theatres, in motion picture studios, in storage battery rooms, in hoistways, in any hazard locations. You cannot embed NM cable in poured cement, concrete or aggregate (Article 336-3(c)).

NM cable should be supported every 4 1/2 feet and within 12 inches of a box, with a staple or strap (Article 336-5).

When installing cable it should follow the building finish. In other words, it should fit snugly against the wall.

SUMMARY

After electricity has passed through the service entrance switch, it enters the distribution panel or load center and from there is carried throughout the building by smaller conductors called branch circuits. There are two types of branch circuits, general purpose and individual or special. All wiring with nonmetallic-sheathed cable will be done according to the National Electrical Code. Just knowing all the articles that pertain to NM cable is not enough; you must be able to install it correctly.

QUESTIONS

1. What are the two types of NM cable?

   a. ______________________________

   b. ______________________________

2. What is the purpose of an overcurrent device in a branch circuit? __________

   ____

3. What is the maximum percent of voltage drop on a branch circuit? __________

   ____

4. How much free conductor should you have at every box? __________

   ____

5. All boxes shall have covers. True or False __________

6. Define: identified conductor. __________

   ____

7. Using a 3/4-inch board to mount a box is permissible by the NEC. True or False

   ____

8. What two things should you take into consideration when figuring the lighting load?

   a. ______________________________

   b. ______________________________

REFERENCES

1. National Electrical Code
2. NFPA Handbook of the NEC,
3. Practical Electrical Wiring, by H.P. Richter
4. Electrical Trades Blueprint Reading, 1969 Edition
5. Electrical Code Diagrams, Volumes I and II

THREE AND FOUR-WAY SWITCHES

Purpose and Uses

A circuit can be controlled from more than one location by using three and four-way switches. Three-way switches can control a circuit from two locations; if more control locations are desirable, four-way switches are used with three-way switches. Multiple control circuits are used to control a light from either end of a hallway or room, to control a light from upstairs or downstairs, to control a garage light from inside the house or garage, to control a light on a fishing pier from the cabin or from either end of the pier, etc. You can see from these examples that three and four-way switches are used in various ways to make a circuit more convenient and useful.

Operation

A circuit can be controlled from two locations by using two, three-way switches. If it is desirable to operate a circuit from more than two locations, it is accomplished by adding four-way switches into the circuit.

Three-Way Switches

Three-way switches are equipped with three connecting terminals. Figure 58 illustrates what happens in a three-way switch when the toggle is moved up and down. Terminal "A" is used for the common (hot wire); terminals "B" and "C" are used for wires connecting the two switches. These wire are called travelers.

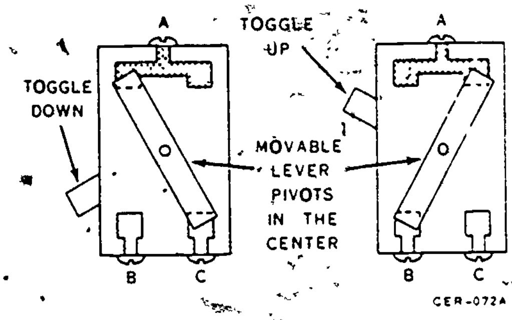

Figure 58. Three-Way Switch

Figure 59 illustrates two three-way switches with no current flowing through the second three-way switch. Figure 60 shows how the circuit is completed if either toggle is thrown.

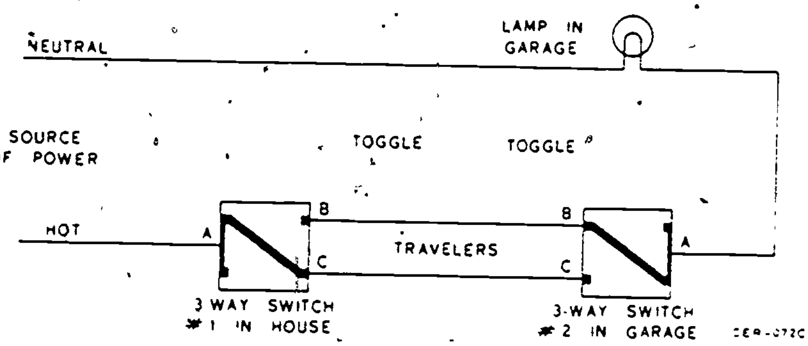

Figure 59. Three-Way Switch Circuit, Circuit Open

In actual wiring a three-way switch looks similar to any single pole switch except that it has three terminals instead of two, and the words ON and OFF do not appear on the toggle handle. The terminal used for the HOT wire is usually located on one end or side of the switch by itself and is usually a darker color than the other two.

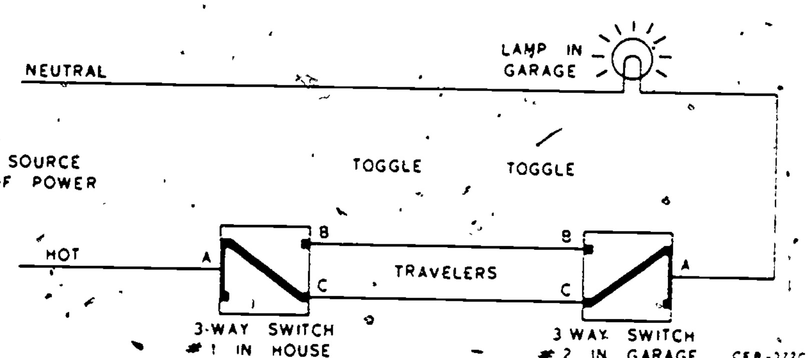

Figure 60. Three-Way Switch Circuit, Circuit Closed

Four-Way Switches

Four-way switches as illustrated in figure 61 are used to control a circuit from three or more places. To accomplish this, two three-way switches must be used in conjunction with four-way switches. Use a three-way switch at the beginning and one at the end of a multi-controlled circuit. All other switches in the multicontrolled circuit are four-way switches.

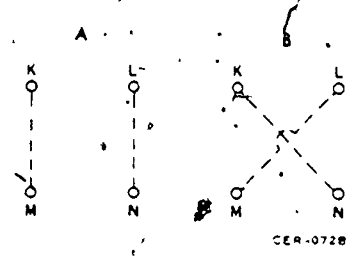

Figure 61. Four-way Switch in Both Positions

In one position of the toggle, the terminal K is connected to the terminal M and the terminal L is connected to terminal N, as shown in figure 61, position A. When the toggle is thrown, K is connected to N and M is connected to L as illustrated in figure 61, position B.

Figures 62 and 63 show a four-way switch installed in a light circuit and how it controls the light.

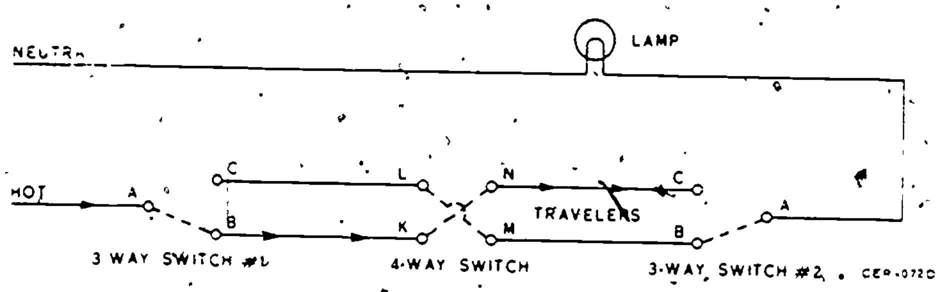

Figure 62. Four-Way Switch Circuit, Circuit Open

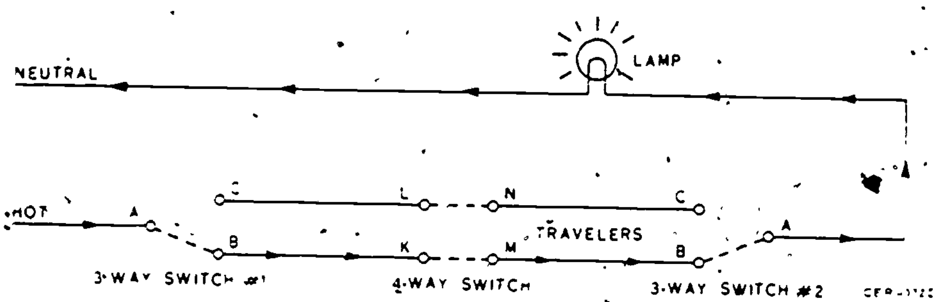

Figure 63. Four-Way Switch Circuit, Circuit Closed

Installation

Three and four-way switches are installed in outlet boxes in the same manner as single pole switches. It is easy to connect three-way switches. The mechanical construction varies among manufacturers so that the marked (common) terminal is sometimes alone on one end of the switch or sometimes alone on one side. These three-way switches will be wired as shown in figures 64 or 65 depending on the location of the marked (darker colored) terminal. Fortunately, no harm is done if the wrong terminals are selected, except that the circuit will not work. If there is any doubt as to which are the correct terminals on a switch, use an ohmmeter or continuity meter to establish the proper connection sequence. It may be necessary to draw a circuit with switch terminals marked to establish the correct switch wiring sequence.

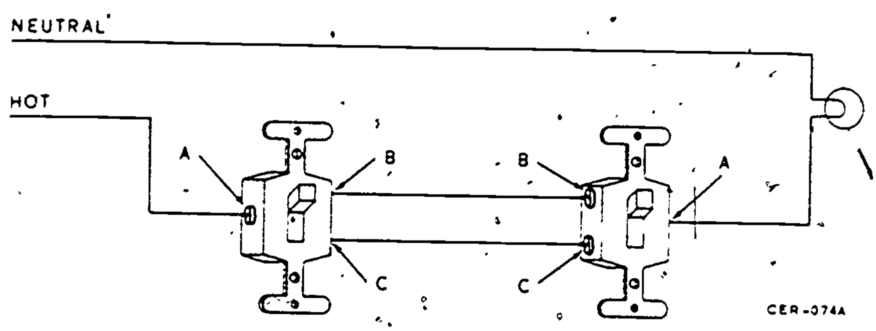

Figure 64. Three-Way Switch--Common Terminal Alone on One Side

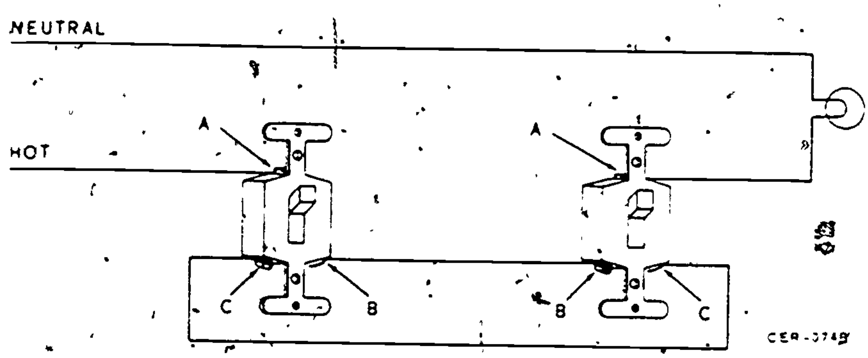

Figure 65. Three-Way Switch--Common Terminal Alone on One End

When installing three and four-way switches, the following rules apply:

- Connect the white wire from the power source to the silver terminal of the outlet being switched.
- Connect the hot (black) wire from the power source to the common terminal on the first three-way switch.
- Connect the hot (black) wire from the common terminal of the second three-way switch to the dark terminal of the outlet being switched.
- Connect traveler wires between the switches.

SUMMARY

Three-way and four-way switches are used to control a circuit from two or more locations. A light can be turned on at one end of a long corridor and turned off at the other end after walking through the corridor.

If it is desired to operate a circuit from two points, two three-way switches are used. If it is desired to operate a circuit from more than two points, four-way switches are installed between the three-way switches. You can add as many four-way switches as desired, depending on the number of control points needed.

If the marked terminals cannot be determined, the circuit through three-way switches can be determined by use of an ohmmeter or continuity meter.

QUESTIONS

1. What is the purpose of a three-way switch?
2. What is the purpose of a four-way switch?
3. How many terminals are on a three-way switch?
4. How many terminals are on a four-way switch?
5. What are the two terminals called that connect three-way switches together?
6. Where are four-way switches installed in relation to three-way switches?
7. In what situation are three wires required to connect switches?
8. Can three-way switches be connected wrong?
9. Diagram the two positions of a four-way switch?
10. How can the terminals usually be identified?

REFERENCES

1. National Electrical Code
2. NFPA Handbook of the NEC, by H. P. Richter
3. Electrical Trades Blueprint Reading,
4. Electrical Code Diagrams, Volumes I and II
5. AFM 91-17, Electrical Interior Facilities
6. AFP 85-1, Electrical Facilities Safe Practices Handbook

LIGHTING SYSTEMS

OBJECTIVE

The purpose of this study guide is to develop your understanding of incandescent and fluorescent lighting.

INTRODUCTION

In the Air Force you will be installing and maintaining incandescent and fluorescent lights.

All lighting fixtures, regardless of whether they use incandescent or fluorescent lamps, are classified according to the manner in which they distribute light.

INFORMATION

PURPOSES AND TYPES OF LIGHTING FIXTURES

The five general classifications are direct, semidirect, general diffuse, semi-indirect, and indirect. If an imaginary horizontal line is drawn on a level with the light source of the fixture, the amount of light directed above and below the line determines the fixture classification.

Direct Lighting

Direct lighting can be defined as a lighting system in which practically all of the light (90 - 100%) is directed in angles below the horizontal, directly toward the working areas as shown in figure 66. This type of lighting is usually produced by industrial type steel or aluminum reflectors.

Although such a system provides illumination on the working surfaces efficiently, it may be at the expense of other factors, such as excessive contrast of the light source with the surroundings, troublesome shadows, or direct and reflected glare.

Semidirect Lighting

Semidirect lighting is obtained from glass reflectors open at the bottom as shown in figure 66B. In this classification, 60 to 90 percent of the light is directed toward the working surface. This system provides, at low cost, illumination suitable for casual seeing for such areas as corridors, stairways, washrooms, etc.

General Diffuse Lighting

General diffuse lighting refers to the system in which the light emerges from the fixture, approximately equal in all directions, as shown in figure 66C. The reflector usually consists of a diffusing glass enclosing globe. Although this system gives illumination of better quality than either direct or semidirect systems, some difficulty may be experienced with brightness and glare.

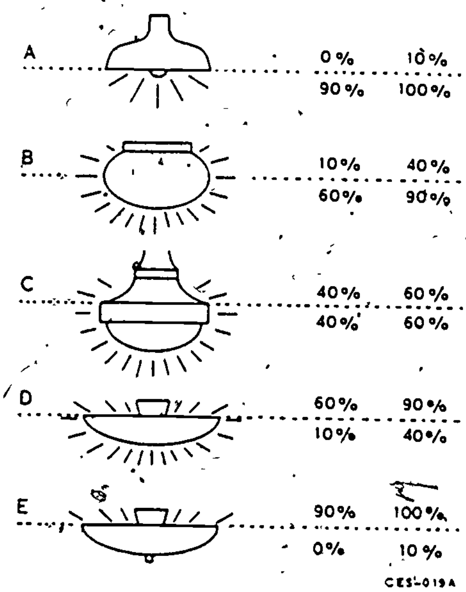

Figure 66. Types of Illumination

Semi-Indirect Lighting

Semi-indirect lighting is obtained when some of the light is transmitted directly to the working surface, but considerably more than half (60 to 90 percent) is emitted upward to the ceiling and upper walls, from which it is reflected to all parts of the room as shown in figure 66D. These reflectors may be open at the top or completely enclosed with a dense or enameled glass on the bottom and clear glass on the top. A properly designed fixture gives very good lighting with low surface brightness and eliminates most of the glare.

Indirect Lighting

Indirect lighting, as the name implies, means that most of the light (90 to 100 percent) reaches the work area indirectly by being reflected from the ceiling as shown in figure 66E. With the entire ceiling becoming a light source of low brightness, direct glare and shadow are practically eliminated. This produces a quality of lighting highly desirable for drafting rooms and offices where a high level of illumination is needed for doing close work with the least eyestrain.

INCANDESCENT LIGHTING

Although more efficient light sources have been introduced, incandescent lighting is not obsolete. Its use is often preferred for many applications because of its economy, flexibility, ease of maintenance, and convenience. A fixture consisting of the lamp, lamp socket, shade or reflector, hanging device, and wiring is called a luminaire.

Incandescent Lamps

Incandescent lamps are readily available, easily replaced, cleaned or removed and they are small in size. Where accurate control of the light distribution of a concentrated beam is required, the incandescent lamp is most convenient. It is capable of being dimmed and it starts instantly. Filament lamps have several disadvantages--too bright in red and yellow light, less efficient in lumens per watt than the newer type light sources and much of the input of these lamps is wasted in heat.

Incandescent lamps are designated by shape and size. They may be obtained in various finishes. Those with the inside frosted are the most common and should be used in all luminaries where elimination of streaks and shadows from the fixture is desired.

There are four lamp base sizes in general use as shown in figure 67. The "Mogul" is used for large watt lamps usually 300 to 1500 watts; the "Medium" is the common size found in most homes and offices, usually up to 300 watts; the "Intermediate" and "Candelabra" are used for special types of lighting fixtures.

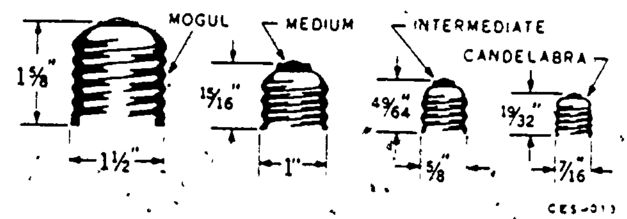

Figure 67. Types of Incandescent Lamp Bases

Lamp Sockets

Lamp sockets are available in many types. Often selection depends on the method of wiring used. Some operate by wall switches, others by pull chain or key switches. Figure 68 illustrates some of the various types of sockets used in electrical lighting systems.

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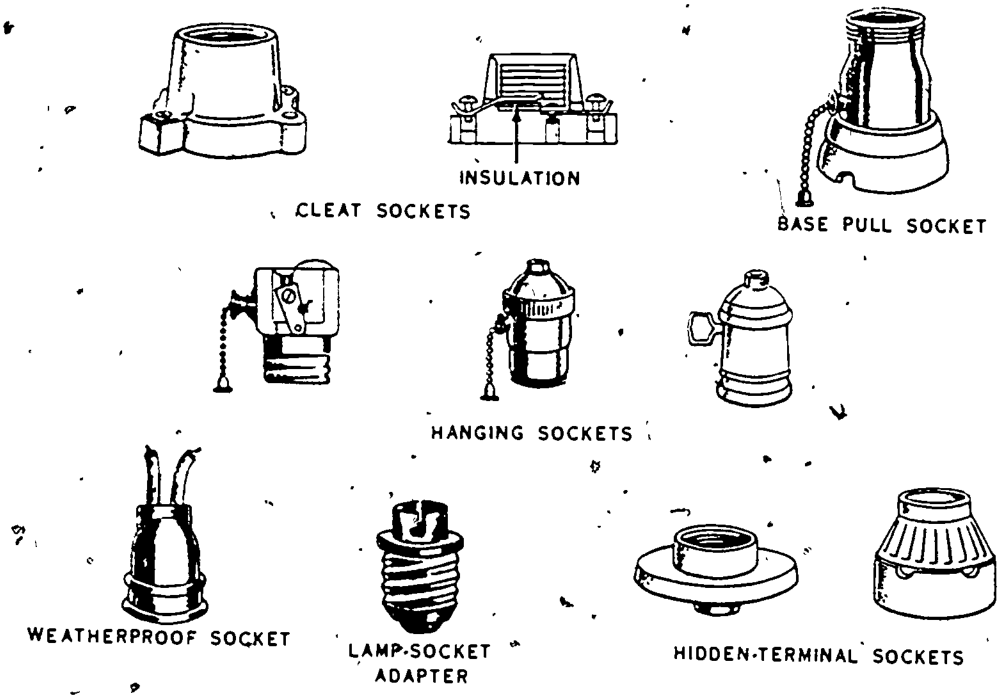


Figure 68. Incandescent Lamp Sockets

Shades and Reflectors

The type of shade or reflector used determines the type of light distribution. Shades are made of different materials: metal, glass, mirrored glass, prismatic glass, and opaque materials. Figure 69 illustrates several types of shades but does not represent a complete selection.

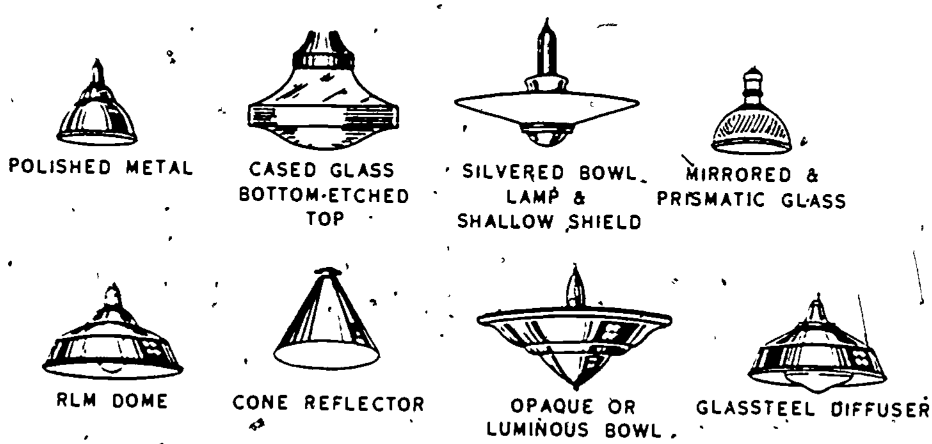


Figure 69. Shades and Reflectors Used on Incandescent Lamps

Wiring

Wiring is accomplished by the manufacturer of most luminaries. A stranded conductor is used for flexibility. The insulation is determined by the wiring method and expected use of the lighting unit.

FLUORESCENT LIGHTING

The development of fluorescent lighting systems has provided a method of lighting that gives a high efficiency per watt of electricity used. Fluorescent lighting provides two or three times as much light as incandescent lights of the same wattage. Since fluorescent lights use less wattage they produce less heat. This is an important factor where air conditioning is used. Basically, a fluorescent lamp is an electronic device. It consists of a glass cylinder that contains either argon or krypton gas, a drop of mercury, and an inner coating of fluorescent chemical. The chemical used for coating determines the color of light emitted from the tube. The end of the tubes are sealed and they contain electrodes necessary to connect the lamp into the electrical circuit. These electrodes are connected inside the lamp to the elements at each end. These elements are emitters and collectors (cathodes and anodes) that give off and accept electrons alternately in frequency with the voltage input sine wave.

In figure 70 are the parts of a fluorescent lamp of the bipin type that would be used in a preheat or rapid start system.

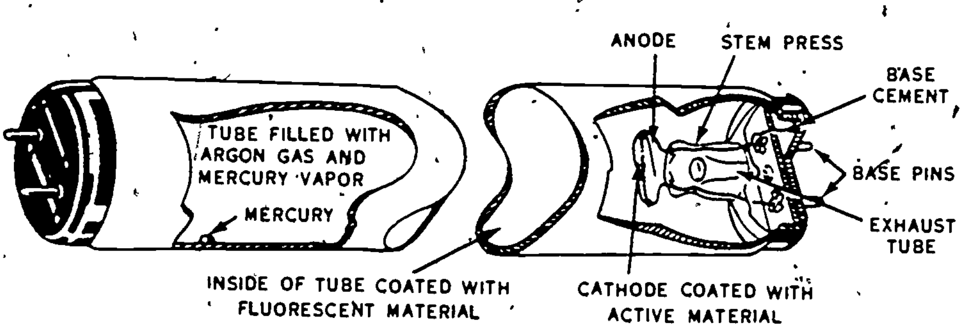


Figure 70. Fluorescent Lamp Construction

In operation, the fluorescent tube is basically an open circuit until certain factors change and provide a path for current to flow. In order to conduct electricity, a drop of mercury inside the tube must be vaporized to provide a path for current across the tube. Neither the current flow nor the vaporized mercury provide any visible light. When the mercury vaporizes, it produces ultraviolet rays which bombard the fluorescent coating inside the tube and cause this material to glow.

Types of Fluorescent Operating Circuits

Three basic types of fluorescent systems in use at this time: preheat, rapid start, and instant start. Each type has certain equipment common to all but may vary in construction. One such item will be a ballast. Ballasts provide the necessary starting voltage and limit current flow.

Each system requires a ballast designed specifically for its electrical characteristics: the kind of circuit in which it is to be operated and the voltage, and frequency of the power supply. The preheat fluorescent system requires a starting means in conjunction with the ballast. This may be either a manual or an automatic switch, commonly called a starter. Figure 71 shows the internal schematics of different types of starters.

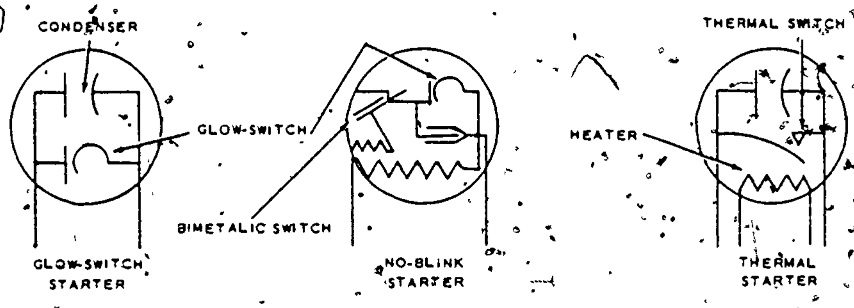
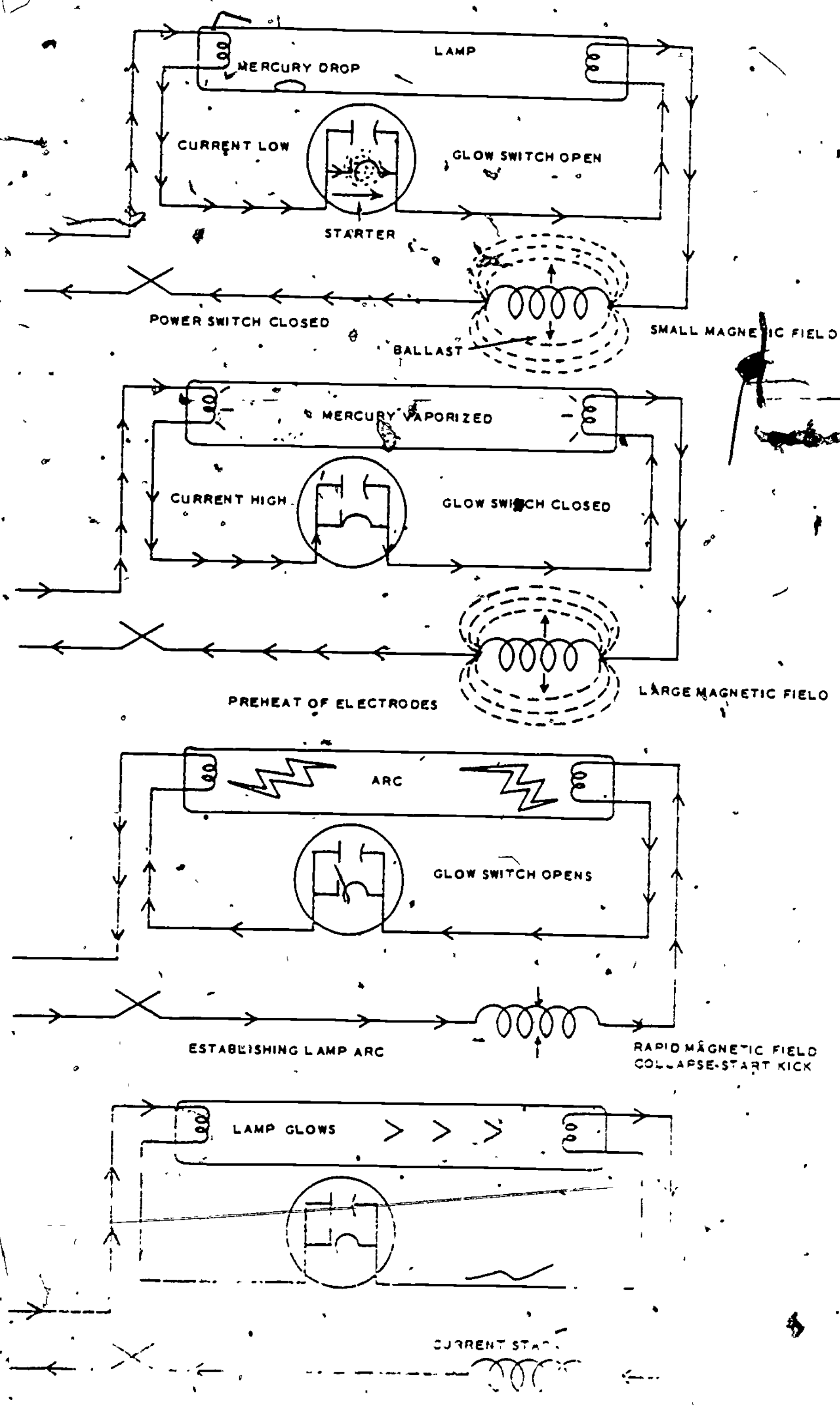


Figure 71. Fluorescent Starters

Basically all starters have certain components in common. These components include a condenser for suppressing radio interference. Some type of bimetallic switch for closing the circuit to preheat the tube is needed. The starter should then open to help give a starting "kick" of voltage from the ballast across the tube to establish the arc and cause the tube to light. In the no blink starter, a second bimetallic switch is added. The second element will actuate and cut the starter out of the circuit after several unsuccessful attempts to start the light. This condition usually takes place near the end of the lamp life. The no blink starter helps protect the ballast against prolonged high preheat current. To understand the operation of a preheat fluorescent lighting system, study items A, B, C, and D in figure 72.

Instant Starter Fluorescent System

The parts of the instant start system are the ballast, lamp, and lamp holders. In this system, the lamps are made with specially designed cathodes to reduce the loss of electron emitting materials when the cathodes are subjected to the high starting voltages (400 to 1000 volts). This high starting voltage ejects electrons from the electrodes by field emission. During operation, a few turns of wire in the cathodes become red hot to continue to provide free electrons. Most of the lamps for instant start systems are single pin type. The lamp holders are designed to reduce high-voltage hazards to


LAMP
MERCURY DROP
CURRENT LOW
GLOW SWITCH OPEN
STARTER
POWER SWITCH CLOSED
BALLAST
SMALL MAGNETIC FIELD
MERCURY VAPORIZED
CURRENT HIGH
GLOW SWITCH CLOSED
PREHEAT OF ELECTRODES
LARGE MAGNETIC FIELD
ARC
GLOW SWITCH OPENS
ESTABLISHING LAMP ARC
RAPID MAGNETIC FIELD
COLLAPSE-START KICK
LAMP GLOWS

maintenance personnel by acting as a switch to disconnect the ballast unless both ends of the lamp are properly positioned in the lamp holder. Figure 73 shows a typical instant start circuit with the disconnect lamp holders incorporated into the system.

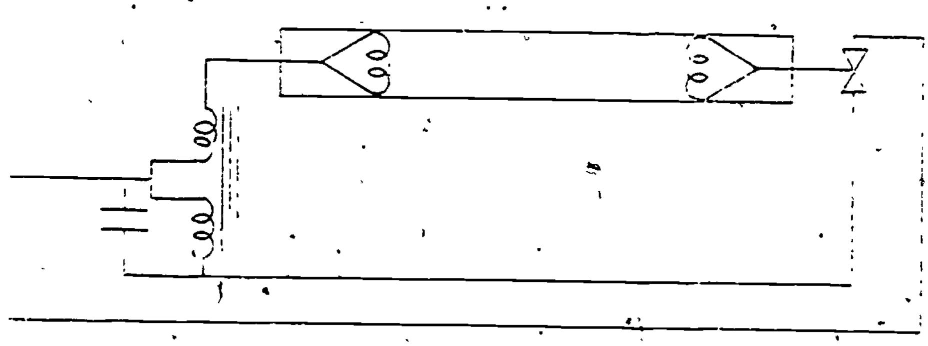


Figure 73. Instant Start Fluorescent Circuit

Rapid Start Fluorescent System

The starting means for the rapid start system is incorporated into the ballast and consists of low-voltage windings or separate transformers used with the system. These ballasts have separate windings or transformers to heat the lamp cathodes continuously; see figure 74. When the circuit is closed and the system energized, these special windings will quickly heat the lamp electrodes. This heating will cause ionization in the tube and allow an arc to strike across the lamp by the voltage in the main ballast windings. The immediate heat of the cathodes reduces the voltage required

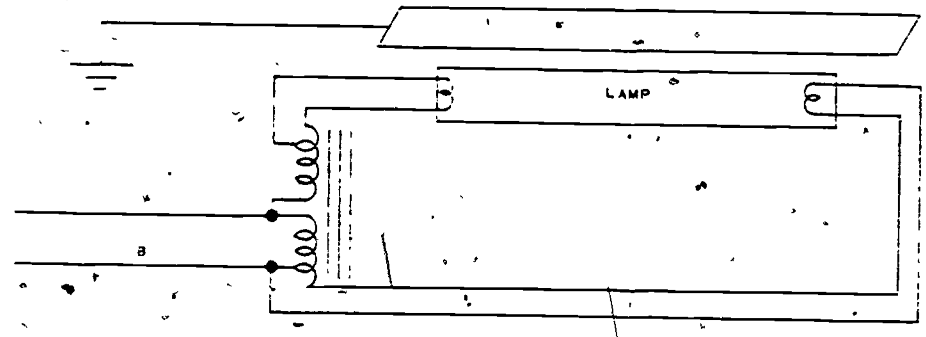


Figure 74. Rapid Start Circuit

to strike the arc across the lamp. The ballast can, therefore, be made smaller and more efficient. An external starting aid consisting of a grounded conducting plate of metal mounted next to and extending the length of the lamp in the rapid start system. The rapid start system starts more quickly than the preheat system, usually within one second under normal conditions. In high wattage tubes used for outside flood, street or sign lighting two design features are incorporated into the lamps. A cooling chamber is added at each end of the tube, behind the electrodes, to reduce mercury vapor pressure and a mixture of gases is used to prolong electrode life and therefore provide good lighting-maintenance.

Troubleshooting Fluorescent System

Because of the difference in circuitry and parts of the three fluorescent systems, this portion of the text will cover troubleshooting by system.

Preheat Circuit

Trouble	Location	Solution
1. Lamp blinks on and off	a. end of lamp life	a. replace lamp
	b. starter ineffective	b. replace starter
	c. low line voltage	c. check voltage
	d. low ballast rating	d. replace ballast
	e. low temperature	e. change fixture
	f. cold drafts	f. shield fixture
	g. leads crossed	g. check wiring of fixture
2. Lamp starts slowly or not at all	a. end of lamp life	a. replace lamp
	b. lamp not making proper contact with lampholder	b. check lamp contact
	c. starter bad	c. replace starter
	d. ballast open	d. replace ballast
3. Lamp ends remain lighted	a. starter capacitor	a. replace starter
	b. starter switch	b. replace starter
	c. circuit incorrect	c. check wiring

Instant Start Troubles

1. Lamp will not light	a. lamp at end of life ballast open	a. replace lamp
2. Lamp spirals	b. Lamp at end of life	b. replace lamp
3. Lamp flashes orange	c. lamp at end of life	c. replace lamp
4. End of lamp black	d. lamp at end of life	d. replace lamp

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CAUTION: Start voltage is extremely high. Continued spiraling or flashing will damage the ballast.

Rapid Start Troubles

1. Lamp start slow or not at all in high humidity conditions	a. lamp dirty	clean lamp
	a. starting aid disconnected	connect starting aid to ground
1. Lamp starts slowly	a. heating at one cathode only	change lamp
		check wiring
		check lampholder contact
		check for shorted leads
		corroded or dirty basepins
		improper wiring

Suspending Fluorescent Fixtures

Fluorescent fixtures are usually suspended from the ceiling by conduit or chains. Wall fixtures are attached directly to the boxes.

SUMMARY

Lighting is classified by the manner in which light is distributed. The five general classifications are direct lighting, semidirect lighting, general diffuse lighting, semi-indirect lighting and indirect lighting.

There are many different types of incandescent lamp sockets available, most of them are controlled by a wall switch; however, some are controlled by pull chains or thumb operated switches for use when the wall switch control is impractical.

Fluorescent lighting is generally preferred over incandescent lighting because of its efficiency and longer lamp life. Fluorescent lamps contain poisonous powder which may cause infection; therefore, care should be taken to prevent breakage of lamps during removal and replacement.

QUESTIONS

1. What are some of the disadvantages of direct lighting?

2. Why is indirect lighting installed in offices and drafting rooms?

3. On what type of lamp is the "Mogul" base used?

4. What is the main purpose of the starter in fluorescent light fixture?

5. What is the purpose of the ballast?

REFERENCES

1. National Electrical Code

2. NFPA Handbook of the NEC by H. P. Richter

3. Electrical Trades Blueprint Reading, 1969 Edition

4. Electrical Code Diagrams, Volumes I and II

TROUBLESHOOTING NONMETALLIC SHEATHED CABLE

OBJECTIVE

This study guide is to help you become familiar with the types of troubles you will find in wiring systems and the procedures for locating and correcting them.

INTRODUCTION

To be a good electrician it is important for you to be able to troubleshoot a defective system. If you do this in a logical sequence it will prevent damage to equipment and save many man-hours.

It is very important that the person troubleshooting a system use common sense. Analyze the problem by considering what the person reporting the trouble says as well as reading the schematic, then try to visualize how a circuit could react to certain situations.

INFORMATION

TYPES OF TROUBLES

Troubles in an electrical system can be classified as either an open, short, ground, or a combination of these.

Open Circuit

An open circuit is one that has no complete path of continuity; therefore, nothing is able to work. A circuit may be intentionally opened by means of a switch, by removing a fuse, or by disconnecting the circuit at some terminal. A circuit may be unintentionally opened by a broken switch, a blown fuse, a burned out unit of resistance, a loose connection, or a broken or burned conductor. An indication that a circuit could be open will be that the unit is not operating. That is, the lamp will not light, the motor will not run or the toaster will not get hot. This is by far the most common type of trouble you will run into.

Short Circuit

A short circuit results when two conductors of different potential come in contact with each other which bypasses a unit of resistance. When this occurs, the protective device is normally opened. A short circuit will also occur when conductors of the same potential come in contact with each other but no resistance is bypassed. This is usually referred to as a shorted control. An example being a switch loop where the [illegible] conductors of the loop are touching and bypassing the switch (not a unit of resis- [illegible]). When this occurs the device being switched will operate continually.

Grounded Circuit

If the conductor is making contact unintentionally with some metallic part of the wiring system such as the conduit, motor frame, or appliance frame as shown in figure 75, it is called a ground.

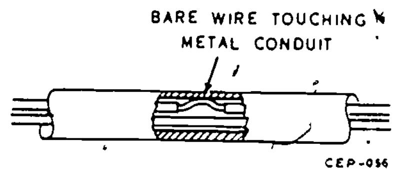

Figure 75. Grounded Conductor

This is not to be confused with an intentional ground such as the service entrance switch ground or the bonded conduit system.

Unbalanced Load

An unbalanced load may result in heating of the wiring and panelboards and blown fuses or tripped breakers. An unbalance occurs when one side of a 3 or 4 wire circuit has a greater load than the other, figure 76A. This can be readily checked by using a clamp-on ammeter and taking ampere readings when the circuits are loaded. The most logical place to take the readings is at the drip loops of the service entrance. Unbalance can be corrected by changing part of the connected load from the overloaded side to the lightly loaded side, figure 76B. If this cannot be done, part of the load may be transferred to another circuit or a new circuit may be installed.

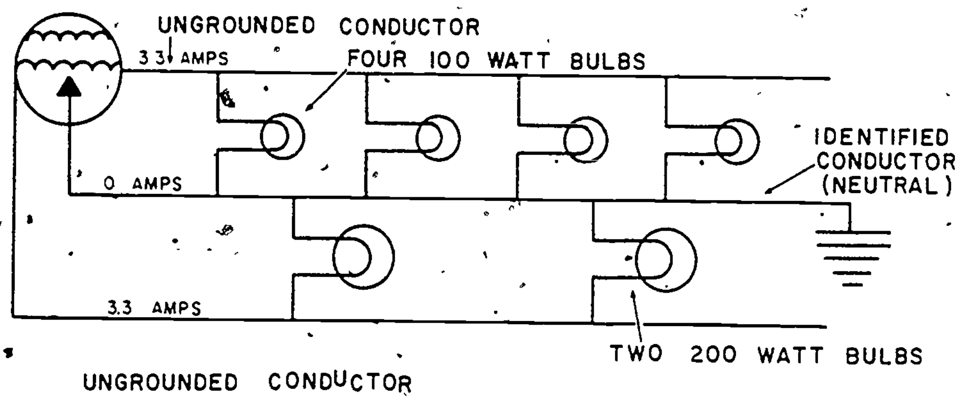

Figure 76B

Right: Correctly balanced 400 watts on each circuit. Minimum current flow in the neutral conductor.

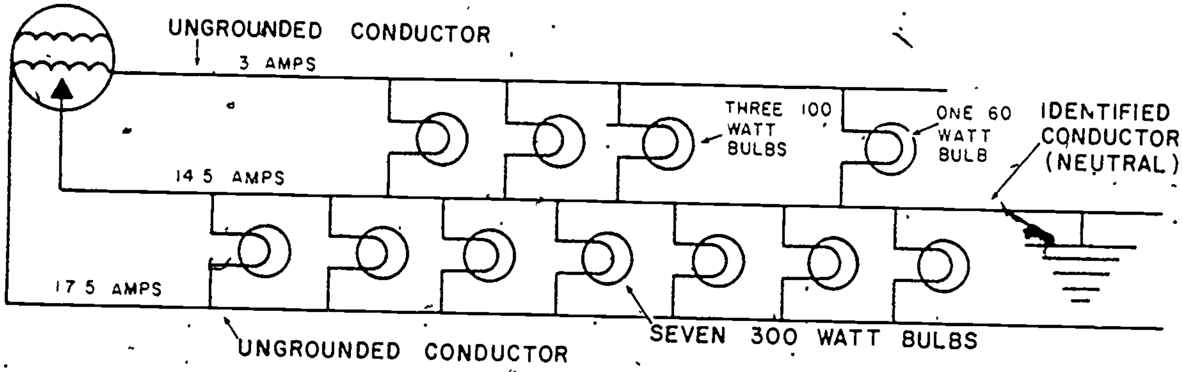

Figure 76A

Wrong: Circuit not balanced. 360 watts on one circuit, 2100 watts on other circuit. Excessive current flow on the neutral conductor.

Types of Shorts and Grounds

Shorts and grounds may be either solid, partial, or floating. These conditions will depend on how complete the connection is through the shorted portion of the circuit. In a solid short or ground, the wires may actually become welded to each other or to the conduit. This welding provides an excellent connection and is the easiest short to locate. A partial short or ground occurs, when part of the resistance is bypassed but not enough to increase current great enough to trip the protective device. A floating short or ground is the type that occurs occasionally or intermittently. This is the most difficult type of trouble to locate. This trouble will normally happen in older wiring, and the usual solution to the problem is to replace the wiring in that circuit with new conductor.

TROUBLESHOOTING PROCEDURES

While many meters and other pieces of equipment are available to you for troubleshooting, the most important thing involved is your common sense. To become skilled at troubleshooting, you need to follow a logical sequence of operations. First, if possible, discuss what happened with someone present when the circuit malfunctioned. Get him to describe what took place and what he observed. Second, make a visual inspection and check for the obvious trouble. Many times the trouble is easily seen. Look for broken wires or connectors, loose terminals, signs of overheating such as blackened spots on equipment or burned or broken insulation. Can you smell any burned insulation? Can you feel any overheated units? Don't overlook the obvious.

Is it a burned out light bulb? Is the appliance plugged in and turned on? A good visual inspection will solve many of your trouble calls. Next, if possible, make an operational check of the circuit. If a short or ground exists, protective devices will actuate before the circuit can operate. Even this fact is useful to you in troubleshooting as it will more closely identify the type of trouble you are hunting. If several outlets are involved on the same circuit, disconnect the load from each outlet and then check the circuit. If the circuit checks clear of trouble, the problem is in one of the units using power. Connect them one at a time and check each individually until you find the one that causes the trouble. This step will locate many of your troubles.

If these previous steps have not located the trouble, you are going to have to THINK! Try to analyze the trouble. The indications that you have received should tell you what type of trouble you have. Lamp bulb won't light? Motor won't run?

You have an open circuit. Lamp bulb burns out as fast as it is turned on --check for improper power. Circuit breaker trips as soon as power is applied? This indicates a short or gound. Can't turn the appliance off? The problem is a shorted control device. If a wiring diagram or schematic of the system is available, make use of it. Check to see where the circuit goes and what equipment is tied into the circuit. See if there is a common junction box or conduit run where shorted circuit could occur.

Use of Meters

If the trouble has still not been located, you will require a meter. The two types of meters generally available to you will be a multimeter and a clamp-on meter. The multimeter is the more versatile of the two meters since most multimeters incorporate a voltmeter, milliammeter, and ohmmeter in the same case. You should already be familiar with this meter from past blocks of instruction. Other test devices sometimes available to you will be a voltage indicator, sometimes called a "wiggins," a megohmmeter, called a "megger," and used to check insulation resistance, and a continuity light. You will see other test equipment that has been assembled locally, but such equipment is best left alone.

Let's start with a voltmeter. A voltmeter is used in live circuits to locate open circuits or improper power. Figure 77 demonstrates troubleshooting an open circuit with a voltmeter.

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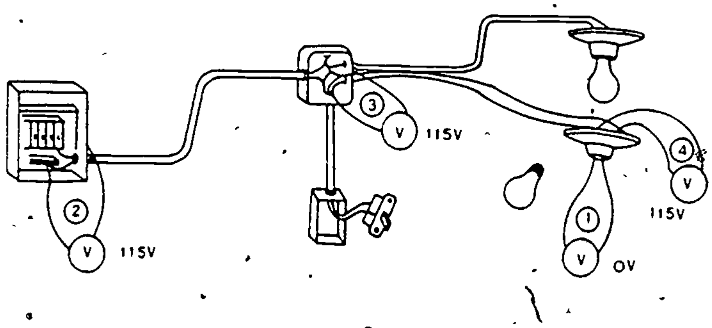

Figure 77. Troubleshooting Open Circuits with Voltmeter

In this situation, two lights are controlled by one switch. One light burns, the other does not. Replacing the bulb has not solved the problem. Meter indications show that voltage is available to the silver and gold terminals at the receptacle but no voltage is available through the receptacle. This indicates that the contacts in the receptacle are open and it must be replaced. You will note that the trouble was between where the meter read 115 volts and where it read 0 volts. Open circuits are the most common problem and generally the easiest to locate. Usually in the case of a shorted or grounded circuit a voltmeter or ammeter will not be used except in very special cases. The preferred test instrument will be the ohmmeter. To prevent damage to the meter BE SURE ALL POWER TO THE CIRCUIT IS DISCONNECTED. Isolate the circuit by disconnecting the conductors from the circuit breaker, open the other end of the circuit by disconnecting any equipment.

Using the ohmmeter, read between any two conductors in any section of the circuit until all conductor combinations have been checked. A zero reading indicates a short. In locating a ground with an ohmmeter the same procedure is used except that the reading is taken from each unidentified conductor to ground. Whan a zero reading is obtained you have located the ground.

Once the malfunction has been identified and located, the steps necessary to repair the circuit should be obvious. After the repairs have been made, don't forget to check the circuit. You should perform a visual inspection to assure that connections are tight, that no bare wire is exposed, extra wire is neatly shaped and folded, wire is of the proper size and type and that the protective devices are the correct size and operate correctly. Perform an operational check to assure that all troubles have been corrected and all units operate correctly. Test for correct voltage with a voltmeter.

SUMMARY

There are three types of electrical troubles. These are opens, shorts and grounds. Each type of trouble has its individual characteristics and signals or indications. These indications will aid you in locating and correcting the problem.

Troubleshooting requires common sense and follows a logical sequence. Try to learn what caused the trouble first. Ask about the trouble. Perform a visual inspection. If possible, within safety limits, perform an operational check. Analyze the trouble. Decide what type of trouble you have from the information you have received. Check a wiring diagram or schematic if available. Know your test instruments and how to use each of them.

An unbalanced load may result on heating of the wiring and panelboards and blown fuses or tripped breakers. It is important that minimum current is always flowing in the neutral conductor.

QUESTIONS

1. What effect will an open circuit have on the unit using power?

2. What is the condition called where all resistance in a circuit has been bypassed?

3. What will be the indication if two hot wires on different phases come in electrical contact?

4. What types of shorted circuits are there?

5. What is meant by "analysis of circuit fault"?

6. What is the preferred meter for locating open circuits?

7. Why can't a voltmeter be used to locate certain kinds of shorted circuits?

8. What must be done to protect the ohmmeter?

9. What is the purpose of balancing a load on 3- or 4-wire circuit?

10. What type of meter is used normally to balance 3- or 4-wire circuits?

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REFERENCES

1. National Electrical Code
2. Electrical Systems, Van Valkenberg, Simon & Schuster, New York
3. AFM 91-17, Facilities Engineering Electrical Interior Facilities
4. Electrical Code Diagrams, Volumes I and II

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Department of Civil Engineering Training

Electrician

BLOCK II

NONMETALLIC SHEATHED CABLE

July 1975

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

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Superseded material may be used until supply is exhausted.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-II-1
July 1975

NATIONAL ELECTRICAL CODE, ELECTRICAL TERMINOLOGY, AND BLUEPRINT READING

PROJECT 1

NATIONAL ELECTRICAL CODE

OBJECTIVE

Given a National Electrical Code, list the purpose and scope of the National Electrical Code.

INSTRUCTIONS

Use the National Electrical Code to obtain the required information for completing each of the following statements:

1. The National Electrical Code is sponsored by ______________________________

____

____

2. What is the purpose of the NEC? ______________________________

____

____

3. List two areas covered by the scope of the NEC.

   a. ____

____

____

____

   b. ____

____

4. The NEC is divided into ______________ chapters.

5. Definitions are covered in article __________ of the NEC.

6. The table that specifies "Properties of Conductors" is located in chapter no. __________ and page no. __________.

7. The maximum size of nonmetallic sheathed cable is __________ Article no. __________.

8. The table that specifies allowable Ampacities of insulated copper conductors in free air is located in chapter no. __________ page no. __________.

9. Article no. __________ page no. __________ pertains to service entrance cable.

10. General requirements for wiring methods is found in article __________ beginning on page no. __________.

11. Nonmetallic sheathed cable shall be secured in place at intervals not exceeding __________ feet and within __________ inches from every cabinet, box, or fitting as required in article no. __________.

12. Service drop conductors shall have a clearance of not less than __________.

13. Soldered splices shall first be so spliced or joined as to be __________ and __________ secure without solder and then soldered. Article no. __________ page no. __________.

14. Article no. __________ page no. __________ pertains to services.

15. Wiring requirements for commercial garages will be located in article no. __________ beginning on page no. __________.

PROJECT 2

ELECTRICAL TERMINOLOGY

OBJECTIVE

Given a National Electrical Code and a list of electrical terms, write the definition of each term.

INSTRUCTIONS

Using the NEC, write the definition of each of the following terms:

1. Accessible (as applied to wiring methods)

2. Accessible (as applied to equipment)

3. Ampacity

4. Approved

5. Bonding

6. Branch Circuit

7. Building

8. Circuit Breaker

9. Concealed

10. Device

11. Disconnecting Means

12. Equipment

13. Feeder

14. Fitting

15. Ground

16. Grounded

17. Grounded Conductor

18. Identified

19. Outlet

20. Panelboard

21. Qualified Person

22. Raceway

23. Receptacle

24. Receptacle Outlet

25. Service

26. Service Drop

27. Service-Entrance Conductors

28. Service Equipment

29. Utilization Equipment

30. Fuses

PROJECT 3

NATIONAL ELECTRICAL CODE

OBJECTIVE

Given a National Electrical Code and selected electrical problems, list the correct answer to each problem

INSTRUCTIONS

Use the National Electrical Code to complete the following statements:

1. When installing ground rods, what article in the NEC should be consulted?

____

2. Four electric ranges of 12 KW each are to be installed. What article of the code should be consulted? ______________________________

____

3. How would you determine the size of the service equipment and conductor to install for a single family dwelling? ______________________________

____

4. A number 2 AWG service-entrance is to be installed. What size must the system ground conductor be? ____________AWG

5. In residential occupancies, the NEC requires one 15-amp lighting circuit for every ______________square feet.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-1	1/student
National Electrical Code	1/student

PROJECT 4

BLUEPRINT READING

OBJECTIVE

Given a blueprint, NEC, and selected electrical installation problems, identify locations and list the wiring requirement for electrical component installation to meet National Electrical Code and blueprint specifications.

INSTRUCTIONS

Provided information and figure 1, complete the following questions concerning blueprint reading:

1. How many home runs are on the print? ________________

2. How many "Special-Purpose Outlets" are on the print? ________________

3. Is the wiring concealed or exposed? ________________

4. How many "Single-Pole Switches" will be needed to wire this project? ________________

5. What is the ampacity rating of the Special-Purpose Outlets? ________________

6. How many conductors are between the switch and the fluorescent fixture? ________________

7. How many lights will be installed in this project? ________________

8. What type and size wire will be used in this project? ________________

9. How many floor outlets are there in this project? ________________

10. How many duplex convenience outlets are there in this project? ________________

11. How high from the floor will the switches be mounted? ________________

12. How high from the floor will duplex convenience outlets be mounted? ________________

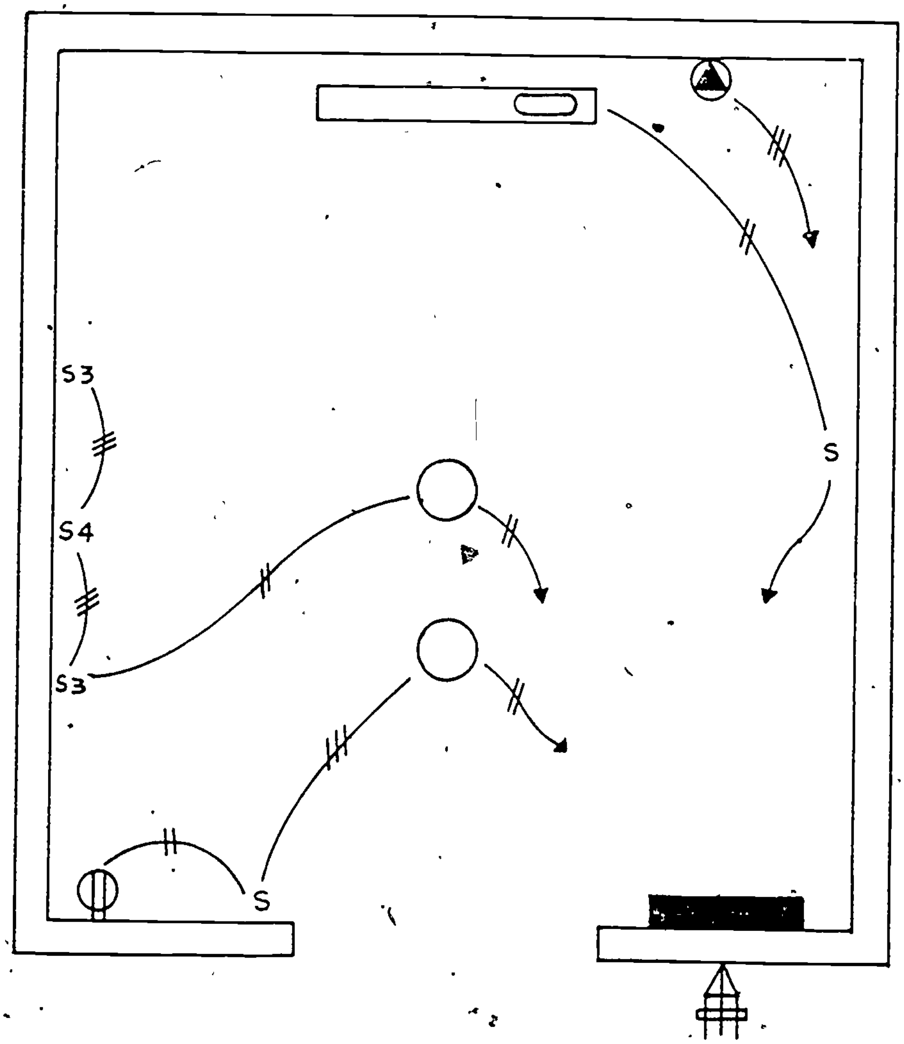
13. Will the conductors supplying the fluorescent fixture run to the fixture first or to the switch first? ________________

14. What is the voltage of the Special-Purpose Outlets? ______________________

15. How many conductors are between the switch and the duplex convenience outlet? ______________________

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-1	1/student



NOTES:

1. Switches will be mounted 48" from the floor.
2. Outlets will be mounted 12" from the floor.
3. Special-purpose outlet is 15 amp, 240 volts
4. Conductors will be #14 copper non-metallic sheathed cable, concealed

S	Switch Single-pole		Ceiling Light
S_3	Switch Three-way		Duplex Convenience Outlet
S_4	Switch Four-Way		Receptacle Special-Purpose
	Panelboard		Light Fluorescent
	Service Entrance		Conductor Two-wire
	Homerun		Conductor Three-wire

Figure 1

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-II-2
July 1975

CONDUCTORS AND OVERCURRENT PROTECTIVE DEVICES

PROJECT 1

CONDUCTORS

OBJECTIVE

Given the National Electrical Code and a list of conductor sizes and insulation types, list the amount of current each conductor will carry.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-2	1/student
National Electrical Code	1/student

INSTRUCTIONS

Using the National Electrical Code, complete the following statements:

1. A 12-gage conductor is (larger, smaller) than a 14-gage conductor.

2. Conductors of the same size and insulation-type will carry (more, less, same) current in free air than in raceway or cable.

3. As the temperature increases in a conductor, the resistance (decreases, increases).

4. A 12-gage single solid aluminum conductor used under the same conditions as a 12-gage single solid copper conductor will carry (more, less, same) current.

5. The type of insulation on a conductor (does, doesnot) affect the current-carrying capacity of the conductor.

6. A no. 4 gage stranded conductor is made of ________________ strands.
number

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7. Use Tables 310-12 and 310-14 and also the notes to Tables 310-12 and 310-14 to assist you in figuring the following problems.

   a. What is the current-carrying capacity of an 8-gage single solid copper TW conductor when used in a raceway or cable containing 4 each of these conductors? (Show your figures.)

   ANSWER

   b. What is the amperage carrying capacity of a 6-gage single solid aluminum RH conductor when used in a raceway or cable containing eight each of these conductors? (Show your figures.)

   ANSWER

CONDUCTOR				CURRENT-CARRYING CAPACITY	
INSULATION TYPE (A)	MATERIAL (B)	CONDUCTORS IN CABLE OR RACEWAY (C)	GAGE (D)	AMPS IN CABLE OR RACEWAY (E)	AMPS IN FREE AIR (F)
TW	COPPER	3	12		
RH	COPPER	2	4/0		
MI	ALUMINUM	4	10		
THWN	COPPER	9	14		
THHN	COPPER	25	6		
AVL	COPPER	2	12		
AVB	COPPER	43	8		
T	ALUMINUM	1	500mcm		
RHH	COPPER	19	10		
RHW	ALUMINUM	1	1		

8. Have your instructor check and sign this project. ____________________ Instructor

PROJECT 2

OBJECTIVE

Given the National Electrical Code and a list of circuits, list the proper size conductor to use in accordance with the National Electrical Code.

INSTRUCTIONS

Use the National Electrical Code to complete the following statement:

1. A circuit for a clothes dryer would require ____________ AWG conductors with TW insulation.

2. A domestic electric range would require ____________ AWG conductors with RHW insulation.

3. A 200-amp service-entrance will require ____________ AWG conductors with TW insulation.

4. The smallest type TW neutral feeder conductor supplying two KW ranges shall be ____________________ AWG.

PROJECT 3

OVERCURRENT DEVICES

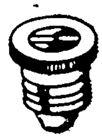
OBJECTIVE

Given the National Electrical Code and a list of overcurrent devices, select facts pertaining to the different types of overcurrent devices in accordance with the National Electrical Code.

INSTRUCTIONS

Using your National Electrical Code, observe the drawings below and determine where each fuse may be used. Determine the maximum voltage that may be applied to each type fuse. Determine the maximum current that each type fuse can carry.

1.



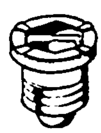
Use: ____________________

Maximum Voltage: ____________________

Maximum Amperage: ____________________

Plug fuse with round window

2.



Use: ____________________

Maximum Voltage: ____________________

Maximum Amperage: ____________________

Plug fuse with hexagon window

3.

Use: ____________________

Maximum Voltage: ____________________

Maximum Amperage: ____________________

Cartridge fuse with knife-blade contacts

4.

Use: ____________________

Maximum Voltage: ____________________

Maximum Amperage: ____________________

PROJECT 4

OVERCURRENT DEVICES

OBJECTIVES

Given a list of overcurrent devices and the National Electrical Code, select the correct overcurrent device to meet the National Electrical Code requirements.

INSTRUCTIONS

Using the National Electrical Code, complete the following questions:

1. Where may plug-type fuses be installed? ______________________________

____

____

2. A 480-volt, 200-amp disconnect is to be installed. What type fuse will be used?

____

3. What type overcurrent device and current range would be used for a residence?

____

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-II-3
July 1975

HANDTOOLS

PROJECT 1

OBJECTIVE

Given a set of selected handtools, identify the use and care of each handtool.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-3	1/student

INSTRUCTIONS

Fill the necessary blanks.

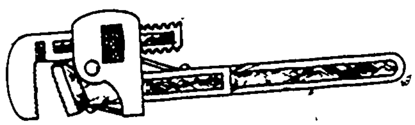
Use: ______________________

____

Maint: ______________________

____

Name: ______________________



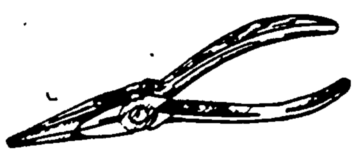
Use: ______________________

____

Maint: ______________________

____

Name: ______________________



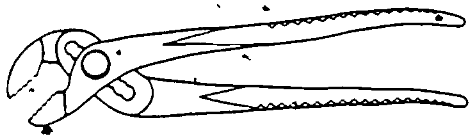
Use: ______________________

____

Maint: ______________________

____

Name: ______________________



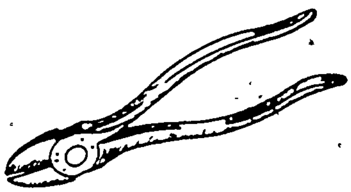
Name: ______________________

Use: ______________________

____

Maint: ______________________

____



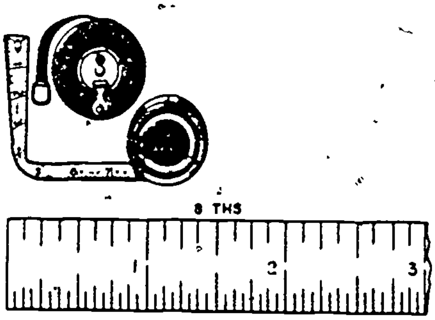
Name: ______________________

Use: ______________________

____

Maint: ______________________

____



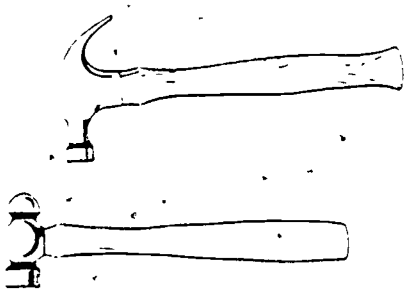
Name: ______________________

Use: ______________________

____

Maint: ______________________

____



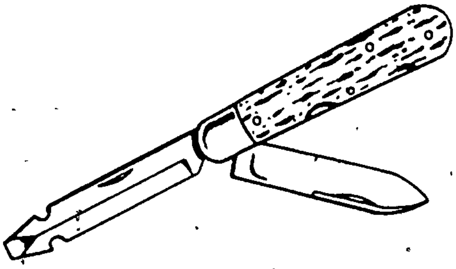
Name: ______________________

Use: ______________________

____

Maint: ______________________

____



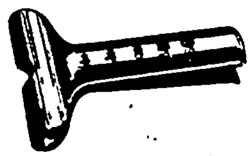
Use: ____________________

____

Maint: ____________________

____

Name: ____________________



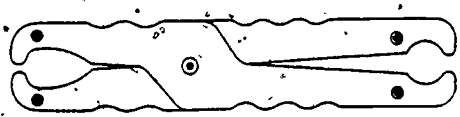
Use: ____________________

____

Maint: ____________________

Name: ____________________

____



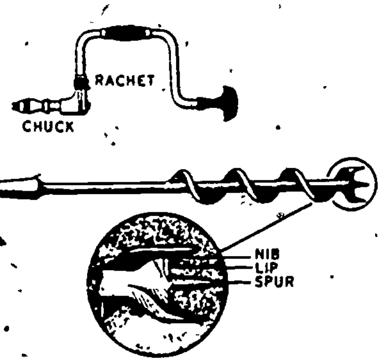
Use: ____________________

____

Maint: ____________________

Name: ____________________

____



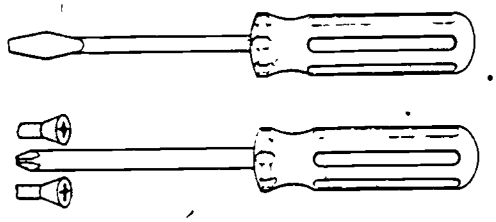
Use: ____________________

____

Maint: ____________________

____

Name: ____________________



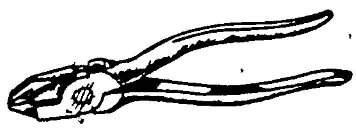
Use: ____________________

____

Maint: ____________________

____

Name: ____________________



Use: ____________________

____

Maint: ____________________

____

Name: ____________________

Have the instructor check your worksheet ____________________
Instructor

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

SINGLE-PHASE SERVICE ENTRANCE AND PANELBOARDS

PROJECT 1

OBJECTIVE

Provided a booth area, handtools, and a working drawing, install a single-phase 120/240-volt service entrance and grounded panelboard according to NEC specifications.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-4	1/student
Wiring Booth	1/student
Handtools	1/student
Weatherhead, S. E. Cable	1/student
Panelboard, S. E. Cable Connector	
Wood screws, cable straps	
Split bolt connectors, ground conductor	
Voltage Tester	1/student
Ohmmeter	1/student

INSTRUCTIONS

You are to complete this project in steps. Read the instructions carefully. Be sure to have your instructor check your work where indicated before proceeding.

Step One

You are to install a service entrance as shown in figure 2. Make a bill of the materials you will require. Have the instructor check your bill of materials before

proceeding ______________________.
Instructor

Step Two

Assemble the service entrance. Have the instructor check your assembly

______________________.
Instructor

Step Three

Install the service entrance components. Have the instructor check your work

______________________.
Instructor

Step Four

Connect the service entrance. Have your instructor check you work

____
Instructor

NOTE: DO NOT apply power until told to do so by your instructor.

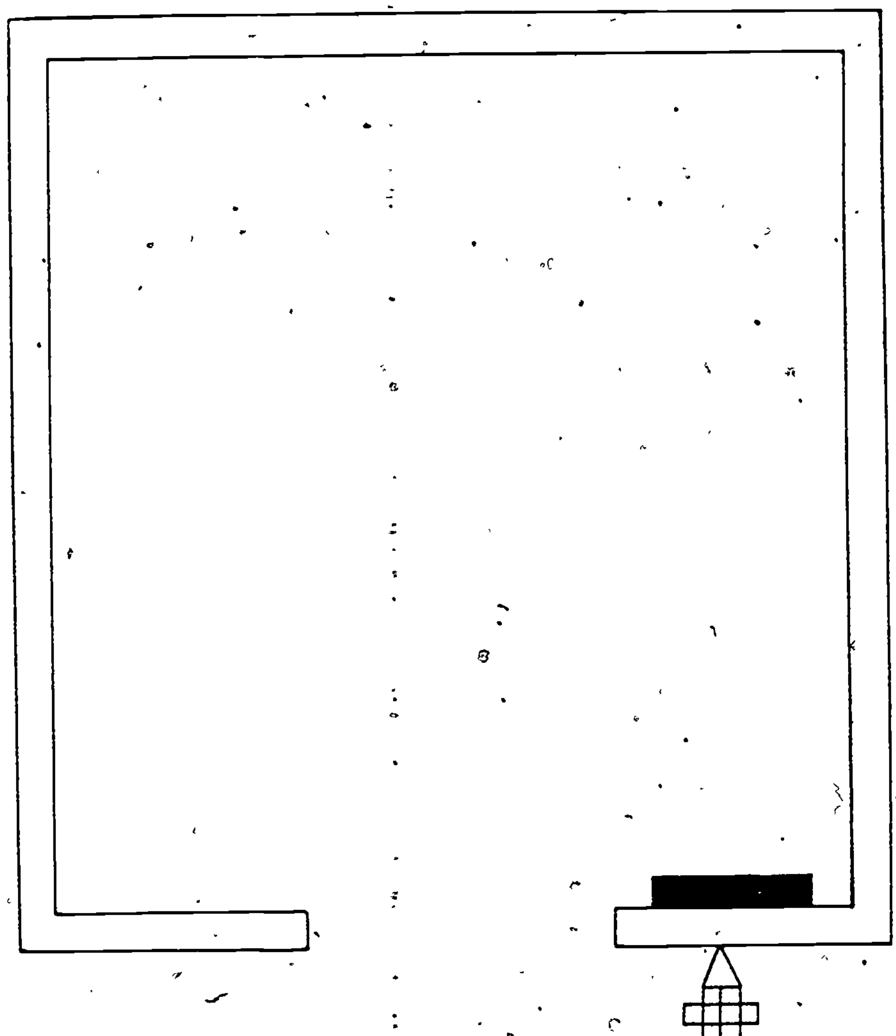


Figure 2

NOTES:

1. Service will be 120/240 volts 1Ø.
2. Panel will be installed at predrilled hole.
3. Panel will be bonded.
4. Ground will be connected to driven ground electrode or waterpipe.

Assembly of Components

Install the panelboard on the wall using wood screws. Make sure the box is straight and properly secured. Fasten the weather head (service cap) to the top plate above the panelboard not farther than 24 inches from the point of attachment to the service drop conductors, refer to the NEC for additional instructions. Install an S. E. cable connector where the S. E. cable will enter the panelboard. Measure the distance between the panelboard and weather head allowing at least 3 feet for the drip loops and 2 1/2 feet for connections in the panelboard. Recheck your measurements, then cut the cable.

Attach the cable to the building with straps or other approved means within 12 inches of the weather head (service cap) and panelboard.

The conductors are now connected to the panelboard, as shown in the panelboard drawing.

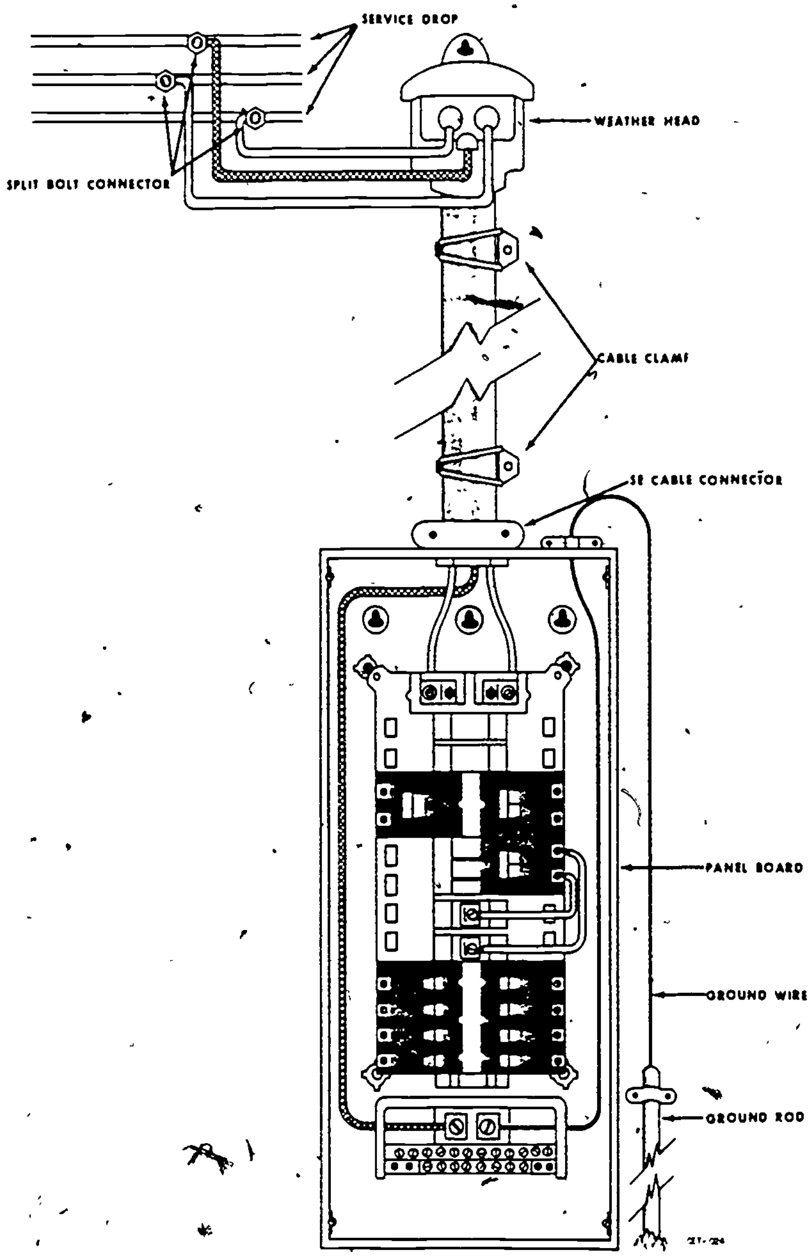

SERVICE DROP
WEATHER HEAD
SPLIT BOLT CONNECTOR
CABLE CLAMP
SE CABLE CONNECTOR
PANEL BOARD
GROUND WIRE
GROUND ROD

Figure 3

PROJECT 2

OBJECTIVE

Provided information, tools, and materials, connect and check the ground conductor to NEC specifications.

INSTRUCTIONS

You will use the drawing in project 1, the blueprint drawing, and multimeter to complete this project.

1. Extend the ground wire into the control panel (do not connect the wire to the neutral bar).

2. Using the multimeter, measure the resistance between the neutral bar and the installed ground. (Be sure neutral wire is connected to the neutral bar.) The resistance should not be greater than 25 ohms.

3. Have the instructor check your work.

____
Instructor

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-II-5
July 1975

NONMETALLIC SHEATHED CABLE

PROJECT 1

OBJECTIVE

Given information pertaining to the construction characteristics, types, and uses of N. M. cable, list the correct answer to each problem by researching the information in the NEC.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-5	1/student
National Electrical Code	1/student

INSTRUCTIONS

Use the National Electrical Code to complete the required information in the following statements:

1. Bends in the cable may not be less than ____________ of the cable.

2. The maximum size of nonmetallic-sheathed cable is ____________ AWG.

3. Nonmetallic-sheathed cable must be secured within ____________ inches at boxes and at ____________ foot interval in a run.

4. Cable, when exposed, passing through a floor must be protected by ____________ inches above the floor.

5. There must be at least ____________ inches of free conductor left in boxes for making connections.

6. The type of cable that may be used in dry or wet location is ____________

7. The purpose of the bare conductor in nonmetallic-sheathed cable is ____________

8. What are guard strips used for? ____________

PROJECT 2

OBJECTIVE

Given the necessary tools, equipment, and instructions, make and solder splices according to NEC specifications.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-5	1/student
National Electrical Code	1/student
Handtools.	1/student
Soldering gun	3/student
Solder and flux	3/student

INSTRUCTIONS

Make at least two pigtail splices. Have the instructor check them and then use an electric soldering iron and solder each of your splices following the steps below:

1. Plug in soldering iron and allow it to heat.

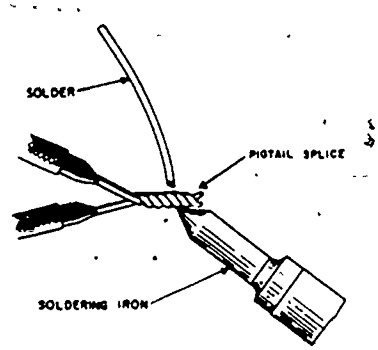
2. Place a small amount of rosin soldering flux along the length of the splice. (If rosin-core solder is used, no additional flux is required.)

3. Place the soldering iron in contact with splice and allow the splice to heat. (Heat splice from beneath whenever possible)

4. Bring solder into contact with splice and work toward other end of the splice.

5. Use the soldering iron to apply only enough heat so the solder will melt and flow into the turns of the splice.

6. Have your instructor check your work and sign ____________________ Instructor



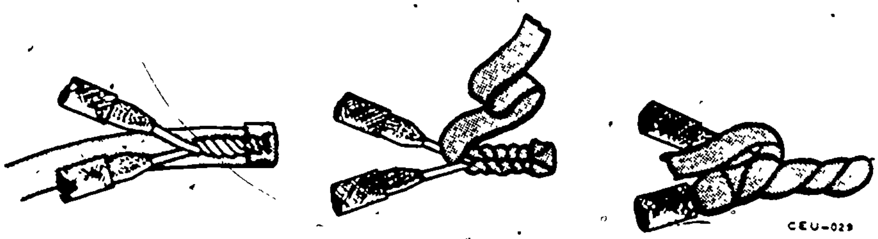
Soldering a Splice

Taping

NOTE: Follow the procedures demonstrated by your instructor and the directions below to tape the splices you have just soldered. Use plastic tape. A plastic or fabric loom is used to insulate splices in motor and generator windings and terminal leads.

1. Start the tape on the tapered part of the insulation and advance toward the other end.

2. Apply tape by overlapping it one-half the width of the tape.



Using Plastic Tape

3. Continue lapping the tape on the splice until the gap is filled and the tape overlaps on the wire insulation.

4. Answer the following questions.

a. Electrical splices must be ______________ and ______________ secure.

b. The pigtail splice must be ______________ inch minimum.

c. Splices in motor and generator windings are usually insulated with a ____
____

d. To prevent oxidation of the bare wire, you apply ______________
______________ to a splice before applying heat.

Checked by ______________________
Instructor

PROJECT 3

OBJECTIVE

Provided a work area and handtools, install a circuit in N. M. cable, containing a ceiling light, a single-pole switch, and a duplex receptacle, according to NEC specifications.

EQUIPMENT AND SUPPLIES

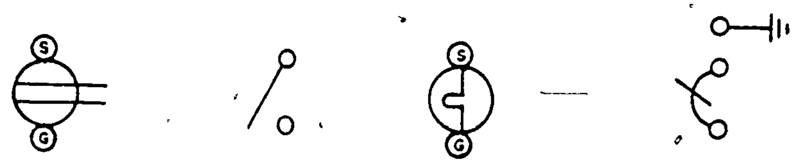
	Basis of Issue
WB 3ABR54230-1-II-5	1/student
National Electrical Code	1/student
Wiring Booth	1/student
Nonmetallic-sheathed cable	1/student
Associated equipment	1/student
Ladder	1/student

INSTRUCTIONS

Using the NEC, materials and handtools, complete the following circuit.

Step one

Observe the symbols below. Connect the symbols below in a schematic drawing. Color code the conductors.



Have the instructor check your drawing ______________________
Instructor

Step two

You will use the blueprint drawing, see figure 4, and the bill of materials to complete this project. Using the bill of materials, select the equipment that you will need to wire this project. List any materials below that you do not have and take this list to your instructor.

Bill of Materials

Sectional boxes	- 2 each
Octagon box	- 1 each
NM cable connectors	- 3 each
14/3 Nonmetallic-sheathed cable	- as required
14/2 Nonmetallic-sheathed cable	- as required
Porcelain keyless fixture	- 1 each
Single-pole switch	- 1 each
Duplex convenience outlet	- 1 each
NM cable staples	- as required
Hanger bar	- 1 each
Nails	- as required
Tape	- as required
Ground clips	- as required

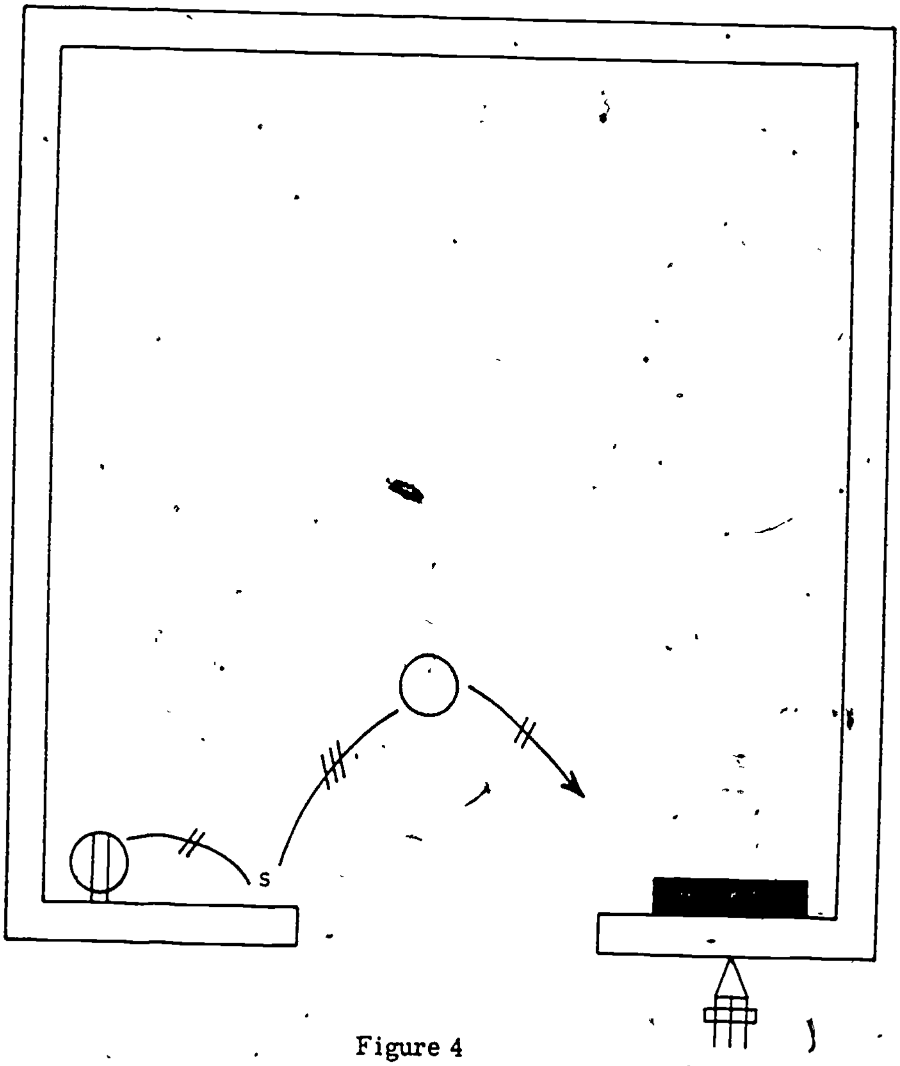
Step Three

In your booth, wire the circuit indicated on the blueprint. CAUTION: DO NOT apply power. Have your instructor check your project.

Step Four

Operate the circuit when told to do so. Have your instructor check your workbook.

____
Instructor



NOTES

Figure 4

1. Switch will be mounted 48" from the floor.
2. Convenience outlets will be mounted 12" from the floor.
3. Only the ceiling outlet will be controlled by the switch.
4. Boxes will be mounted to accommodate 1/2" plywood finish on ceilings and walls.
5. Ceiling light fixture will be a porcelain keyless type.

PROJECT 4

OBJECTIVE

Provided a work area and handtools, install a circuit in N. M. cable containing a 15-amp, 220-volt receptacle, according to NEC specifications.

EQUIPMENT AND SUPPLIES

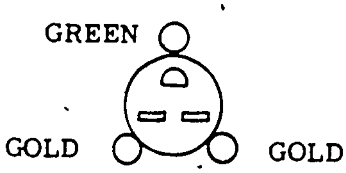
	Basis of Issue
WB 3ABR54230-1-II-5	1/student
National Electrical Code	1/student
Nonmetallic-sheathed cable	1/student
220-volt outlet	1/student
Associated Equipment	1/student
Handtools	1/student

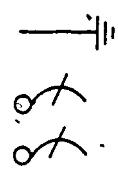
INSTRUCTIONS

Using the NEC, materials, and handtools, complete the following circuit:

Step One

Observe the symbols below and complete the circuit by drawing and color coding the conductors.





Have your instructor check your work ______________________
Instructor

Step Two

Use this corrected drawing, the blueprint, see figure 5, and the bill of materials to complete this part of the project. Using the bill of materials, select the necessary equipment. List any equipment not available.

Bill of Materials

Sectional box	- 1 each
15-amp 240-volt outlet	- 1 each
Metal box clamps	- 2 each
14/3 Nonmetallic-sheathed cable	- as required
NM cable staples	- as required
Tape	- as required
NM cable connector	- 1 each
Nails	- as required
Ground clips	- as required

Step Three

Wire the circuit as indicated on the blueprint. CAUTION: Note that this is a 220-volt circuit. Do not apply power. Have your instructor check your project.

____
Instructor

Step Four

Apply power when told to do so by your instructor. Secure a voltmeter and check the voltage at the plug. The voltage between the two gold terminals is __________.

The voltage between the green terminal and either gold is __________.

Have your instructor check your work______________________________
Instructor

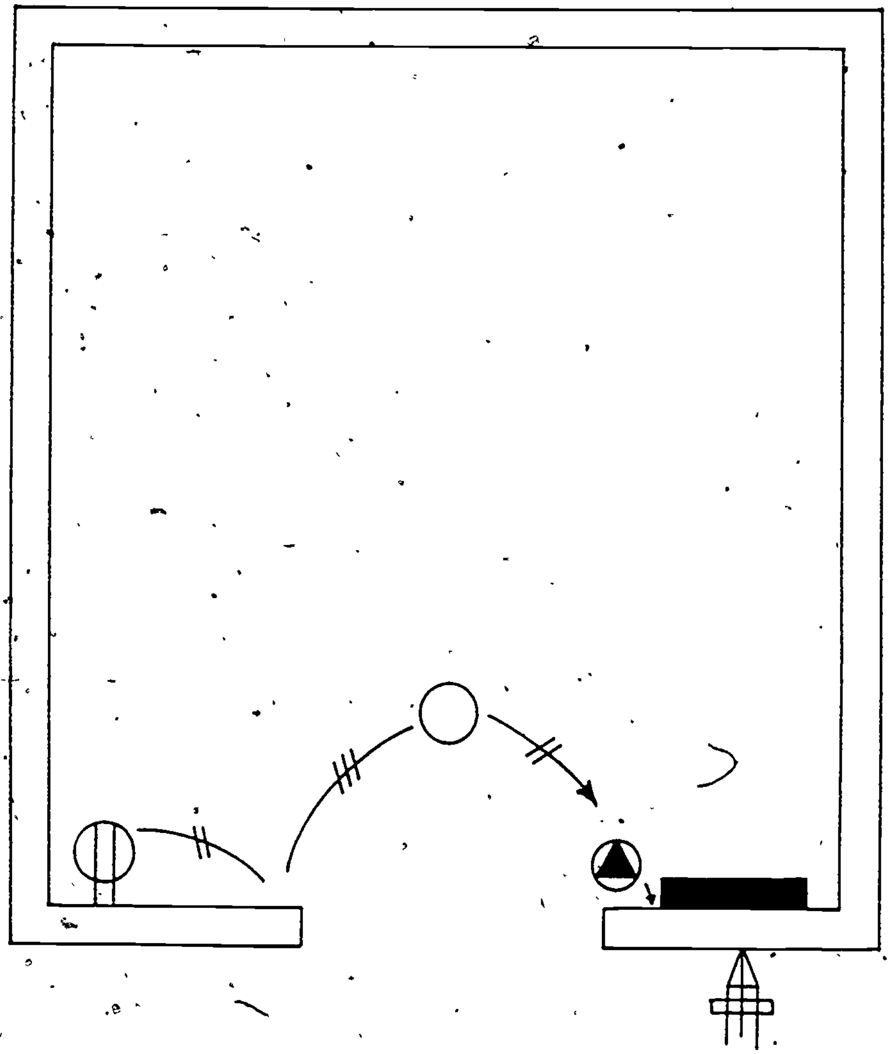


Figure 5

NOTES:

1. Special purpose outlet will be 15 amp 240 volt.

2. Outlet will be mounted 12" from the floor.

3. Box will be mounted in existing sheetrock wall by means of metal box clamps.

4. Box will be mounted flush with the finished wall.

PROJECT 5

OBJECTIVE

Provided a work area and handtools, install a circuit in N. M. cable containing two three-way switches to control a ceiling light, according to NEC specifications.

EQUIPMENT AND SUPPLIES

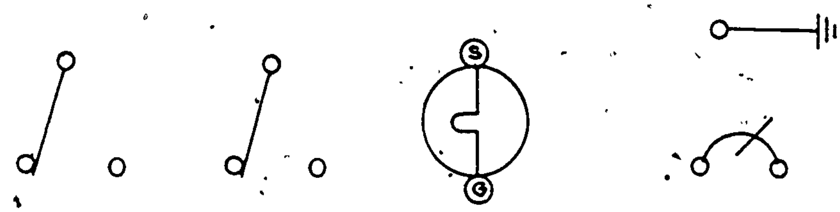
	Basis of Issue
WB 3ABR54230-1-II-5	1/student
National Electrical Code	1/student
Nonmetallic-sheathed cable	1/student
Handtools	1/student
Associated equipment	1/student
Ladder	1/student

INSTRUCTIONS

Using the NEC, materials, and handtools, complete the following circuit:

Step one

Observe the symbols below. Connect the symbols by drawing and color coding the conductors.



Have your instructor check your drawing ______________________
Instructor

Step Two

You will use this corrected drawing, the blueprint drawing, see figure 6, and the bill of materials to complete this project. Use the bill of materials and select the equipment that you will need to complete this project. List any materials that are not available and take this list to your instructor.

____
Instructor

Bill of Materials

Octagon box	- 1 each
Sectional boxes	- 2 each
Hanger bar	- 1 each
Three-way switches	- 2 each
NM cable connectors	- 3 each
14/3 Nonmetallic-sheathed cable	- as required
14/2 Nonmetallic-sheathed cable	- as required
Porcelain keyless fixture	- 1 each
NM cable staples	- as required
Nails	- as required
Tape	- as required

Step three

Wire this project as indicated on the blueprint. CAUTION: DO NOT apply power.

Have instructor check your project ________________________
Instructor

Step four

Operate the circuit when told to do so. Have the instructor sign this workbook

____
Instructor

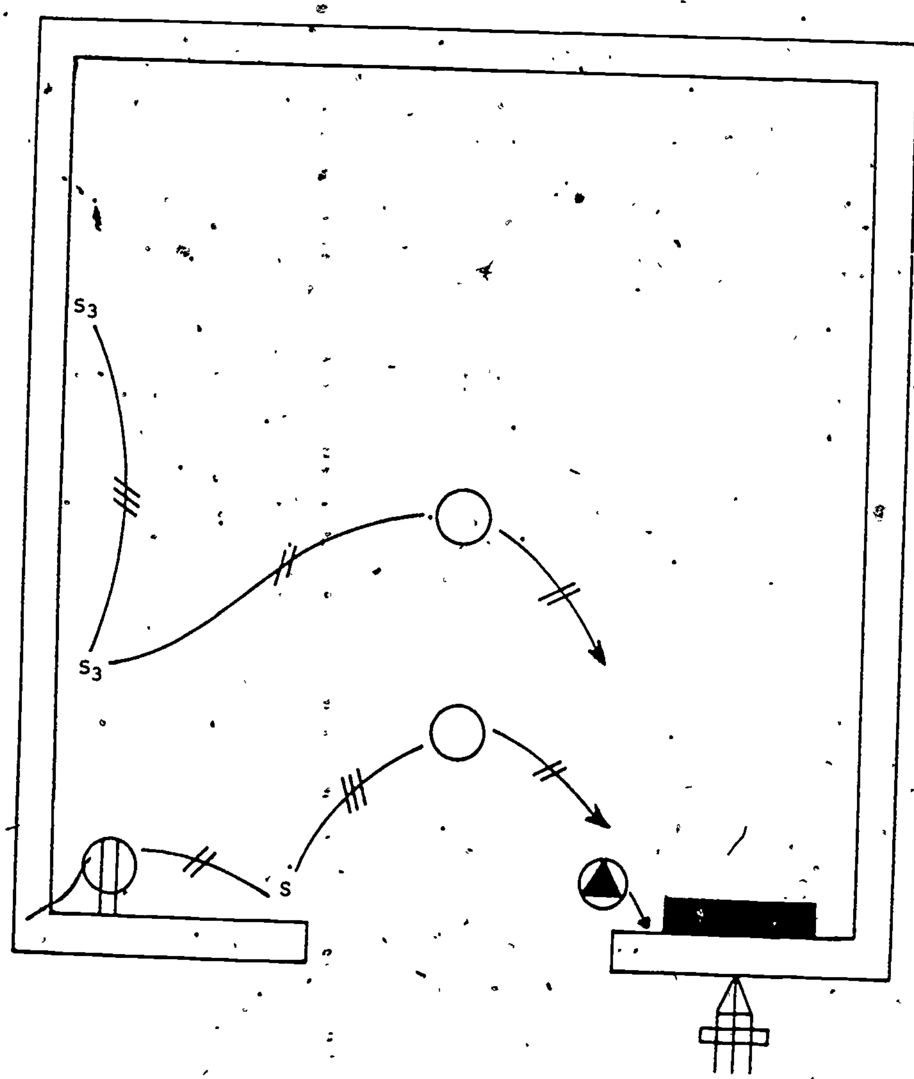


Figure 6

NOTES:

1. Switches will be mounted 48" from the floor.

2. Boxes will be mounted to accommodate 1/2" plywood finish on ceilings and walls.

3. Ceiling light fixture will be a porcelain keyless type.

PROJECT 6

OBJECTIVE

Using the previously installed three-way switch system, install a four-way switch between the two three-way switches to control the ceiling light from three locations, according to NEC specifications.

EQUIPMENT AND SUPPLIES

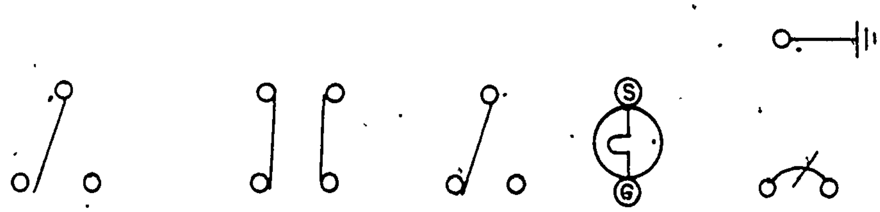
	Basis of Issue
WB 3ABR54230-1-II-5	1/student
National Electrical Code	1/student
Handtools	1/student
Associated Equipment	1/student

INSTRUCTIONS

Using the NEC, materials, and handtools, complete the following circuit:

Step one

Observe the symbols below. Connect the symbols by drawing and color coding the conductors.



Have your instructor check your work ____________________
Instructor

Step two

Use this corrected drawing, the blueprint drawing, see figure 7, and the bill of materials to complete this project. Use the bill of materials and select the equipment you will need. List any materials that are not available and take the list to the instructor.

Bill of Materials

Four-way switch	- 1 each
Sectional box	- 1 each
14/3-Nonmetallic sheathed cable	- as required
NM cable staples	- as required
Nails	- as required
Tape	- as required

407

Step three

Wire this project as indicated on the blueprint. CAUTION: DO NOT APPLY POWER. Have your instructor check your work ______________________

Instructor

Step four

Operate the circuit when told to do so. Have your instructor check this workbook

____

Instructor

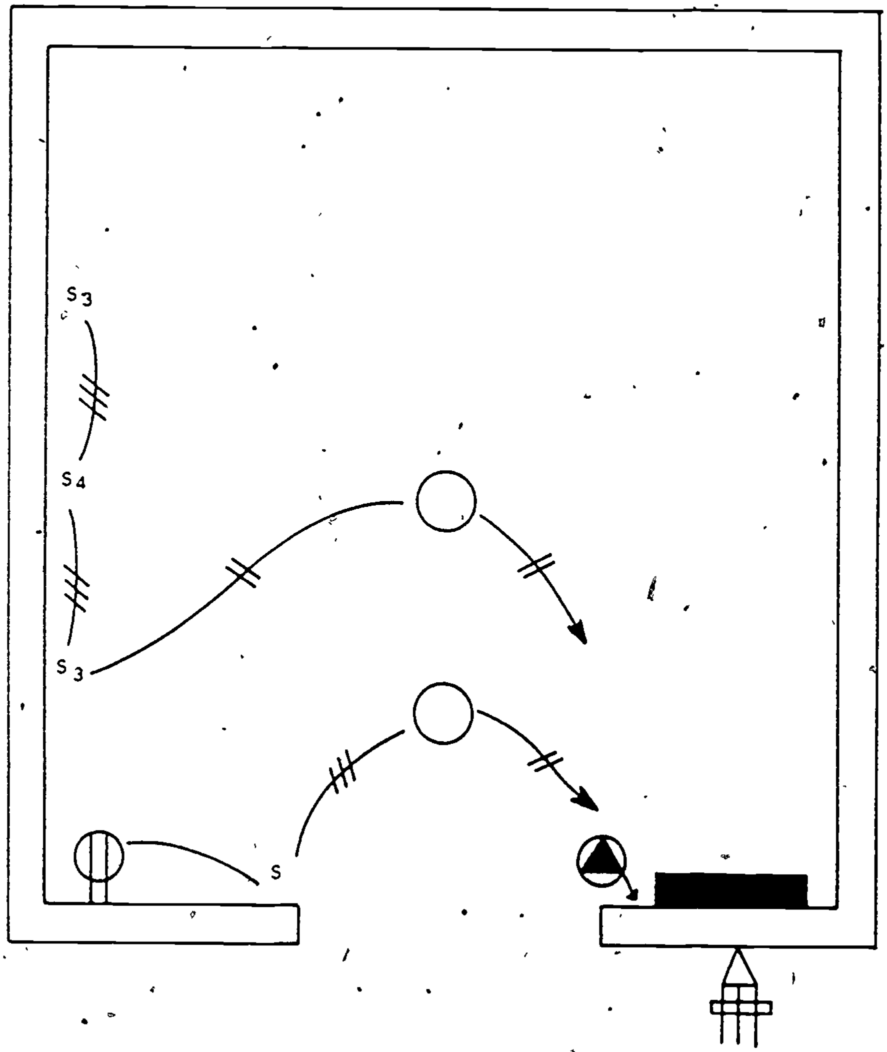


Figure 7

NOTES:

1. Four-way switch will be added to the three-way switch system.

2. Switch will be mounted 48" from the floor.

3. Box will be mounted to accommodate 1/2" plywood finish on ceilings and walls.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

LIGHTING SYSTEMS

PROJECT 1

OBJECTIVE

Given information pertaining to incandescent lighting, list the correct solution to each problem.

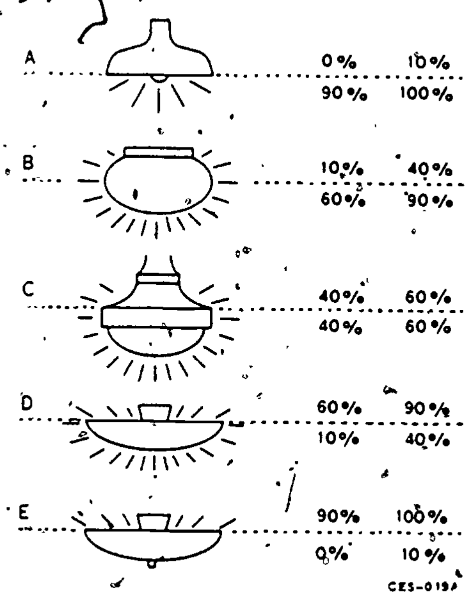
EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-6	1/student

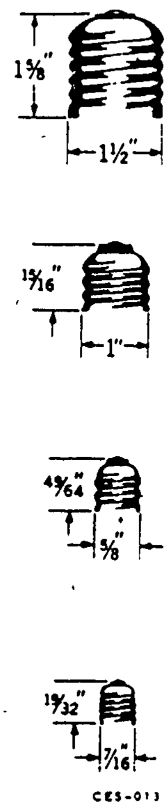
INSTRUCTIONS

Complete the following statement:

1. What classifications of lighting are indicated below?



2. What lamp bases are indicated below?



PROJECT 2

411

OBJECTIVE

Given information pertaining to fluorescent lighting, list the correct solution to each problem.

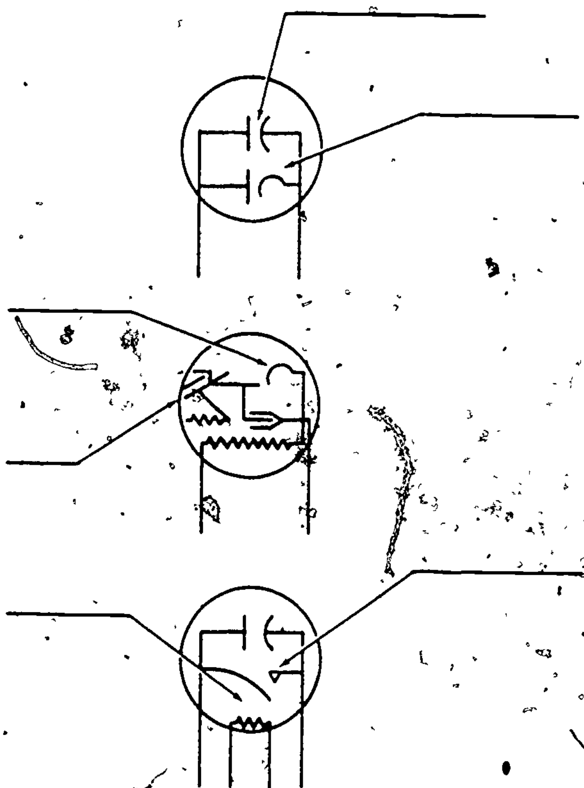
EQUIPMENT AND SUPPLIES

WB 3ABR54230-1-II-6	Basis of Issue 1/student

INSTRUCTIONS

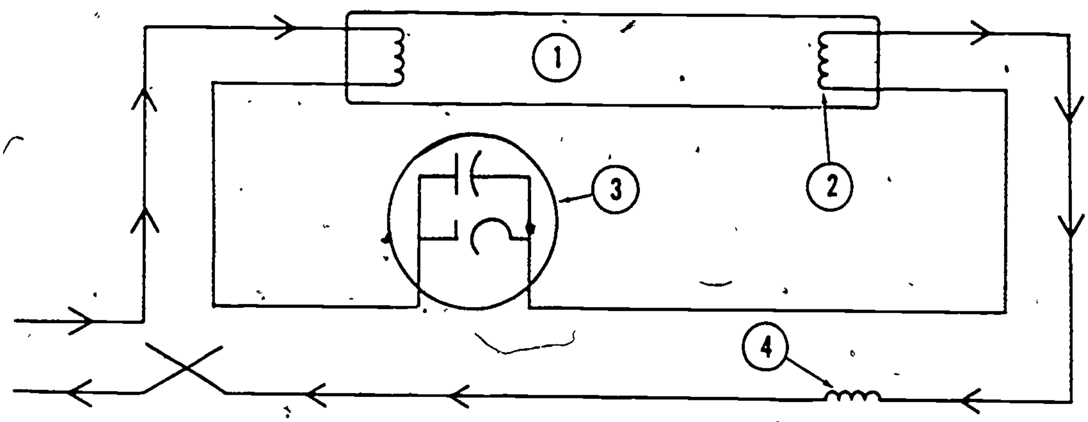
Complete the following statements:

1. Identify the parts as indicated by the arrows.



412

2. Identify the parts of the fluorescent fixture.



a. ____________

b. ____________

c. ____________

d. ____________

PROJECT 3

OBJECTIVE

Provided a work area and handtools, install a circuit in N.M. cable containing a fluorescent light and a single-pole switch, according to NEC specifications.

EQUIPMENT AND SUPPLIES

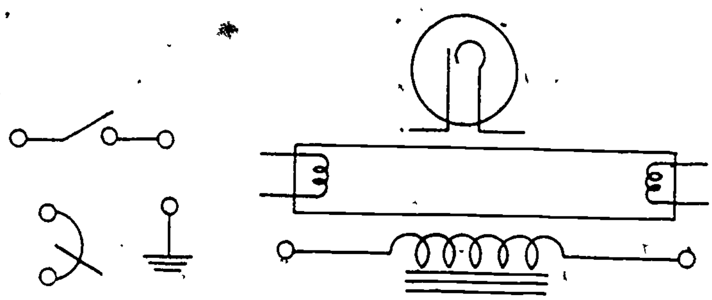
	Basis of Issue
WB 3ABR54230-1-II-6	1/student
National Electric Code	1/student
Handtools	1/student
Fluorescent Light	1/student
Associataed Equipment	1/student

INSTRUCTIONS

Using the NEC, materials, and handtools, complete the following:

Step one

The symbols below represent the components of a fluorescent fixture. Draw in the conductors to complete the circuit.



Have your instructor check your drawings ________________________
Instructor

Step two

The following is a list of terms associated with fluorescent lighting and a scrambled list of their definitions. In the spaces provided, write in the number which will associate the term with its definition.

Term		Definition
a. Ballast	______	1. Electron Emitter
b. Rapid Start	______	2. Fluorescent Chemical
c. Bipin	______	3. Reactor or Step-Up Transformer
d. Starter	______	4. Cold Cathode
e. Preheat	______	5. Automatic Switch
f. Phosphor	______	6. Dual Contact
g. Mercury		7. Hot Cathode
h. Cathode		8. Provides Arc Path

Step three

Study the blueprint, see figure 8, carefully and determine what equipment and supplies are needed. Using your bill or materials draw the needed equipment from supply. List any equipment or supplies not available and give the list to the instructor.

Bill of Materials

Octagon	- 1 each
Sectional box	- 1 each
Hanger bar	- 1 each
NM cable connectors	- 2 each
14/2 Nonmetallic-sheathed cable	- as required
NM Cable Staples	- as required
Nails	- as required
Tape	- as required
Two tube fluorescent fixture	- 1 each

Step four

Use your blueprint and install the fluorescent fixture. Do not apply power. Your installation should look like figure 77. Have the instructor sign your project

____
Instructor

Step five

Operate the equipment when instructed. Have the instructor sign this workbook.

____
Instructor

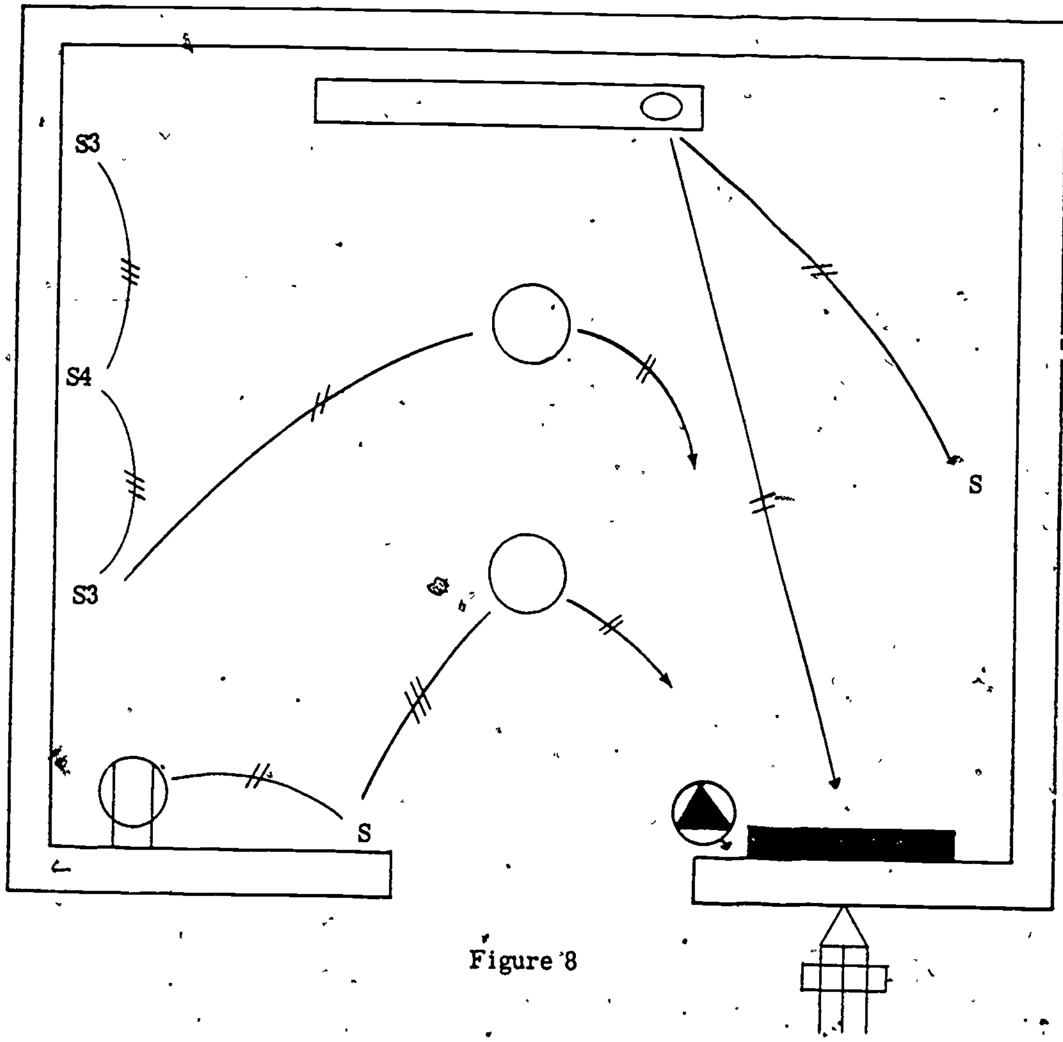


Figure 8

NOTES:

1. Fluorescent fixture will be a 2-40 watt fixture.
2. Fixture will be flush mounted to the ceiling joist.
3. Switchbox will be mounted 48" from the floor.
4. Switchbox will be mounted to accommodate 1/2" plywood finish.

Department of Civil Engineering Training
Sheppard Air Force Base, Texas

WB 3ABR54230-1-II-7
July 1975

TROUBLESHOOTING NONMETALLIC-SHEATHED CABLE

PROJECT 1

OBJECTIVE

1. Provided a multimeter and instructions, troubleshoot an energized (120/240 volt) electrical circuit to locate troubles inserted in the circuit by the instructor.

2. Provided a multimeter and instructions, troubleshoot a deenergized circuit to locate troubles inserted in the circuit by the instructor.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-7	1/student
Multimeter	1/student
Handtools	1/student

PROJECT 1a

INSTRUCTIONS

You are to use the wiring booth that you have wired. Your instructor will insert a trouble in your booth. You are to complete this project step by step.

Step One

The instructor will tell you which circuit is malfunctioning and how it malfunctioned.

You are to decide what type of trouble exists ______________________________

______________________________. Have your instructor check your answer

____
Instructor

Step Two

You are to select the type of meter you will need to locate the troubles ________

____

Step Three

Make a visual inspection.

Step Four

Use the schematic drawing that you prepared when installing this circuit. Study this drawing. Check with the instructor prior to performing an operational check.

Step Five

Locate and indicate the exact locations of the troubles ____________________

____

Step Six

Repair the troubles. Have the instructor sign this worksheet when you have completed all assigned troubles ______________________________.
Instructor

PROJECT 1b

INSTRUCTIONS

You are to use the wiring booth that you have wired. Your instructor will insert a trouble in your booth. You are to complete this project step by step.

Step One

The instructor will tell you which circuit is malfunctioning and how it malfunctioned.

You are to decide what type of trouble exists ______________________________

______________________________. Have your instructor check your answer.

____
Instructor

Step Two

You are to select the type meter you will need to locate the troubles ______________

____

Step Three

Make a visual inspection.

Step Four

Use the schematic drawing that you prepared when installing this circuit. Study this drawing. Check with the instructor prior to performing an operational check.

Step Five

Locate and indicate the exact locations of the troubles ____________________

____

Step Six

Repair the troubles. Have the instructor sign this worksheet when you have completed all assigned troubles ______________________.
Instructor

PROJECT 2

OBJECTIVE

Given information pertaining to balancing branch circuits, balance the circuits installed.

EQUIPMENT AND SUPPLIES

	Basis of Issue
WB 3ABR54230-1-II-7	1/student
Clamp-on Ammeter	1/student
Handtools	1/student

INSTRUCTIONS

1. You are to use the wiring booth that you have wired. Make sure that all troubles have been corrected in the circuits and that they are in working order.

2. Turn the electrical power on all the circuits wired, making sure that the proper load is on each circuit.

3. Using the clamp-on ammeter provided measure and record the current on the 3-wire service entrance at the drip loops.

Unidentified conductor #1 ____________. Unidentified conductor #2__________.

Neutral conductor ____________________.

Have your instructor check your work.

4. If the load is not balanced between the unidentified service conductors, rearrange the branch circuits in the panelboard to provide minimum current in the neutral service conductor.

ATC-SHEPPARD AFB TEX 75-180

PREPARE THE MAN 2TPT-3100-01

TECHNICAL TRAINING

INTRODUCTION TO ELECTRICAL SYMBOLS

April 1967

AIR TRAINING COMMAND

Original Material Prepared
by
Naval Air Technical Training Command

Designed For ATC Course Use

ASSIGNMENT SHEET

This assignment sheet should be used when:

- You are to complete only a part of this text.
- Your assignment within this text is divided into two or more reading periods.

Your instructor will make assignments by identifying specific objectives, text material, and review questions.

ASSIGNMENTS

OBJECTIVES (by No)	TEXT MATERIAL (by page and/or frame)	REVIEW QUESTIONS (by No)

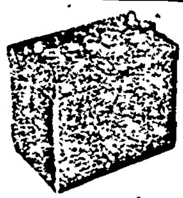
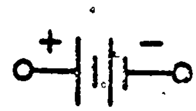
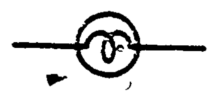
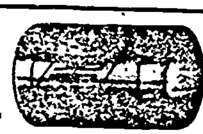
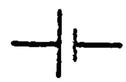
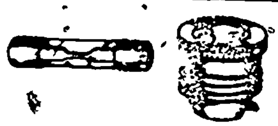
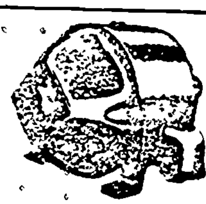
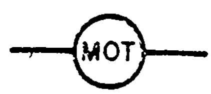
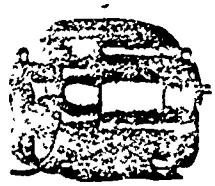
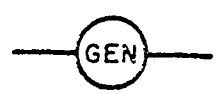
OBJECTIVES

1. Given a list of electrical symbols and a list of the names of electrical components, match the component names to their respective symbols.
2. Describe the difference between a wiring diagram and a schematic diagram.

As a maintenance man, much of your time will be spent trouble-shooting the equipment you are required to maintain. In order to understand how a system or a component operates, you must know the different electrical symbols used in electrical diagrams.

This lesson introduces some of the most common electrical symbols, and the most frequently used type of electrical diagrams. If you learn these symbols and diagrams thoroughly, you will find electrical work much easier.

SUGGESTED READING TIME 30 MIN.

NAME	COMPONENT	SYMBOL
POLARITY-- positive negative		+ −
GROUND		
CONNECTION		
NO CONNECTION		
BATTERY		
LAMP		
CELL		
FUSE		
MOTOR		
GENERATOR		

Match the components in column B to the respective symbols in column A.

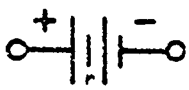
COLUMN A

1. ____ 

2. ____ 

3. ____ 

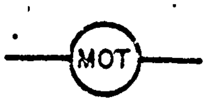
4. ____ 

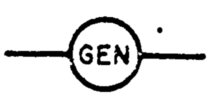
5. ____ 

6. ____ 

7. ____ 

8. ____ 

9. ____ 

10. ____ 

COLUMN B

a. Fuse

b. Motor

c. Lamp

d. Polarity-- Pos & Neg

e. Ground

f. Battery

g. Generator

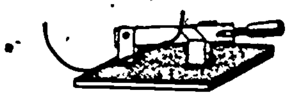
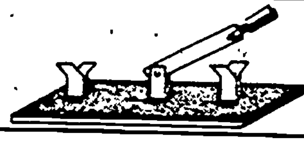
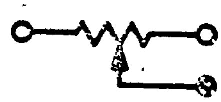
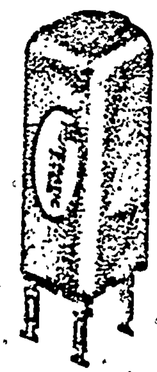
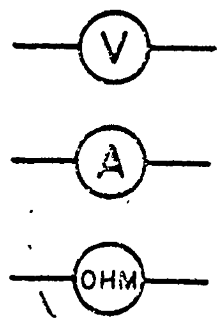
h. Connection

i. Cell

j. No Connection

Answers to the above:

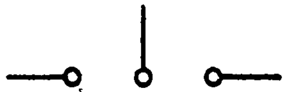
1 - d	6 - c
2 - e	7 - i
3 - h	[illegible] - a
[illegible]	9 - b
5 - f	10 - g

NAME	COMPONENT	SYMBOL
SINGLE-POLE SINGLE-THROW SWITCH		
SINGLE-POLE DOUBLE-THROW SWITCH		
RESISTOR		
RHEOSTAT		
TRANSFORMER, IRON CORE		
TRANSFORMER, AIR CORE		
VOLTMETER AMMETER OHMMETER		

Match the components in column B to the respective symbols in column A.

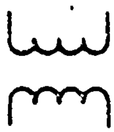
COLUMN A

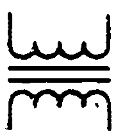
1. ____ 

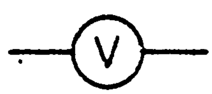
2. ____ 

3. ____ 

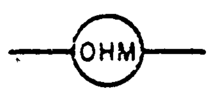
4. ____ 

5. ____ 

6. ____ 

7. ____ 

8. ____ 

9. ____ 

COLUMN B

a. Voltmeter

b. Resistor

c. Transformer, iron core

d. Transformer, air core

e. Ammeter

f. Ohmmeter

g. Rheostat

h. Single-pole Single-throw switch

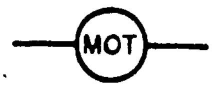
i. Single-pole Double-throw switch

Answers to the above:

1 - h
2 - i
3 - b
4 - g
5 - d
6 - c
7 - a
8 - e
9 - f

Name each symbol shown below.

1.  ______________________

2. 

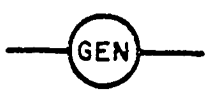
____

3.  ______________________

4.  ______________________

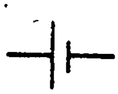
5.  ______________________

6.  ______________________

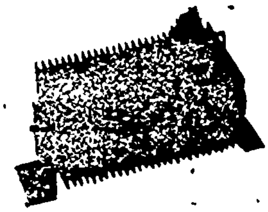
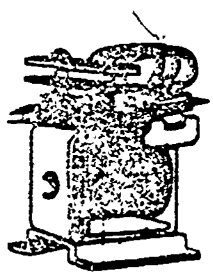
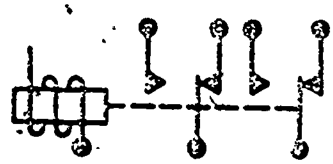
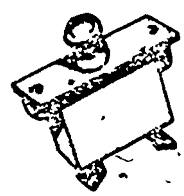
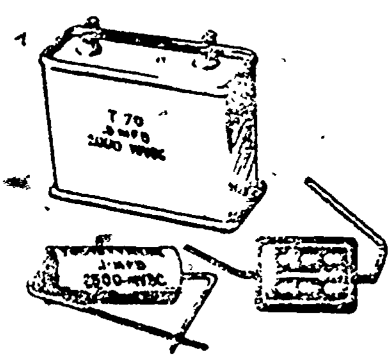
7. 

____

8.  ______________________

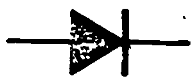
9.  ______________________

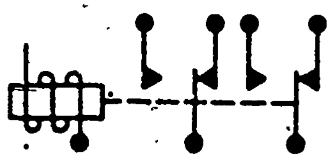
10.  ______________________

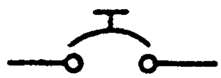
NAME	COMPONENT	SYMBOL
METALLIC RECTIFIER		
RELAY COIL WITH CONTACTS		
PUSH-PULL CIRCUIT BREAKER		
CAPACITOR, FIXED		

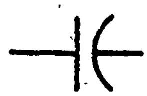
Match the components in column B to the respective symbols in column A.

COLUMN A

1. ________ 

2. ________ 

3. ________ 

4. ________ 

COLUMN B

a. Capacitor, fixed

b. Push-pull circuit breaker

c. Metallic rectifier

d. Relay coil with contacts

Answers to the above:

1 - c

2 - d

3 - b

4 - a

Name each symbol shown below.

1.  ________________

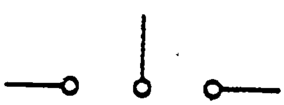
2.  ________________

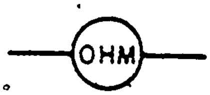
3.  ________________

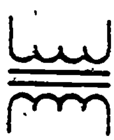
4.  ________________

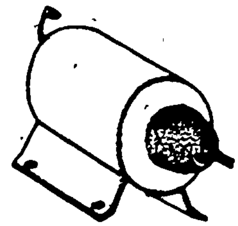
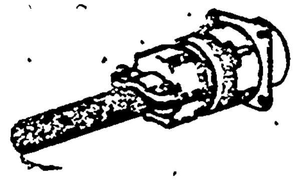
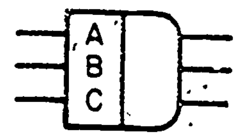
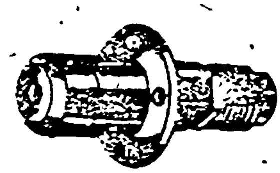
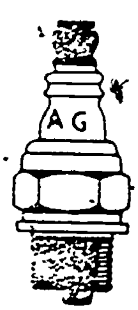
5.  ________________

6.  ________________

7.  ________________

8.  ________________

9.  ________________

NAME	COMPONENT	SYMBOL
SOLENOID		
CONNECTOR, PLUG AND RECEPTACLE (Cannon Plug)		
DISCONNECT		
SPARK IGNITER		
SPARK PLUG		

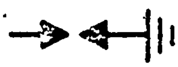
Match the components in column B to the respective symbols in column A.

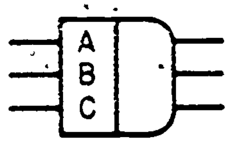
COLUMN A

1. ______ 

2. ______ 

3. ______ 

4. ______ 

5. ______ 

COLUMN B

a. Disconnect

b. Connector, Plug and Receptacle (cannon plug)

c. Solenoid

d. Spark Plug

e. Spark Igniter

Answers to the above:

1 - c

2 - a

3 - e

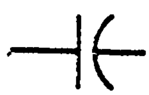
4 - d

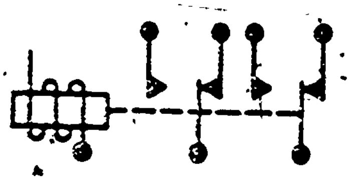
5 - b

Name each symbol shown below.

1.  ______________________

2.  ______________________

3.  ______________________

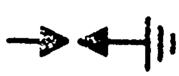
4.  ______________________

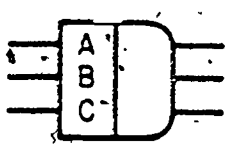
Name each symbol shown below.

1.  ____________________

2.  ____________________

3.  ____________________

4.  ______________________________

5. 

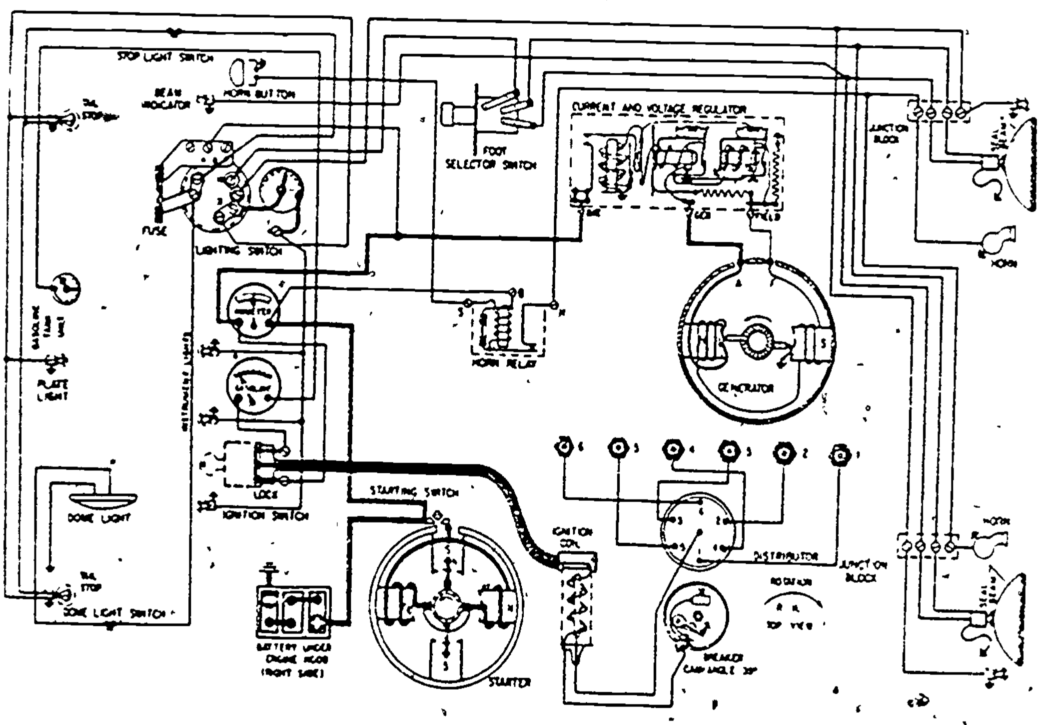
____

There are many different types of drawings used to illustrate electrical layouts, but it would be impractical to discuss all of them. Therefore, only those drawings that you, the maintenance man, are apt to use frequently will be explained.

The drawings that will be discussed are the wiring diagram and the schematic diagram. These two types of drawings are the ones most often used in connection with maintenance work.

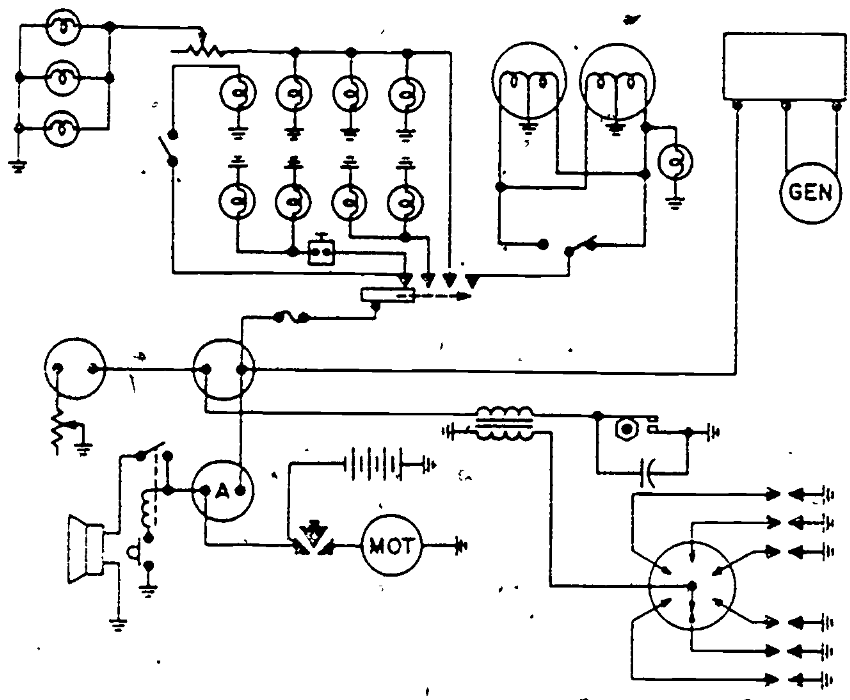
A wiring diagram is a drawing showing a circuit in a simplified form, and is arranged so the physical location of parts is similar to the layout of the actual equipment.

Here is a drawing of an automobile electrical system. Notice the simplified form and how the physical location of the parts is similar to the actual equipment. This type of drawing is a ________ ________.



WIRING DIAGRAM	Describe a wiring diagram. ___ ___ ___
YOUR ANSWER SHOULD HAVE THE SAME MEANING AS THE ONE ON THE RIGHT.	A drawing showing a circuit in a simplified form, and arranged so the physical location of the parts is similar to the layout of the actual equipment.

A schematic diagram is a drawing of a circuit in which the parts are represented by symbols, and they may be arranged quite differently from their actual physical arrangement. Shown below is a drawing of an automobile electrical system. Notice the parts are represented by symbols arranged differently from their actual arrangement. This type of drawing is a ______________ ______________.



SCHEMATIC DIAGRAM	Describe a schematic diagram.
YOUR ANSWER SHOULD HAVE THE SAME MEANING AS THE ONE ON THE RIGHT.	A schematic diagram is a drawing of a circuit in which the parts are represented by symbols, and arranged quite differently from their actual physical arrangement.
	Describe the difference between a wiring diagram and a schematic diagram.
YOUR ANSWER SHOULD HAVE THE SAME MEANING AS THE ONE ON THE RIGHT.	A wiring diagram is a drawing showing a circuit in a simplified form, and is arranged so the physical location of the parts is similar to the layout of the actual equipment. A schematic diagram is a drawing of a circuit in which the parts are represented by symbols, and they are arranged quite differently from the actual equipment. END OF LESSON

SELF-TEST

Match each component to its respective symbol.

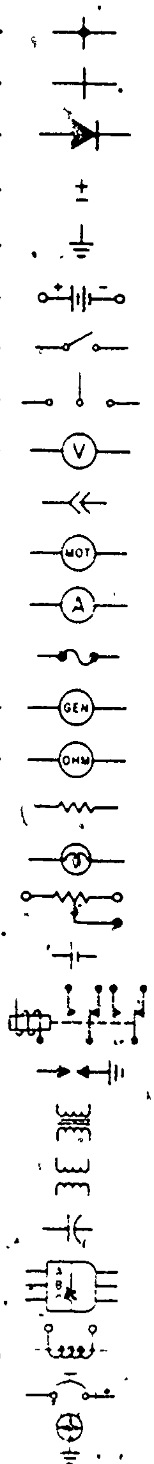
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____
21. _____
22. _____
23. _____
24. _____

_____

_____

_____

_____



a. Polarity-- Pos. & Neg.
b. Ground
c. Lamp
d. Connection
e. No Connection
f. Cell
g. **Battery**
h. Fuse
i. Generator
j. Motor
k. Resistor
l. Rheostat
m. Voltmeter
n. Ammeter
o. Ohmmeter
p. Disconnect
q. Single-pole single-throw switch
r. Single-pole double-throw switch
s. Push-pull circuit breaker
t. Capacitor, fixed
u. Transformer, air core
v. Transformer, iron core
w. Relay coil with contacts
x. Solenoid
y. Metallic rectifier
z. Spark igniter
aa. Spark plug
bb. Connector, plug and receptacle (Cannon Plug)

2. Describe the difference between a wiring diagram and a schematic diagram.

C-SHEPPARD AFB TEX 71-553

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2TPT-3101-01

TECHNICAL TRAINING

DC CIRCUITS - SERIES

February 1967

AIR TRAINING COMMAND

3-17

Original Material Prepared
by
Naval Air Technical Training Command

Designed For ATC Course Use

INSTRUCTIONS

This booklet is called a program, and it will be easy for you to learn the subject this program covers. It will be easy because of the way the information you are to learn is broken down into small, easily understood parts, called frames. Each frame contains information you are to learn and presents you with a question to answer. This keeps your brain active -- just like answering questions in class. After you have written your answer to a frame, you will be able to see immediately the correct answer. This lets you know whether your answer is right or wrong -- just like having an instructor tell you whether your answer is correct or not. These three things: reading, answering questions, and being shown the correct answer will ensure that learning takes place.

Even though the program is designed to make it easy for you to learn, there are certain things you must do in order for it to be successful. If you will follow the suggestions listed below, you should have no trouble learning the material in this program.

1. Read the objectives very carefully before you begin, so you will know what you are to learn.
2. Keep the answer to the frame you are working on covered with a slip of paper until you have written your answer. (The correct answer is usually found to the left of the frame following the one you are working on.)
3. After writing your answer to a frame, move the slip of paper to expose the correct answer, so you can see whether you are right or not.
4. Always follow, very carefully, any directions given in the program.
5. When you have finished the program, read the objectives again to make sure you can do what the objectives require.
6. Take the self-test at the end of the program; this will indicate whether you have learned what you were supposed to learn.

LEARNING OBJECTIVES

1. The trainee will define a series circuit.
2. Given a series circuit diagram, the trainee will identify the various circuit functions by specifying the proper letters and subscripts, and indicate with arrows the direction of current flow.
3. The trainee will write the law of resistance for a series circuit.
4. The trainee will write the mathematical formula for finding total resistance of a series circuit having three resistors.
5. The trainee will write the law of voltage for a series circuit.
6. The trainee will write the mathematical formula for finding total voltage of a series circuit having three resistors.
7. The trainee will write the law of current for a series circuit.
8. Given a series circuit diagram, with each individual resistance known, the trainee will solve for total resistance.
9. Given a series circuit diagram, with each individual voltage drop known, the trainee will solve for total voltage.
10. Given a series circuit diagram, with total voltage and resistance known, the trainee will solve for total current.
11. The trainee will state the voltage law that applies to cells grouped in series.
12. The trainee will state the reason for grouping cells in series.
13. The trainee will state the voltage that usually exists in a wet cell.
14. The trainee will state the voltage that usually exists in a dry cell.
15. The trainee will state the reason why the internal resistances of dry cells and wet cells differ.

Once you complete this program, please turn back to the objectives and read them again to see if you know what was expected of you.

Turn to the next page and start the program.

SUGGESTED READING TIME 60 MINUTES

SERIES CIRCUITS

INTRODUCTION

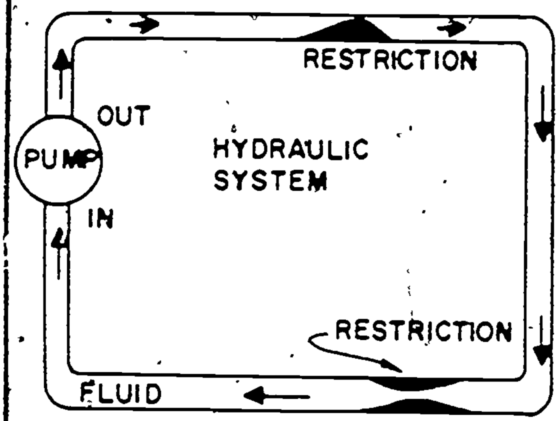
An electric circuit is a complete path through which electrons can flow. Within a D.C. circuit, the electrons flow from the negative terminal of a voltage source, through the connecting wires of conductors, through the resistor or resistance, and back to the positive terminal. A circuit is thus made up of a voltage source, the necessary connecting conductors, and the effective resistance.

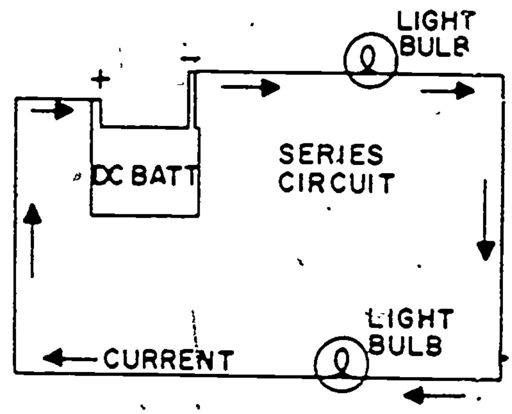
If the circuit is so arranged that the electrons have only one possible path, the circuit is called a SERIES CIRCUIT.

In any type of work that utilizes the effects of electron flow, a knowledge of series circuits is desirable. None of the effects accompanying electron flow-- for example: heating, lighting, or magnetic effects-- would be possible without the use of electrical circuits, and many electrical devices can be utilized more effectively if the operator has a knowledge of how they work. The purpose of this program is to give, in simplified form, conventional methods of calculating resistance in basic series circuits and to show how problems involving current, voltage, and resistance may be solved by the use of basic formulas.

The circuit we are going to talk about is the series circuit. A series circuit is defined as two or more component parts connected end to end to form only one path for current flow.

In the drawings below, you will see how a series circuit compares to a hydraulic system.





You will notice that in both drawings the fluid or current has only one path to flow. Therefore, if you have two or more electrical components connected in such a way as to provide only one path for current to flow, you have a SERIES CIRCUIT.

	1. A circuit that has two or more component parts connected end to end to form only one path for current flow is a ________________ circuit.
SERIES	2. A series circuit has two or more components connected end to end to form only __________ path for current flow.
ONE	3. A ______________ circuit has two or more components connected ________ to ____________ to form only ____________ path for current flow.

CONTINUE ON NEXT PAGE

SERIES END TO END ONE	4. Write the definition of a series circuit. ____ ____.

TWO OR MORE COMPONENTS CONNECTED END TO END TO FORM ONLY ONE PATH FOR CURRENT FLOW.

To be able to talk about circuits or solve problems dealing with circuits, we have to be able to identify the various components and their functions to the circuit. This is done by using letters and subscripts.

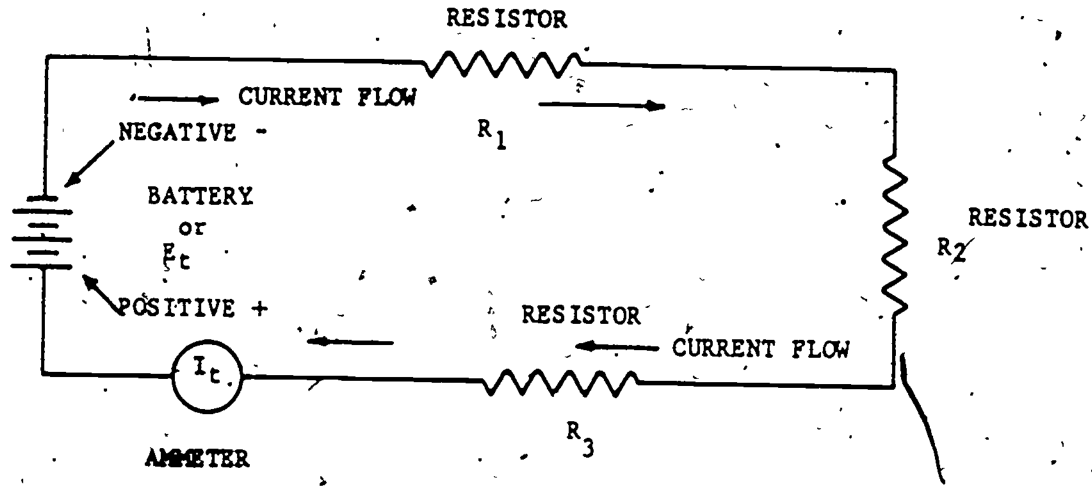
If you will remember your lesson Dynamic Electricity, you learned that the letter E stood for voltage, I stood for current, and R stood for resistance.

Now, in a series circuit we know that we are going to have two or more of these components, so we have to have some means of identifying them. The method used is called subscripts. This merely means that we use a letter or number below and to the right of the original circuit function letter.

An example of this would be: R_1, E_2, I_t. The capital letter is the original circuit function letter; the number or letter to the right is the subscript.

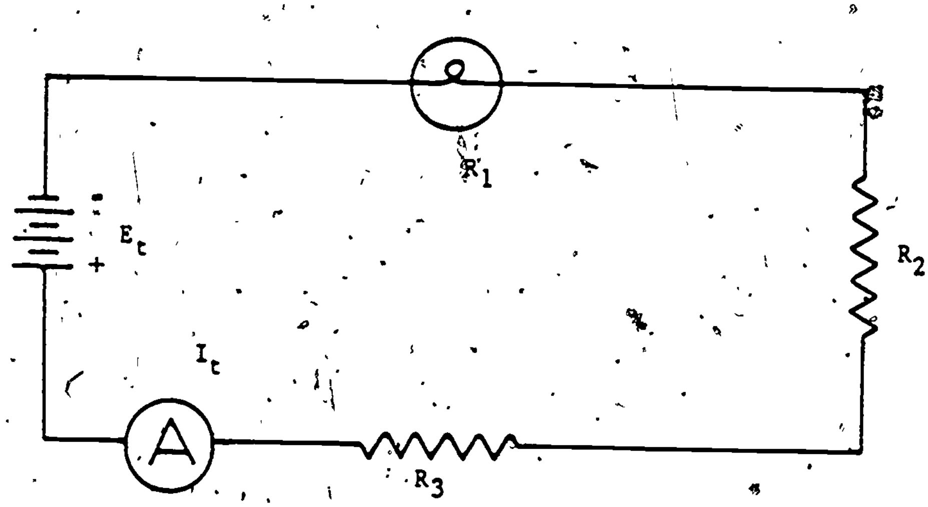
In the circuit diagram shown at the top of page 3, you will see how all these letters and subscripts are used; the direction of current flow is indicated by arrows. As you can see, current flows from the negative terminal of the voltage source (battery), thru the circuit, and back to the positive terminal of the voltage source.

CONTINUE ON NEXT PAGE



In our circuit diagram below, you will notice that the battery is represented by the electrical symbol —|||||— ; also, the battery is designated by the letters E_t. The E_t stands for VOLTAGE total. Next, we have our resistors connected end to end to form our series circuit. You will notice R_1 is a light bulb and R_2 and R_3 are just resistance symbols. It makes no difference which symbol we use or what we number our resistors, as long as they are numbered differently so we can tell them apart. Last, but not least, we have the ammeter. This will be shown as I_t, or written out CURRENT total.

On this drawing, indicate with arrows the direction of current flow.



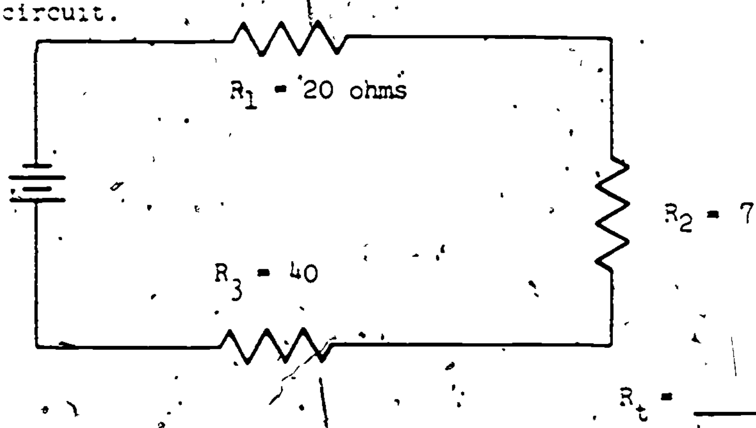
CONTINUE ON NEXT PAGE

1.  is a symbol for a/an ______________.
2.  is a symbol for a/an ______________.
3.  is a symbol for a/an ______________.
4. E_t stands for __________ __________.
5. I_t stands for __________ __________.
6. Does it make any difference which resistor is labeled R_1, R_2, or R_3? (Yes/No) ______________.

1. RESISTOR
2. BATTERY
3. AMMETER
4. VOLTAGE TOTAL
5. CURRENT TOTAL
6. NO

Now that you know the definition of a series circuit and how to designate the component parts of a circuit, we will start learning the laws that apply to series circuits.

The first law is the law of resistance. <u>The law of resistance states: The total resistance of a series circuit is equal to the sum of the individual resistors in the circuit.</u> Written as a formula, we have $R_t = R_1 + R_2 + R_3$. This merely means that to find total resistance of a series circuit, we add up all the separate resistances in the circuit. If you had a circuit where the resistance of R_1 was 5 ohms, R_2 was 10 ohms, and R_3 was 15 ohms, the total resistance would be 5 + 10 + 15 = 30 ohms. See how simple that was. Now, here is a problem for you to work. Find the total resistance of this circuit.



R_t = ______________

CONTINUE ON NEXT PAGE

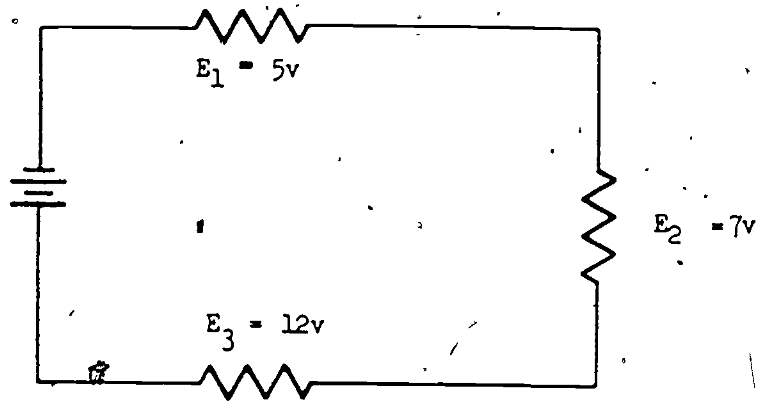
67 OHMS	1. The law of resistance for series circuits states that the total resistance is equal to the ______ of each individual resistor.
SUM	2. The law of resistance for series circuits states that ______ resistance is equal to the sum of the ______ resistances.
TOTAL INDIVIDUAL	3. The mathematical formula for total resistance of a series circuit containing three resistors is R_t = ______.
$R_1 + R_2 + R_3$	4. Write the law of resistance for series circuits. ______ ______.

TOTAL RESISTANCE EQUALS THE SUM OF THE INDIVIDUAL RESISTORS.

The next law is the law of voltage. This law states: Around any closed circuit the total applied voltage must equal the sum of the individual voltage drops. Or stated another way, total voltage will equal the sum of all the separate voltages. Our formula for finding total voltage is $E_t = E_1 + E_2 + E_3$. If you know the voltage drop across each resistor you can find total voltage by adding up each separate drop.

Example: If you had a circuit where E_1 was 10 volts, E_2 was 15 volts, and E_3 was 30 volts, your total voltage would be 10 + 15 + 30 = 55 volts. Now, here is a problem for you to work. Solve for E_t. Problem shown on next page.

CONTINUE ON NEXT PAGE



E_t = ____________

24 VOLTS	1. The voltage law states that the total voltage must be ____________ to the ____________ of the individual voltage drops.
EQUAL SUM	2. The voltage law states that the ____________ voltage must be equal to the sum of the ____________ voltage drops.
TOTAL INDIVIDUAL	3. The mathematical formula for total voltage of a series circuit containing three resistors is E_t = ____________
$E_1 + E_2 + E_3$	4. Write the law of voltage for series circuits. ____________ ____________

CONTINUE ON NEXT PAGE

TOTAL VOLTAGE EQUALS THE SUM OF THE INDIVIDUAL VOLTAGE DROPS.	The last law is the law of current. The law of current states: The current in any part of a series circuit is EQUAL to the current in any other part of the same circuit. This means that if you have 2 amps. of current at the first resistor, then any other place in the same circuit, you will have 2 amps. of current. This law is very important and you must remember it. Stated as a formula, we have $I_t = I_1 = I_2 = I_3$. The I_t stands for current total. If we have one amp. coming out of the battery and going around a circuit having three resistors, what would I_t equal? __________.
1 AMP.	1. The current in any part of a series circuit is __________ to the current in any other part of the same circuit.
EQUAL	2. The formula for total current of a series circuit containing three resistors is $I_t =$ __________.
$I_t = I_1 = I_2 = I_3$	3. The law of current for series circuits states that current in any part of the same circuit is equal to the __________ in any other part of the __________ circuit.
CURRENT SAME	4. Write the law of current for a series circuit. ____________________ ____________________.

CONTINUE ON NEXT PAGE

CURRENT IN ANY PART OF A SERIES CIRCUIT IS EQUAL TO THE CURRENT IN ANY OTHER PART OF THE SAME CIRCUIT.

REVIEW

1. Definition of a series circuit
   Two or more components connected end to end to form only one path for current flow.

2. Law of resistance
   The total resistance of a series circuit is equal to the sum of the individual resistors in the circuit.

3. Law of voltage
   The total applied voltage must equal the sum of the individual voltage drops.

4. Law of current
   Current in any part of a series circuit is equal to the current in any other part of the same circuit.

5. Ohm's law
   Ohm's law states that the current is directly proportional to the voltage and inversely proportional to the resistance.

6. Mathematical formulas:

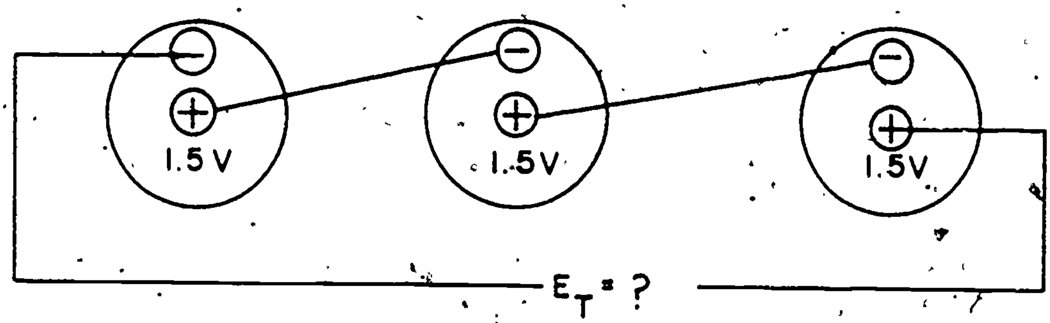
Ohm's law	$E = I \times R$ $\quad I = \frac{E}{R}$ $\quad R = \frac{E}{I}$
Resistance	$R_t = R_1 + R_2 + R_3$
Voltage	$E_t = E_1 + E_2 + E_3$
Current	$I_t = I_1 = I_2 = I_3$

SERIES CELL GROUPING

This part of the lesson will cover the practical application of series circuits. As you know, batteries are made up of two or more cells. These cells can be connected either in series or parallel. In this lesson, we will only be concerned with the series-type connection.

Cells grouped in series are connected from the negative terminal to the positive terminal, as shown in the drawing on the next page.

CONTINUE ON NEXT PAGE



This drawing shows three dry cells connected in series. The voltage law for cells grouped in series is the same as the voltage law for series circuits. <u>Total voltage equals the sum of the individual voltages</u>. This means, to find the total voltage of a group of cells connected in series, add all the individual cell voltages.

	1. The series cell grouping voltage law states that total voltage equals the ____________ of all the individual voltages.
SUM	2. To find total voltage in a series cell group, you would add all the individual ______________.
VOLTAGES	3. The series cell grouping voltage law states that ____________ voltage equals the __________ of all the ________________ voltages.
TOTAL SUM INDIVIDUAL	4. Solve for E_t in the problem at the top of this page. E_t = ________________.

CONTINUE ON NEXT PAGE

4.5 VOLTS	5. Write the series cell grouping voltage law. ________________ ________________
TOTAL VOLTAGE EQUALS THE SUM OF ALL THE INDIVIDUAL VOLTAGES.	All the laws that apply to series circuits also apply to cells grouped in series. The reason some cells are grouped in series is to increase voltage while conserving current. By knowing that dry cells have an EMF of 1.5 volts and that wet cells have an EMF of 2 volts, and by knowing the resistance of each cell, we can work any problem involving cells grouped in a series. The resistance of cells, either wet or dry, will vary because of the charge and the construction of the cell. This resistance will vary from .001 ohm to 1 ohm.
	1. The voltage that usually exists in a wet cell is ________ and the voltage that exists in a dry cell is ________________.
2v 1.5v	2. The reason some cells are grouped in series is to conserve ________________ and to increase ________________.
CURRENT VOLTAGE	3. The reason we group cells in series is to ________ current and to ________________ voltage.
CONSERVE INCREASE	4. Internal resistance in wet and dry cells will differ because of the ________________ and construction of the cells.

CONTINUE ON NEXT PAGE

CHARGE	5. The internal resistance of cells will differ because of the ________ and ________ of the cell.
CHARGE CONSTRUCTION	The rest of this lesson will be a review of what you have already learned. Take your time and be sure you fill in every blank. Remember to check each answer as you go. O.K., now let's run back through some of the things we have covered in this lesson.
	1. A circuit that has two or more components connected end to end to form only one path for current flow is a ________ circuit.
SERIES	2. A series circuit has two or more components connected end to end to form only ________ path for current flow.
ONE	3. A ________ circuit has two or more components connected ________ to ________ to form only ________ path for current flow.
SERIES END TO END ONE	4. Numbers are sometimes written to the right and below a letter (R_1). These numbers designate a particular part and are known as ________.
SUBSCRIPTS	5. Subscripts are numbers, letters, or symbols used to designate a ________ part.

CONTINUE ON NEXT PAGE

PARTICULAR	6. Write the definition of a series circuit. ______________________ ______________________.
TWO OR MORE COMPONENTS CONNECTED END TO END TO FORM ONLY ONE PATH FOR CURRENT FLOW.	7. The law of resistance for series circuits states that the total resistance is equal to the ________ of the individual resistances.
SUM	8. The law of resistance for series circuits states that ____________ resistance is equal to the sum of the ______________ resistances.
TOTAL INDIVIDUAL	9. The mathematical formula for total resistance of a series circuit containing three resistors is R_t = ______________________.
$R_1 + R_2 + R_3$	10. Write the law of resistance for a series circuit. ______________________ ______________________.
TOTAL RESISTANCE IS EQUAL TO THE SUM OF THE INDIVIDUAL RESISTANCES.	11. The current in any part of a series circuit is __________ to the current in any other part of the same circuit.
EQUAL	12. The formula for total current for a series circuit containing three resistors is I_t = __________.

CONTINUE ON NEXT PAGE

$I_1 = I_2 = I_3$	13. The voltage law states that the total voltage must be ________ to the ____________ of the individual voltage drops.
EQUAL SUM	14. The voltage law states that the ____________ voltage must be equal to the sum of the ______________ voltage drops.
TOTAL INDIVIDUAL	15. The mathematical formula for total voltage of a series circuit containing three resistors is $E_t =$ ______________
$E_1 + E_2 + E_3$	16. Write the law of current for a series circuit. ______________________ ____________________.
CURRENT IS EQUAL IN ANY PART OF THE SAME CIRCUIT.	17. The series cell grouping voltage law states that total voltage equals the ________ of all the separate voltages.
SUM	18. To find total voltage in a series cell group, you would add all the separate ____________.
VOLTAGES	19. The series cell grouping voltage law states that ____________ voltage equals the ________ of all the ______________ voltages.

CONTINUE ON NEXT PAGE

TOTAL SUM INDIVIDUAL	20. Write the law of voltage for a series circuit. ____________________ ____________________.
TOTAL VOLTAGE EQUALS THE SUM OF THE INDIVIDUAL VOLTAGES.	21. The voltage that usually exists in a wet cell is _____ ________ and the voltage that exists in a dry cell is _____ __________.
2 VOLTS 1.5 VOLTS	22. The reason some cells are grouped in series is to conserve __________ and to increase __________.
CURRENT VOLTAGE	23. The reason we group cells in series is to ________ current and to ____________ voltage.
CONSERVE INCREASE	24. Internal resistance in wet and dry cells will differ because of the _________ and construction of the cells.
CHARGE	25. The internal resistance of cells will differ because of the _________ and ____________.
CHARGE CONSTRUCTION	26. Write the series cell grouping voltage law. _____ ____________________ ____________________.
TOTAL VOLTAGE WILL EQUAL THE SUM OF THE INDIVIDUAL VOLTAGES.	You have now completed this program. Feel free to refer to any page that you want. Please reread the objectives. Then turn to page 15 for a Self-Test.

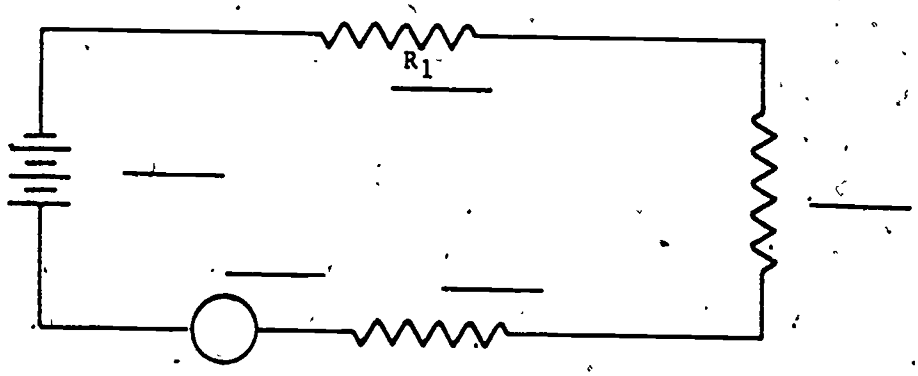
CONTINUE ON NEXT PAGE

SELF-TEST

SERIES CIRCUITS

1. Write the definition for a series circuit.

2. In the circuit below, identify the various circuit functions by specifying the proper letters and subscripts, and indicate with arrows the direction of current flow.



3. Write the law of resistance for series circuits.

4. Write the mathematical formula for finding total resistance of a series circuit having three resistors.

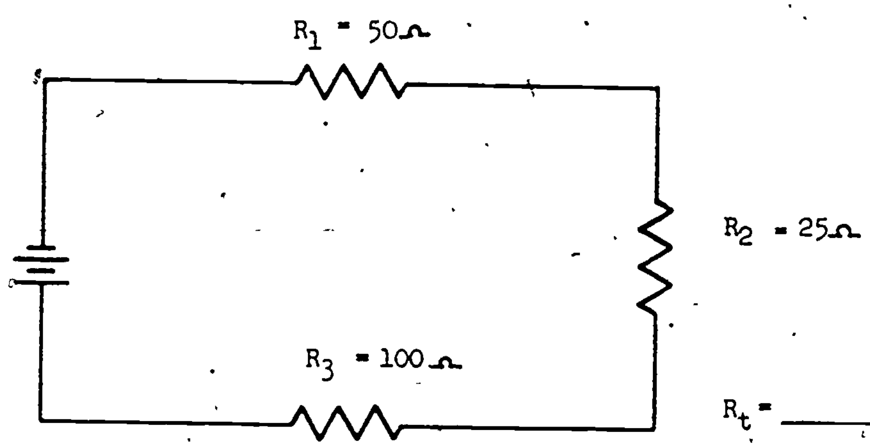
5. Write the law of current for a series circuit.

6. Write the law of voltage for a series circuit.

7. Write the mathematical formula for finding total voltage in a series circuit having three resistors.

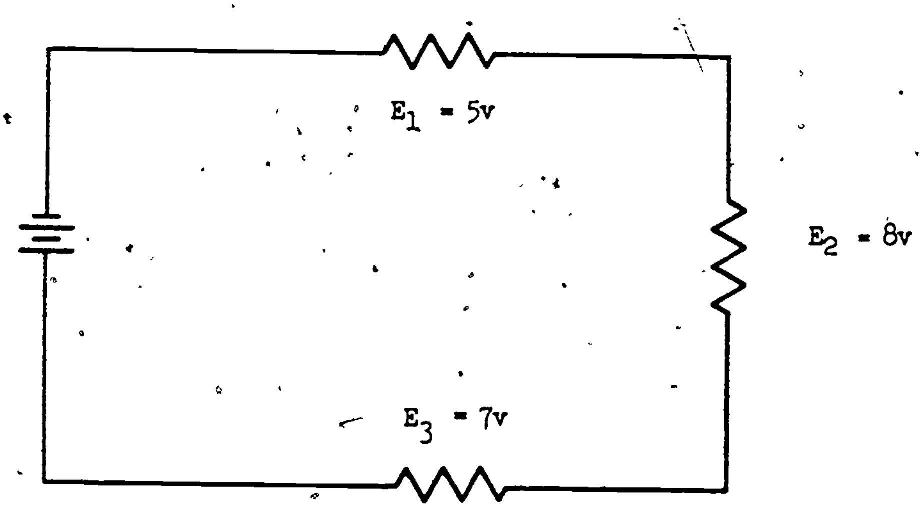
CONTINUE ON NEXT PAGE

8. Solve for R_t.



R_t = ____________.

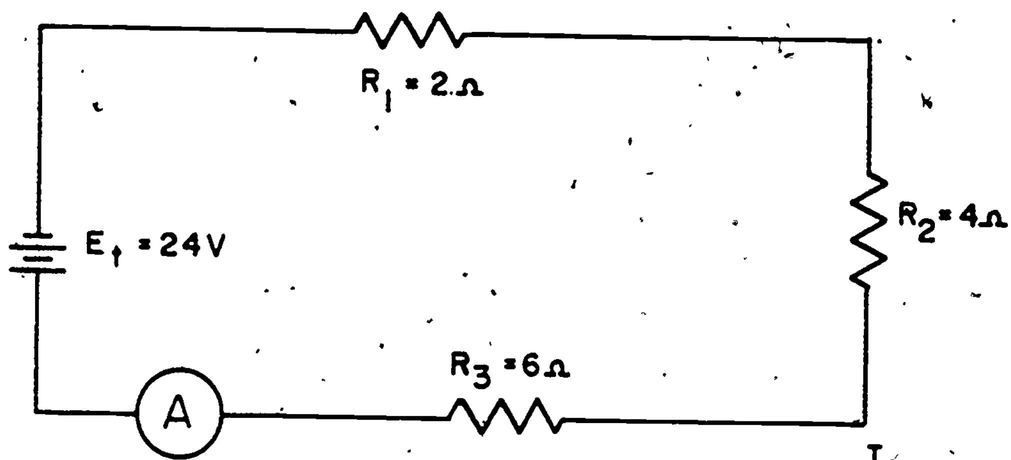
9. Solve for E_t.



E_t = ____________.

CONTINUE ON NEXT PAGE

10. Solve for I_t.



$I_t =$ ________

11. State the series cell grouping voltage law.

12. State the voltage that usually exists in:

Wet cells ____________. Dry cells ________________.

13. State the reason why some cells are grouped in series.

14. State the reason why the internal resistance in dry and wet cells differs.

TECHNICAL TRAINING

DC CIRCUITS - PARALLEL

February 1967

AIR TRAINING COMMAND

Original Material Prepared
by
Naval Air Technical Training Command

Designed For ATC Course Use

INSTRUCTIONS

This lesson gives you instruction at your own speed. The material is presented to you in small amounts called frames. In the first part of each frame, you will be given some information. You will then be required to complete a statement on the information just given. After you fill in the blanks or complete a statement, you may confirm your answer by looking to the left side of the next frame. If you make an incorrect response, go back to the preceding frame, carefully reread the information, and correct your response.

You may fold a piece of scratch paper which should be used to cover up the correct answers at the left side of the frames until you are ready to check your answers. Just place it on the left-hand margin and slide it down as you progress.

EXAMPLE:

	1. Matter is anything that has weight and occupies space. Your pencil has weight and occupies space; therefore, it is matter.
matter	2. Air also is matter because it has weight and occupies space.
occupies space	3.

You will not be graded on your answers, but you must decide on an answer before uncovering the correct answer.

A list of learning objectives is included in this program. These learning objectives are of importance to you, as they tell you exactly what you must learn from this lesson. Read them carefully. The self-test, included at the end of the program, is based on these objectives. It will be to your advantage to work the self-test.

Be sure to follow instructions when they are given.

PARALLEL CIRCUITS

OBJECTIVES

1. The student will define a parallel circuit.
2. Given several symbols for electrical components, the student will draw a parallel circuit.
3. The student will write the law of voltage for parallel circuits.
4. The student will write the law of current for parallel circuits.
5. The student will write the mathematical formula for the current law, as used in parallel circuits.
6. The student will write the mathematical formula for solving total resistance in a parallel circuit.
7. Given a diagram of a parallel circuit, the student will solve for total resistance.
8. Given a diagram of a parallel circuit, the student will solve for total current.
9. Given a number of diagrams of parallel circuits, the student will solve for unknown voltages, currents, and resistances.
10. The student will write the law for voltage in parallel cell grouping.
11. The student will write the law for current in parallel cell grouping.
12. The student will write the law for resistance in parallel cell grouping.
13. Given a diagram of a circuit composed of dry cells wired in parallel, the student will solve for total voltage, total current, and total resistance.

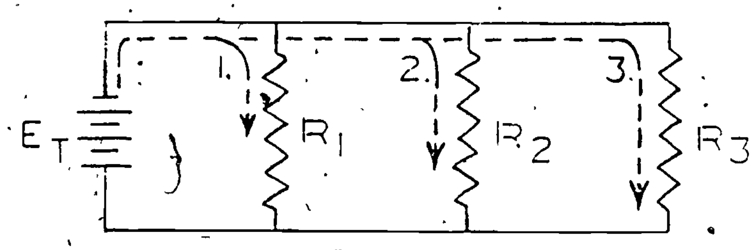
INTRODUCTION

Parallel circuits are used extensively in most modern homes and buildings. A common example of a use for parallel circuits is Christmas tree lights. With the older lights, when one bulb burned out, they would all go out. Those lights were wired in a series circuit. There was only one path for the current flow, and if that path was broken, everything quit. With the newer lights, however, if one light burns out, it does not affect the others. This is a parallel circuit. There is more than one path for the current flow. In a previous lesson, you learned that a series circuit is one that has two or more electrical components connected end to end so as to form only one path for the current flow. The first few frames are a brief review of what you should know about series circuits.

	1. The law for voltage in a series circuit states the total voltage is equal to the sum of the individual voltage drops. Therefore, in order to solve for total voltage in a series circuit, we simply _______ the individual voltage drops.
add	2. The law for current in a series circuit states the current in any one part of the circuit is equal to the current in any other part of the same circuit. Therefore, in order to solve for total current in a series circuit, we need only know the current in any other part of the same _______________.
circuit	3. The law for resistance in a series circuit states the total resistance is equal to the sum of the individual resistances. Therefore, in order to solve for total resistance in a series circuit, we simply add the individual _______________.
resistances	4. In this lesson, we will be working with the same components, but they will be connected a little differently. To be more specific, they will be connected in parallel. This lesson is about parallel circuits. NO RESPONSE REQUIRED.

CONTINUE ON NEXT PAGE

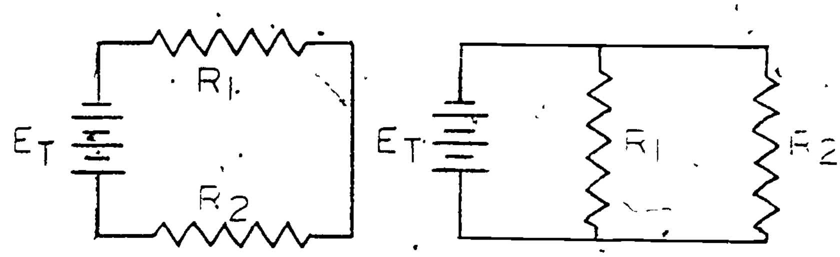
5. A parallel circuit is defined as a circuit having more than one path for the current flow. In the example of the parallel circuit shown below, notice there is more than one path for the current flow.



A circuit having more than one path for the current flow is a ______________ circuit.

parallel

6. If a parallel circuit has more than one path for the current flow, select from the sketches shown below the drawing most representative of a parallel circuit. (Circle correct answer.)

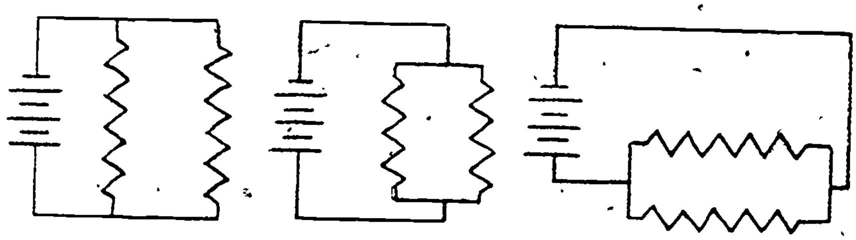
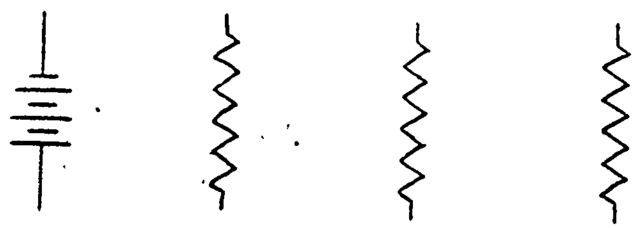


A B

B

7. Define a parallel circuit.

CONTINUE ON NEXT PAGE

A circuit having more than one path for current flow.	8. Now that we know the definition of a parallel circuit, let's look at some more examples of parallel circuits. The sketches shown below all represent parallel circuits, because each circuit has more than one path for the current flow.  Therefore, a parallel circuit is one having _______ than one path for the current flow.
more	9. Using the electrical symbols shown below, draw in the connecting lines to complete a parallel circuit having three (3) resistors in parallel. 

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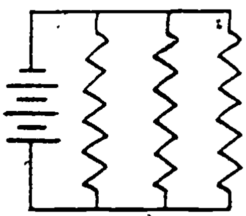
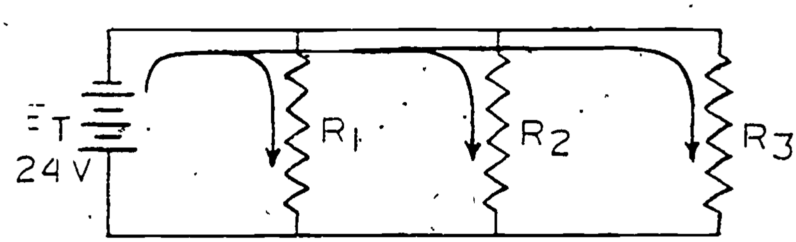


10. The next thing we are going to cover pertaining to parallel circuits is the law for voltage. The law for voltage in a parallel circuit states, the voltage across any one branch of a parallel circuit is equal to the voltage across any other branch of the same circuit. In other words, the voltage drop across each resistor will be the same as the total voltage. The voltage across any one branch of a parallel circuit is ____________ to the voltage across ____________ other branch of the same parallel circuit. This is a statement of the law for ________________ in a parallel circuit.

11. Now let's see how this law for voltage is applied to a parallel circuit. In the sketch below, notice that our source voltage (emf) is 24 volts. Now follow the arrows from the battery as they go to each resistor, and you will see that the full battery voltage reaches each resistor.



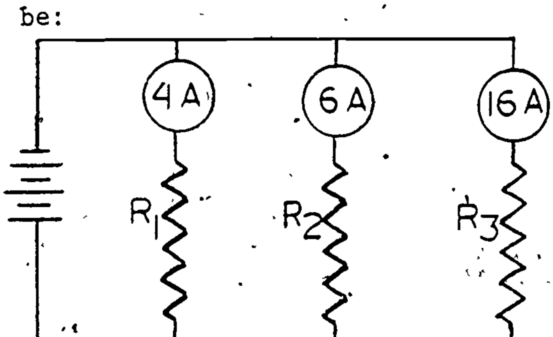
If the voltage across any one branch of a parallel circuit is equal to the voltage across any other branch of the same circuit, then the voltage across R_3 should be ____________ volts.

equal
any
voltage

CONTINUE ON NEXT PAGE

24 volts	12. The mathematical formula for the voltage law is $E_t = E_1 = E_2 = E_3$. Actually, this formula tells us the same thing that the voltage law tells us, and that is that the voltage across any one branch of a parallel circuit is equal to the voltage across any other branch of the same circuit. The mathematical formula for voltage in a parallel circuit is ________________.
$E_t = E_1 = E_2 = E_3$	13. Write the law for voltage in a parallel circuit.
The voltage across any one branch of a parallel circuit is equal to the voltage across any other branch of the same circuit.	14. Now that we have covered voltage in a parallel circuit, let's move on to the next topic, which is current in a parallel circuit. The law of current in a parallel circuit states the total current in a parallel circuit is equal to the sum of the individual branch currents. The total current in a parallel circuit is equal to the ________ of the individual branch currents. This is a statement of the law for __________ in a parallel circuit.

CONTINUE ON NEXT PAGE.

sum current	15. The mathematical formula for determining total current in a parallel circuit is $I_t = I_1 + I_2 + I_3$, or the total current (I_t) is equal to the current passing through the 1st branch (I_1), plus the current passing through the 2nd branch (I_2), plus the current passing through the 3rd branch (I_3). So in order to determine total current in a parallel circuit, the mathematical formula to use is ______ ______.
$I_t = I_1 + I_2 + I_3$	16. Therefore, the law for current in a parallel circuit states that the total current is equal to the ______ of the individual branch currents. The mathematical formula used to determine total current in a parallel circuit is $I_t =$ ______.
sum $I_t = I_1 + I_2 + I_3$	17. If the total current is equal to the sum of the individual branch currents in a parallel circuit, the total current in the circuit shown below would be:  $I_1 =$ 4a $I_2 =$ 6a $I_3 =$ 16a $I_t =$ ______
26a $I_t = I_1 + I_2 + I_3$	18. Write the law for current in a parallel circuit.

CONTINUE ON NEXT PAGE

Total current is equal to the sum of the individual branch currents.	19. The total current is equal to the sum of the individual branch currents. This is a statement of the law for ________ in a parallel circuit of which the mathematical formula is ________.
current $I_t=I_1+I_2+I_3$	20. Write the mathematical formula for the current law.
$I_t=I_1+I_2+I_3$	21. The next topic to be covered is the law for resistance in a parallel circuit. The law for resistance states the total resistance in a parallel circuit is always <u>smaller</u> than the <u>smallest</u> resistor in the circuit. The total resistance is always ________ than the smallest resistor in a ________ circuit.
smaller parallel	22. One method used to determine total resistance in a parallel circuit is by using the mathematical (reciprocal) formula which is $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. One method of determining total resistance in a parallel circuit is by using the formula $\frac{1}{R_t} =$ ________. This is known as the ________ formula.

CONTINUE ON NEXT PAGE

2F-73-9093

$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

mathematical
or
reciprocal

23. In a previous lesson, you were taught reciprocals. Just to refresh your memory, remember that the reciprocal of a number is a fraction with a numerator of 1 and a denominator of the number itself. As an example, the reciprocal of 5 would be $\frac{1}{5}$ and the reciprocal of 8 would be $\frac{1}{8}$. Match the numbers and their reciprocals shown below.

A. 6 — 1. $\frac{1}{2}$

B. 2 — 2. $\frac{1}{53}$

C. 53 — 3. $\frac{1}{26}$

D. 26 — 4. $\frac{1}{6}$

A. 4

B. 1

C. 2

D. 3

24. Now that you remember how to find the reciprocal of a number, let's talk about the reciprocal of a fraction. If you remember, you were taught that the reciprocal of a fraction is found by simply inverting the fraction, and then reducing to the lowest terms. In order to find the reciprocal of a fraction, we must ______________ the fraction and ______________ to the lowest terms.

CONTINUE ON NEXT PAGE

	25. In order to help refresh your memory, the following are some examples of reciprocals of fractions. The reciprocal of the fraction $\frac{2}{3}$ is $\frac{3}{2}$ and reduced to its lowest terms $1\frac{1}{2}$. The reciprocal of the fraction $\frac{3}{5}$ is $\frac{5}{3}$ and reduced to its lowest terms $1\frac{2}{3}$. Find the reciprocals of the following fractions: 1. $\frac{3}{8}$ __________ 2. $\frac{7}{8}$ __________ 3. $\frac{3}{4}$ __________ 4. $\frac{1}{2}$ __________
invert reduce	
1. $2\frac{2}{3}$ 2. $1\frac{1}{7}$ 3. $1\frac{1}{3}$ 4. 2	26. Up to this point, we have reviewed the reciprocal of a number and the reciprocal of a fraction. You have also previously learned that the symbol R_t stands for resistance total. The symbol R_t (resistance total) represents a number, doesn't it? Therefore, the reciprocal of R_t would be $\frac{1}{R_t}$, and the reciprocal of R_1 would be $\frac{1}{R_1}$, the reciprocal of R_2 would be $\frac{1}{R_2}$, etc. NO RESPONSE REQUIRED.
	27. Therefore, in order to determine total resistance in a parallel circuit, the mathematical (reciprocal) formula must be used. In order to determine the total resistance in a parallel circuit, the ________________ formula must be used.

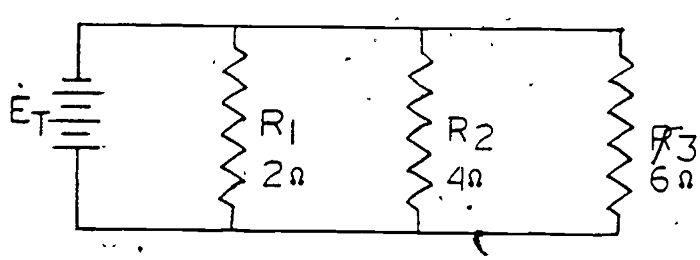
CONTINUE ON NEXT PAGE

mathematical or reciprocal	28. The mathematical (reciprocal) formula used to determine total resistance in a parallel circuit is $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. The mathematical (reciprocal) formula is used to determine total __________ in a parallel circuit.
resistance	29. Write the mathematical formula for total resistance in a parallel circuit.
$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	30. Now before we go any farther, let's review some of the things we have covered up to this point. This lesson is about __________ circuits.
parallel	31. A parallel circuit is defined as a circuit having __________ than one path for the current flow.
more	32. A __________ circuit has more than one path for the current flow.
parallel	33. In a parallel circuit, the voltage across any one branch is __________ to the voltage across any other branch of the same circuit.
equal	34. In a parallel circuit, the __________ voltage is applied across each resistor.

CONTINUE ON NEXT PAGE

total or same	35. The mathematical formula for total voltage in a parallel circuit containing three (3) resistors is $E_t =$ ____________.
$E_t = E_1 = E_2 = E_3$	36. The current law states that the total current in a parallel circuit is ________ to the sum of the individual branch currents.
equal	37. The total current is equal to the sum of the individual branch currents. This is a statement of the law for current in a ________ circuit.
parallel	38. The current law states that the ________ current is equal to the ________ of the individual branch currents.
total sum	39. The law for current in a parallel circuit states the total current is equal to ____________ ____________.
the sum of the individual branch currents	40. The mathematical formula for total current in a parallel circuit containing three resistors is $I_t =$ ____________.
$I_t = I_1 + I_2 + I_3$	41. In a parallel circuit, the total resistance is always ____________ than the smallest resistor in the circuit.

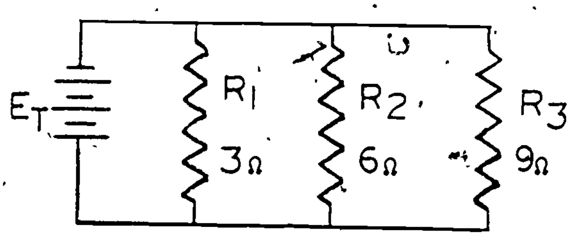
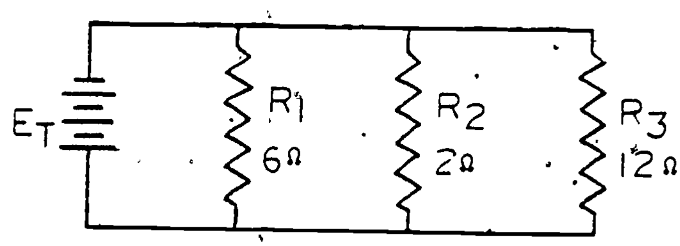
CONTINUE ON NEXT PAGE

smaller	42. Total resistance in a parallel circuit must be solved by using the ______________ formula.
mathematical or reciprocal	43. The mathematical (reciprocal) formula for total resistance in a parallel circuit is $\frac{1}{R_t}$ = ______________.
$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	44. Now that we have reviewed the laws and formulas of parallel circuits, it's time we started to work some problems. Just in case some of the formulas have slipped your mind, write them down so you can refer to them later. Ohm's Law-- $E = I \times R$ $I = \frac{E}{R}$ $R = \frac{E}{I}$ Law of Voltage-- $E_t = E_1 = E_2 = E_3$ Law of Current-- $I_t = I_1 + I_2 + I_3$ Law of Resistance-- $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ NO RESPONSE REQUIRED.
	45. In the following circuit, we will solve for R_t. Notice that the parallel circuit shown below has three resistors in parallel. They are $R_1 = 2\Omega$, $R_2 = 4\Omega$, and $R_3 = 6\Omega$. Keep in mind now that the reciprocal formula must be used to find total resistance.  The mathematical (reciprocal) formula for total resistance in a parallel circuit is $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. Therefore, replacing the letters with the values of the resistors in the circuit, we should now have $\frac{1}{R_t}$ = ______________.

CONTINUE ON NEXT PAGE

$\frac{1}{R_t} = \frac{1}{2} + \frac{1}{4} + \frac{1}{6}$	46. The next step in this problem is to do as the formula tells us: $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. To add the reciprocals of the individual resistances $(\frac{1}{2} + \frac{1}{4} + \frac{1}{6})$, we must first find the lowest common denominator. In this case, the lowest common denominator is ____.
12	47. Having found that the lowest common denominator is 12, we can now add $\frac{1}{2}$ or $\frac{6}{12}$, $\frac{1}{4}$ or $\frac{3}{12}$, and $\frac{1}{6}$ or $\frac{2}{12}$. Adding these reciprocals, we find that $\frac{1}{R_t}$ = ________.
$\frac{11}{12}$	48. We now know that the reciprocal of the total resistance $(\frac{1}{R_t})$ is equal to $\frac{11}{12}$, or to put it in mathematical terms, $\frac{1}{R_t} = \frac{11}{12}$. Now in order to find the total resistance, there are still a couple of things left for us to do. Our answer up to this point tells us we must find the reciprocal of the total resistance $(\frac{11}{12})$. In order to find the reciprocal of a fraction, we must ____________ that fraction.
invert	49. Now if we invert one part of our answer $(\frac{11}{12})$, we must invert the other part, $(\frac{1}{R_t})$. Hence our answer is $R_t = \frac{12}{11}$. Now our final step is to __________ to the lowest terms.

CONTINUE ON NEXT PAGE

reduce	50. R_t (resistance total) in this case now is $1\frac{1}{11}$ or 1.09 Ω. Remember that, in a parallel circuit, the total resistance is always smaller than the smallest resistor in the circuit. In this circuit, the smallest resistor is 2 Ω and the total resistance is 1.09 Ω. NO RESPONSE REQUIRED.
	51. Now that we have gone through one problem together, let's see if you can handle one by yourself. Keep some scratch paper handy, and in the following problem, solve for total resistance. Don't forget to use the reciprocal formula!  Answer ________
$1\frac{7}{11}$ Ω or 1.636 Ω	52. If you are still with us up to this point, let's try one more. If you're lost, return to frame 44 and review up to this point. Solve for total resistance.  Answer ________

CONTINUE ON NEXT PAGE

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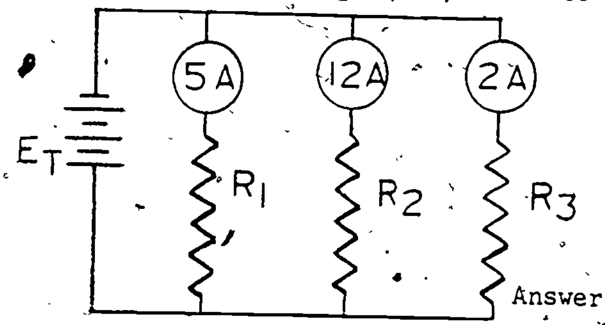
$1\frac{1}{3}\Omega$ or $1.33\,\Omega$

53. Now let's continue. The next thing we'll do is solve for I_t (current total). Remember, now, the total current is equal to the ______ of the individual branch currents. Mathematically, this is written as $I_t =$ ______.

sum

$I_t = I_1 + I_2 + I_3$

54. In the following problem, solve for total current:



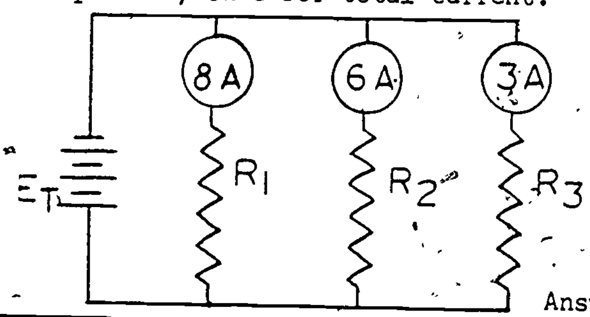
Answer ______

19 amps.

55. In the problem you just finished, each ammeter indicates the current going through each individual branch of the circuit. As shown, there are 5 amps. going through R_1, 12 amps. going through R_2, and 2 amps. going through R_3. In order to find the total current (I_t), we simply ______ the branch currents.

add

56. **All right, let's try one more. In the following** problem, solve for total current:



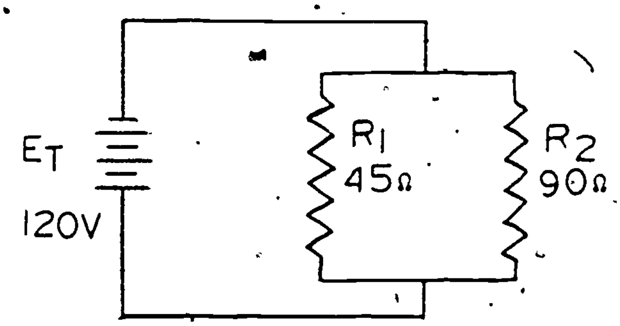
Answer ______

CONTINUE ON NEXT PAGE

17 amps.

57. Now that we have worked a few problems solving for total resistance (R_t) and for total current (I_t), let's combine these and solve for all the unknowns, both current and resistance. We are now going to have to use Ohm's Law along with the various laws we have learned for current, resistance, and voltage in a parallel circuit. NO RESPONSE REQUIRED.

58. Before we get going, let's try working a problem together, and in the next 12 frames we will solve for all the unknowns in the following circuit:



E_1= ________ I_1= ________

E_2= ________ I_2= ________

I_t= ________ R_t= ________

This circuit represents a parallel circuit, because there is ________ than one path for the current flow.

CONTINUE ON NEXT PAGE

Complete answer will be found in a later frame in the program. more	59. First of all, let's solve for E_1 and E_2. As you learned earlier in the lesson, the voltage across any one branch of a parallel circuit is equal to the voltage across any other branch of the same circuit, or $E_t=E_1=E_2=E_3$. So if the total voltage (E_t) is 120v, then E_1 should be ________ volts and E_2 should be ________ volts.
120 120	60. Now briefly return to frame 58 and insert the answer for E_1 and E_2. The next thing we can do is solve for resistance total (R_t). Remember, we must use the reciprocal formula. Therefore, the reciprocal of R_1 (45) would be ________ and the reciprocal of R_2 (90) would be ________.
$\frac{1}{45}$ $\frac{1}{90}$	61. There are only two (2) resistors in this circuit, so our reciprocal formula would read $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$, or $\frac{1}{R_t} = \frac{1}{45} + \frac{1}{90}$. Now our next step is to find the ________ common denominator, which in this case is ________.
lowest 90	62. With 90 as the lowest common denominator, our problem should now read $\frac{1}{R_t} = \frac{2}{90} + \frac{1}{90}$ or $\frac{1}{R_t} = \frac{3}{90}$. In order to find the reciprocal of the total resistance, we must ________ the fraction.

CONTINUE ON NEXT PAGE

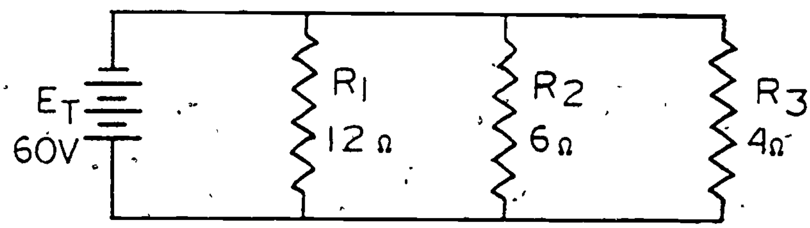
invert	63. Once we have inverted, our problem should now look like this: $R_t = \frac{90}{3}$. But, we still have one more thing to do and that is ________ to the lowest terms.
reduce	64. In order to reduce to the lowest terms, we must divide 90 by 3. This will give us an R_t of ______ ohms.
30	65. Now briefly return to frame 58 and insert the answer for R_t. Well, this leaves us just I_1, I_2, and I_t to solve. As you can see, we cannot use the mathematical formula for finding total current just yet, because I_1 and I_2 are not known. So, let's find the values of I_1 and I_2. NO RESPONSE REQUIRED.
	66. Here is where we are going to have to put Ohm's law to use. Let's start with I_1. We do not know the value of I_1, but we do know that the value of E_1 is 120v and the value of R_1 is 45Ω. So in order to solve for current using Ohm's law, the formula to use is $I = \frac{E}{R}$. In order to solve for I_1 in this problem, we must use ________ law, of which the formula is ____________.
Ohm's $I = \frac{E}{R}$	67. Using Ohm's law, and substituting the values for the letters $I = \frac{E}{R}$, we now have $I = \frac{120}{45}$. Therefore, $I_1 = \frac{E_1}{R_1}$ or $I_1 = \frac{120}{45}$, which gives us ________ amps.

CONTINUE ON NEXT PAGE

2.666 or 2.67 amps.	68. Briefly return to frame 58 and insert your answer for I_1. Now I_2 can be solved by the same method. We know the value of E_2 is 120v and the value of R_2 is 90Ω; so using Ohm's law once again ($I = \frac{E}{R}$), we can determine the value of I_2. In this case, $I_2 = \frac{E_2}{R_2}$ or $I_2 = \frac{120}{90}$, which gives us ________ amps.
1.33 amps.	69. Once again return to frame 58 and insert your answer for I_2. Now all we have left to do is solve for I_t, and this is no problem because we know that the mathematical formula for finding total current is $I_t = I_1 + I_2 + I_3$. Naturally, in this case, there are only two (2) resistors, so the formula would read $I_t = I_1 + I_2$, and I_t would be ________.
4.0 amps.	70. Now return to frame 58 and insert your answer for I_t. You should now have solved for all the unknowns, and all your answers should be written down in frame 58. Your answers should be as follows: E_1 = 120v I_1 = 2.67a E_2 = 120v I_2 = 1.33a I_t = 4.0a R_t = 30 Ω NO RESPONSE REQUIRED.

CONTINUE ON NEXT PAGE

71. If your answers are the same as those shown in the previous frame, then you're ready to try another problem. If your answers are not the same, return to frame 58 and review up to frame 70. All right, in the following problem, solve for the unknowns:



E_1 = ____	I_1 = ____	R_1 = 12Ω
E_2 = ____	I_2 = ____	R_2 = 6Ω
E_3 = ____	I_3 = ____	R_3 = 4Ω
E_t = 60v	I_t = ____	R_t = ____

E_1 = 60v
E_2 = 60v
E_3 = 60v
E_t = 60v

I_1 = 5a
I_2 = 10a
I_3 = 15a
I_t = 30a

R_1 = 12Ω
R_2 = 6Ω
R_3 = 4Ω
R_t = 2Ω

72. Up to this point, we have been studying voltage, current, and resistance in a parallel circuit. Now let's see how this all applies when wiring cells together (either dry or wet cells) in parallel. This wiring of cells together in parallel is referred to as parallel cell grouping. NO RESPONSE REQUIRED.

CONTINUE ON NEXT PAGE

	73. Just as in parallel circuits, there are laws that apply to parallel cell grouping for voltage, current, and resistance. The law for voltage in parallel cell grouping states the total voltage of a group of cells wired in parallel is the same as the voltage of a single cell. The total voltage of a group of cells wired in parallel is the ____________ as the voltage of a ____________ cell.
same single	74. The total voltage of a group of cells wired in parallel is the same as the voltage of a single cell. This is a statement of the law for ____________ in parallel ____________ grouping.
voltage cell	75. Because the total voltage is the same as the voltage of a single cell in parallel cell grouping, the mathematical formula we can use to determine total voltage will be the same as the one we used for parallel circuits: $E_t = E_1 = E_2 = E_3$. In order to solve for total voltage in parallel cell grouping, the formula we must use is E_t = ____________
$E_t = E_1 = E_2 = E_3$	76. Write the law for voltage in parallel cell grouping.

CONTINUE ON NEXT PAGE

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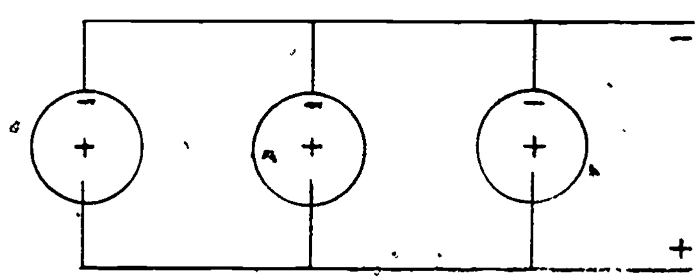
The total voltage of a group of cells wired in parallel is equal to the voltage of a single cell.	77. The next thing we will cover about parallel cell grouping will be the law for current. The law for current in parallel cell grouping states the total current from parallel cell grouping is equal to the sum of the currents available from each cell. The total current from parallel cell grouping is equal to the ______ of the currents available from ______ cell.
sum each	78. The total current from parallel cell grouping is equal to the sum of the currents available from each cell. This is a statement of the law for ______ in parallel ______ grouping.
current cell	79. The total current from parallel cell grouping is equal to the ______ ______.
sum of the currents available from each cell	80. Since the total current is equal to the sum of the currents available from each cell, the mathematical formula we can use to determine total current from parallel cell grouping will be the same as the one we used for parallel circuits: $I_t = I_1+I_2+I_3$. Therefore, in order to solve for total current in parallel cell grouping, the formula we must use is $I_t =$ ______.

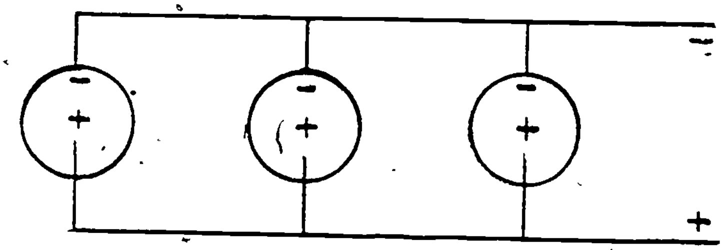
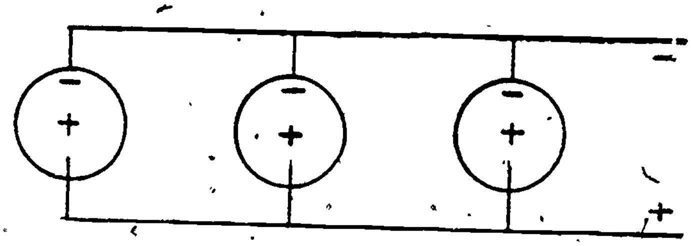
CONTINUE ON NEXT PAGE

$I_t = I_1 + I_2 + I_3$	81. Write the law for current in parallel cell grouping. ______________________ ______________________ ______________________
The total current from parallel cell grouping is equal to the sum of the currents available from each cell	82. Finally, we must cover resistance in parallel cell grouping. The law for resistance in parallel cell grouping states <u>the total resistance in parallel cell grouping is always smaller than the resistance of any one of the cells</u>. In parallel cell grouping, the total resistance is always __________ than the resistance of any one of the __________.
smaller cells	83. The total resistance in parallel cell grouping is always smaller than the resistance of any one of the cells. This is a statement of the law for __________ in parallel __________ grouping.
resistance cell	84. The total resistance in parallel cell grouping is always ______________________ ______________________.
smaller than the resistance of any one of the cells	85. In solving for total resistance in a parallel circuit, we had to use the reciprocal formula, $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$. Since the same formula is used in solving for total resistance in parallel cell grouping, the mathematical formula we must use is $\frac{1}{R_t} =$ __________.

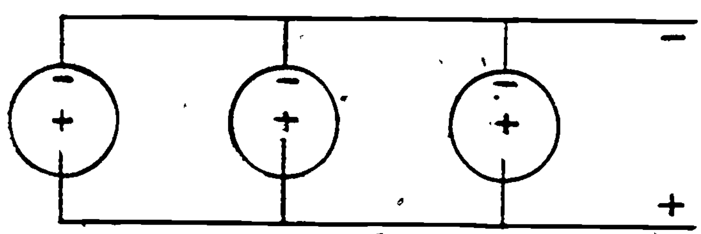
CONTINUE ON NEXT PAGE

$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	86. Write the law for resistance in parallel cell grouping.
The total resistance in parallel cell grouping is always smaller than the resistance of any one of the cells.	87. Now that we have gone through the laws for voltage, current, and resistance in parallel cell grouping, it's time we worked some problems in parallel cell grouping. Just to refresh your memory, here are the mathematical formulas once again: Ohm's Law $E = I \times R$ $I = \frac{E}{R}$ $R = \frac{E}{I}$ Law of Voltage $E_t = E_1 = E_2 = E_3$ Law of Current $I_t = I_1 + I_2 + I_3$ Law of Resistance $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ NO RESPONSE REQUIRED.
	88. In the circuit shown below consisting of three cells wired in parallel, solve the total voltage, when each cell is delivering 1.5v of emf.  Answer:

CONTINUE ON NEXT PAGE

1.5v	89. In the problem you just completed, if you remembered the correct mathematical formula to use, you should not have had a bit of trouble. Remember, you were looking for E_t, and you were told that each cell delivered 1.5v. Therefore, $E_t = E_1 = E_2 = E_3$ or $E_t = 1.5 = 1.5 = 1.5$. In the following circuit of three cells wired in parallel, solve for total current if each cell is delivering 30 amps. of current.  Answer ______
90 amps.	90. If you got 90 amps. for your answer, this is very good, because it shows that you used the correct mathematical formula, $I_t = I_1 + I_2 + I_3$. Now let's try working a problem solving for total resistance in parallel cell grouping. In the following problem, solve for total resistance, if the resistance of each cell is .05Ω. Don't forget the reciprocal formula!  Answer ______

CONTINUE ON NEXT PAGE

.0166 Ω or .017 Ω	91. Just in case you had trouble with the last problem, let's go through it together. Using the reciprocal formula $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ and inserting the values, we should now have $\frac{1}{R_t} = \frac{1}{.05} + \frac{1}{.05} + \frac{1}{.05}$ or $\frac{1}{R_t} = \frac{3}{.05}$. Now our next step should be to invert the fraction and reduce to the lowest terms. Inverting the fraction then would give us $R_t = \frac{.05}{3}$. Now our final step is to reduce to the lowest terms, which means we must divide .05 by 3. The result for R_t is ______ ohms.
.0166 or .017	92. All **right**, let's try working another problem on parallel cell grouping. In the following problem, solve for total voltage, total current, and total resistance:  E_1 = 1.5v I_1 = .25a R_1 = 6Ω E_2 = 1.5v I_2 = .25a R_2 = 6Ω E_3 = 1.5v I_3 = .25a R_3 = 6Ω E_t = ____ I_t = ____ R_t = ____

CONTINUE ON NEXT PAGE

$E_t = 1.5v$ $I_t = .75a$ $R_t = 2\Omega$	93. Now that you have completed the entire lesson on parallel circuits and parallel cell grouping, let's review everything that was covered. A parallel circuit is defined as a circuit having ______ than one path for the current flow.
more	94. A circuit that has more than one path for the current flow is known as a ______ circuit.
parallel	95. In a parallel circuit, the ______ voltage is applied across each component.
total	96. Since the total voltage is applied across each component in a parallel circuit, the voltage will be the ______ across any branch of the same circuit.
same	97. In a parallel circuit, the voltage across any branch is ______ to the voltage across any other branch of the same circuit.
equal	98. The law for voltage in a parallel circuit states the voltage across any one branch is ______ to the voltage across any other branch of the same circuit.
equal	99. Write the law for voltage. ______ ______

CONTINUE ON NEXT PAGE

The voltage across any one branch of a parallel circuit is equal to the voltage across any other branch of the same circuit.	100. The mathematical formula for total voltage of a parallel circuit that has three (3) resistors is E_t = ______________.
$E_t = E_1 = E_2 = E_3$	101. Since there is more than one path for current flow in a parallel circuit, the current will divide itself between the different ______________.
paths or branches	102. Therefore, the total current in a parallel circuit is equal to the ______________ of the individual branch currents.
sum	103. The current law states that the total current in a parallel circuit is ______________ to the sum of the individual branch currents.
equal	104. The current law states that the ______________ current is equal to the ______________ of the individual branch currents.
total sum	105. Write the current law for parallel circuits. ______________ ______________.
Total current is equal to the sum of the individual branch currents	106. The mathematical formula for total current in a parallel circuit containing three (3) resistors is I_t = ______________.

CONTINUE ON NEXT PAGE

$I_t = I_1 + I_2 + I_3$	107. The total resistance in a parallel circuit is always smaller than the ______ resistor in the circuit.
smallest	108. The law for resistance in a parallel circuit states that the total resistance is always ______ than the ______ resistor in the circuit.
smaller smallest	109. Write the law for resistance in a parallel circuit. ______ ______
The total resistance is always smaller than the smallest resistor in the circuit	110. If the total voltage (E_t) and the total current (I_t) are not known in a parallel circuit, then the total resistance (R_t) must be solved by using the ______ formula.
reciprocal	111. The mathematical (reciprocal) formula for finding total resistance in a parallel circuit is $\frac{1}{R_t}$ = ______.
$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	112. A number of dry cells wired together in parallel are referred to as parallel cell ______.
grouping	113. The law for voltage in parallel cell grouping states that the total voltage (E_t) of a group of cells connected in parallel is the same as the voltage of a ______ cell.

CONTINUE ON NEXT PAGE

single	114. Write the law for voltage in parallel cell grouping. ______________________________ ______________________________
The total voltage of a group of cells connected in parallel is the same as the voltage of a single cell	115. Therefore, the total voltage (E_t) from parallel cell grouping would be the same as the ________ of any ________ cell.
voltage one/single	116. The mathematical formula that can be used to determine total voltage (E_t) from parallel cell grouping is E_t = ________________.
$E_t = E_1 = E_2 = E_3$	117. The law for current in parallel cell grouping states that the total current (I_t) from parallel cell grouping is equal to the ________ of the currents available from each cell.
sum	118. Write the law for current in parallel cell grouping. ______________________________ ______________________________ ______________________________.
The total current from parallel cell grouping is equal to the sum of the currents available from each cell	119. So, in parallel cell grouping, to determine total current (I_t), we simply ________ the currents available from each cell.

CONTINUE ON NEXT PAGE

add	120. The mathematical formula for finding total current (I_t) in parallel cell grouping is I_t = ________.
$I_t = I_1+I_2+I_3$	121. The law for resistance in parallel cell grouping states that the total resistance in parallel cell grouping is always ________ than the resistance of any one of the cells.
less/smaller	122. The total resistance is always smaller than the resistance of any one of the cells. This is a statement of the law for ________ in parallel cell grouping.
resistance	123. Write the law for resistance in parallel cell grouping. ________ ________ ________.
Total resistance in parallel cell grouping is always smaller than the resistance of any one of the cells	124. If the total voltage (E_t) and the total current (I_t) are not known in parallel cell grouping, then the total resistance must be solved by using the ________ formula.
reciprocal	125. The mathematical (reciprocal) formula for finding total resistance from parallel cell grouping is $\frac{1}{R_t}$ = ________.

CONTINUE ON NEXT PAGE

$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	This is the end of the lesson on parallel circuits. If there is anything you do not understand, feel free to refer to any frame in the program you desire. Finally, return to the learning objectives, read them again; if you can do what they require, you are ready to take the self-test.

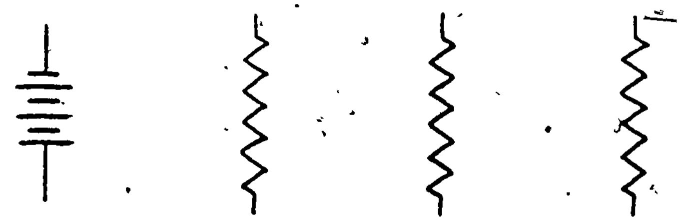
SELF-TEST

1. A parallel circuit is defined as: ______________________________

____

____

2. Using all the components shown below, draw the connecting lines to complete a parallel circuit.



3. The law for voltage in a parallel circuit states that:

Mathematically, this is written as:

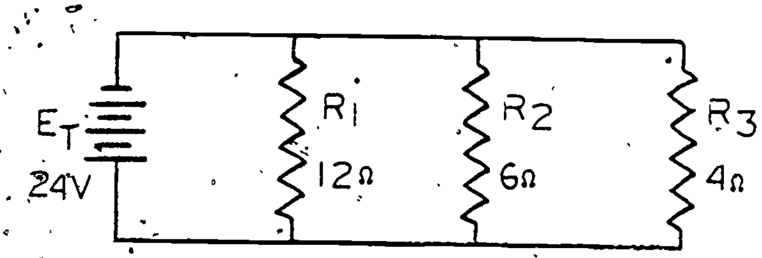
4. The law for current in a parallel circuit states that:

5. Write the mathematical formula for current in a parallel circuit.

6. Write the mathematical (reciprocal) formula for total resistance in a parallel circuit.

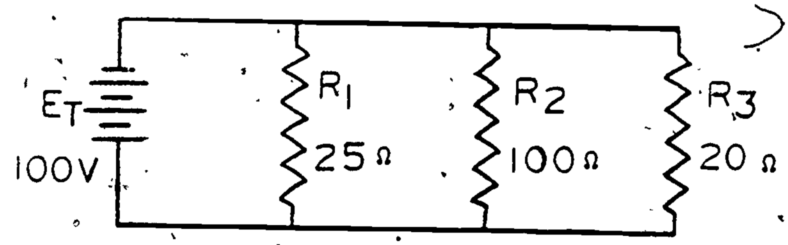
A

7. From the parallel circuit shown below, solve for R_t (resistance total).



E_1 = 24v	I_1 = ______	R_1 = 12Ω
E_2 = 24v	I_2 = ______	R_2 = 6Ω
E_3 = 24v	I_3 = ______	R_3 = 4Ω
E_t = 24v	I_t = ______	R_t = ______

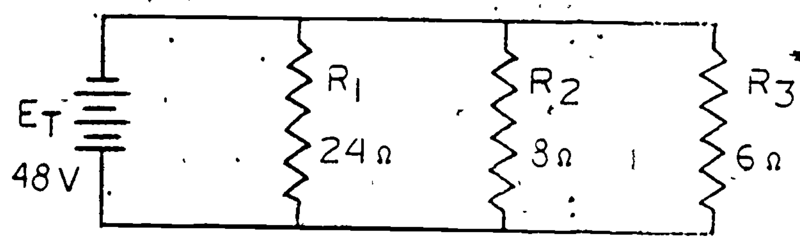
8. From the parallel circuit shown below, solve for total current.



E_1 = 100v	I_1 = ______	R_1 = 25Ω
E_2 = 100v	I_2 = ______	R_2 = 100Ω
E_3 = 100v	I_3 = ______	R_3 = 20Ω
E_t = 100v	I_t = ______	R_t = ______

9. In the following problems, solve for unknown voltages, currents, and resistance:

PROBLEM I



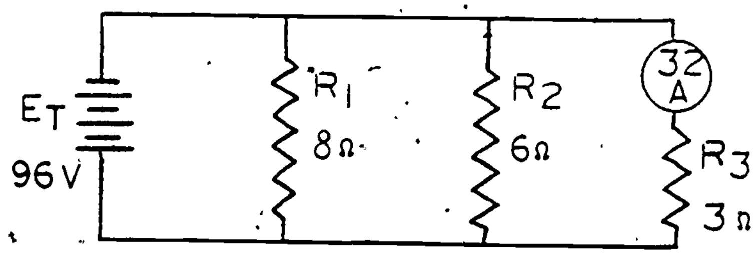
E_1 = ______ I_1 = ______ R_1 = 24 Ω

E_2 = ______ I_2 = ______ R_2 = 8 Ω

E_3 = ______ I_3 = ______ R_3 = 6 Ω

E_t = 48v I_t = ______ R_t = ______

PROBLEM II



E_1 = ______ I_1 = ______ R_1 = 8 Ω

E_2 = ______ I_2 = ______ R_2 = 6 Ω

E_3 = ______ I_3 = 32a R_3 = 3 Ω

E_t = 96v I_t = ______ R_t = 1.6 Ω

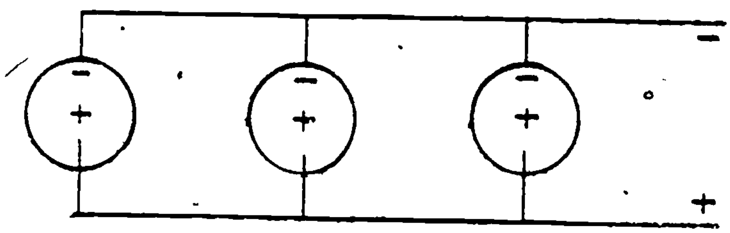
10. The law for voltage in parallel cell grouping states:

11. The law for current in parallel cell grouping states:

C

12. The law for resistance in parallel cell grouping states:

13. From the parallel cell grouping shown below, solve for total voltage, total current, and total resistance.



E_1 = 1.5v	I_1 = .25a	R_1 = 6Ω
E_2 = 1.5v	I_2 = .25a	R_2 = 6Ω
E_3 = 1.5v	I_3 = .25a	R_3 = 6Ω
E_t =	I_t =	R_t =

D

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PREPARE THE MAN 2TPT-3100-02

Technical Training

OHM'S LAW—SERIES CIRCUITS

May 1967

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SHEPPARD AIR FORCE BASE

Original Material Prepared
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Naval Air Technical Training Command

Designed For ATC Course Use

502

OHM'S LAW

LIST OF OBJECTIVES

1. Show what happens to current in a simple circuit when the resistance is increased with the voltage held constant.

2. Show what happens to current in a simple circuit when the resistance is decreased with the voltage held constant.

3. Show what happens to current in a simple circuit when the voltage is increased with the resistance held constant.

4. Show what happens to current in a simple circuit when the voltage is decreased with the resistance held constant.

5. Write the three forms of Ohm's Law.

6. Given values of resistance and voltage in a simple circuit, solve for the current.

7. Given values of current and voltage in a simple circuit, solve for the resistance.

8. Given values of resistance and current in a simple circuit, solve for the voltage.

9. Write a complete statement of Ohm's Law.

SUGGESTED READING TIME 50 MINUTES

5038

ASSIGNMENT SHEET

This assignment sheet should be used when:

- You are to complete only a part of this text.
- Your assignment within this text is divided into two or more reading periods.

Your instructor will make assignments by identifying specific objectives, text material, and review questions.

ASSIGNMENTS

OBJECTIVES (by No)	TEXT MATERIAL (by page and/or frame)	REVIEW QUESTIONS (by No)

The study of electronics at first glance appears to be extremely complicated, and many students feel that they will never master the subject. In reality, however, the theory of electronics rest on a few relatively simple concepts.

One of these concepts expresses the relationship that exists between current, voltage, and resistance. The relationships of current, voltage, and resistance were first reduced to a formula by a German physicist named George Simon Ohm in the early part of the nineteenth century. These relationships are expressed in Ohm's Law: in an electrical circuit, current varies directly with the voltage and inversely with the resistance.

	1. The law relating to voltage, current, and resistance is ____________ Law.
Ohm's	2. If the voltage is not changed, and resistance is increased, the current will ____________. (increase/decrease)
decrease	3. The single letter for resistance is R. The single letter for voltage or emf is ( ). And for current, the letter is ( ).
E I	4. Ohm's Law relates to ____________, ____________, and ____________.
current, voltage, resistance (any order)	5. Ohm's Law states: The current in a circuit depends on the circuit resistance and ____________.
voltage	6. The current in a circuit varies directly with voltage and inversely with the ____________.

Continue on page 3

2A

YOUR ANSWER: An ampere is equal to resistance times voltage.
(From P-7B)

No. This is a wild attempt at rendering Ohm's Law in different form. In addition, it is a hopelessly imprecise statement.

In expressing any scientific law, you have to be precise about the quantities involved. "An" ampere means "one" ampere. Your answer seems to say, "one ampere is equal to an indefinite amount of resistance multiplied by an indefinite amount of voltage."

To make matters worse, the form in which you have met Ohm's Law so far is E = I x R, current (in amperes) equals voltage divided by resistance. That's something we'll come to shortly.

To get back to the question: Do you recall what an ampere is? It is another way of saying electrons are flowing past a given point at the rate of one coulomb per second, isn't it?

Bear that in mind as you return to Page 7B to select another answer.

2B

YOUR ANSWER: The unit in which I is measured is the ohm.
(From P-5)

No. And since you are apparently still uncertain about what unit measures which quantity, or which letter is the symbol for which quantity, here they are again.

Resistance (denoted by the letter R) is measured in ohms.

Voltage (denoted by the letter E) is measured in volts.

Current (denoted by the letter I) is measured in amperes.

Return to Page 5 for the correct answer.

resistance	7. If the resistance is not changed and the voltage is increased, the current will ________. (increase/decrease)
increase	8. In symbols, Ohm's Law states $I = \frac{E}{R}$. If E = 100 volts and R = 20 ohms, $I = \frac{100}{20} = 5$ amps. If E = 175 volts and R = 25 ohms, I = ( ) amps.
7 amps	9. In symbols, Ohm's Law is written ________.
$I = \frac{E}{R}$	10. Current varies directly with voltage. When E increases, I increases. When E decreases, I ________.
decreases	11. E is emf. E is the force used to push the electrons through the conductor. The larger E is, the ________ current flows. (more / less)
more	12. R is resistance. It tries to hold back or resist the current flow. If R gets larger, the ________ current flows. (more / less)
less	13. The more the resistance, the ________ the current. The more the emf, the ________ the current.
less more	14. Current varies directly with ________. (resistance/voltage) Current varies inversely with ________.

Continue on Page 5

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4A

YOUR ANSWER: Voltage is the electrical pressure needed to move
(From P-8B) a coulomb through one ohm of resistance.

Almost, but not quite.

Somewhere in that statement you need a reference to time. You can say, for instance, that a volt is the electrical pressure needed to move one coulomb through one ohm of resistance in one second.

You could say that voltage is electromotive force and that it is measured in volts.

Unfortunately, neither of these complete answers is available to you.

There is another way of arriving at voltage, and that is through Ohm's Law. If you know the resistance and the current present in a circuit, you can calculate voltage.

And that should be enough of a hint for you to return to Page 8B and select the correct answer.

4B

YOUR ANSWER: One coulomb of electrons flowing past a given point
(From P-7B) in one second.

Correct. One of the wrong answers, "The electrons that will flow through a standard column of mercury" is not a complete statement. If it had been stated as: "The number of electrons that will flow through a standard column of mercury in one second when one volt of electrical pressure is being applied," it would have been accurate.

Now, what does E stand for?

Resistance.	Page 6B
Voltage.	Page 8B
Current.	Page 10B

5A	
voltage resistance	15. Which formula is correct for Ohm's Law? $I = \frac{R}{E}$, $I = \frac{E}{R}$, $I = ER$
$I = \frac{E}{R}$	16. If the resistance in a circuit increases, voltage held constant, the current will ________.
decrease	17. Write the formula for Ohm's Law: I =
$\frac{E}{R}$	18. We know from algebra that a formula can be rewritten so as to solve for different parts. If $A = \frac{B}{C}$, THEN $C = \frac{B}{A}$, and $B = AC$. If $I = \frac{E}{R}$, THEN R = ( ), and E = ( ).
$R = \frac{E}{I}$ $E = IR$	19. The ohm has been agreed to be the amount of resistance offered to electrical current by a <u>column of mercury</u> of standard specification.

The atomic structure of a material is the greatest determining factor for the resistance of that material. An aluminum bar of the same dimensions as the standard column of mercury would not have a resistance of one ohm.

Ohm's Law can be summed up: Current (I) equals Voltage (E) divided by Resistance (R).

$$I = \frac{E}{R}$$

What is the unit in which I is measured?

The ohm. Page 2B

The ampere. Page 7B

The volt. Page 9A

509

6A

YOUR ANSWER: Voltage can be found by multiplying resistance times current flow.
(From P-8B)

Ohm's Law, E = IR. Right you are. The statement that voltage is the electrical pressure needed to move a coulomb through one ohm of resistance was almost correct as a definition of one volt. But it lacked a time factor. If it had been modified in either of two ways, it would have been correct:

1. A volt is the amount of electrical pressure needed to move one coulomb through one ohm in one second, or
2. A volt is the amount of electrical pressure needed to move one ampere through one ohm.

The Greek letter Omega, which looks like this Ω, is the abbreviation for ohm. The shorthand for volt is simply v, that for amperes is a: We could say:

$$v = a\ \Omega.$$

That statement is true. It is Ohm's Law written in different symbols. However, it is not proper usage. Now, here is a problem which illustrates the proper usage:

If E = 24v and R = 96 Ω, what is I?

I = .25a. Page 8A

I = 4a. Page 11A

I = 2304a. Page 13A

6B

YOUR ANSWER: E stands for resistance.
(From P-4B)

Oh, come now!

E is the symbol for voltage, or, if you like, electromotive force.

As you have just seen, I is the symbol for current and R is the symbol for resistance.

Return to Page 4B, vowing never to forget that I stands for current, E for voltage, and R for resistance.

7A

YOUR ANSWER: In a circuit with an 80-volt battery and a 20-ohm resistor, the current will be 1600 amperes.
(From P-8A)

That's an awful lot of current for this or any other circuit. Let's see where you went wrong in your calculation.

We said that if $E = IR$, that formula could be solved for I merely by dividing both sides of the equation by R, and that step would produce $I = \frac{E}{R}$. This means that to solve for I in our circuit, we'll have to divide our voltage, 80v, by our resistance, 20 ohms.

Make sure that you understand this process, then return to Page 8A and select the correct answer.

7B

YOUR ANSWER: The ampere.
(From P-5)

Right. Current is measured in amperes.

What is an ampere equal to?

Resistance times voltage.	Page 2A
One coulomb of electrons flowing past a given point in one second.	Page 4B
The electrons that will flow through a standard column of mercury.	Page 9B

511

8A

YOUR ANSWER: .25a.
(From P-6A)

If you got that answer right the first time, you did well, because you discovered one of the two variations of Ohm's Law. We began with this: E = IR. The variation is written:

$$I = \frac{E}{R}$$

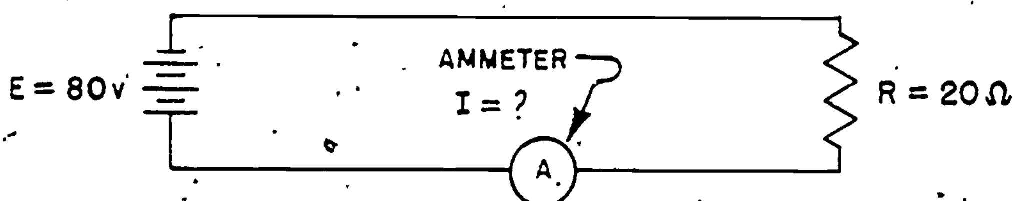
It is used when E and R are shown and you need to find I.

Of course, both the original statement and the variation are the same thing. If E = IR, then

$$I = \frac{E}{R}$$

It is perfectly legitimate to perform the same mathematical operation to both sides of an equation. To change Ohm's Law for purposes of discovering current, we merely divided both sides of the equation by R.

In the circuit shown below, solve for I.



1600 amperes	Page 7A
4 amperes	Page 11B
.25 ampere	Page 14B

8B

YOUR ANSWER: Voltage.
(From P-4B)

Good for you. E stands for voltage. This is not as hard to remember as it may seem. Voltage is the unit in which we measure electromotive force (EMF, as it is called).

Which of the following would be an accurate statement about voltage?

Voltage is the electrical pressure needed to move a coulomb through one ohm of resistance.	Page 4A
Voltage can be found by multiplying resistance times current.	Page 6A
Voltage is the electromotive force of a standard column of mercury.	Page 10A

68-9234 2P

9A

YOUR ANSWER: The unit in which I is measured is the volt.
(From P-5)

No. And since you are apparently still uncertain about which quantity it measures, or which letter is the symbol for which quantity, here they are again.

Resistance (denoted by the letter R) is measured in ohms.

Voltage (denoted by the letter E) is measured in volts.

Current (denoted by the letter I) is measured in amperes.

Return to Page 5 for the correct answer.

9B

YOUR ANSWER: An ampere is equal to the electrons that will flow through a standard column of mercury.
(From P-7B)

No. You have begun to say something. But you have not finished.

Amperes denote coulombs-per-second. Your answer is an incomplete statement, because it contains no mention of the time involved or the quantity of electrons.

You can't just splash around with words and hope they come out right -- not in electronics, at any rate.

One of the alternative statements is much more precise. Return to Page 7B and select that one for your answer.

10A

YOUR ANSWER: Voltage is the electromotive force of a standard column of mercury.
(From P-8B)

No. This is one of those answers that doesn't really say anything. It would be as sensible to say that voltage is the electromotive force of a stick of licorice.

A standard column of mercury got into the conversation as the standard by which resistance was measured. The standard column of mercury supplied a resistance of one ohm, through which it was possible to pass a current of one ampere by applying a voltage of one volt.

And, you may recall, that led us to Ohm's Law in the form E = IR -- voltage equals current times resistance.

You should now be well enough informed to return to Page 8B and select the correct answer.

10B

YOUR ANSWER: E stands for current.
(From P-4B)

No. No. And again, no. You've seen enough of these symbols by now to be able to recognize them.

E is the symbol for voltage, or, if you like, electromotive force.

As we saw just a moment ago, the symbol for current is I. And R is the symbol for resistance.

Return to Page 4B, vowing never to forget that I stands for current, E for voltage, and R for resistance.

11A

YOUR ANSWER: 4a.
(From P-6A)

Wrong. Here is the problem again: If $E = 2v$ and $R = 96\Omega$, what is the value of I?

Ohm's Law as we have considered it so far says: $E = IR$.

Obviously, we need it in different form, since I is the unknown quantity.

To isolate I, divide both sides of the equation by R. This gives you:

$$\frac{E}{R} \quad \frac{IR}{R}$$

Thus I = E/R = 24 volts/96 ohms = ? amperes.

Return to Page 6A with the correct answer.

11B

YOUR ANSWER: In a circuit with an 80-volt battery and a 20-ohm
(From P-8A) resistor, the current will be <u>4 amperes</u>.

Good. We used our Ohm's Law formula,

$$I = \frac{E}{R}$$

simply by plugging in the given values:

$$I = \frac{80 \text{ volts}}{20 \text{ ohms}}, \quad I = 4 \text{ amperes.}$$

If E and I are known, but not R, how would we vary the formula?

$R = \frac{I}{E}$	Page 12B
$R = \frac{E}{I}$	Page 15B
You can't find R from the other two factors.	Page 16B

515

12A

YOUR ANSWER: .05 Ω.
(From P-15B)

Wrong. You've got things topsy-turvy.

The equation you should be working with says:

$$R = \frac{E}{I}$$

The equation you seem to have used says:

$$R = \frac{I}{E}$$

Go back to the version you should have used and, when you have the answer, return to Page 15B.

12B

YOUR ANSWER: $R = \frac{I}{E}$
(From P-11B)

No. You're getting tangled up in transposing this equation.

We know that Ohm's Law can be expressed E = IR.

In a case where we do not know the value of R, the equation can be adjusted to isolate R by dividing both sides by I, like this:

$$\frac{E}{I} = \frac{\not{I}R}{\not{I}}$$

You see that the top and bottom I in the right-hand group cancel each other, leaving the final equation:

$$R = \frac{E}{I}$$

Work it over once more for yourself and then return to Page 11B for another answer.

13A

YOUR ANSWER: 2304a.
(From P-6A)

Wrong. Here is the problem again: If $E = 24v$ and $R = 96\ \Omega$, what is the value of I?

Ohm's Law as we have considered it so far says: $E = IR$. Obviously, we need it in different form, since I is the unknown quantity.

To isolate I, divide both sides of the equation by R. This gives you:

$$\frac{E}{R} \quad \frac{I\cancel{R}}{\cancel{R}}$$

Thus $I = E/R = 24$ volts/96 ohms = ? amperes.

Return to Page 6A with the correct answer.

13B

YOUR ANSWER: .03 ohm.
(From P-18A)

No. You seem to have divided the voltage into the current, and this procedure will never give you a reasonable answer. Remember,

$$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}} \text{ or } R = \frac{E}{I}.$$

We have arrived at this form of Ohm's Law by solving for R in the formula $E = IR$.

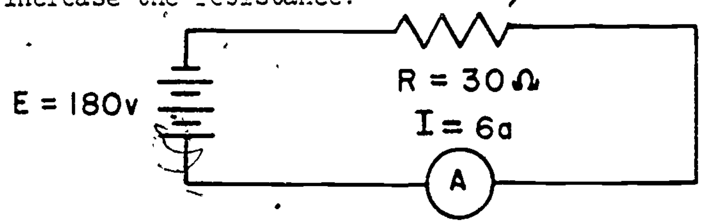
All you have to do is substitute the given values for E and I and perform the indicated division. Return to Page 18A and select the correct answer.

517

14A

YOUR ANSWER: 30 ohms.
(From P-18A)

Very good. Now, what would happen to the current in the circuit if we were to increase the resistance?



Increase.	Page 17B
Decrease.	Page 18B
Remain the same.	Page 20B

14B

YOUR ANSWER: In a circuit with an 80-volt battery and a 20 -ohm resistor, the current will be .25 ampere.
(From P-8A)

No. You seem to have divided the resistance by voltage rather than the voltage by the resistance.

We said that in our Ohm's Law formula, E = IR, we could solve for I simply by dividing both sides of the equation by R. Then, I would equal E divided by R.

Now, simply substituting the given values of the circuit in the formula for I, you should come up with the correct answer. Return to Page 8A.

15A

YOUR ANSWER: 2 volts.
(From P-18B)

Wrong. Obviously, you needed prompting after all on the form of Ohm's Law to be used.

You should have been back with the first version of the formula, the one you should have committed to memory. Here it is again. Memorize it.

$$E = IR$$

In this case, we know that R = 10 ohms and I = 2 amperes.

E = IR = 2 amperes x 10 ohms = ? volts.

Return to Page 18B with the correct answer.

15B

YOUR ANSWER: $R = \frac{E}{I}$
(From P-11B)

Right. In this case, both sides of the equation are divided by I. So, Ohm's Law can be written in three different ways, depending on which variable is unknown. The three ways are:

$$E = IR \qquad R = \frac{E}{I} \qquad I = \frac{E}{R}$$

Now, if you are given E = 6 and I = .3a, what is R?

.05 Ω.	Page 12A
.2 Ω.	Page 16A
20 Ω.	Page 18A

16A

YOUR ANSWER: 2 Ω.
(From P-15B)

No. Decimals can be a nuisance, but ignoring them won't make them go 'way.

The equation you need is the version of Ohm's Law with which we began the last page, R = E/I.

If we apply that to the present problem, in which E = 6v and I = .3a, we get:

R = E/I = 6 volts/.3 ampere = ? ohms.

Complete the calculation, this time allowing for the decimal point, and return with your answer to Page 15B.

16B

YOUR ANSWER: You can't find R from the other two factors.
(From P-11B)

Your mathematics is coming unstuck.

In an equation involving three factors, if you know any two, you can find the third.

You have an example in Ohm's Law when it is expressed E = IR. If you do not know E but have values for I and R, then multiplying together the known values will give you the value of E. That is what the equation tells us.

And if we divide both sides of the original equation by I, we can obtain an equation which isolates R and expresses it in terms of the other values, like this:

$$\frac{E}{I} = \frac{\not{I}R}{\not{I}}, \text{leaving } R = \frac{E}{I}.$$

If you have trouble in following this, substitute simple numbers for the factors in the original equation, thus: Instead of E = IR, write 12 = 3 x 4. If you want to isolate the factor 4, divide both sides of the equation by 3, like this:

$$\frac{12}{3} = \frac{\not{3} \times 4}{\not{3}}, \text{leaving } 4 = \frac{12}{3}.$$

This method of substituting simple figures for factors within a formula is useful as a check in many cases.

And now, return to Page 11B and select the correct answer.

17A

YOUR ANSWER: 1080 ohms.
(From P-18A)

No. That's far too much resistance to allow 6 amperes of current flow with only 180 volts applied to the circuit.

To solve for R in the formula E = IR, we must divide both sides of the equation by I. This will isolate R on one side of the equation:

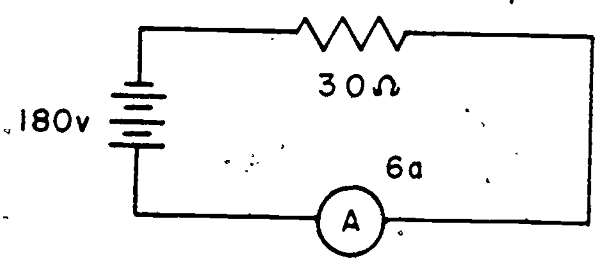
$$E = IR, \quad \frac{E}{I} = \frac{IR}{I}, \quad \frac{E}{I} = \frac{\not{I}R}{\not{I}} \quad R = \frac{E}{I}$$

Now substitute the values for E and I that are given in the problem, do the indicated division, and select the correct answer on Page 18A.

17B

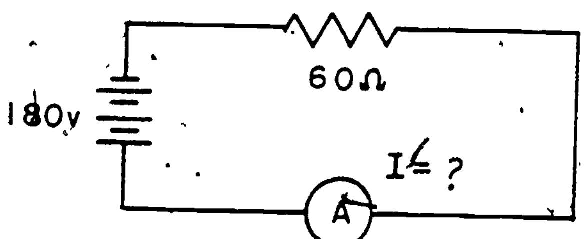
YOUR ANSWER: In our circuit, if we were to increase the resistance, the current would increase.
(From P-14A)

No. No, <u>no</u>. It wasn't too long ago that you agreed with us when we said that resistance was an opposition to current flow, and that if we increased resistance, we would have less current, unless we increased the voltage. Let's actually increase the resistance in this circuit.



$I = \frac{E}{R} = \frac{180}{30} = 6$ amps

Increasing the resistance to 60 ohms:



$I = \frac{E}{R} = \frac{180}{60} =$ ___?___ amps

What happened to I?

Return to Page 14A and select the correct answer.

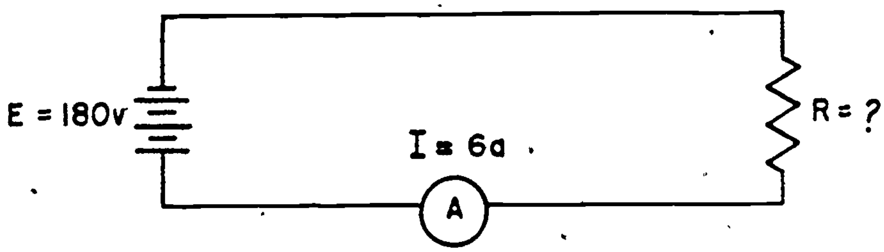
521

18A

YOUR ANSWER: 20 ohms. Correct.
(From P-15B)

$$R = \frac{E}{I} = \frac{6}{.3} = 20 \text{ ohms.}$$

Now solve this problem:



.03 ohm. Page 13B

30 ohms. Page 14A

1080 ohms. Page 17A

18B.

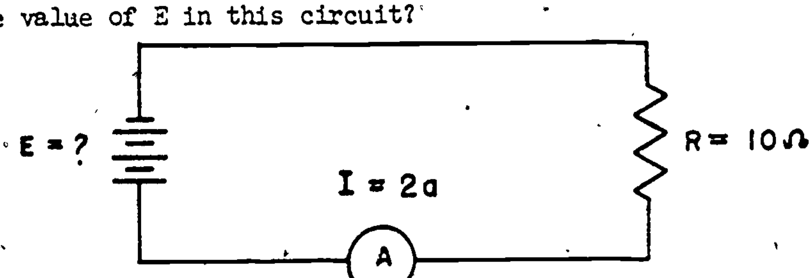
YOUR ANSWER: The current would decrease in a circuit if the value of
(From P-14A) the resistance increased.

Right you are. If we look at it mathematically, we can see that I will decrease if R is increased.

$$I = \frac{E}{R}$$

An increase in R will cause it to go less times into E, thereby giving us a smaller figure for I.

Now without any prompting on the form of Ohm's Law you're to use, what is the value of E in this circuit?



2 volts. Page 15A

5 volts. Page 21B

20 volts. Page 22A

19A

YOUR ANSWER: 1.2 volts.
(From P-22A)

Wrong. This looks like a guess that was guided by the form of the answers. And if it wasn't, then your arithmetic isn't working too well today.

Let's go over the simple calculation: The resistance is 6 ohms, the current is .02 ampere The equation you need to find the voltage is E = IR.

E = IR = .02 ampere x 6 ohms = ? volts.

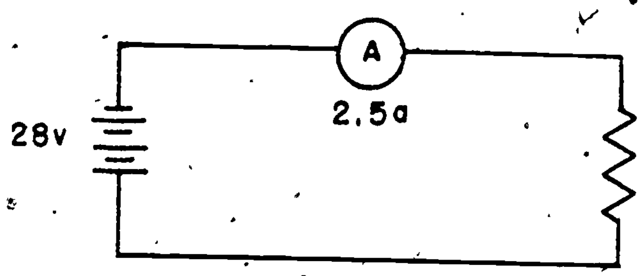
When you have the answer, return to Page 22A.

19B

(From P-27)

To fix more firmly in your mind the relationship which Ohm's Law expresses, we'll conclude this lesson by working some circuit problems for practice.

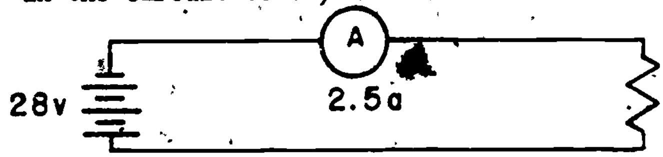
In the circuit below, what is the value of resistance?



1.12 ohms.	Page 20A
60 ohms.	Page 22B
11.2 ohms.	Page 26B

20A

YOUR ANSWER: (From P-19B) In the circuit below, R = 1.12 ohms.



No. You seem to be having trouble with your decimal point here. Your calculation should look like this:

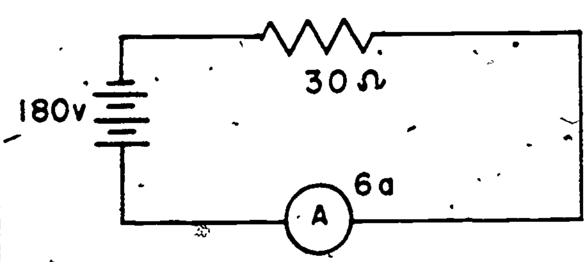
$$R = \frac{E}{I} \qquad R = \frac{28v}{2.5a}$$

Now divide 2.5 into 28, watching that decimal point, and return to Page 19B for the correct number.

20B

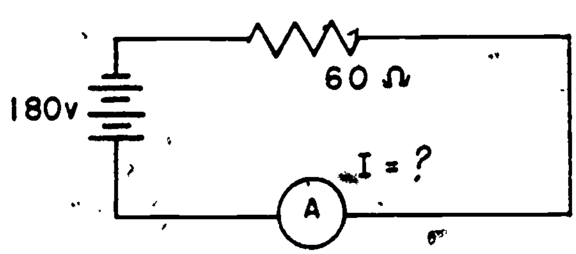
YOUR ANSWER: (From P-14A) In our circuit, if we increase the resistance, there will be no change in the amount of current.

No. And you know better than that, don't you? It wasn't too long ago that you agreed with us when we said that resistance was an <u>opposition</u> to current flow, and that if we increased resistance, we would have less current, unless we increased the voltage. Let's actually increase the resistance in this circuit.



$$I = \frac{E}{R} = \frac{180}{30} = 6 \text{ amps}$$

Increasing the resistance to 60 ohms:



$$I = \frac{E}{R} = \frac{180}{60} = \underline{\quad ? \quad} \text{ amps}$$

Do you still think that current would remain the same? Return to Page 14A and select the correct answer.

21A

YOUR ANSWER: Not 1.2 volts.
(From P-22A)

Correct. This is the calculation:

$E = IR$ .02 x 6 = .12 volts

This form of Ohm's Law, $E = IR$, is the most important and most often used version. In addition, it has the advantage that it is the easiest version to convert to other forms. Merely dividing both sides by the unwanted quantity will leave you a desired quantity at the right.

Pages 25 and 27 will require that you answer fill-in-type questions. Although the material will seem simple to you now, DO NOT rush through it. Read the material given, think out the answer, and then write it in the space provided. The correct answer to the question will appear to the left of the next question. Use the card provided to cover the answer until you have written your answer in the space provided. Move card down and cover answer of next question and continue down the page.

One more word on how to answer the questions: Don't move your card until you have written your answer. You are not graded on your answers, but you must decide on an answer before you move your card to check it.

Now turn to Page 25 and continue.

21B

YOUR ANSWER: 5 volts.
(From P-18B)

Wrong. Obviously, you needed prompting after all on the form of Ohm's Law to be used.

You should have been back with the first version of the formula, the one you should have committed to memory. Here it is again. Memorize it.

$$E = IR$$

In this case, we know that R = 10 ohms and I = 2 amperes.

E = IR = 2 amperes x 10 ohms = ? volts.

Return to Page 18B with the correct answer.

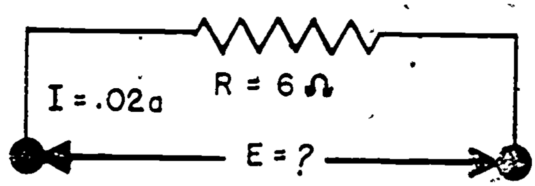
22A.

YOUR ANSWER: 20 volts.
(From P-18B)

Correct. $E = IR = 2 \times 10 = 20$ volts.

Keep in mind what the letter E stands for: It is voltage, the unit of measurement for electromotive force. Voltage is really a measurement of the difference in electrical pressure between two points. It is the difference in electrical pressure between two points. It is this difference in pressure that exerts the force to make electrons move from one point (the point of higher pressure) to another point (the point of lower pressure).

What is the emf of this circuit?



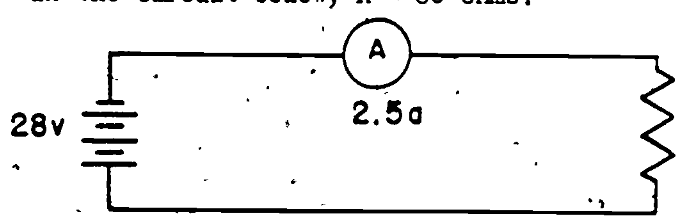
1.2 volts. Page 19A

Not 1.2 volts. Page 21A

I don't know. Page 24A

22B

YOUR ANSWER: In the circuit below, R = 60 ohms.
(From P-19B)

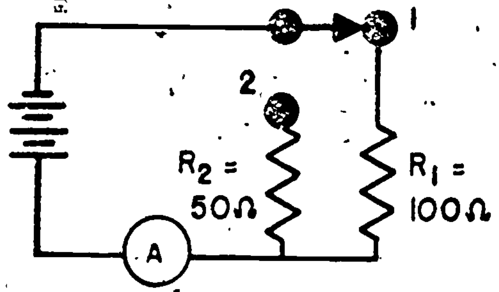


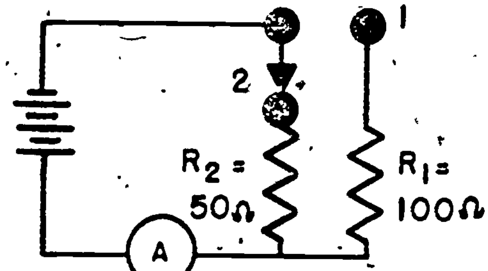
No. The only way you could have arrived at this answer would have been to multiply the current by the voltage, and that isn't at all consistent with Ohm's Law, is it?

To solve for R, the form of Ohm's Law we must use is $R = \frac{E}{I}$. Substitute the given values for voltage and current, complete the calculation, then return to Page 19B and select the correct answer.

23A

YOUR ANSWER: In the circuit below, if the switch is moved to position 2, the current will increase.
(From P-30B)





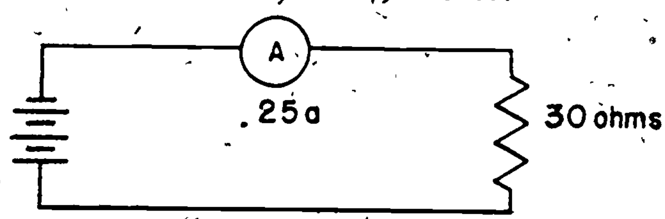
Correct. Switching to position 2 took R_1, the 100-ohm resistor, out of the circuit and put R_2 in its place. Now R_2 is determining how much current will flow, and since it is smaller than R_1, the current will increase.

In a circuit with 75 volts applied and 18 amperes of current flowing, what is the resistance?

4.2 ohms.	Page 26A
42 ohms.	Page 29A
1350 ohms.	Page 30A

23B

YOUR ANSWER: In the circuit below, E = 750 volts.
(From P-26B)



No. And that decimal point seems to be causing all the trouble.

Since we want to find the voltage, and Ohm's Law states that E = IR, we simply multiply .25 by 30.

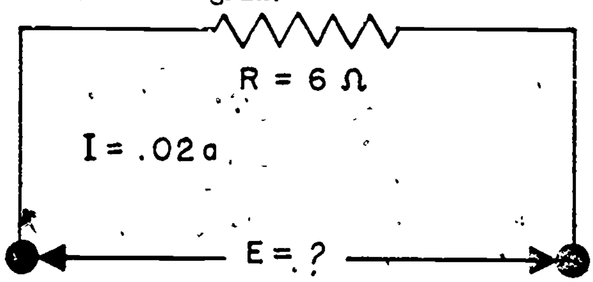
Complete the calculation, watching the decimal point, and return to Page 26B for the correct answer.

527

24A

YOUR ANSWER: I don't know.
(From P-22A)

There's nothing new in the text at this point. Is it the diagram that bothers you? Here it is again:



And the only thing that is new about this diagram is the method of showing the voltage source. This is the reason for the reminder that preceded it: "Voltage is a measurement of the difference in electrical pressure between two points. It is this difference in pressure that makes electrons move from one point (the point of higher pressure) to another point (the point of lower pressure)."

In this diagram, we are showing a voltage source without indicating just what form that source takes -- it might be a battery, it might be a generator, it could be that this is an offshoot of some larger circuit. You are not told what it is, and it doesn't matter what it is, as far as the problem is concerned. The important thing is that voltage is being imposed on this circuit and that it is causing a current of .02 ampere.

Once again, the voltage can be found by using the E = IR form of the Ohm's Law formula. When you have a value of E, return to Page 22A and select the correct answer.

528

	1. In a circuit, if we hold the voltage constant and increase the resistance, the current will ________. (increase/decrease.)
(decrease)	2. We can see from the formula $I = \frac{E}{R}$ that, as the resistance gets very large, only a small amount of current will flow. As R gets larger, I gets ______.
(smaller)	3. If we decrease the resistance, we would expect the current to ______________(increase/decrease).
(increase)	4. This indicates that resistance and current vary in the (same/opposite) directions.
(opposite)	5. Another way to express this relationship is to say that current and resistance are ______________ (directly/inversely) proportional.
(inversely)	6. When two quantities are inversely proportional, and one of them increases, the other must ________.
(decrease)	7. Ohm's Law states that E = IR. The variation of Ohm's Law that we can use to find current is I = ____________.
$(\frac{E}{R})$	8. If we increase resistance, the ________will decrease.
(current)	9. If the current has increased, and the voltage hasn't changed, then the resistance must have ______________.
(decreased)	10. In a circuit, the amount of __________ flowing is inversely proportional to the ______________.
(current) (resistance)	11. If we increase the amount of voltage pushing the current through a resistor, we have more current flowing. As E gets larger, I gets ____________.
(larger)	12. In a circuit, when we increase the voltage, holding the resistance constant, the current will ________ (increase/decrease).

Go to Page 27.

26A

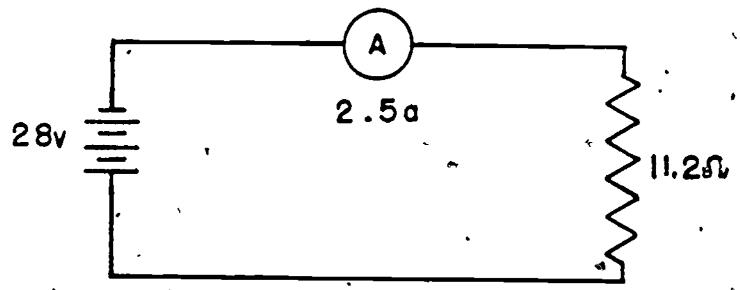
YOUR ANSWER: (From P-23A) In a circuit with 75 volts applied and 18 amperes of current flowing, the resistance is 4.2 ohms.

Correct. $R = \frac{E}{I} = \frac{75}{18} = 4.2$ ohms.

This completes this lesson.

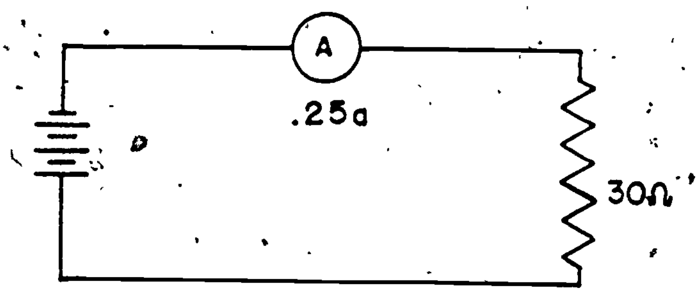
26B

YOUR ANSWER: (From P-19B) In the circuit below, R = 11.2 ohms.



Correct. $R = \frac{E}{I}$ was the form of Ohm's Law to be used here, and dividing 28 volts by 2.5 amperes resulted in 11.2 ohms for the value of resistance in this circuit.

What is the voltage applied to the circuit below?



750 volts.	Page 23B
120 volts.	Page 29B
7.5 volts.	Page 30B

(increase)	13. If we decrease the voltage, we can expect the current to ______________ (increase/decrease).
(decrease)	14. This indicates that current and voltage vary in the ______________ (same/opposite) direction.
(same)	15. Another way to express the relationship between current and voltage is to say that they are ______________ (inversely/directly) proportional.
(directly)	16. When two quantities are directly proportional and one of them decreases, the other must ________
(decrease)	17. If we increase the voltage, ________ will increase.
(current)	18. If current decreases, and the resistance hasn't changed, then the voltage must have ____________.
(decreased)	19. In a circuit, the amount of __________ flowing is directly proportional to the __________ applied.
(current) (voltage)	20. In a circuit, the amount of current flowing is ______________ proportional to the resistance and __________ proportional to the voltage applied.
(inversely) (directly)	21. Current is directly proportional to the ________ and inversely proportional to the __________.
(voltage) (resistance)	22. Ohm's Law states that in a circuit, the amount of ________ flowing is __________ proportional to the __________ applied to the circuit and ________ proportional to the ______________.
(current) (directly) (voltage) (inversely) (resistance)	23. Mathematically, this is stated as ______________ ______________ (write all three forms of Ohm's Law).
$(E = IR)$ $(I = \frac{E}{R})$ $(R = \frac{E}{I})$	

24. Continue on Page 19B

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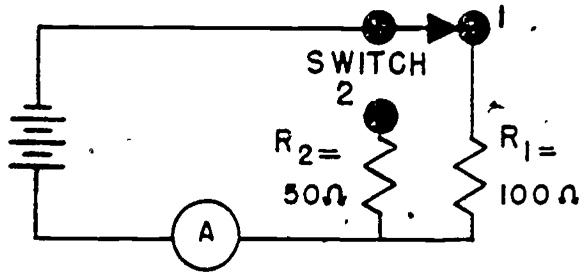
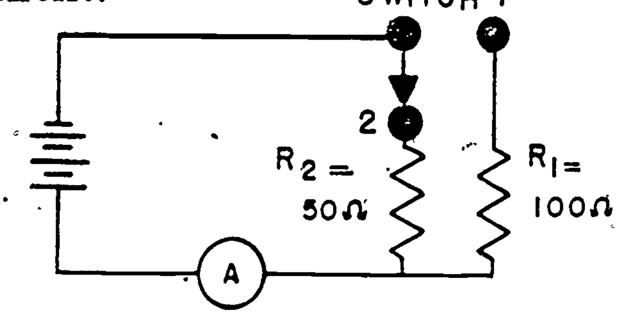
28A

YOUR ANSWER: (From P-30B) In the circuit below, if the switch is moved to position 2, the current will decrease.



No. Perhaps the function of the switch has confused you. Notice above that, in position 1, the switch allows current to flow from the battery through R_1, the 100-ohm resistor.

When we move the switch down to position 2, no current can flow through R_1, and now R_2, the 50-ohm resistor, is determining how much current will flow in the circuit.



You should be able to see that by moving the switch to position 2, we have decreased the opposition to one-half of what it was in position 1. Now the question to ask yourself is: What happens to current when we decrease the resistance. After consulting with George Simon Ohm, return to Page 30B for the correct answer.

29A

YOUR ANSWER: (From P-23A) In a circuit with 75 volts applied and 18 amperes of current flowing, the resistance is 42 ohms.

No. That decimal point is causing the trouble here. Using the form of Ohm's Law to solve for resistance,

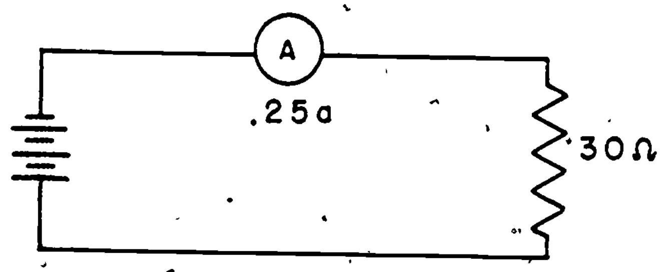
$$R = \frac{E}{I},$$

we substitute our known values of voltage and current, $R = \frac{75}{18}$, and...

Now finish the calculation, watching that decimal point, and return to Page 23A for the correct answer.

29B

YOUR ANSWER: (From P-26B) In the circuit below, E = 120 volts.



Wrong. And the way you tried to solve this problem raises some doubts about your knowledge of Ohm's Law. The only way you can arrive at your answer is by dividing the resistance by the current, and this is not Ohm's Law.

The correct form of the law to use when solving for voltage is E = IR. Substitute the values given in the problem for current and resistance, complete the calculation, and select the correct answer on Page 26B.

30A

YOUR ANSWER: In a circuit with 75 volts applied and 18 amperes
(From P-23A) of current flowing, the resistance is 1350 ohms.

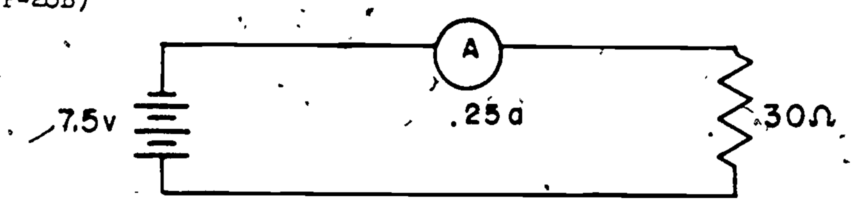
No. And you certainly didn't apply Ohm's Law properly to arrive at this answer. You seem to have multiplied the voltage by the current, and Ohm's Law states that to find resistance, we must divide the voltage by the current.

$$R = \frac{E}{I}$$

Return to Page 23A and select a better answer.

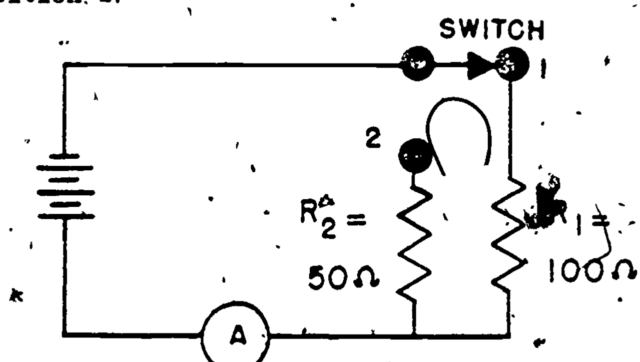
30B

YOUR ANSWER: In the circuit below, E = 7.5 volts.
(From P-26B)



Correct. E = IR was the form of Ohm's Law we had to use, and simply multiplying the values given for current and resistance gave us the voltage applied to the circuit.

In the circuit below, what will happen to the current if the switch is moved to position 2?



Current will increase. Page 23A

Current will decrease. Page 28A

TECHNICAL TRAINING

ELECTRICITY-ELECTROMAGNETISM

June 1975

SHEPPARD AIR FORCE BASE

Original Material Prepared
by
Naval Air Technical Training Command

Designed For ATC Course Use

DO NOT USE ON THE JOB

535

ASSIGNMENT SHEET

This assignment sheet should be used when:

- You are to complete only a part of this text.
- Your assignment within this text is divided into two or more reading periods.

Your instructor will make assignments by identifying specific objectives, text material, and review questions.

ASSIGNMENTS

OBJECTIVES (by No)	TEXT MATERIAL (by page and/or frame)	REVIEW QUESTIONS (by No)

This supersedes 2TPT-3112-04, May 1967 (Copies of the superseded publication may be used until stock is exhausted.)

ELECTROMAGNETISM

OBJECTIVES

1. List at least four electrical devices made possible by the invention of the electromagnet.

2. Write the definition of electromagnetism.

3. Given a sketch of a straight electrical conductor, with current direction known, determine and mark the direction of travel of the lines of force.

4. Given a sketch of a straight electrical conductor, with direction of lines of force known, determine and mark the direction of current flow.

5. Given a sketch of a straight electrical conductor, showing only the symbols (+) (-), determine and mark the direction of current flow and lines of force.

6. Given a sketch of a pair of straight electrical conductors showing only the symbols (+) (-), demonstrate a knowledge of "magnetic effects around straight conductors" by sketching in the lines of force. Also, indicate probable movement of conductors in respect to each other.

7. Given a sketch of a coiled conductor, with electron flow marked by the symbols (+) (-), determine the north and south poles of the coil and mark sketch accordingly.

8. Write the definition of an electromagnet.

9. List the ways in which a solenoid differs from an electromagnet.

10. Given an otherwise completed sketch of an electromagnet, with current flow being indicated by the symbols (+) (-), determine and label the north and south poles.

11. List the reasons soft iron is used for the core of an electromagnet.

12. List at least two ways in which the strength of an electromagnet may be increased.

13. Write the definition of "residual magnetism."

14. Define a "relay switch."

15. List at least two parts of a relay switch.

16. Write the definition of a solenoid relay switch.

17. List the ways in which the solenoid relay switch differs from a plain relay switch.

18. List at least three uses of a solenoid relay switch in the aviation field.

SUGGESTED READING TIME 137 MINUTES

	1. Now that you have learned about magnetism, our next step in the field of electricity is to learn something about electromagnetism. Don't let that word throw you. Actually, it is the link between electricity and magnetism. In 1819, Hans Christian Oersted(er-stet), a Danish physicist, found that a small compass needle was deflected when brought near a conductor carrying an electric current. This was the first evidence of a link between electricity and magnetism. As a result of this discovery, the electromagnet was invented. NO RESPONSE REQUIRED.
	2. As a result of the invention of the electromagnet, we now have electric motors and generators. Since the invention of the electromagnet, we have been enjoying the conveniences furnished by electric _______________ and _______________.
motors generators	3. The electromagnet is also the basis for many other devices used in aviation such as buzzers, relay switches, magnetic circuit breakers, meters, etc. A few of the electrical devices made possible by the invention of the electromagnet include, but are not limited to meters __________, __________ __________, and __________ __________.

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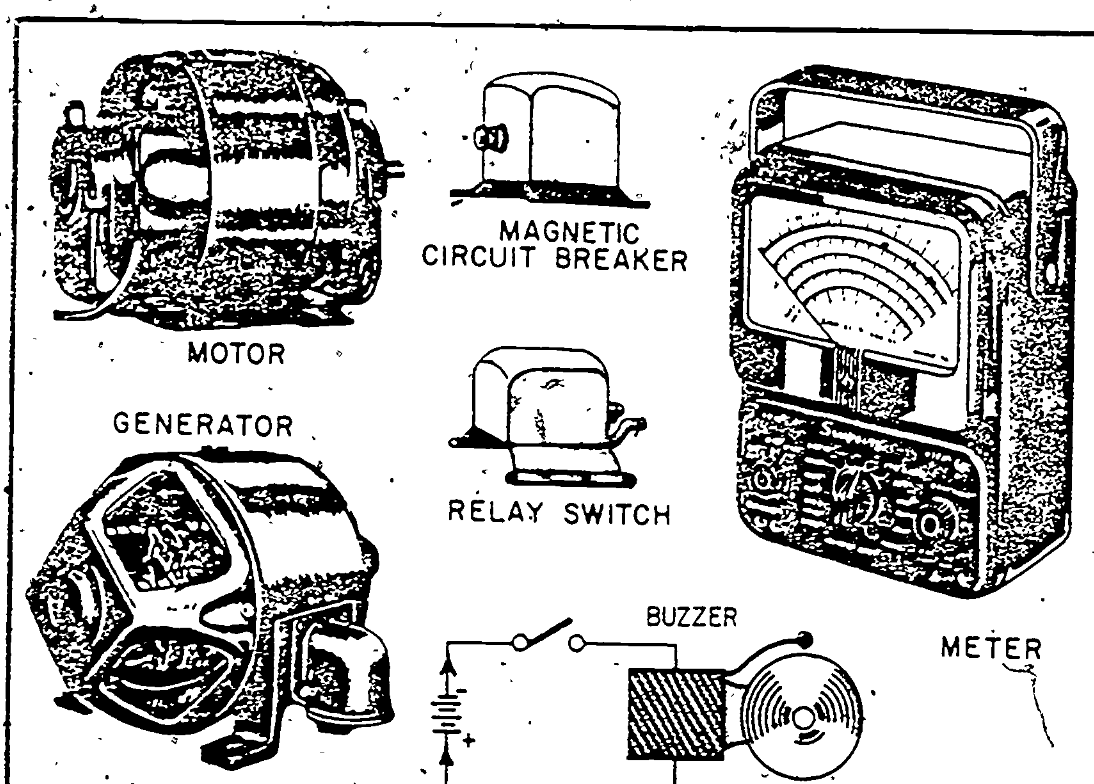

buzzers relay switches magnetic circuit breakers	4. Electrical devices made possible by the invention of the electromagnet are motors, ____________, buzzers, relay ________, magnetic circuit ____________, and ____________.
generators switches breakers meters	5. List six electrical devices made possible by the invention of the electromagnet. ____________ ____________ ____________ ____________ ____________ ____________
motors, generators, magnetic circuit breakers, relay switches, meters, buzzers.	6. Anytime current flows through a conductor, there will be a magnetic field set up around the conductor. Therefore, electromagnetism is magnetism produced by a ____________ flow.

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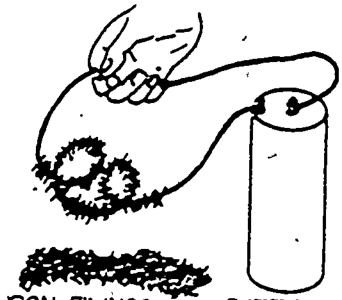

current	7. If iron filings are placed in the vicinity of a conductor with a current flow, as shown in the above illustration, the iron filings are attracted to the conductor, indicating the presence of a magnetic force. In the above illustration, magnetism is being produced by a ____________ ____________.
current flow	8. The result of producing magnetism by current flow would be called electro____________.
magnetism	9. Electromagnetism is magnetism produced by a ____________ ____________.
current flow	10. The definition of electromagnetism is ____________ produced by a ____________ ____________.
magnetism current flow	11. Define electromagnetism. ____________ ____________ ____________

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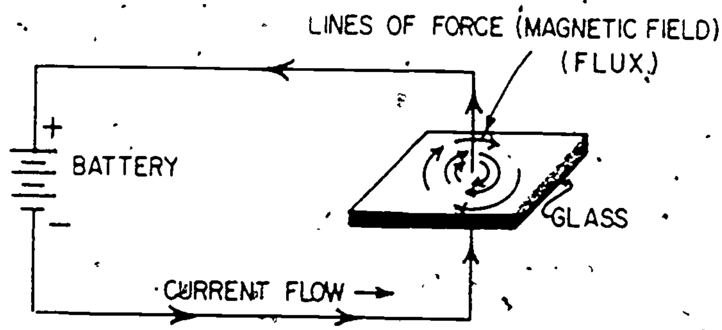
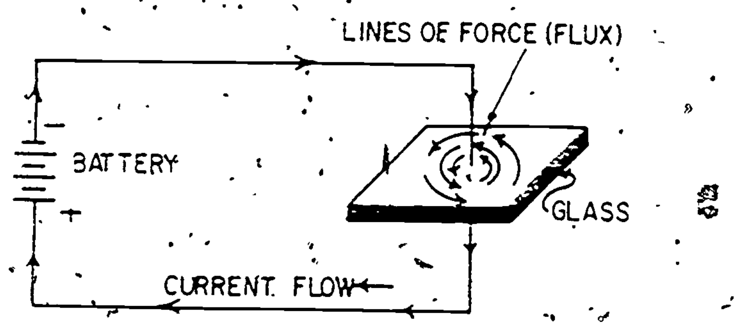


Magnetism produced by a current flow.	12. If we were to construct a simple circuit, as shown above, a ________ field would be formed around the conductor. (Note lines of force traveling in a clockwise direction.)
magnetic	13. However, if we were to reverse the current flow, as shown below, the lines of force would be in the ________ direction or counterclockwise.



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	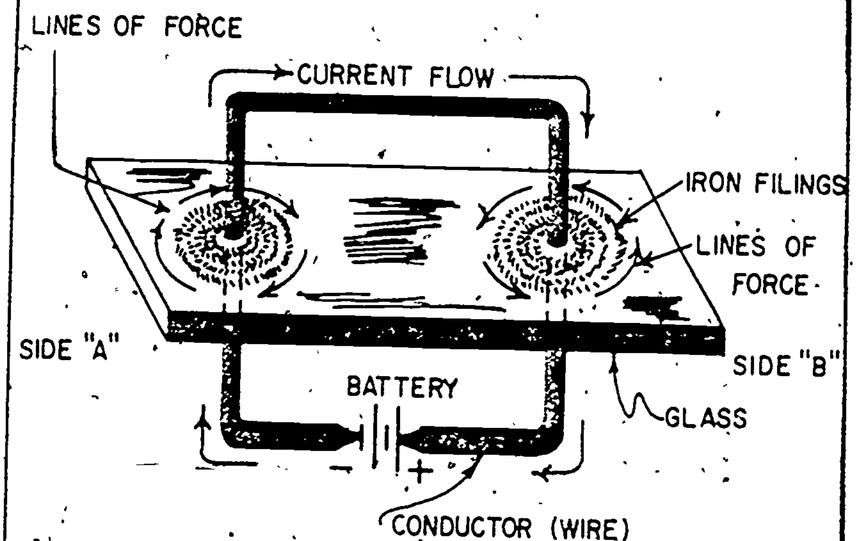
opposite	14. In the illustration above, the lines of force on side A are traveling in a clockwise direction, but the lines of force on side B are traveling in a ______________ direction.
counter-clockwise	15. The "left-hand rule," is used for determining the direction of the magnetic lines of force around a straight conductor carrying a current, providing current direction is known. By the application of the "left-hand rule," it is possible to determine the ______________ of the __________ lines of ______________.
direction magnetic force	

CONTINUE ON NEXT PAGE

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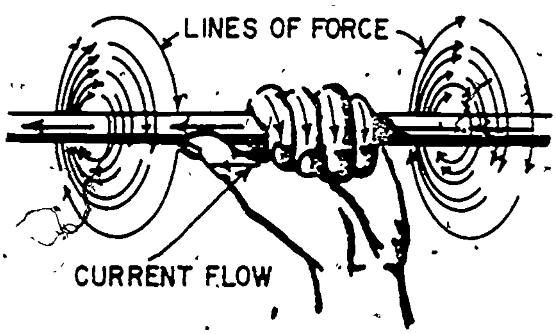
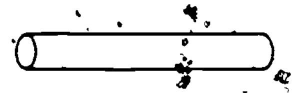
	16. LEFT-HAND RULE: Simply make believe you are grasping the conductor in your left hand with your thumb extended in the direction of current flow. Your fingers will then circle the conductor in the direction of the lines of force (flux travel), as in the illustration below. This is known as the __________-hand rule for straight conductors. 
left	17. The rule for determining the direction of the lines of force (flux) around a straight conductor involves the __________ hand. In the illustration below, indicate the direction of the lines of force (flux) with arrows. 

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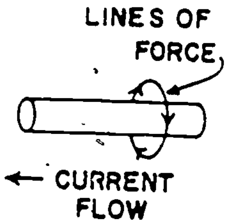
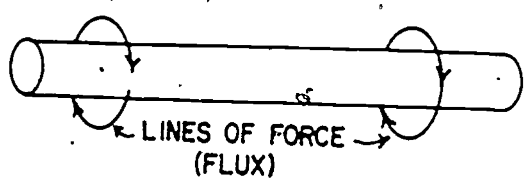
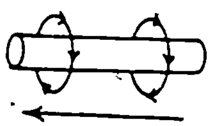
left

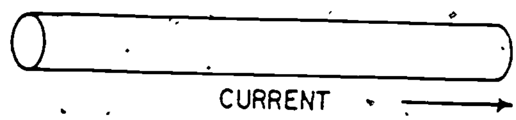


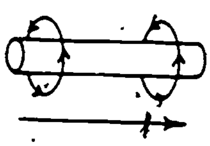
18. If we know the direction of the lines of force, we can also determine the current direction. Merely make believe you are wrapping the fingers of your left hand around a straight conductor in the direction of lines of force and your extended thumb will point in the direction current is flowing. In the illustration below, indicate current direction with an arrow.



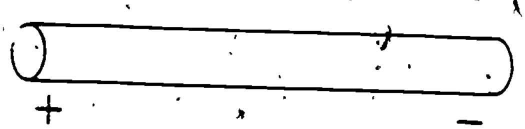


19. In the illustration below, indicate the direction of the lines of force.





20. To indicate the direction of current flow in a conductor, arrows are generally used. However, in some cases it is necessary to use symbols: (+) or (-). Current always flows from negative (-) to positive (+). In the illustration below, indicate with arrows the direction of current travel.



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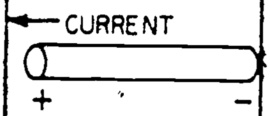
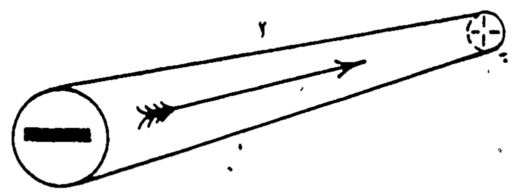
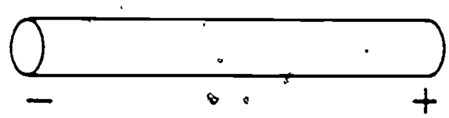
	21. In a cross-sectional view of a straight conductor, carrying current away from the observer, the current direction would be indicated by the symbol (____). In the illustration below, current is flowing ______________ from the observer. (toward/away) 
(-) away	22. In a cross-sectional view of a straight conductor carrying current toward the observer, the current direction would be indicated by the symbol (____).
(+)	23. In the illustration below, draw in the direction of current travel and lines of force. 

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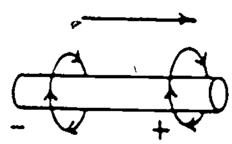
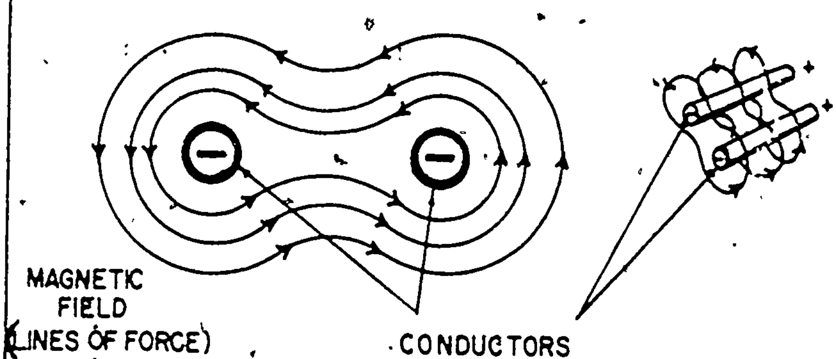


24. When two or more parallel conductors are carrying current in the same direction, the magnetic fields tend to encircle all conductors. In the illustration below, the magnetic field tends to encircle both __________ which are carrying current in the __________ direction.
(same/opposite)



conductors

same

25. When two or more parallel conductors are carrying current in the same direction, the __________ field tends to encircle __________ conductors.

magnetic

both

26. When the magnetic field encircles conductors carrying current in the same direction, the conductors have a tendency to attract each other. Therefore, parallel conductors carrying current in opposite directions would have a tendency to __________ each other.

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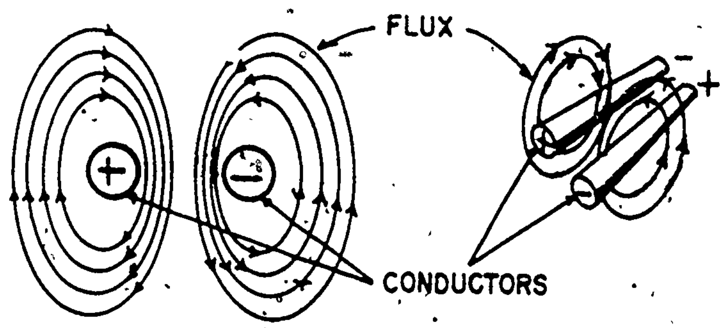
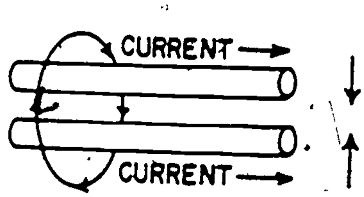
repel	27. The diagram below shows conductors carrying current in ______________ directions. 
opposite	28. The magnetic fields around conductors carrying current in opposite directions repel each other. That is, they ______________ (do/do not) encircle all conductors as one. The flux of these fields also travel in ______________ directions.
do not opposite	29. Two conductors having current flow in the same direction will cause an attraction to each other. In the illustration below, the tendency of the conductors would be to ______________ each other. 

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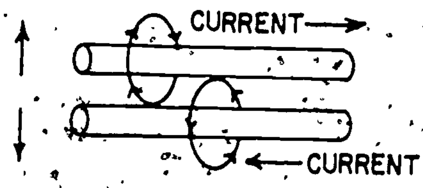
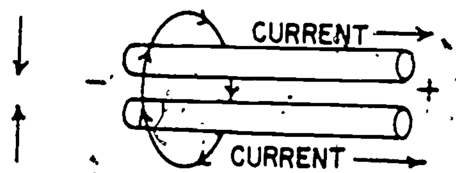
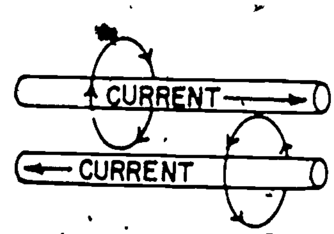
attract	30. When two conductors have current flowing in opposite directions, the tendency of the conductors would be to repel each other. In the illustration below, the probable movement of the conductors is to ______________ each other. 
repel	31. When two conductors have current flowing in the same direction, the lines of force encircle both conductors. In the illustration below, the lines of force encircle both conductors because the current is flowing in the ______________ direction. 
same	32. When two conductors have current flowing in opposite directions, the lines of force encircle each conductor. In the illustration below, the lines of force encircle each conductor because the current is flowing in ______________ directions. 

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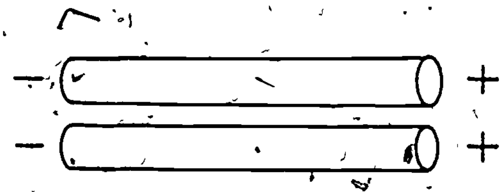
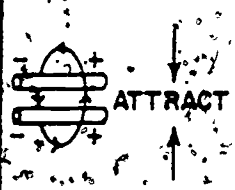
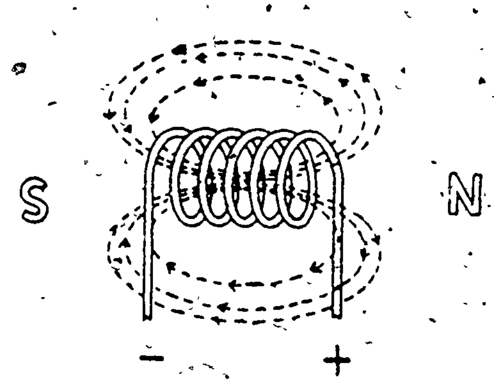
opposite	33. In the sketch below, indicate the direction of lines of force (flux lines) and the probable movement of the conductors by arrows. 
	34. Conductors carrying current produce magnetic fields without magnetic poles. Magnetic poles are important because machines make use of these points of flux concentration. Therefore, a solenoid or an electromagnet would not operate without ______________ poles.
magnetic	35. To produce magnetic poles, we simply coil a conductor as illustrated below. Instead of the magnetic field forming around each wire separately, it forms a single loop around all wires running parallel with each other. This causes poles to develop at each end of the coil. In the sketch below, there are ______________ (how many) magnetic __________, one at each end. 

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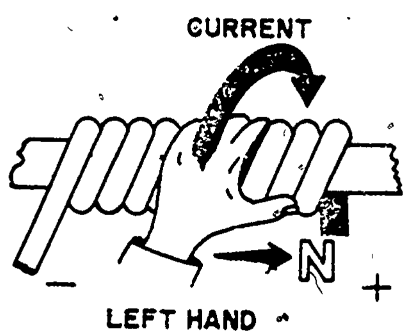
two poles	36. There is a simple method for determining the north and south poles of a coil, providing the direction of current flow is known. Remember, current flows from negative (-) to positive (+). If you make believe you are grasping the coil in your left hand, with your fingers wrapped around the coil in the direction of current flow, your thumb will point to the north pole. In order to determine the north and south poles of a coil, you must know the direction of ________ ________________. This is the ____________-hand rule for a coil. Label the south pole in the illustration below.
current flow left South pole is on the left.	37. A coiled conductor carrying a current flow is magnetized with a definite ______________ and ____________________ pole.



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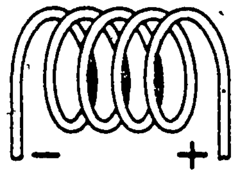
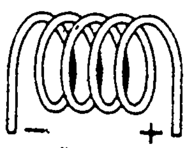
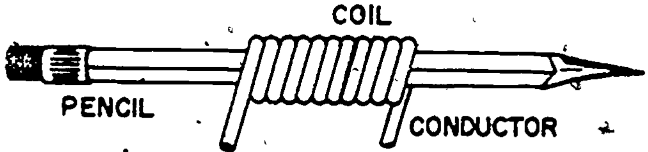
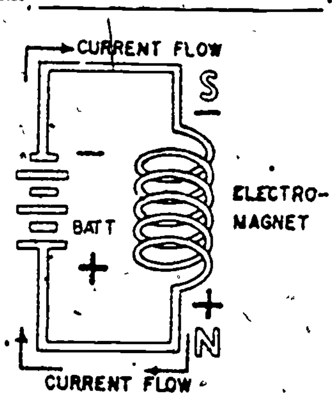
north south	38. Label the north and south poles of the coil in the illustration below. 
 	39. A loop-wound conductor is a coil. By taking a straight conductor (wire) and looping it around a pencil, the conductor then would be called a ____________. 
coil	40. However, if we were to hook the coil to a power source, as illustrated below, and permit current to flow through the coil, we would have an electromagnet. A coiled conductor with current flow is an ____________. 

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electromagnet	41. The center of the coil from which you removed the pencil is called the <u>core</u>. If you were to put the pencil back inside the coil and hook the coil to a power source, you would have a wood-________ electromagnet.
core	42. Even if the pencil were removed, the coil would still be an electromagnet, but the core would be ________.
air	43. When current flows through the coil, the core of each loop, or turn, becomes a magnet. The core of the coil is a magnetic tube through which practically all the magnetic flux passes. When we produce a magnet in this manner, it is called an ________________.
electromagnet	44. An electromagnet is a coiled conductor with ____________ flowing through it.
current	45. An electromagnet is a coiled ____________ carrying a ____________ flow.
conductor current	46. Define an electromagnet. ________________ ________________ ________________

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An electromagnet is a coiled conductor carrying a current flow.

47. A solenoid is the same as an electromagnet, except a solenoid has a movable iron core. Fig. 1 shows a solenoid relay switch in the closed position with current flowing through the circuit. The position of the movable core is centered in the coil.

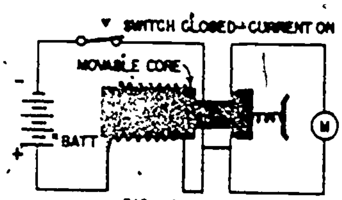


FIG 1

Fig. 2 shows a solenoid relay switch with the switch in the open position with no current flowing through the circuit. The spring attached to the movable core is holding the movable core off center in the coil.

Detail A shows a solenoid in more detail.

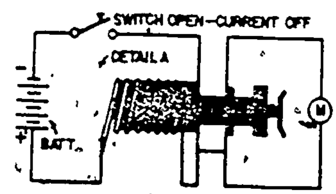
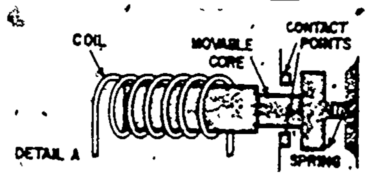
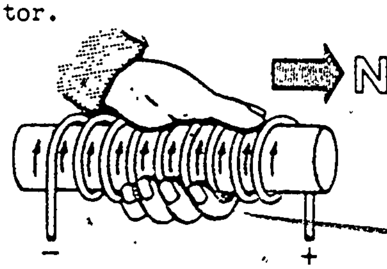
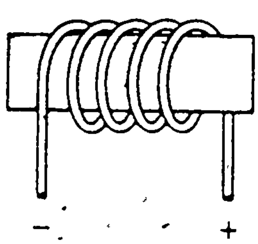


FIG 2



A solenoid is the same as an electromagnet except the solenoid has a movable iron core which is free to center itself when power is applied. The main difference between a solenoid and an electromagnet is that the solenoid has a _______________ _______________.

CONTINUE ON NEXT PAGE

movable core	48. An electromagnet has a stationary ____________, but a solenoid has a ____________ core.
core movable	49. The difference between an electromagnet and a solenoid is: ______________________________ ______________________________.
Solenoid has a movable iron core and an electromagnet has a stationary iron core.	50. The rule for determining the north and south poles of an electromagnet is the same as that for a coiled conductor.  By grasping the coil with the __________ hand and pointing the fingers in the direction of __________ flow, the extended thumb will point to the __________ pole.
left current north	51. In the illustration below, label the north and south poles of the electromagnet. 

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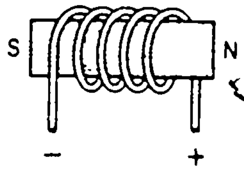	52. An electromagnet having a core of air, wood, copper, or some other nonmagnetic material does not produce a very strong electromagnet. By using a magnetic material such as soft iron for the core, the electromagnet will be much ____________. (Remember, soft iron has higher permeability than nonmagnetic materials.)
stronger	53. Soft iron is used for electromagnet cores because it has higher ________________ than nonmagnetic materials.
permeability	54. Soft iron is also used for electromagnet cores because it retains less magnetism after current flow has stopped. Two reasons soft iron is used for the core of electromagnets are: it has higher ____________________ and it retains ________ magnetism after current flow has stopped.
permeability less	55. List two reasons why soft iron is used as the core for electromagnets. ______________________________. ______________________________.
Has a higher permeability. Retains less magnetism after current flow has stopped.	56. Magnetism retained by a material after current flow has stopped is called <u>residual</u> <u>magnetism</u>. Residual magnetism is magnetism retained after ____________ ____________ has stopped.

CONTINUE ON NEXT PAGE

current flow	57. Define residual magnetism. ________________
Magnetism retained after current has stopped.	58. The strength of the electromagnet depends on the core material, the amount of current, and the number of turns of the coiled conductor. Therefore, if we ________ the current or increase the number of turns of the coil, the electromagnet strength will also be ________.
increase increased	59. The strength of an electromagnet is dependent upon three factors; they are: the number of ________; the amount of ________, and the type of ________ material.
turns current core	60. List three ways the strength of an electromagnet may be increased. ________ ________ ________.
Increasing number of turns. Increasing amount of current. Changing the core to a more permeable material.	61. The electromagnet is necessary in countless aviation devices. A few of these devices are the relay switch, the solenoid relay switch, electric motors, and generators. The operation of various electric devices is dependent upon ________.

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electromagnetism or electromagnets	62. A relay switch is an electromagnetic device having a stationary iron core which remotely controls a circuit. A pilot in the cabin of an aircraft would be able to control several electrical circuits located in remote parts of his aircraft through the use of __________ __________.
relay switches	63. An electromagnetic device having a stationary iron core and used to control a circuit remotely is called a __________ __________.
relay switch	64. A relay switch is an __________ device having a stationary ______ ______, and is used for __________ controlling electrical circuits.
electromagnetic iron core remotely	65. Electrical circuits may be controlled remotely by __________ __________.
relay switches	66. Define a relay switch. ____________________ ____________________.

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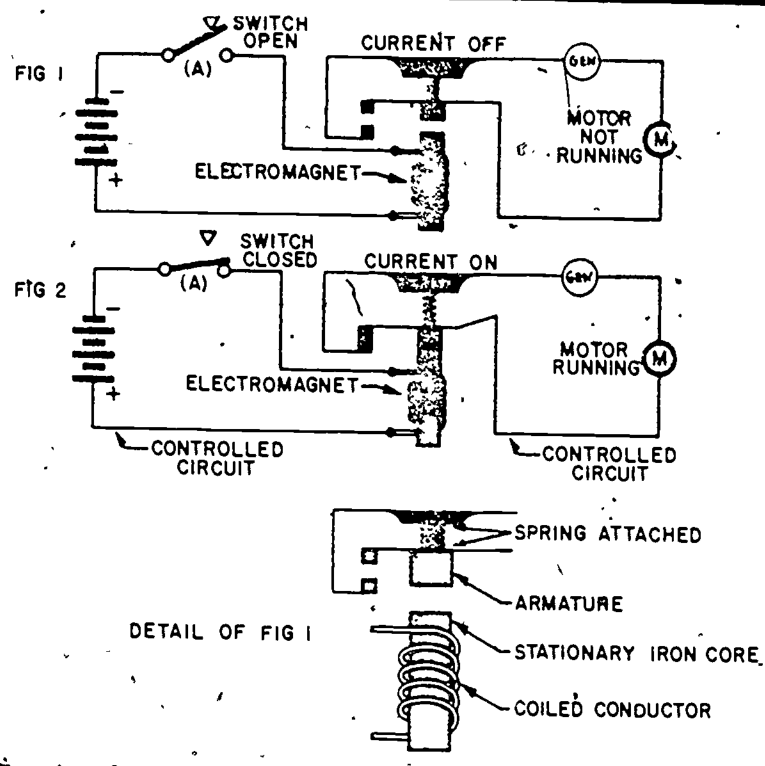
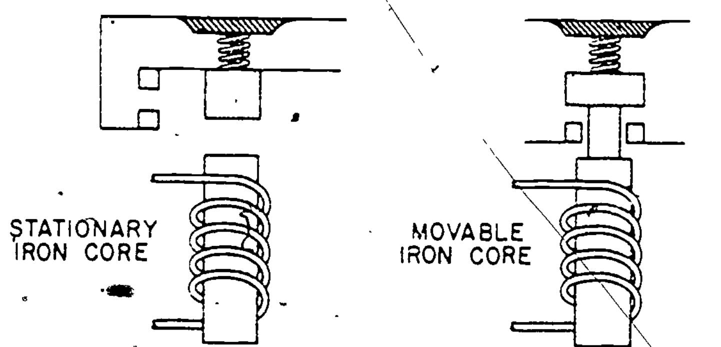


A relay switch is an electromagnetic device having a stationary iron core.

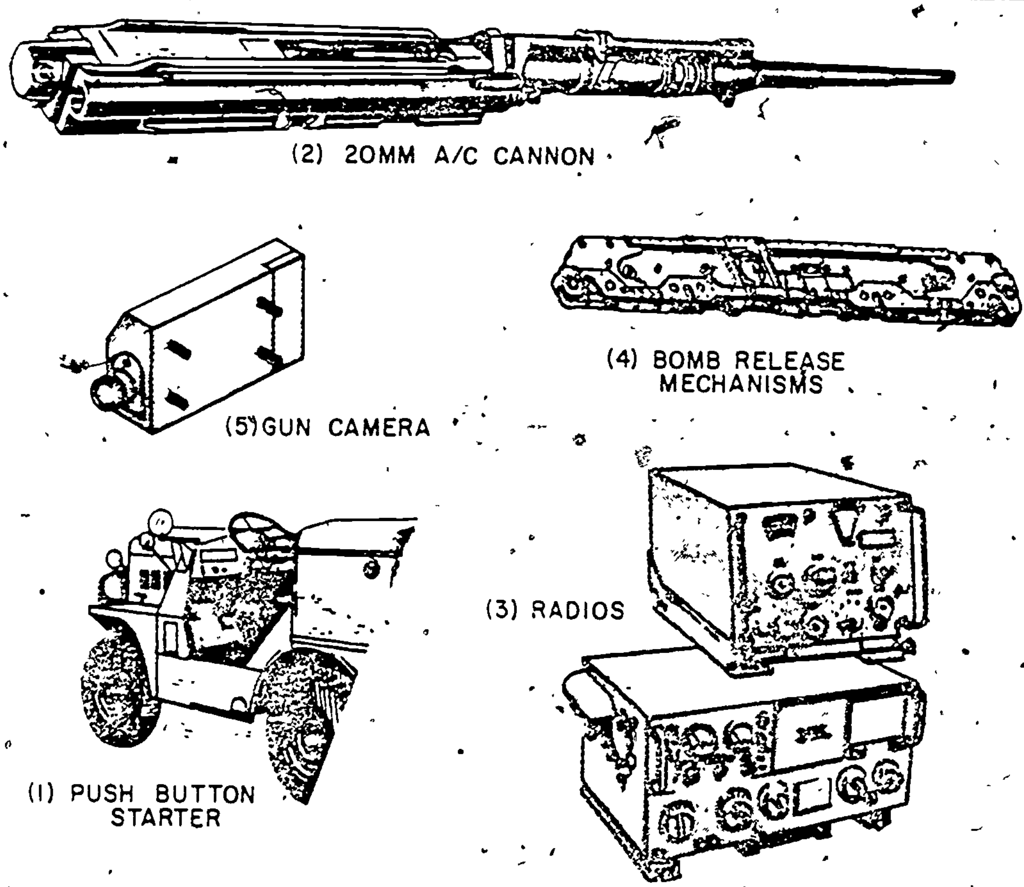
67. A relay switch consists of a switch, a set of contact points, an armature, and an electromagnet. As shown in the illustration above, when the controlling switch (A) in Fig. 2. is closed, it permits current flow to magnetize the electromagnet. This attracts the armature, against spring tension, closes the contact points of the controlled circuit, and allows current to flow through the controlled circuit. A relay switch uses an ________________ to close the contact points of the controlled circuit.

CONTINUE ON NEXT PAGE

electromagnet	68. A relay switch has four essential parts: __________, __________ __________, armature, and an __________.
switch, contact points, electromagnet	69. List four essential parts of a relay switch. __________, __________, __________, __________.
electromagnet, armature, switch, contact points.	70. In the illustration below, write the name of the switch in Fig. A and in Fig. B.  FIG. A FIG. B __________ __________
Fig. A: relay switch Fig. B: solenoid relay switch	71. A solenoid relay switch may be defined as an electromagnetic device having a movable iron core to actuate a set of contact points. A solenoid relay switch is an __________ device having a __________ iron __________.
electromagnetic movable core	72. Define a solenoid relay switch. __________ __________.

CONTINUE ON NEXT PAGE

Electromagnetic device having a movable iron core.	73. A solenoid relay switch is similar to a relay switch, except that it uses a movable iron core. A movable iron core is used in the ______________ ______________ switch.
solenoid relay	74. A solenoid relay switch has a ____________ iron core and a relay switch has a ____________ iron core.
movable stationary	75. State the way a solenoid switch differs from a relay switch. ______________________________.
Solenoid relay switch has a movable iron core.	76. Solenoid relay switches are used in the aviation field to operate starters, guns, radios, bomb releases, and cameras. NO RESPONSE REQUIRED.



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	77. Five uses of the solenoid relay switch can be found on starters, guns, radios, bomb release mechanisms, and ________.
cameras	78. List five uses of the solenoid relay switch ________, ________, ________, ________, ________, and ________
starters, guns, radios, bomb release mechanisms, cameras.	Now, let's briefly review the lesson.
	79. Motors, generators, circuit breakers, relay switches, meters, and buzzers are electrical devices made possible by the invention of the electro________. Electromagnets have made possible such devices as ________, ________, ________ breakers, ________ switches, ________, and ________.
magnets motors, generators, circuit, relay, meters, buzzers.	80. Electromagnetism is ________ produced by a ________ flow. Magnetism produced by current flow is ________.

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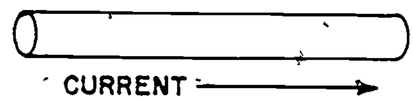
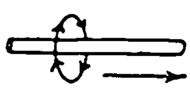
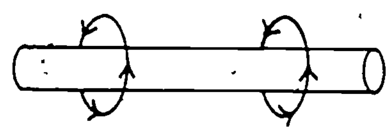
magnetism current electromagnetism	81. In the following sketch, mark the direction of travel of the flux.  NOTE: Grasp the conductor with the left hand with the thumb pointing in the direction of current flow. The finger tips will point in the direction of travel of the flux. The thumb points in the direction of __________ __________ and the finger tips point in the direction of __________ of the __________.
 current flow travel flux	82. In the following sketch, determine and mark the direction of current flow with arrows.  Using the LEFT-HAND RULE, the fingers point in the direction of travel of the flux and the __________ points in the direction of current flow.

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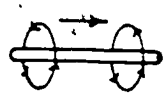
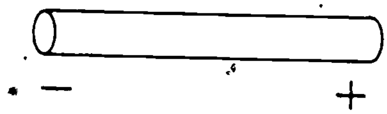
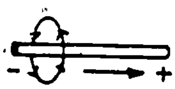


thumb

83. In the following sketch, mark the directions of current flow and lines of force travel.

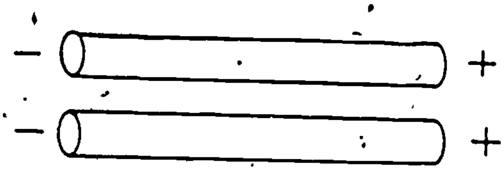


Electricity flows from negative (-) to ________ (+). Using the left-hand rule, your thumb will point to the positive end of the conductor, indicating direction of current flow. Your fingers will then indicate lines of force travel.



positive

84. In the following sketch of multiple straight conductors, sketch in the lines of force and mark their direction of travel. Also, indicate probable movement (by arrow) of conductors in respect to each other.



When conductors have current flowing in the same direction, the conductors will ____________ each other and the lines of force will encircle both conductors. By using the left-hand rule for straight conductors, your thumb will point in the direction of current flow and your fingers will then point in the direction of the lines of ____________________.

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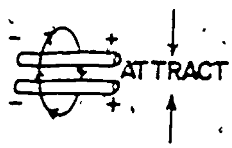
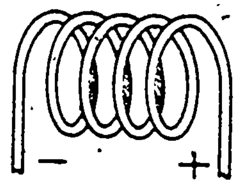
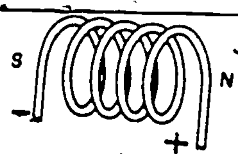
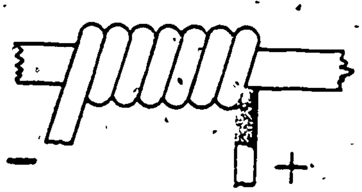
 attract force	85. In the following sketch of a coiled conductor, mark the north and south poles.  To apply the left-hand rule for a coiled conductor, merely grasp the conductor with your fingers pointing in the direction of current flow. Your extended thumb will point to the ________ pole.
 north	86. A coiled conductor carrying a current is an ________________. An electromagnet is a coiled conductor carrying a ________________.
electromagnet current	87. An electromagnet is a coiled ________________ carrying a current. A solenoid is the same except that a solenoid has a ________________ core.
conductor movable	88. In the following sketch of an electromagnet, determine and label the <u>north</u> and <u>south</u> poles.  To use the left-hand rule for a coiled conductor, grasp the conductor with your fingers pointing in the direction of current flow. Your extended thumb will point to the ________ pole.

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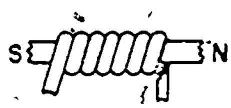
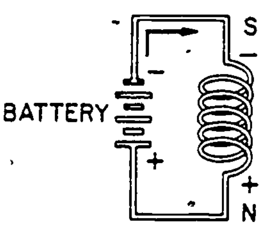
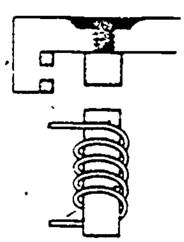
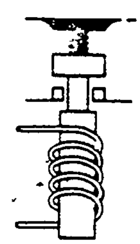
 north	89. The ability of a material to conduct lines of force is called ______________. We use ______________ iron as the core of an electromagnet because it has higher permeability than non-magnetic materials.
permeability soft	90. Increase the current flow thru an electromagnet and the strength will be increased. Increase the amount of coils (turns) and the strength will also be increased. Two ways to increase the strength of an electromagnet are to increase the ______________ flow or increase the amount of ______________.
current coils or turns	91. Residual magnetism is magnetism retained after ______________ ______________ has been stopped. Magnetism ______________ after current flow has been stopped is called ______________ ______________.
current flow retained residual magnetism	92. A relay switch is an electromagnetic device having a stationary ______________ ______________; it is used for remotely controlling electrical circuits. The definition of a relay switch is an ______________ device having a ______________ iron core.

CONTINUE ON NEXT PAGE

iron core electromagnetic stationary	93. A relay switch has four essential parts: (1) switch, (2) contact points, (3) armature, (4) electromagnet. A ______ switch has four essential parts: ______ (1), ______ (2) points, ______ (3), ______ (4).
relay switch, contact, armature, electromagnetic	94. A solenoid relay switch is an electromagnetic device with a movable iron core to actuate a set of contact points. The definition of a solenoid relay switch is an ______ device with a ______ iron core.
electromagnetic movable	95. A relay switch has a stationary iron core and a solenoid relay switch has a movable iron core. A solenoid relay switch differs from a relay switch by having a ______ iron core.
movable	96. Electromagnet: A coiled conductor carrying a current. Relay Switch: An electromagnetic device having a stationary iron core. Solenoid Relay Switch: An electromagnetic device having a movable iron core. Write the name of the device shown in Figure 1, Figure 2, and Figure 3.  FIG. 1  FIG. 2  FIG. 3 1. ______. 2. ______. 3. ______.

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electromagnet relay switch solenoid relay switch	97. Push-button starters, aircraft guns, radio mechanisms, bomb release mechanisms, and gun cameras use solenoid relay switches. Solenoid relay switches are used to operate ____________ ____________ starters, aircraft ________, radio ________, bomb ____________ mechanisms, and gun ________.
push-button guns mechanisms release cameras	THIS CONCLUDES THE LESSON. Please read over the objectives again at the front of this lesson. If you are still in doubt about any one of the objectives, SEE YOUR INSTRUCTOR.

SELF-TEST

1. List at least four electrical devices made possible by the invention of the electromagnet.

_______________ _______________ _______________

_______________ _______________ _______________

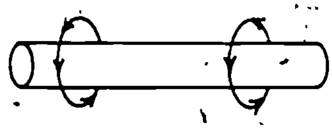
2. Write the definition of electromagnetism. _______________

____

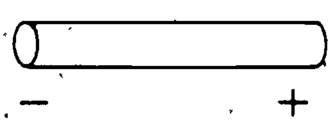
____

3. In the following sketch, mark the direction of travel of the lines of force.

4. In the following sketch, mark the direction of current flow.



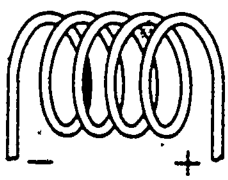
5. In the following sketch, mark the direction of current flow and lines of force travel.



A

6. In the following sketch of multiple straight conductors, sketch in the lines of force and mark their direction of travel. Also, indicate probable movement (by arrows) of conductors in respect to each other.

7. In the following sketch of a coiled conductor, label the north and south poles.



8. Define "electromagnet." ______________________________

____

____

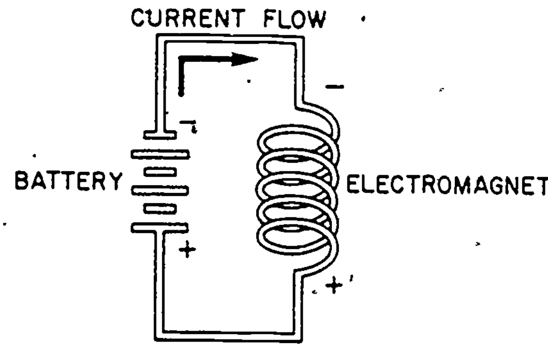
9. List the way(s) in which a solenoid differs from an electromagnet.

____

____

B

10. In the following sketch of an electromagnet, label the north and south poles.



11. List the reason(s) that soft iron is used for the core of an electromagnet.

____

____

12. List at least two ways in which the strength of an electromagnet may be increased.

____

____

13. Define "residual magnetism."

____

____

14. Define "relay switch." ______________________

____

____

15. List at least two parts of a relay switch.

______________________ ______________________

16. Define "solenoid relay switch."

____

____

____

17. List the way(s) in which the solenoid relay switch differs from the relay switch.

____

18. List at least three uses of a solenoid relay switch in the aviation field.

______________________ ______________________

______________________ ______________________

D

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2TPT-3103-15

TECHNICAL TRAINING

TRANSFORMERS

January 1968

Designed For ATC Course Use

VALIDATION DATA

This programmed text on Transformers has been validated on 41 students enrolled in ABR 54330 Electrical Power Production.

The Criterion Examination has a total of 19 responses, with 17 out of 19 being the standard of performance. Seventeen correct responses is 100%.

The following results indicate time taken to complete the text and scores obtained on Criterion Examination.

	RANGE	AVERAGE
Time	15 - 86 Minutes	47 Minutes
Scores	82 - 100%	95%

- LEARNING OBJECTIVES -

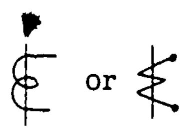
After completing this unit of instruction, you will be able to accomplish the following:

1. Select from a list of statements the one that defines a transformer as being a stationary unit which changes electrical energy at one voltage to electrical energy at another.

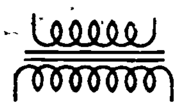
2. Define transformer operation as using principles of mutual induction.

3. List the main components of a potential transformer as being an iron core, primary, and secondary winding.

4. Recognize the following symbols, which represent -



current transformers



potential transformers

5. Recognize that when voltage is increased by transformer action the current is decreased and the opposite is also true.

6. Compute for unknown values of volts and amps in step-up and step-down transformer circuits.

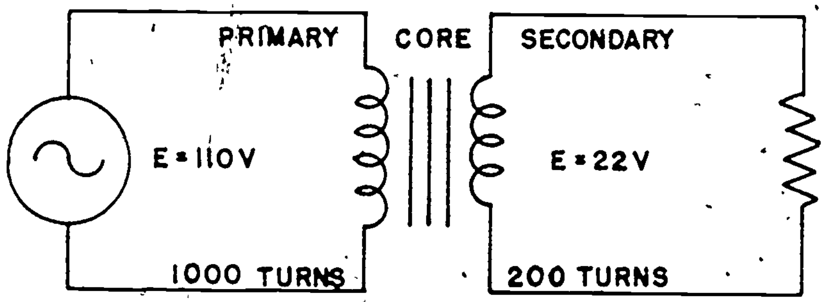
INTRODUCTION

The efficient use of electrical energy, like the efficient use of mechanical energy, often requires converting the form of energy at the source to a form that can be used at the load. Gear trains, for instance, between a gasoline engine and cutting saws may be designed to cause one saw to turn slowly with great force while another saw turns with great speed and less force, each for a specific purpose.

In the same manner, it is necessary to adjust electrical circuits so that the power available may appear at the load as one of various combinations of voltage and current; that is, as high voltage with low current, as high current with low voltage, or as any combination of the two. The electrical device which corresponds to a gear train in mechanics is the transformer, which converts the electrical power available from one voltage-current level to another voltage-current level. It should be noted, however, that neither the gear train nor the transformer changes the amount of power available. The amount of power used by the saws, at any instant, is the power delivered by the gasoline engine (less friction losses), and the amount of power dissipated by the load in an electrical circuit is the same as the power delivered by the source (less internal losses); but in either case, the power to be used can be adapted to the particular work to be done.

A transformer is a stationary unit with no moving parts which transforms voltage and current of one circuit into variations of voltage and current for another circuit, using the principles of mutual induction.

Potential transformers usually consist of three parts: an iron core which provides a circuit of low reluctance for the magnetic flux, a primary winding which receives the electrical energy from the supply source, and a secondary winding which receives the electrical energy by induction from the primary winding and delivers it to the load circuit.



The primary and secondary coils are not electrically connected but arranged so that the magnetic flux surrounding one coil links through or "cuts" the other coil. The iron core is laminated (sliced into thin slices, insulated and glued together) to minimize magnetic current losses (eddy currents) and is usually made of specially prepared silicon steels, since these steels have a low hysteresis loss. Hysteresis loss is due to heat caused by molecular friction in a metal when a magnet reverses polarity.

Indicate correct answer to first item by placing a check (√) by the letter of your choice, and complete the following sentences.

1. A transformer is a

____ a. mechanically moving unit which steps up or steps down electrical energy.

____ b. stationary unit which can change alternating current to direct current.

____ c. rotary moving unit which performs like a rheostat.

____ d. stationary unit which changes electrical energy at one voltage to electrical energy at another.

2. A transformer operates on the principles of ____________________ ____________________.

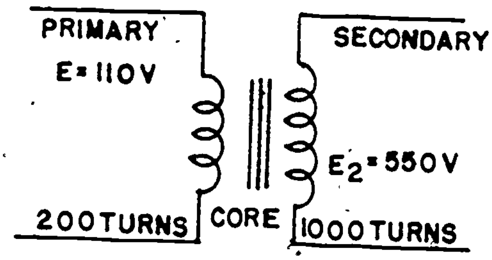
3. The main components of a potential transformer are ____________ ____.

4. Electrical energy from the supply source enters the ____________ ____________ winding first.

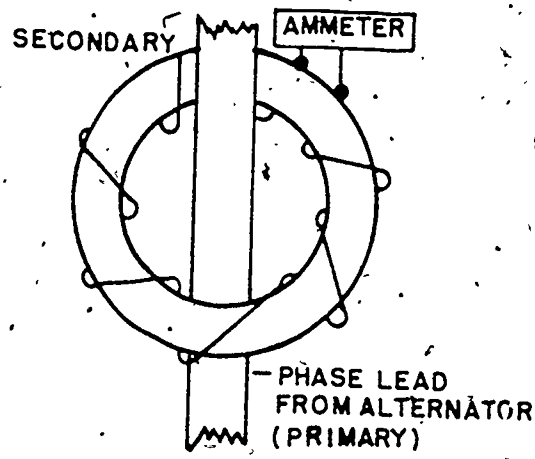
5. The secondary winding receives electrical energy by ____________ ____________ and delivers it to the ____________ circuit.

Answers:
1. d
2. mutual induction
3. iron core, primary and secondary winding
4. primary
5. induction load

There are two classes of transformers: potential transformers for stepping up or stepping down voltages, and current transformers which are used for stepping down current in instrument circuits.



POTENTIAL TRANSFORMER



CURRENT TRANSFORMER

Current transformers have only one winding, a secondary winding, which is connected to ammeters, or wattmeters, etc, which are designed to operate on lower current values, but are scaled to indicate line current.

> CAUTION: The secondary circuit of a current transformer must never be opened while a system is energized: extremely high voltage will result if the secondary is opened.

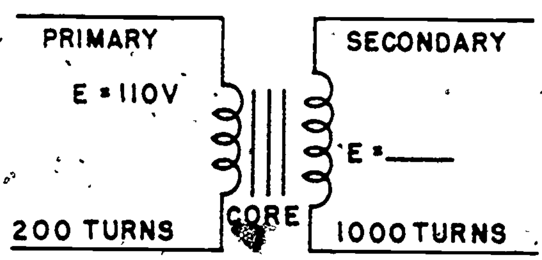
Complete the following sentences.

1. A potential transformer primary coil has 200 turns, its secondary coil has 1000 turns; it is a ______________ (step up/step down) type transformer.
2. When the secondary coil circuit or load circuit has less voltage than the primary coil circuit, it is a ______________ (step up/step down) potential transformer.
3. The transformer that steps down current for instrument operation is a ____________________.
4. There is/are ______ (number) type(s) of potential transformer(s) and ______ (number) type(s) of __________ transformer(s).

Answers: 1. Step up 2. Step down 3. Current transformer
4. 2 1 current

To compute the output voltage of a potential transformer, you must know the ratio of turns between the primary and secondary coils. For example, if you have a primary coil with 200 turns and a secondary with 1000 turns, as below, you use the formula $R = \frac{Np}{Ns}$, R meaning ratio of turns, Np meaning number of turns in primary coil and Ns meaning number of turns in secondary coil. This applied to illustration below means $\frac{200}{1000} = \frac{1}{5}$ or 1:5 ratio or 5 times as many turns in the secondary coil as in the primary coil.

1:5



Complete the following sentences.

1. The illustration above illustrates a ________________ type potential transformer.

2. If the turns ratio was reversed, $\frac{5}{1}$ or 5:1, it would be a ____________________ potential transformer.

3. When Np is 10,000 and Ns is 200, the ratio is ____________, and the transformer is a ___________ type.

Answers:
1. Step up
2. Step down
3. $\frac{50}{1}$ or 50:1 step down

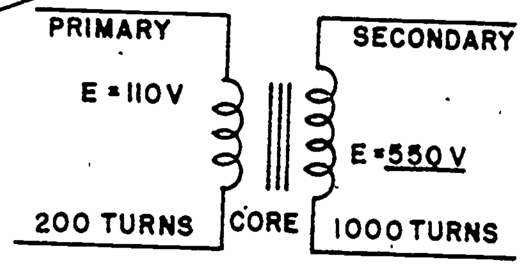
To determine output voltage (volts in secondary) of transformer, you must cross multiply $\frac{Ep}{Es} = \frac{Np}{Ns}$. The turns ratio $\frac{Np}{Ns}$ is equal to voltage ratio $\frac{Ep}{Es}$ - volts in primary. - volts in secondary.

EXAMPLE:

$$\frac{Ep}{Es} = \frac{Np}{Ns}$$

$$\frac{110}{Es} = \frac{200}{1000} \quad \text{ratio } \frac{1}{5}$$

1:5



$$\frac{110}{Es} = \frac{1}{5}$$

$$\frac{Es \times 1}{1} = \frac{110 \times 5}{1}$$

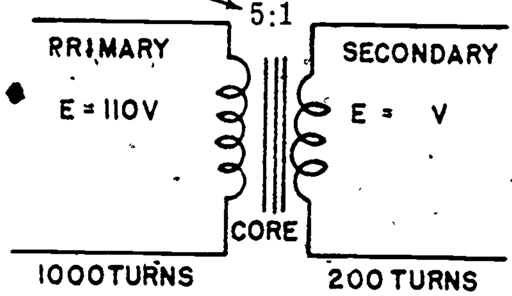
ES = 550

Compute output voltage for the transformer below. Use space provided for all computations.

$$\frac{Ep}{Es} = \frac{Np}{Ns}$$

$$\frac{110}{Es} = \frac{5}{1}$$

5:1



Answer: 22 V

Complete the following sentences.

1. The two types of potential transformers are ____________ and ________________.

2. In a step-up potential transformer the secondary coil has ____________ turns than the primary coil.
(more/less)

3. The voltage in the secondary of a step-up potential transformer is ________________ than primary voltage.
(greater/lesser)

> NOTE: Review the last page before completing #4 and #5.

4. To compute the voltage of a <u>step-up</u> potential transformer you ____________________ volts by largest ratio number.
(multiply/divide)

5. To compute the voltage of a <u>step-down</u> potential transformer you ____________________ volts by largest ratio number.
(multiply/divide)

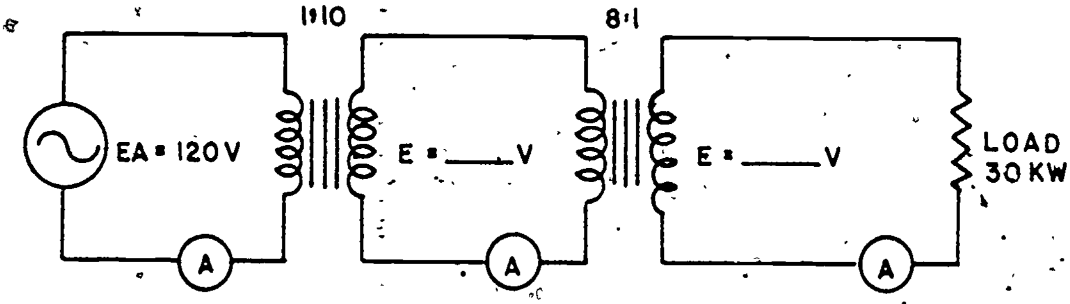
Answers:
1. step-up and step-down
2. more
3. greater
4. multiply
5. divide

582

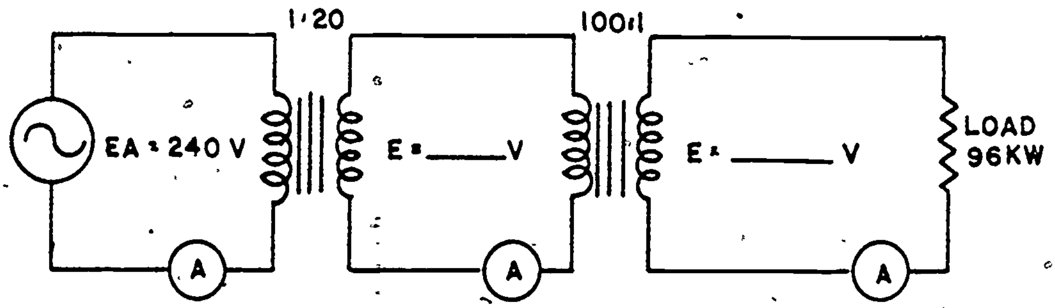
Compute voltages for the transformers below and enter values in spaces provided. Ratio of turns are listed above each set of coils.

After you have computed Es (secondary voltage) for the first transformer - that voltage is Ep (primary voltage) of the next transformer.

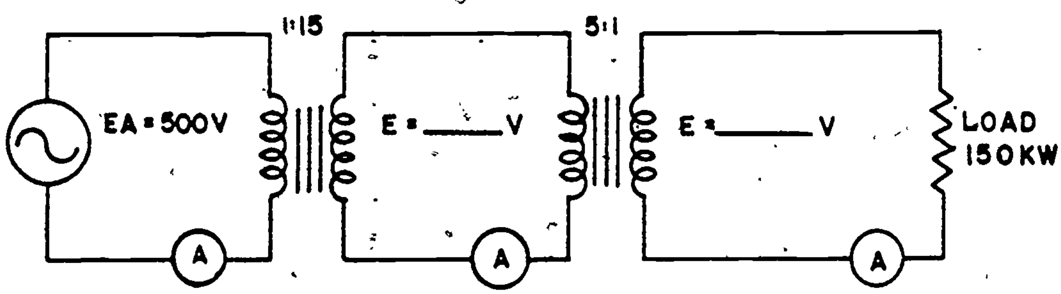
1.



2.

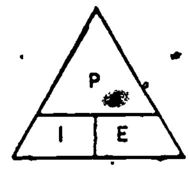


3.



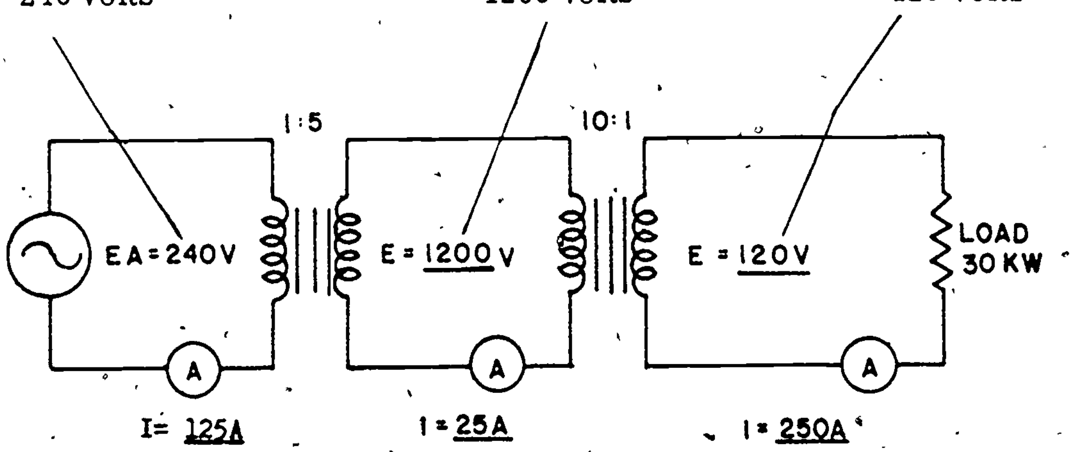
Answers:
1. 1200V (120V multiplied by 10) 150V (1200V divided by 8)
2. 4800V (240V multiplied by 20) 48V (4800V divided by 100)
3. 7500V (500V multiplied by 15) 1500V (7500V divided by 5)

After computing transformer voltages, convert power load from KW to watts by multiplying number of KW by 1000. Divide watts (power) by voltage to obtain current values as indicated by power triangle.

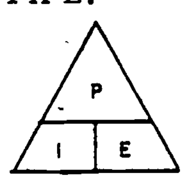


EXAMPLE: 30KW x 1000 = 30,000 watts (power)

$\frac{30,000 \text{ watts}}{240 \text{ volts}} = 125 \text{ amps}$ $\frac{30,000 \text{ watts}}{1200 \text{ volts}} = 25 \text{ amps}$ $\frac{30,000 \text{ watts}}{120 \text{ volts}} = 250 \text{ amps}$

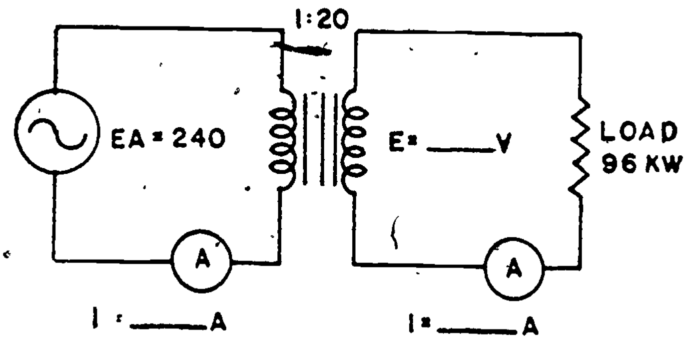


Since power is the product of volts times amperes, you can check your computation by multiplying I X E.

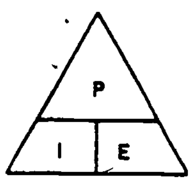


Solve the following transformer circuit exercise and enter computed values in the spaces provided. Show all computations.

240 x 20 = E ______ V

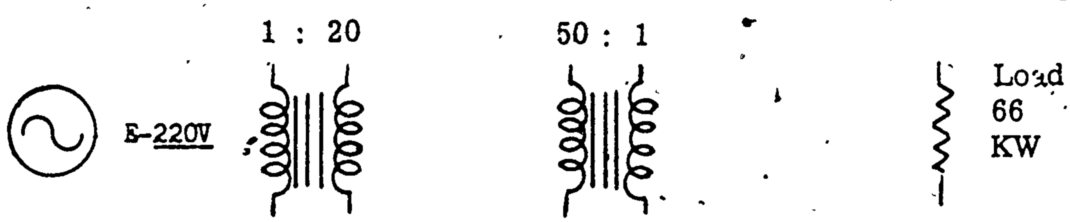


NOTE: Use the Power Triangle to compute and check for correct amps (I).



Answers: (Es = 4800V) (Ip = 400A) (Is = 20A)

To check your computation, 400A x 240V = 96,000 watts
20A x 4800V = 96,000 watts



1. Complete the above schematic diagram by drawing lines to show the correct connection of

   a. Number 1 transformer to the alternator and to Number 2 transformer.

   b. Number 2 transformer to the load.

2. Compute for the following values.

   a. Number 1 transformer secondary voltage ________.

   b. Number 2 transformer secondary voltage ________.

   c. Number 1 transformer secondary current ________.

   d. Number 2 transformer secondary current ________.

   e. Number 1 transformer primary current ________.

Answers: 2.
a. 4400V
b. 88V
c. 15A
d. 750A
e. 300A

Complete the following sentences.

1. You must change the KW load to ________ before computing (I) current.

2. Power divided by ____________ equals (I) current.

3. (E) volts multiplied by __________ equals (P) watts.

4. (I) current multiplied by ___________ equals (P) watts.

5. In a step-up potential transformer the primary has ________ (more/less) current than the secondary.

6. In a step-down potential transformer the secondary has ________ (more/less) current than the primary.

7. The primary of a step-down potential transformer has ________ (more/less) current than the secondary.

8. When a transformer steps-up voltage the amps ________________ (remain constant/rise/drop)

9. When a transformer steps-down voltage the amps ________________ (remain constant/rise/drop)

Answers:

1.	watts	5.	more
2.	(E) volts	6.	more
3.	(I) current	7.	less
4.	(E) volts	8.	drop
		9.	rise

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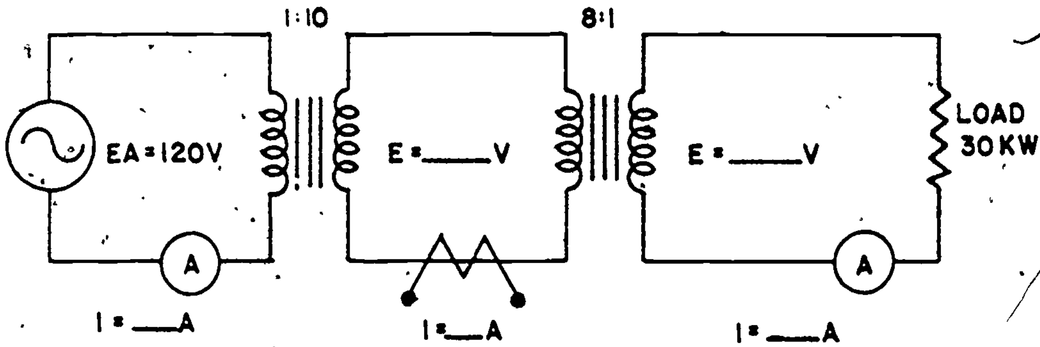
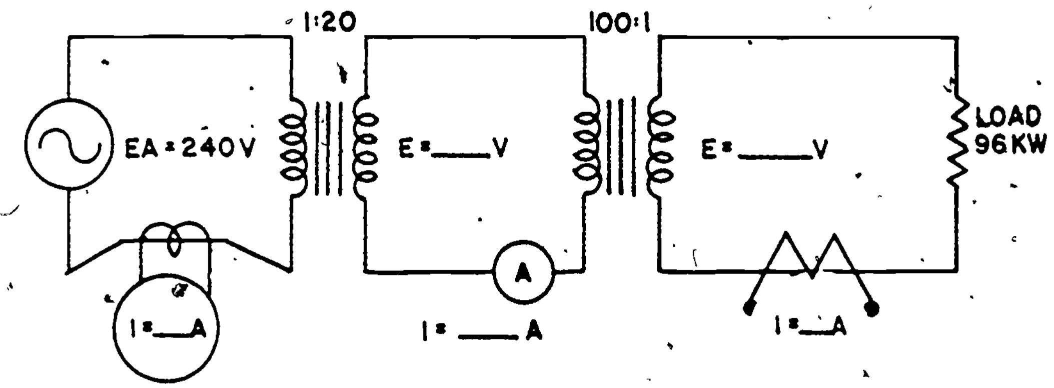
Computing Values in Transformer Circuits

Solve the following transformer circuit exercises and enter computed values in the spaces provided.

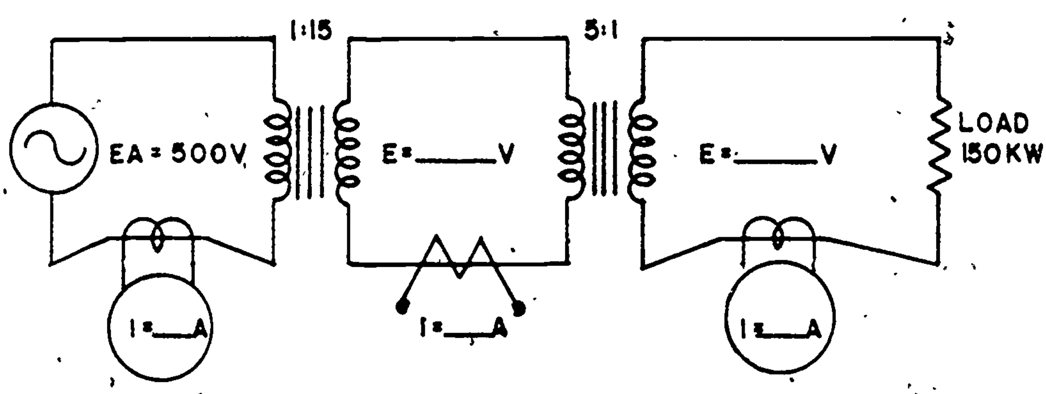
1.



2.



3.



Answer:			
1.		E=1200V	E=150V
	I=250A	I=25	I=200A
2.		E=4800V	E=48V
	I-400A	I=20A	I=2000A
3.		E=7500V	E=1500V
	I=300A	I=20A	I=100A

CRITERION TEST

1. A stationary unit which changes electrical energy at one voltage to electrical energy at another voltage is called a

____ a. rheostat.

____ b. capacitor.

____ c. rectifier.

____ d. transformer.

2. A transformer operates on the principle of

____ a. rectification.

____ b. relative motion.

____ c. mutual induction.

____ d. mechanical linkage.

3. The main components of a potential transformer are

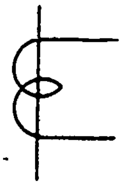
____ a. primary plate, iron core, and secondary plate.

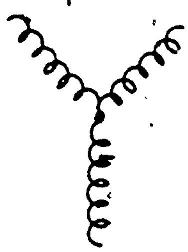
____ b. one coil and core.

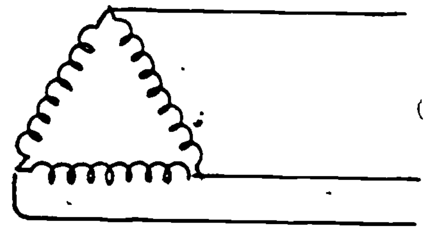
____ c. primary coil, iron core, and secondary coil.

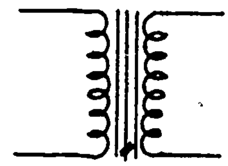
____ d. two coils separated by a dielectric.

4. The symbol for a potential transformer is

___ a. 

___ b. 

___ c. 

___ d. 

5. Two types of potential transformers are

___ a. potential and current.

___ b. potential delta.

___ c. potential and single-phase.

___ d. step-up and step-down.

6. In a step-up potential transformer the secondary has

___ a. more turns than the primary.

___ b. more current than the primary.

___ c. fewer turns than the primary.

___ d. the same current as the primary.

7. The voltage in the secondary of a step-up potential transformer is

____ a. less than the primary voltage.

____ b. the same as the primary voltage.

____ c. greater than the primary voltage.

____ d. less than the applied voltage.

8. In a step-up potential transformer the secondary has

____ a. a greater current than the primary.

____ b. less current than the primary.

____ c. less turns than the primary.

9. In a step-down potential transformer, the

____ a. secondary is connected to the source of power.

____ b. primary carries all the current.

____ c. secondary has more turns than the primary.

____ d. primary has more turns than the secondary.

10. The voltage in the primary of a step-down potential transformer is

____ a. less than the secondary voltage.

____ b. greater than the secondary voltage.

____ c. the same as the secondary voltage.

____ d. less than the applied voltage.

11. The primary of a step-down potential transformer has

____ a. less current than the secondary.

____ b. more current than the secondary.

____ c. less turns than the secondary.

____ d. less voltage than the secondary.

12. A device used to step current down for instrument operation is the

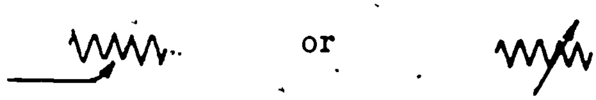
____ a. rectifier.

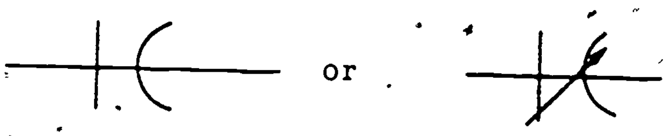
____ b. rheostat.

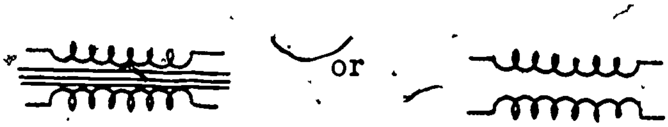
____ c. current transformer.

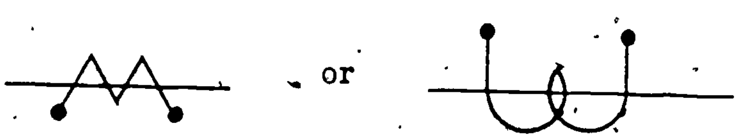
____ d. potential transformer.

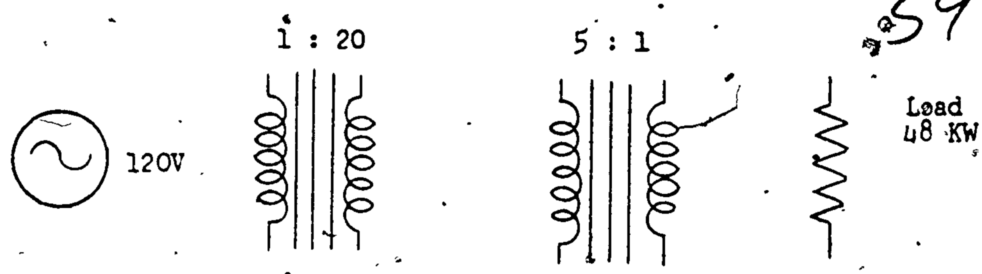
13. The symbol for a current transformer is

____ a. 

____ b. 

____ c. 

____ d. 



Complete the above schematic diagram by drawing lines to show connection of

14. Number 1 transformer to the alternator and to Number 2 transformer.

15. Number 2 transformer to the load.

Compute the following values.

16. Number 1 transformer secondary voltage __________.

17. Number 2 transformer secondary voltage __________.

18. Number 1 transformer secondary current __________.

19. Number 2 transformer secondary current __________.

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