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IDENTIFIERS Military Curriculum Project

ABSTRACT

This independent self-study course on electricity was developed from military sources for use in vocational education. The course provides a source of study materials on the principles of electricity. The five lessons are divided into two parts, each of which contains criterion objectives and self-tests. The course provides basic coverage of atomic structures and matter; series and parallel circuits; measuring devices; batteries and electromagnetism. The course is presented in a programmed instruction format, in small steps using frames, and is easy to read and understand. Criterion objectives, self-tests, and answers are given. The materials are suitable for supplementing classroom activities, for enrichment materials, and for additional help for slow learners. (KC)

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.

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

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Military Curriculum Materials
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1960 Kenny Road, Columbus, Ohio 43210
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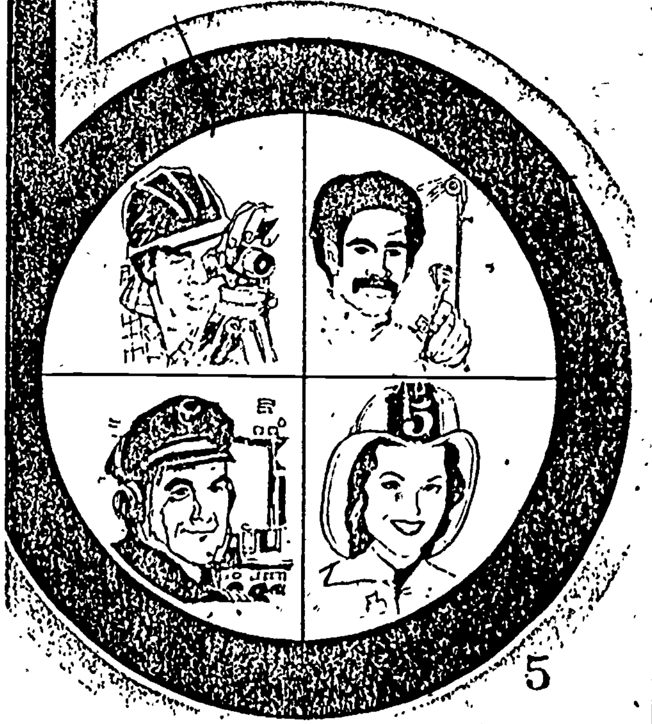
Military Curriculum Materials for Vocational and Technical Education

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
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100 North First Street
Springfield, IL 62777
217/782-0759

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FUNDAMENTALS OF ELECTRICITY

Table of Contents

Course Description

This introductory course provides learners with a source of study materials on the principles of electricity. Each lesson is divided into two parts, each of which contains criterion objectives and self-tests. The course provides basic coverage of atomic structures and matter; series and parallel circuits, measuring devices; batteries and electromagnetism.

Lesson 1 – *Matter and Atomic Structure* is divided into two parts, the first dealing with matter, covers matter, volume, density, weight, porosity, inertia, and impentrability. The second part focused on atomic structure covers parts of the atom, atomic number and weight, positive, negative, and neutral charges, and electron direction.

Lesson 2 – *Introduction to Electricity and Electrical Symbols* is also divided into two parts. The first is an introduction to electricity and covers static electricity, charged bodies, current flow, potential difference, Ohm's Law, and resistance. The second part covers electrical symbols and schematic diagrams.

Lesson 3 – *Series Circuits and Parallel Circuits* also contains two parts. Part A solves series-circuit problems for current, voltage drop across an individual component, resistance of an individual component, total resistance, and total voltage. This section also covers short circuits, open circuits, and the use of the ohmmeter, ammeter, and voltmeter. Part B solves problems in parallel circuits for total resistance, resistance of an individual branch, total current, current flow of an individual branch, and total voltage. It also covers reciprocals.

Lesson 4 – *Series-Parallel Circuits and Batteries,* Part A, covers series-parallel circuits and is concerned with solving for the unknown values of resistance, current, and voltage in series circuits connected in parallel, and in parallel circuits connected in parallel, and in parallel circuits connected in series. Part B covers batteries.

Lesson 5 – *Magnetism and Electromagnetism and Electromagnetic Induction,* Part A, is concerned with magnetism and covers natural and artificial magnets and the laws of polarity. Part B covers electromagnetism and electromagnetic induction.

The course is presented in a programmed instruction format. The information is presented in small steps by using frames, and is easy to read and understand. These materials could supplement classroom activities, be used as enrichment materials, and be helpful to the slower learner who needs additional help.

Developed by:

United States Marine Corps

Development and Review Dates

Unknown

Occupational Area:

Building and Construction

Cost:	**Print Pages:**
$6.25	305

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

Suggested Background:

None

Target Audiences:

Grades 10-14

Organization of Materials:

Programmed instruction, criterion objectives, self-tests, answers

Type of Instruction:

Individualized, self-paced

Type of Materials:

		No. of Pages:	Average Completion Time:
Lesson 1 –	*Matter and Atomic Structure*	64	180 minutes
Lesson 2 –	*Introduction to Electricity and Electrical Symbols*	59	180 minutes
Lesson 3 –	*Series Circuits and Parallel Circuits*	68	180 minutes
Lesson 4 –	*Series-Parallel Circuits and Batteries*	47	180 minutes
Lesson 5 –	*Magnetism and Electromagnetism and Electromagnetic Induction*	67	170 minutes

Supplementary Materials Required.

None

Expires July 1, 1978

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FUNDAMENTALS OF ELECTRICITY

Lesson 1

Matter and Atomic Structure

STUDY ASSIGNMENT: Information for MCI Students.
Course Introduction.
MCI 11.16a, Fundamentals of Electricity, part A and B of lesson 1.

STUDY NOTES: This course is presented in a form known as PROGRAMMED INSTRUCTION, a method by which you learn the material at your own rate of speed. The subject matter is presented in small steps called FRAMES. You should read each frame very carefully and then answer the question(s) asked. Be sure to keep the answer for the frame you are working on covered up with a slip of paper until you have written your answer. Compare your answer with the correct answer(s) found in the frame below it in the column on the left side. Below we have printed sample frames.

	1. The universe contains nothing but matter. The sun and a particle of dust are parts of the universe; therefore, each is an example of ________.
MATTER	2. Everything in the universe is composed of matter. Underline the items below that are matter. a. Truth b. Rock of Gibraltar c. Freedom d. Air e. A tree

The answer to the first frame, question #1, is found in the frame below, in the column to the left of question #2. In other words, MATTER is the correct answer to question #1. Your answer should be the same or very similar to the given answer. IF IT IS NOT, GO BACK AND READ THE FRAME AGAIN. You SHOULD NOT be worried about time. You SHOULD be concerned about understanding the material given. If you find yourself having difficulty, you should return to where your difficulty began and go through it again. If you follow these instructions carefully, you will find yourself gaining a great deal of knowledge. GOOD LUCK!

SELF TESTS: At the end of each programmed booklet is a short self-test based on the objectives for that booklet; answer these to the best of your ability and check your answers on the pages following the self-test. If necessary, review the lesson until you are satisfied that you have accomplished the lesson objectives.

APPROXIMATE READING TIME: 180 minutes for this lesson.

LESSON 1

PART A

MATTER

OBJECTIVES

1. Given a list of definitions pertaining to the words listed below, match each word to its proper definition.

   a. Matter

   b. Mass

   c. Volume

   d. Density

   e. Weight

   f. Porosity

   g. Inertia

   h. Impenetrability

2. For a given body of matter, state what happens to its mass if its location, volume, or state is changed.

3. Given the volume and weight of a body, determine its density.

4. State what effect the distance an object is from the surface of the earth has on the weight of the object.

5. State the results of matter having the property of porosity.

6. List three examples of the inertia of objects (balls, aircraft, vehicles) being overcome.

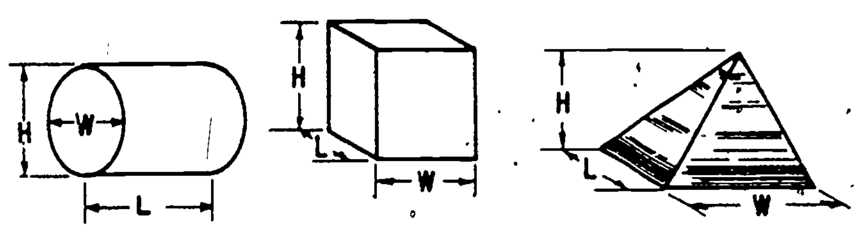
7. List the three states of matter.

8. Select from a list of the characteristics of matter those characteristics pertaining to each state of matter.

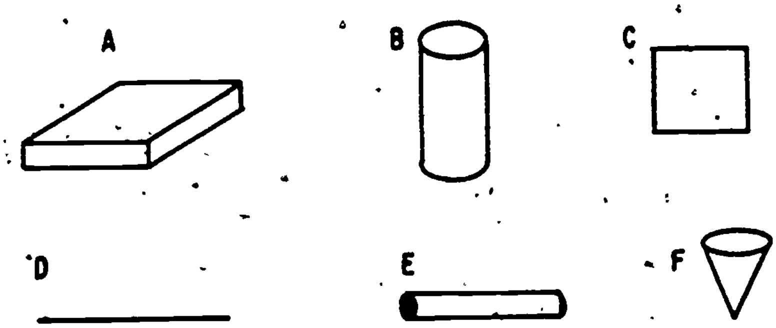
INTRODUCTION

Electricity cannot be seen. No one can draw a picture of electricity nor can anyone capture a boxful of it. Electricity and the laws associated with it are theory. You will have to accept this theory, as science has done, before you can understand any of the rules or laws of electricity.

6

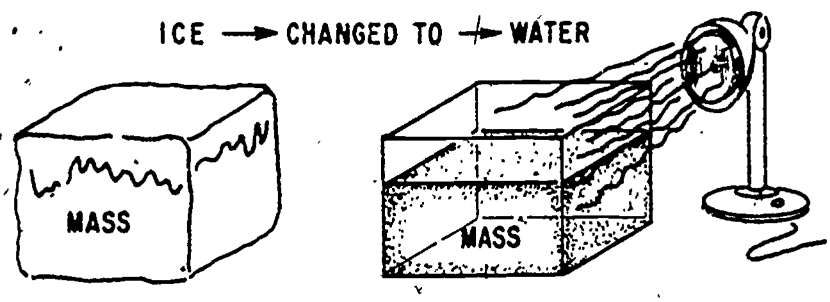
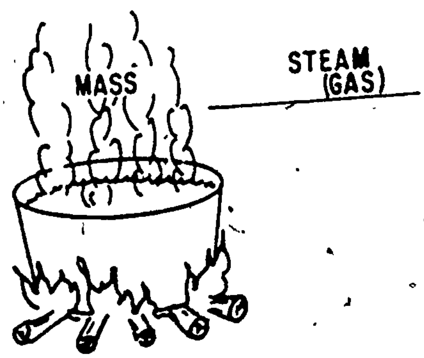
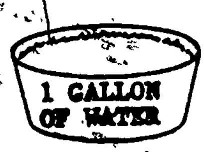
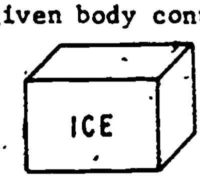
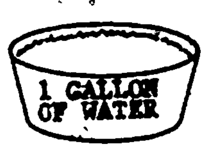
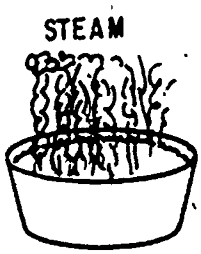
	1. The universe contains nothing but matter. The sun and a particle of dust are parts of the universe; therefore, each is an example of ______________.
MATTER	2. Everything in the universe is composed of matter. Underline the items below that are matter. a. Truth b. Rock of Gibraltar c. Freedom d. Air e. A tree
b. <u>ROCK OF GIBRALTAR</u> d. <u>AIR</u> e. <u>A TREE</u>	3. The chair in which you are sitting, the pencil with which you are writing, and the page of the book you are reading are all examples of ______________.
MATTER	4. Since everything in the universe has weight and occupies space, matter can be defined as anything that has ____________ and occupies ____________.
WEIGHT SPACE	5. Define matter. ______________________________ ______________________________ ______________________________
ANYTHING THAT HAS WEIGHT AND OCCUPIES SPACE.	6. All matter has the property of volume. Since matter has volume, it will have three dimensions.  L=LENGTH W=WIDTH H=HEIGHT The dimensions that give matter the property of volume are ____________, ____________, and ____________.

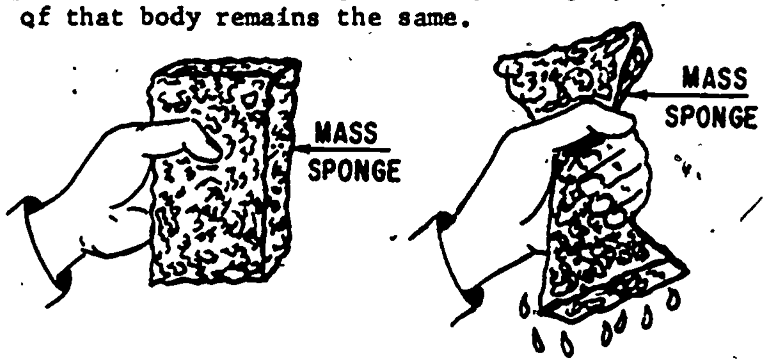
7

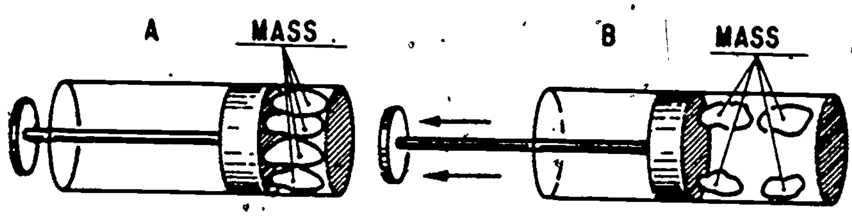
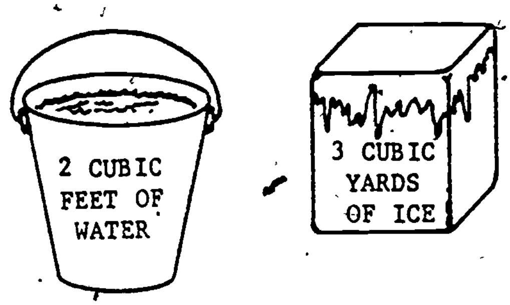
LENGTH WIDTH HEIGHT	7. To have the property of volume, matter must have <u>all</u> three dimensions. Underline the illustrations that <u>represent</u> a body having volume. 
A B E F	8. Matter is defined as anything that has weight and occupies space. By occupying space, it will have the property of ______________.
VOLUME	9. Matter also has ______________. 
MASS	10. The mass of a given body does not change although its state (solid, liquid, gas) changes. If a given body is changed from a solid to a liquid, what will happen to the mass of the body? ____

11.16
lsn 1; p. 5

8

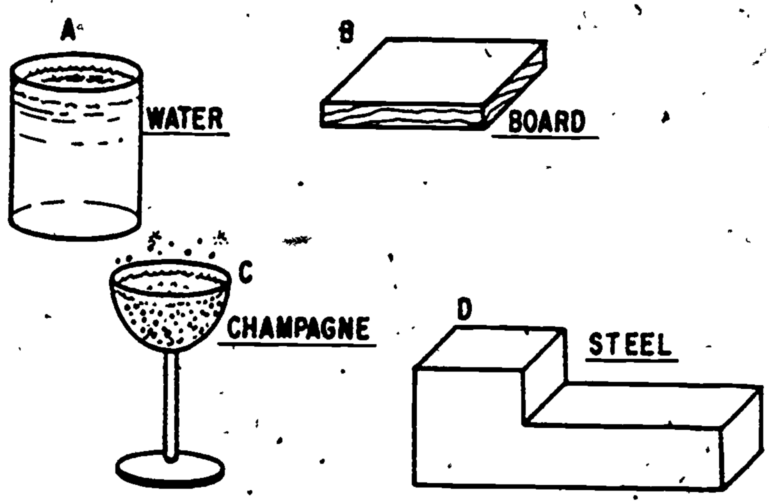
REMAINS UNCHANGED. (OR EQUIVALENT)	11.  In the illustration above, the mass of the body ______________ change. (did/did not)
DID NOT	12.  The state of the water (liquid) has now been changed to steam (gas). What has happened to its mass? ______________________________
REMAINED THE SAME.	13. Mass is the amount of matter a given body contains. If  is frozen into  , then melted into  , then heated to form  , the matter has been changed to the three different states. In all three states, the body of matter contained the same ______________.

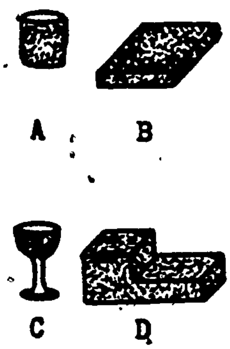
MASS	14. The amount of matter a given body contains is its ________.
MASS	15. Mass is the ____.
AMOUNT OF MATTER A GIVEN BODY CONTAINS	16. A gallon of paint, which has a certain mass, is carried from the basement to the second floor of a building. The location of the paint has been changed. What has happened to its mass? ________________
REMAINED UNCHANGED. (OR EQUIVALENT)	17. A baseball hit by a batter to an outfielder would have the same mass when caught as when hit. If this baseball could be hit to the moon, its <u>mass</u> would remain ________________.
UNCHANGED (OR EQUIVALENT)	18. The mass of a body ____________ (is/is not) affected by changing its location.
IS NOT	19. When the <u>state</u> or <u>location</u> of a given body is changed, the mass will remain ____________.
CONSTANT (OR EQUIVALENT)	20. When the volume of a given body changes, the mass of that body remains the same.  In the illustration above, the mass of the sponge remains constant, although the volume has ________________ (increased/decreased).

DECREASED	21.  In item A, the piston is in; in item B, it is out. Going from illustration A to illustration B, the volume has ______________, while mass has ______________________________.
INCREASED REMAINED CONSTANT	22. Define mass. ____________________________ ____________________________________ __________________. When the location, state, or volume of a given body is changed, its mass will ________________________________.
THE AMOUNT OF MATTER A GIVEN BODY CONTAINS REMAIN CONSTANT	23.  Volume is the space mass occupies. In the illustrations above, the bucket contains ___ ______ feet of water, and there are ___ ________ yards of ice. These are measurements of the volume of the two masses. Volume is always measured in ________ units.
2 CUBIC 3 CUBIC CUBIC	24. The space mass occupies is its ______________.
VOLUME	25. A tank contains 2 cubic feet of gas; this is a measure of the ____________ of the gas.

VOLUME

26. Shade the volume of the mass in each of the following:





27. Volume is the ______________________________
______________________________.

SPACE THAT MASS OCCUPIES

28. The density of a body is the weight per cubic unit of its volume. For example, the density of fresh water is 62.5 pounds per cubic foot.

The density of a body is found by dividing its weight by its volume:

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}} \quad \text{or} \quad D = \frac{W}{V}$$

Use the formula above to solve the following problem.

Two cubic feet of salt water has a weight of 128 pounds. What is the density of salt water? NOTE: Density must be expressed in weight per cubic unit.

$D = \frac{W}{V}$

$D = \frac{128}{2}$

D = 64 POUNDS PER CUBIC FOOT

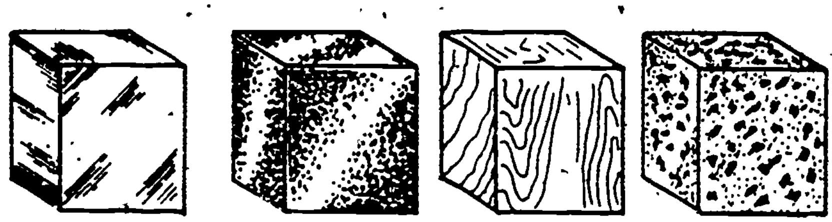
29. Dividing the weight of a body by its volume will give you the ________________ of that body.

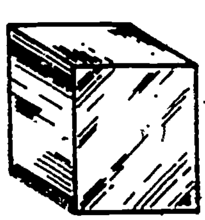
DENSITY

30. Density is the weight of a unit volume of matter. Iron has a greater density than wood. This means that one cubic foot of iron weighs more than one cubic foot of wood. The more matter (mass) there is in a given volume of a substance, the greater the density of the material.

Shown below are some examples of the density of different materials. Circle the item that has the greatest density.

DENSITIES IN POUNDS PER CUBIC FOOT





31. A tank with a volume of 32 cubic feet is filled with a fluid weighing 1280 pounds. What is the density of this fluid? NOTE: Density must be expressed in weight per cubic unit.

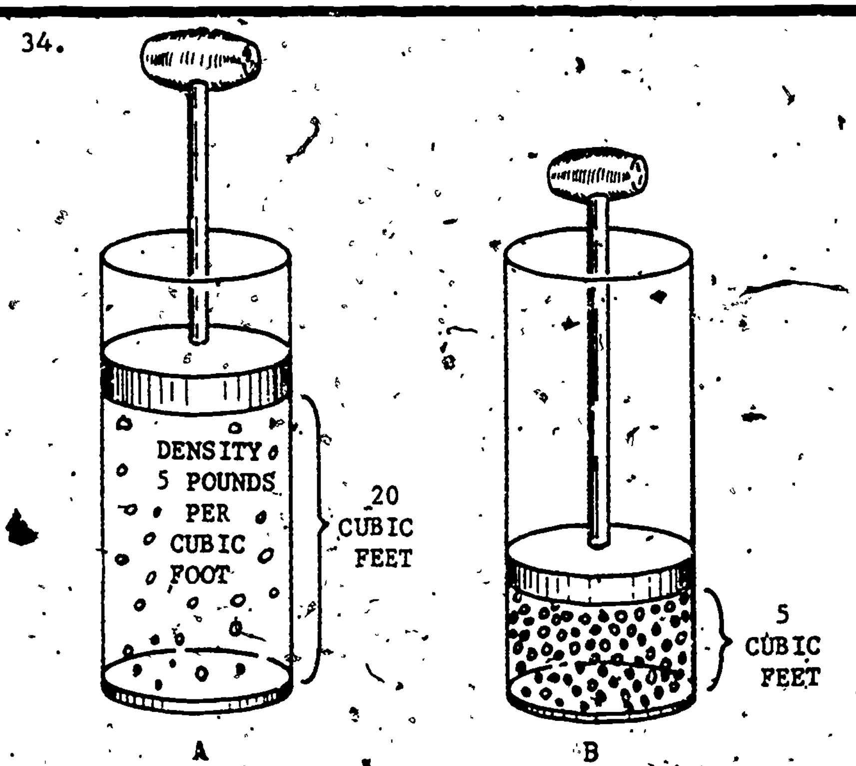
$D = \frac{W}{V}$ $D = \frac{1280}{32}$ D = 40 POUNDS PER CUBIC FOOT	32. When volume and density are known, the total weight of a body can be found by transposing the formula in this manner: WEIGHT = DENSITY × VOLUME (OR) $W = D \times V$ - Solve this problem - A tank contains 10 cubic feet of salt water. What is the total weight of the salt water? NOTE: The density of salt water is 64 pounds per cubic foot.
$W = D \times V$ $W = 64 \times 10$ W = 640 POUNDS	33. A tank with a volume of 100 cubic feet is filled with a gas which has a density of 4 pounds per cubic foot. What will be the density of this gas if it is compressed to a volume of 2 cubic feet? To solve for the new density, follow the steps below and fill in all blanks. STEP (1) Find the total weight of the gas. $W = D \times V$ $W = 4 \times 100$ W = ______ pounds STEP (2) To determine the new density, divide the weight of the gas by its new volume (2 cubic feet). $D = \frac{W}{V}$ $D = \frac{400}{2}$ D = ______ pounds per cubic foot Circle the number beside the statement that is correct for the problem above. a. As volume decreased, density decreased. b. As volume decreased, density increased. c. As volume decreased, density remained the same.

W = 400

D = 200

b. AS VOLUME DECREASED, DENSITY INCREASED.

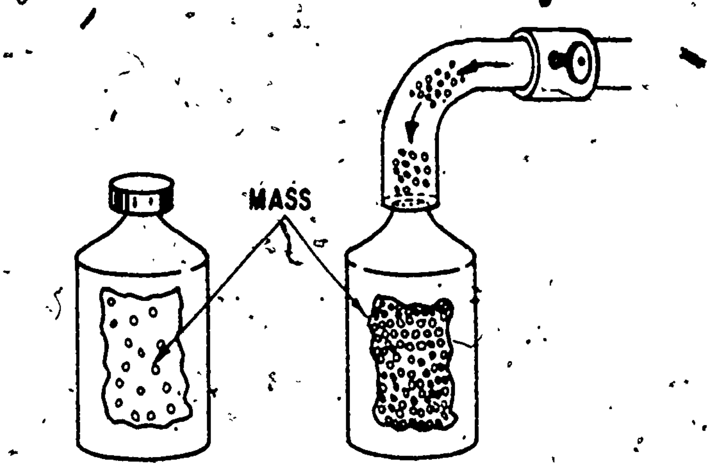
34.



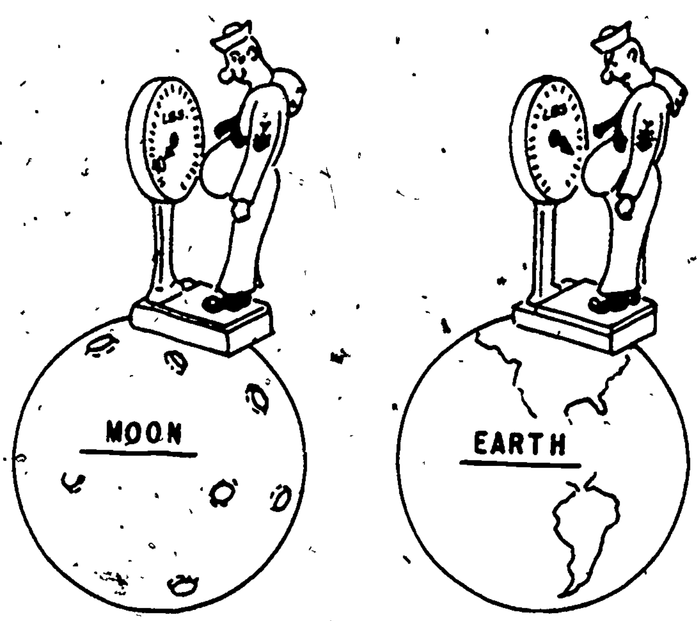
A gas with a density of 5 pounds per cubic foot has a volume of 20 cubic feet, as in item A above. What is the density of the gas after it has been compressed as in item B? ______

20 POUNDS PER CUBIC FOOT

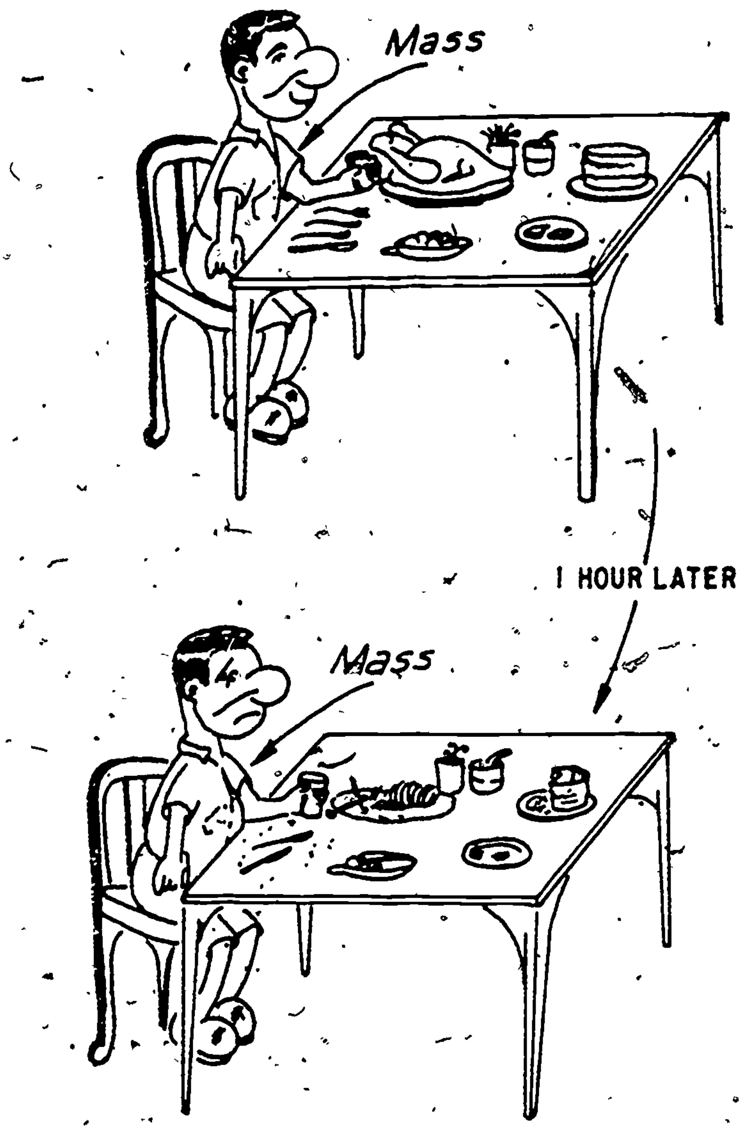
35.



As the bottle is filled with gas, the mass will increase but the volume will remain the same, while the weight and density will ______.
(increase/decrease)

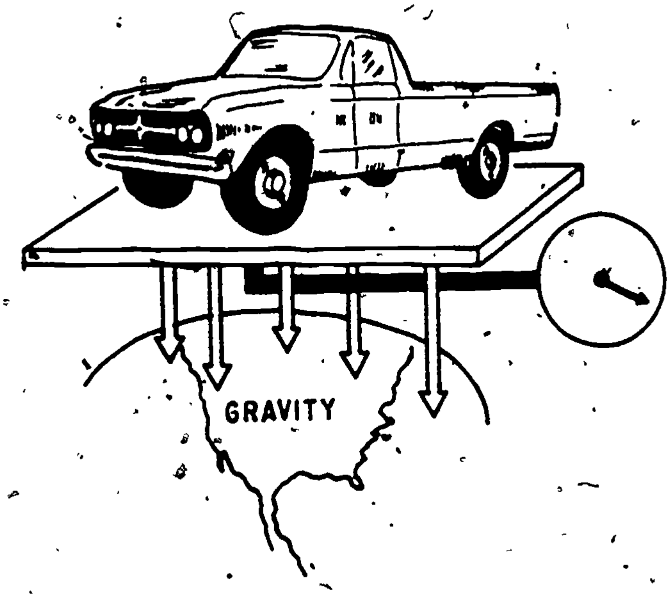
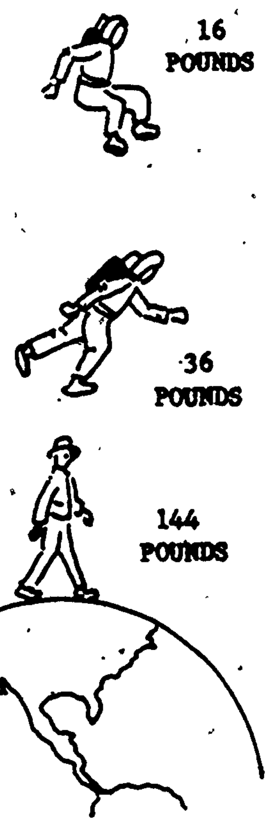
INCREASE	36. Two cubic feet of mercury have a weight of 1692 pounds. What is the density of mercury? ______
846 POUNDS PER CUBIC FOOT	37. Place a check mark by the correct statement. ____ a. Density is the amount of mass a given body contains, and the formula for finding density is $D = \frac{V}{W}$. ____ b. Density is weight per unit volume, and the formula for finding density is $D = \frac{W}{V}$. ____ c. Density is weight per unit volume, and the formula for finding density is $W = D \times V$.
b.	38. The gravitational pull of the earth is six times greater than the gravitational pull of the moon.  How much will the man on the moon weigh if he is moved from the moon to the earth? ________ pounds

240 POUNDS	39. An increase in mass will cause an increase in gravitational pull.



In the illustration above, the mass of the man has ______________. This has caused a(n) ______________ in his weight.

11.16
lsn 1; p. 14

INCREASED INCREASE	40.  Weight is a measure of the effect of ________ on a body.
GRAVITY	41. The attractive force of the earth on matter is gravity. This attractive force decreases as the distance from the earth's surface increases; therefore, as a body increases its distance from the earth, its weight will ______________. 

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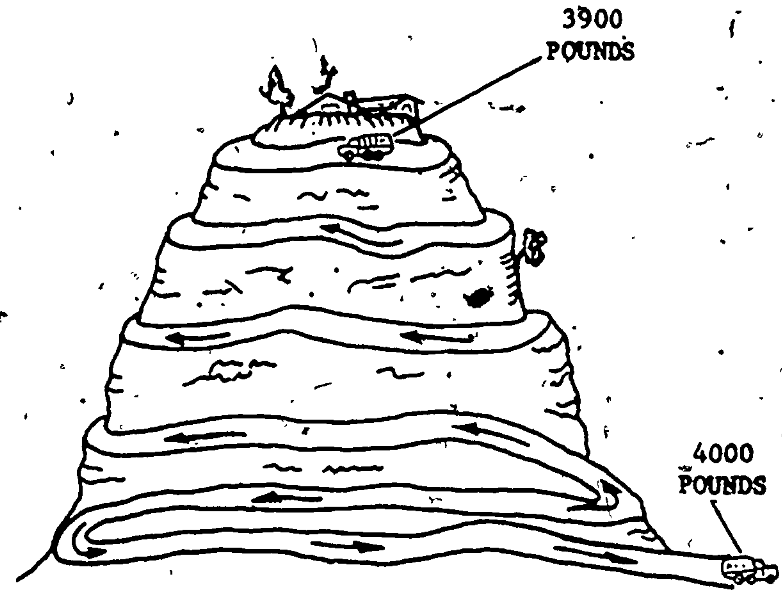
lsn 1; p. 15

18

DECREASE

42.



Compare the weight of the body (car) at sea level with its weight on top of the mountain. At which point does it weigh the more? ____________

SEA LEVEL

43. Weight is a measure of ____________

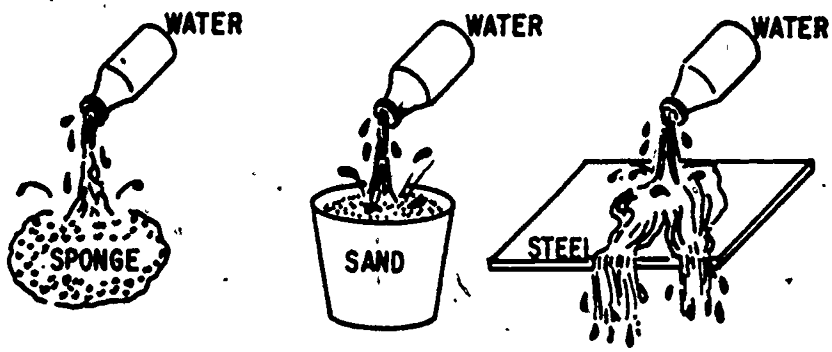
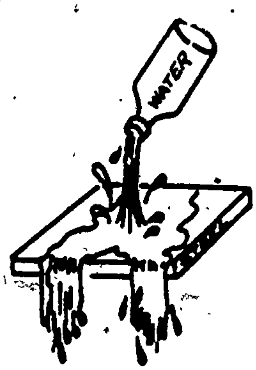
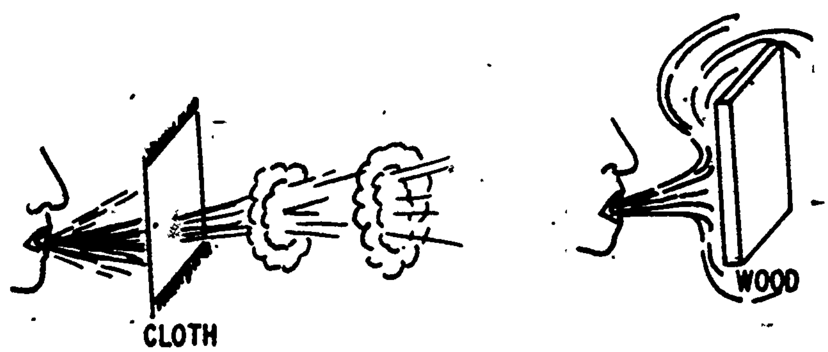
____

____

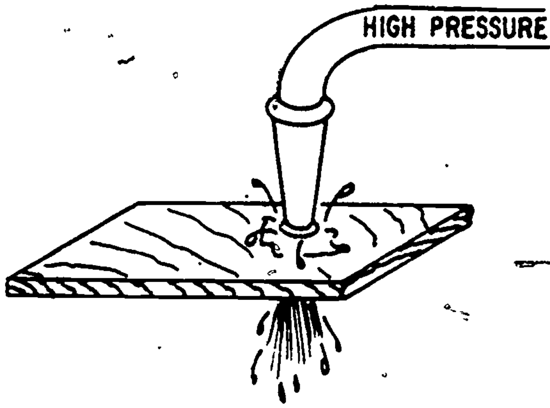
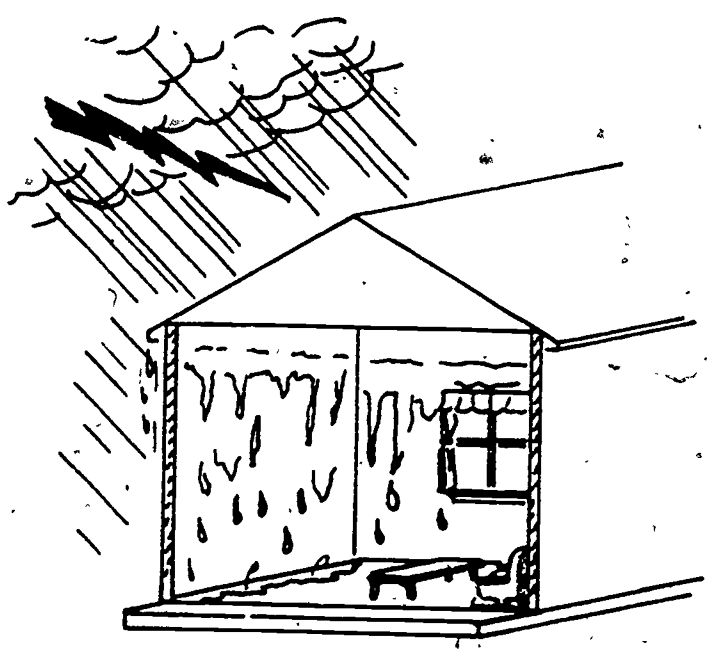
THE EFFECT OF GRAVITY ON A BODY

44. Another property of matter is universal attraction. This means that all matter attracts all other matter.

All matter attracts all other matter. This is the property known as ____________ ____________

UNIVERSAL ATTRACTION	45. Another property of matter is porosity.  Some matter is more porous than others. In the illustration above, circle the matter that will absorb the smallest amount of water.
	46.  In the illustration above, the smoke will travel through the cloth because it has more space between its particles. The smoke will not travel through the wood because it has less ______ ______.

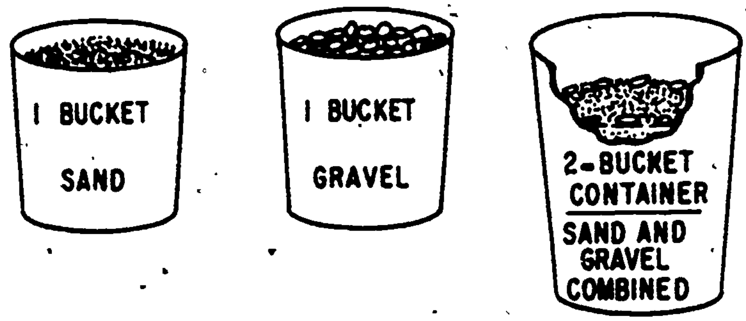
11.16
lsn 1; p. 17

SPACE BETWEEN ITS PARTICLES	47.  All matter has the property of porosity. We normally think of steel, or even wood, as being very solid; but water, under high pressure, can be forced through their minute openings because they have the property of __________.
POROSITY	48.  "Mama, get the mop, because these walls have the property of ______________."

11.16
lsn 1; p. 18

POROSITY

49. Porosity permits two substances to be combined and occupy less space than both would occupy separately.



What does the illustration above show is possible since matter has the property of porosity?

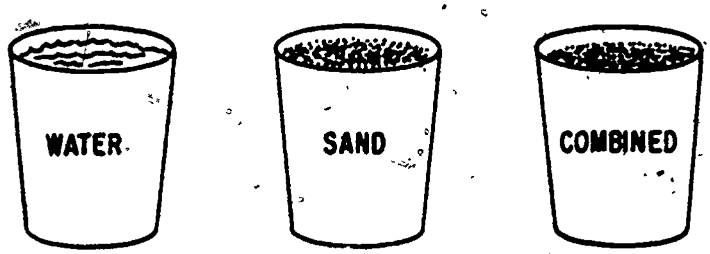
____

____

____

TWO SUBSTANCES CAN BE COMBINED AND OCCUPY LESS SPACE THAN BOTH OCCUPIED SEPARATELY.

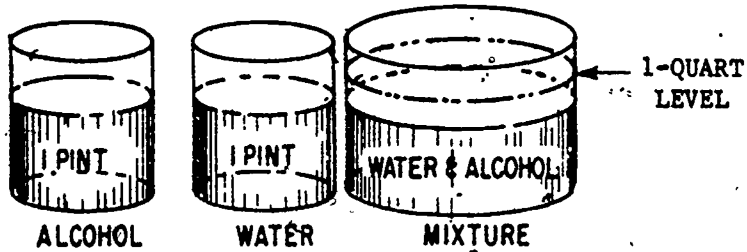
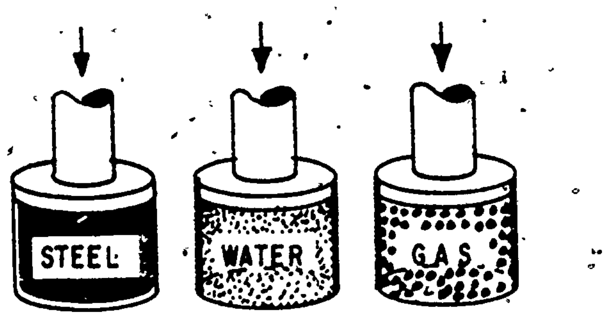
50. The space between the particles of one type of matter, which gives it the property of porosity, may be occupied by particles of another matter. The two will occupy less space when __________.

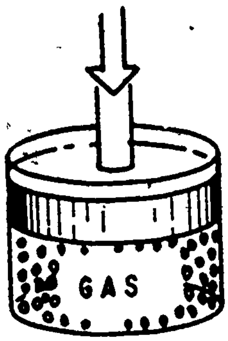
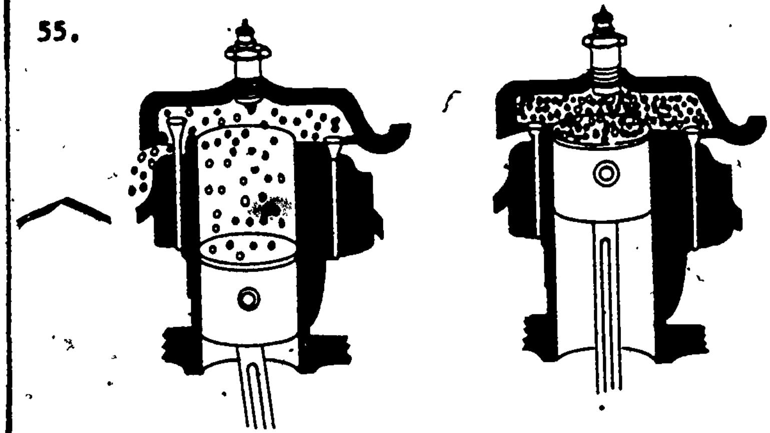
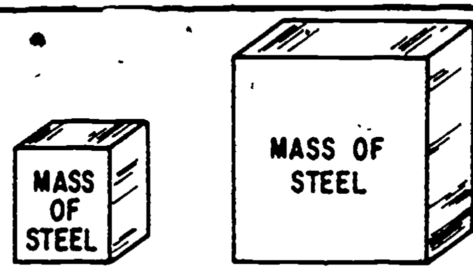
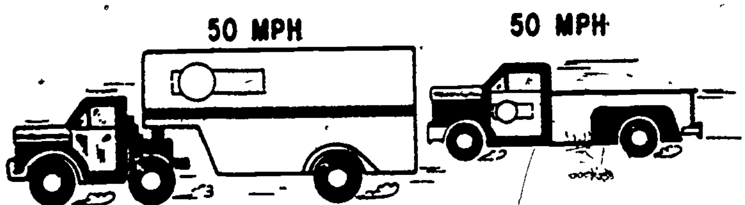


What makes it possible to pour a bottle of water into a bucket of sand without running it over?

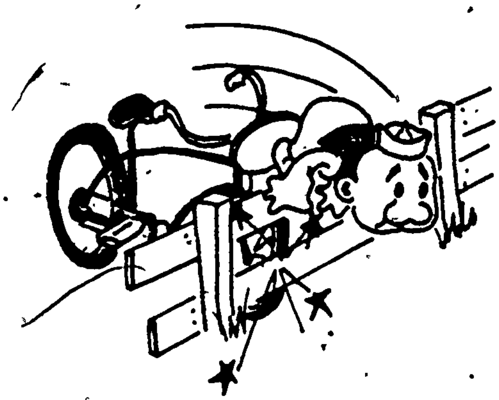
____

11.16
lsn 1; p. 19

COMBINED POROSITY	51. All matter has space between its particles (molecules). This is what gives matter the property of porosity.  Complete the statement below concerning the above demonstration. Porosity permits two substances to be combined and occupy less ____________ than both occupy ____________.
SPACE SEPARATELY	52. What gives matter the property of porosity? ____ ____
THE SPACE BETWEEN THE PARTICLES OF MATTER.	53. Porosity permits some matter to be compressed easier than others. Gas is matter that can be easily compressed. What property of matter permits this? ____________
POROSITY	54.  Circle the matter which is the easiest to compress.

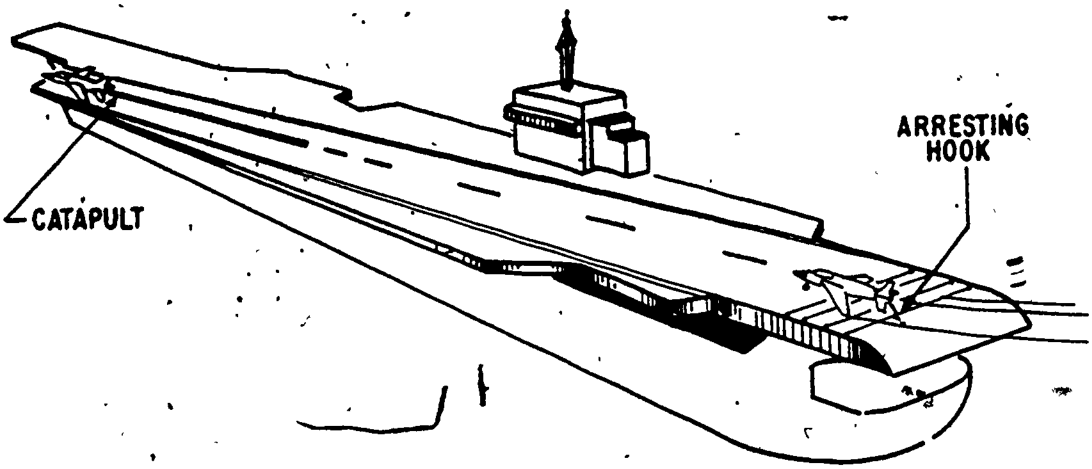
	55.  What property of matter permitted the large volume of air to be taken into the cylinder and be compressed? ____________
POROSITY	56. The amount of matter a given body contains is its ____________.
MASS	57.  A B Which item above would require more force to move it (overcome its inertia)? ______
B	58.  A B Which truck would require more force to overcome its inertia and stop it? ______

11.16
lsn 1; p. 21

A	59. The more mass, the more force required to overcome its ________________.
INERTIA	60. The property of matter that requires an outside force to be applied to stop or start that matter is inertia. Inertia is the property of matter that requires an ______________ ____________ to be applied to stop or start that matter.
OUTSIDE FORCE	61. A body at rest will remain at rest unless acted upon by an outside force. A body in motion will remain in motion unless acted upon by an outside force.  What is required to stop the above man? ______________________________ What property of matter requires this? ______________
AN OUTSIDE FORCE. INERTIA	

11.16
lsn 1; p. 22

62.

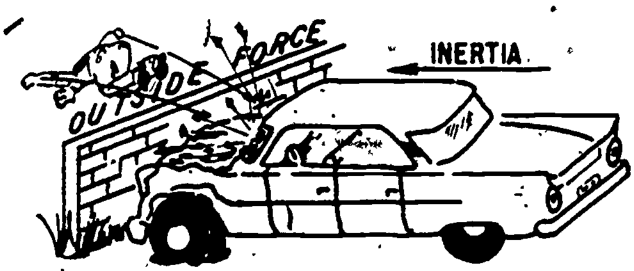


What two devices are being used to overcome the inertia of the above aircraft? a. ______________ b. ______________

a. CATAPULT

b. ARRESTING HOOK

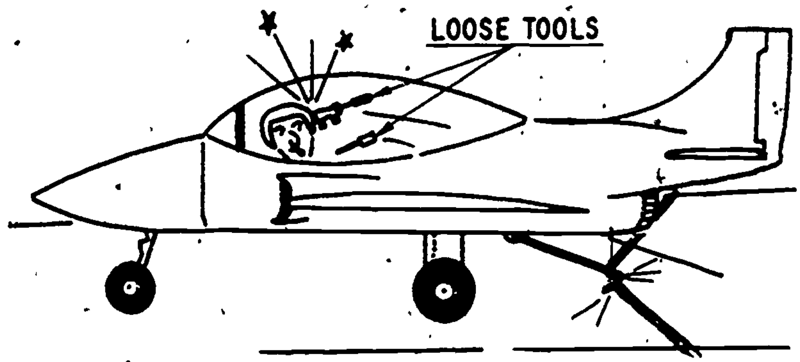
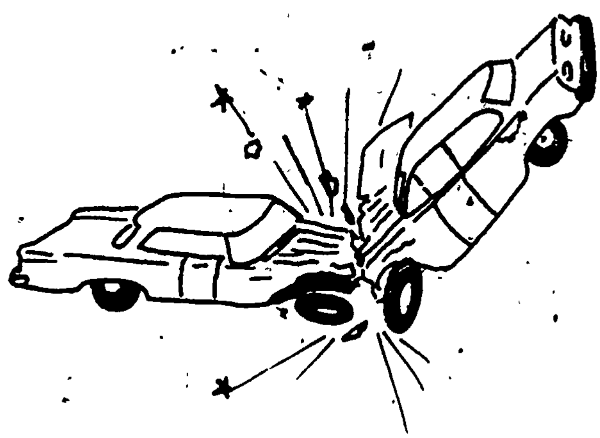
63.



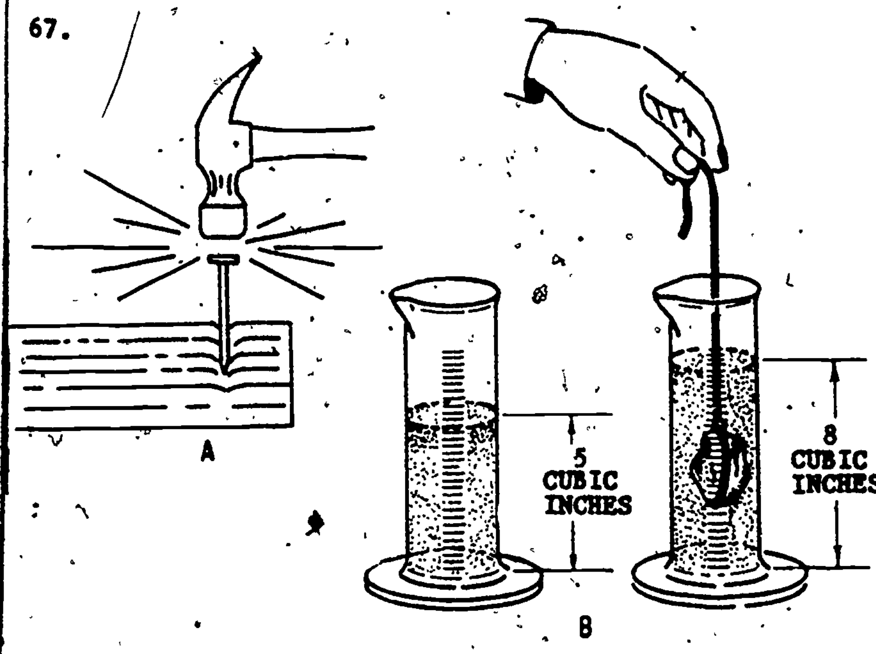
"Well, the property of ____________ has done it again."

11.16

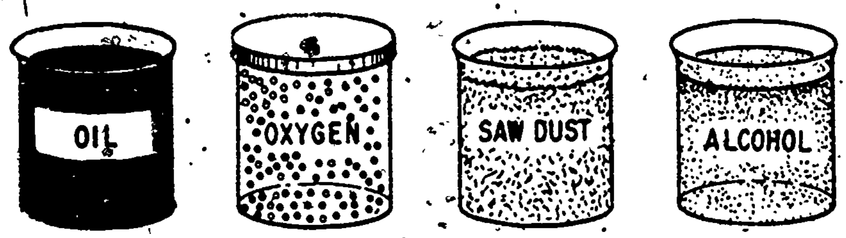
lsn 1; p. 23

INERTIA	64.  What property of matter did the plane captain overlook? ________________
INERTIA	65. Matter cannot start or ____________ itself.
STOP	66. All matter possesses the property of <u>impenetrability</u>.  The two vehicles could not occupy the same space at the same time because they possess the property of ______________________________.

11.16
lsn 1; p. 24

IMPENETRABILITY	67.  As the nail is driven into the wood, illustration A, the grains of wood will move aside. When the irregular-shaped object is placed in the container of fluid, illustration B, the fluid will rise an amount equal to the volume of the object. This is due to the fact that no two objects can occupy the same ______________ at the same time. What is the volume of **the irregular-shaped object?** ________ CUBIC INCHES
SPACE 3 CUBIC INCHES	68. Impenetrability **is the property of matter that will allow no two objects to** ______________ ______________________________.
OCCUPY THE SAME SPACE AT THE SAME TIME	69. **The states of matter are SOLID, LIQUID, and GAS.** **There are** _________ **states of matter.** (number)
THREE	70. **Matter may be a LIQUID.**  What is the **state of** matter **in the illustration?** ______________

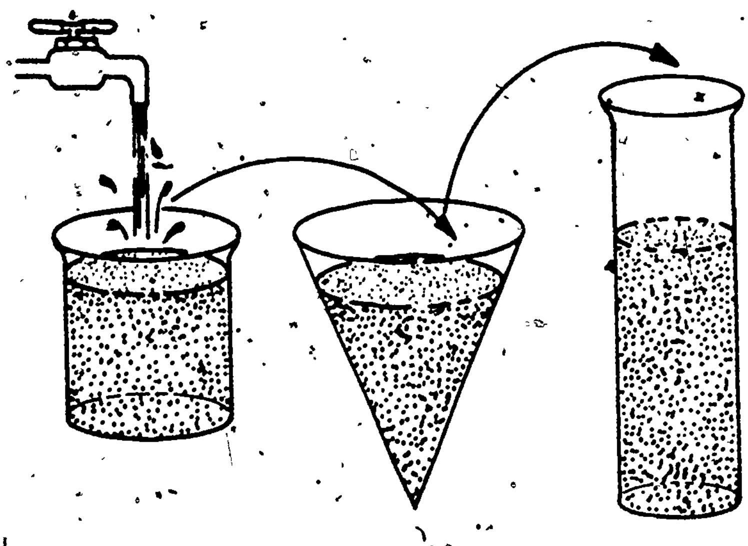
LIQUID	71.



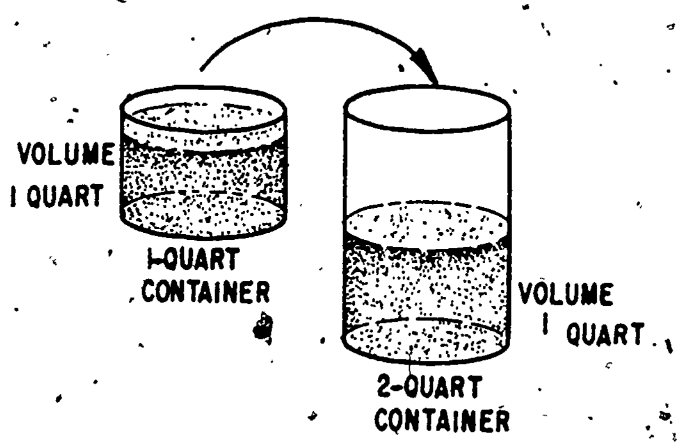
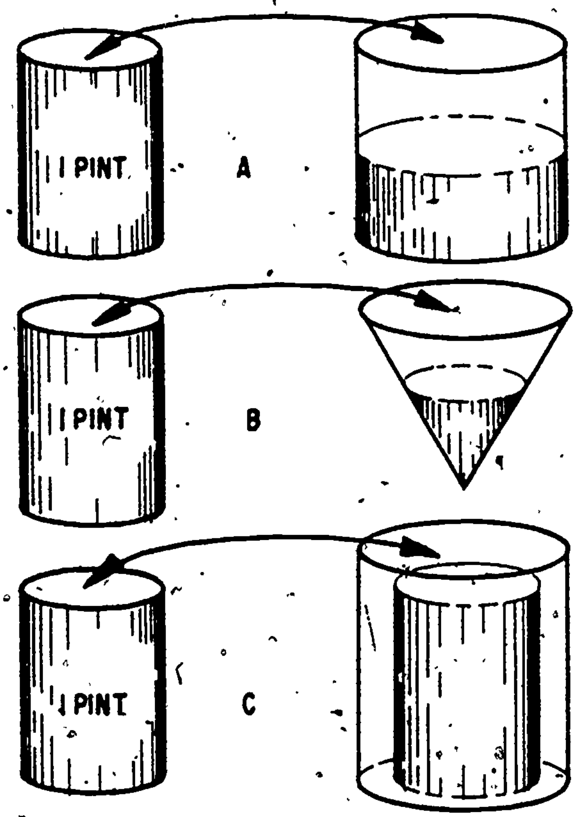
A B C D

Circle the letter under the illustration(s) of a liquid.

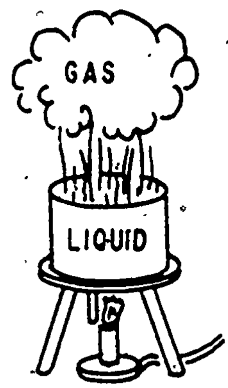
A D	72. A fluid is matter that flows easily and requires a container in which to store it or keep it confined.
	Liquid is a ____________.
FLUID	73.

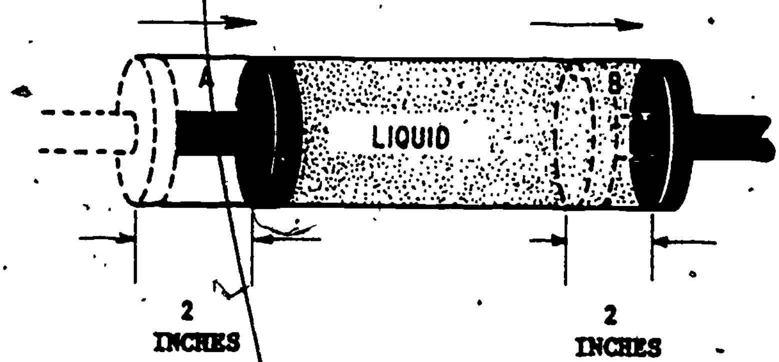
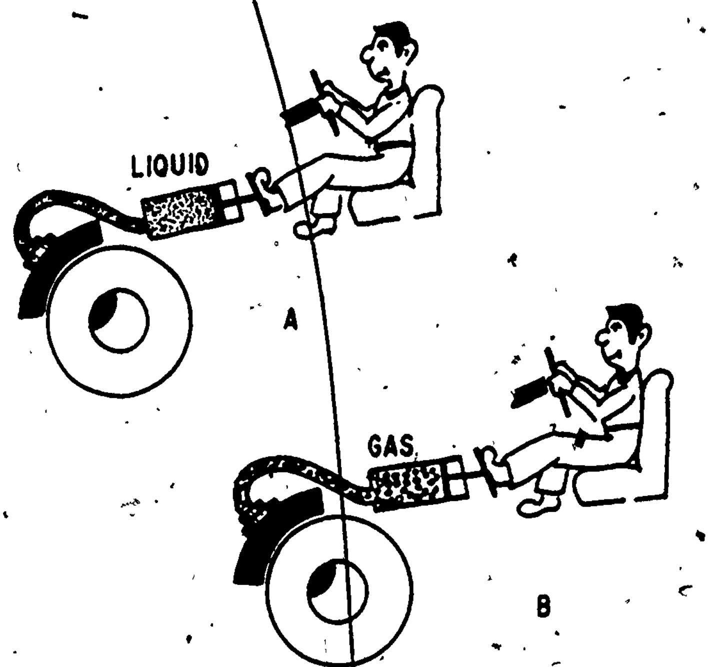


Liquid will assume the ______________ of the
(volume / shape)
container in which it is placed (see illustration).

SHAPE	74.  A liquid, as indicated above, will not assume the ________ of a larger container.
VOLUME	75.  Select the illustration(s) above which correctly represent(s) the transfer of a liquid from one container to another. ________

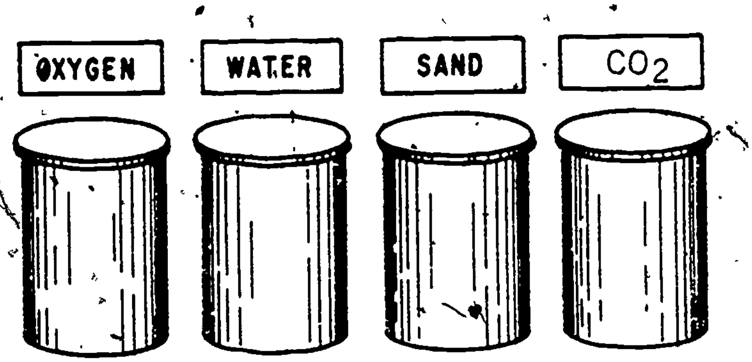
11.16
lsn 1; p. 27

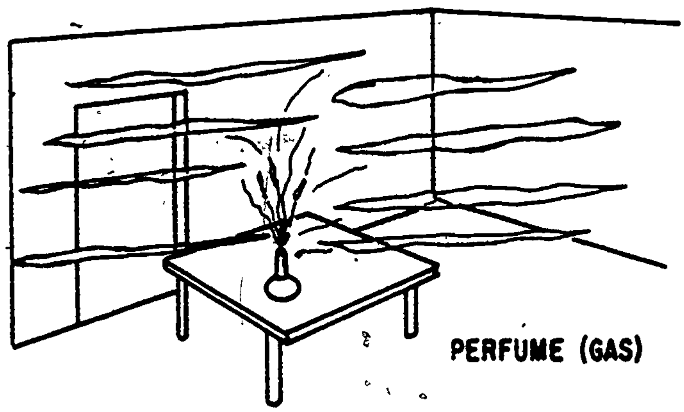
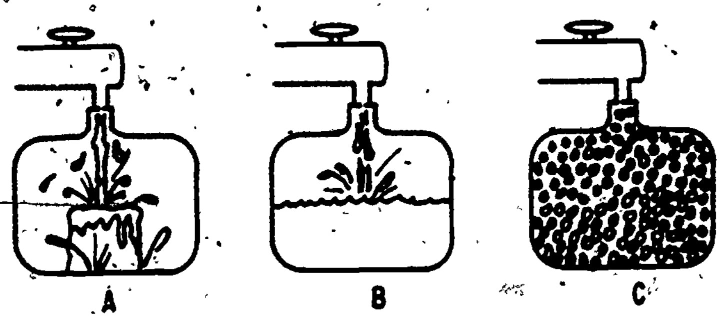
A B	76. A liquid will assume the ________ of any container but will not assume the ________.
SHAPE VOLUME	77.  As illustrated above, a liquid can be changed from a liquid to a ________.
GAS	78.  A liquid can be changed from a liquid to a ________.
SOLID	79. Liquids can be changed to a ________ or a ________.

GAS SOLID	80. A liquid, for all practical purposes, cannot be compressed.  When piston A moves 2 inches, piston B will move 2 inches. This is because liquids cannot be _______________________.
COMPRESSED	81.  Why will the person in illustration A get better braking action than the one in illustration B? _______________________________________ _______________________________________ _______________________________________

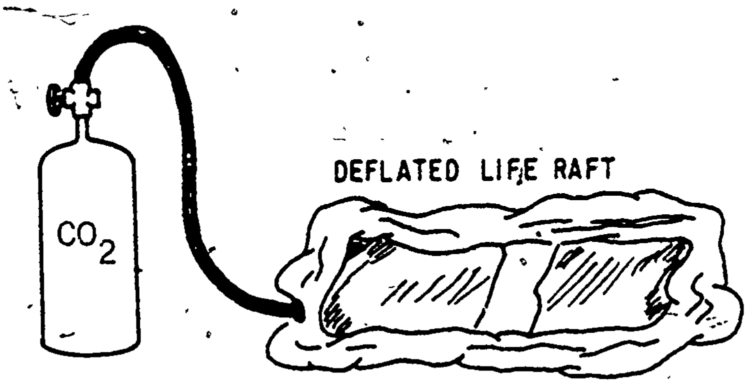
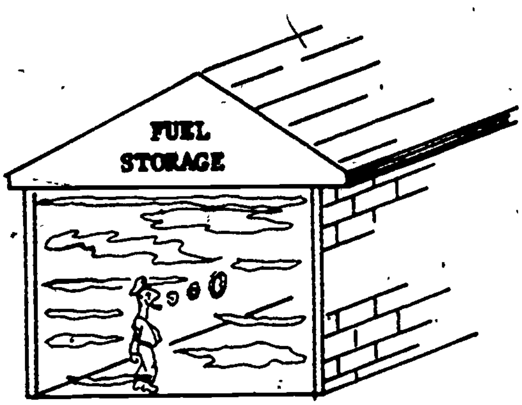
11.16

lsn 1; p. 29

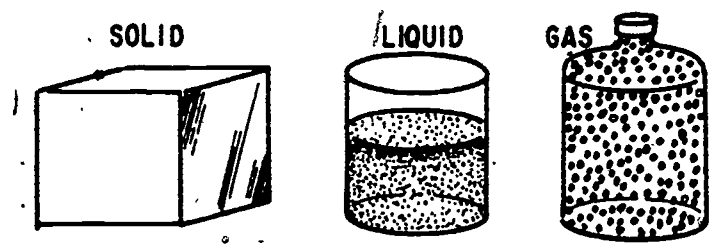
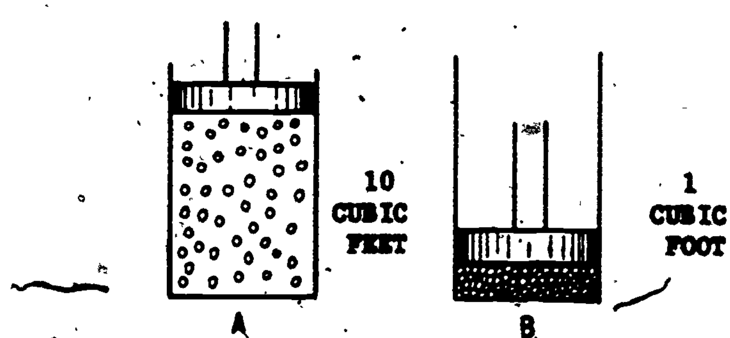
LIQUIDS, FOR ALL PRACTICAL PURPOSES, CANNOT BE COMPRESSED.	82. Select the characteristics of a liquid. a. Can be compressed. b. Is a fluid. c. Can be changed to a gas or a solid. d. Will assume the volume of any container. e. Will assume the shape of its container.
b., c., e.	83. Matter is anything that has weight and occupies space. Gas has weight and occupies space. Therefore, gas is __________.
MATTER	84.  A B C D Circle the letter under the illustrations representing matter as a gas.
A D	85. A fluid flows easily and requires a container in which to store it; therefore, both liquids and gases are __________.

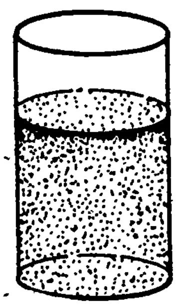
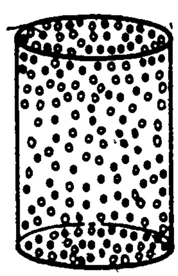
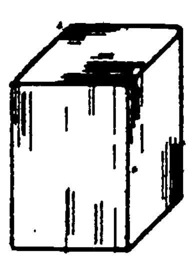
FLUIDS	86. The molecules (particles) of a gas move freely as compared to those of a solid or liquid. All matter has movement of its molecules (particles); but, in comparison, the molecules of a _______ will move more freely than those of a solid or a liquid.
GAS	87.  What characteristic of a gas allows the molecules (particles) of the perfume to fill the entire room? _______________________________________ _______________________________________
THE MOLECULES IN A GAS MOVE FREELY.	88. Gas will assume the shape and volume of any container in which it is placed.  Circle the illustration above that represents the transfer of a gas from one container to another.

11.16
lsn 1; p. 31

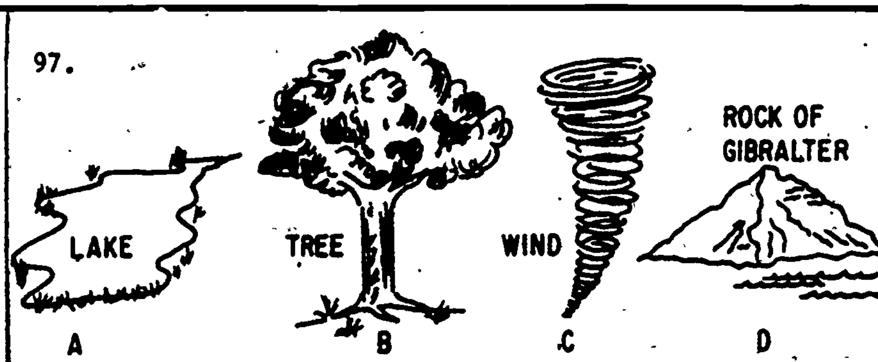
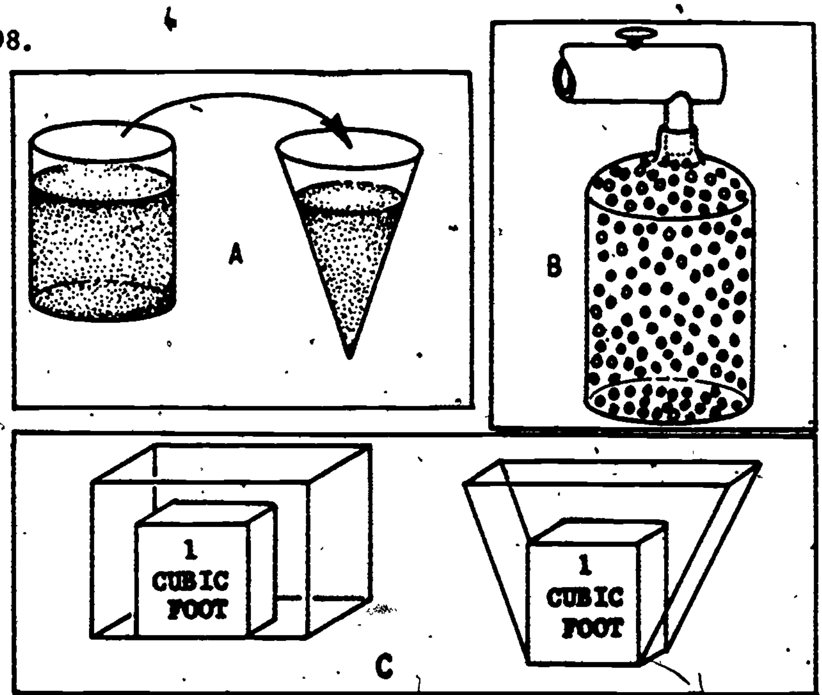
C	89.  What will happen to the shape and volume of the gas when it is released from the bottle into the life raft? ______ ______
IT WILL ASSUME THE SHAPE AND VOLUME OF THE LIFE RAFT.	90.  Mr. Dilbert may soon be pushing up daisies because a gas will assume the ______ and ______ of its container.

II.16
lsn 1; p. 32

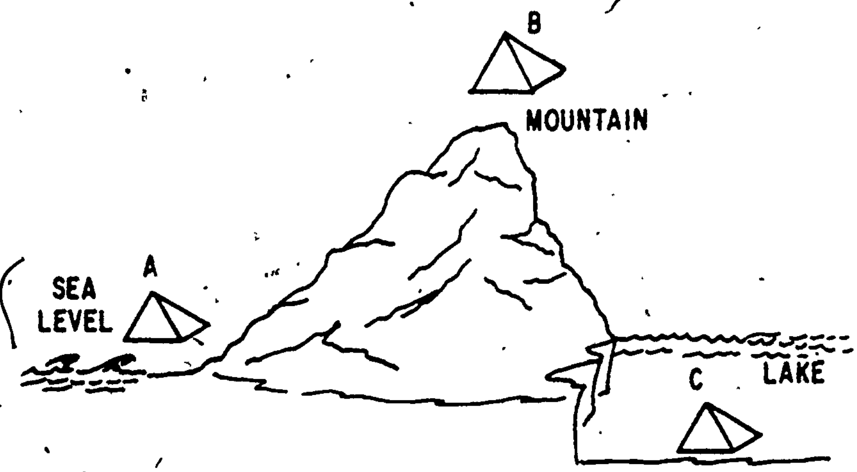
SHAPE VOLUME	91. The space between the particles (molecules) of matter gives it the property of porosity. Some matter may be compressed because of the property of ______________.
POROSITY	92.  If you could see the molecules (particles) in matter, as indicated above, the molecules would be very far apart in the ________.
GAS	93. A gas ______________ be compressed. (can/cannot)
CAN	94.  The illustrations indicate that a gas can be ______________.

COMPRESSED	95. Select the characteristics of a gas. a. May be compressed. b. Will assume the shape of its container. c. Has molecules that are solidly fixed. d. Will assume the volume of any container. e. Does not have weight. f. Is a fluid.
a., b., d., f.	96. There are three states of matter.  Matter may be a ______________.  Matter may be a ______________.  Matter may be a ______________.

11.16
lsn 1; p. 34

LIQUID GAS SOLID	97.  Circle the illustrations above that represent examples of solids.
B D	98.  Illustration A: When a liquid is moved from one container to another, it will assume the shape of the new container but not its volume. Illustration B: When a gas is moved from one container to another, it will assume the shape and volume of the new container. Illustration C: When a solid is moved from one place to another, it will maintain the same ____________ and ______________.

11.16
lsn 1; p. 35

SHAPE VOLUME	99. Solids have a definite shape. The shape of a solid is not changed when moved from one place to another. This is because the molecules of solids are close together and are more fixed. A solid differs from a liquid or a gas in that the molecules are ______ ______ and are close ______.
MORE FIXED TOGETHER	100.  As illustrated above, a solid moved from SEA LEVEL to the top of a MOUNTAIN and then to the bottom of a LAKE will retain its shape and volume because its molecules are ______ ______.
MORE FIXED AND CLOSE TOGETHER	101. Select the characteristics of a solid. a. Its shape is not changed when moved from one container to another. b. It can be compressed. c. Its particles are more fixed and are very close together.

a, c.	102. List the three states of matter in the blanks below. Below the blanks is a list of characteristics that pertain to these states when they are moved from one container to another. Place the number(s) found beside each characteristic under the state of matter to which it pertains. a. ________ b. ________ c. ________ (1) Will assume the shape of its container. (2) Will assume the volume of any container. (3) Will maintain its shape and volume.
a. SOLID (3) b. LIQUID (1) c. GAS (1)(2)	

11.16
lsn 1; p. 37

FUNDAMENTALS OF ELECTRICITY

LESSON 1

PART A
MATTER

SELF-TEST

1. Match each word in column A with its correct definition in column B by placing the letter found beside each word in the blank beside the appropriate definition.

A	B
a. Matter	____ That property of matter requiring an outside force to start or stop it.
b. Mass	____ Anything that has weight and occupies space.
c. Volume	____ No two bodies can occupy the same space at the same time.
d. Density	____ It is the space that mass occupies.
e. Weight	____ The amount of matter a given body contains.
f. Porosity	____ Weight per unit volume.
g. Inertia	____ A property of matter that specifies there is space between the particles of matter.
h. Impenetrability	____ A measure of the effect of gravity on a body.

2. Will the mass of a given body change if it is moved from sea level to 35,000 feet?

3. If one gallon of water is changed to steam, its volume will

   a. decrease and its mass will decrease.
   b. increase and its mass will increase.
   c. increase and its mass will remain constant.

4. Which of the following is a measure of volume?

   a. Square units
   b. Cubic units
   c. Linear units

5. What is the formula for finding the density of a body?

6. A body weighs 2400 pounds and has a volume of 24 cubic feet; what is its density?

7. Ten cubic feet of gas with a density of 5 pounds per cubic foot are compressed to 2 cubic feet; what will the new density be

8. As an object's distance from the earth's surface is increased, the weight of that object will ______________.

9. At which location will a given body weigh the more?

   a. On top of a mountain.
   b. At sea level.
   c. Weight would be the same at both a and b.

10. What property allows some matter to be compressed easier than others?

11. Give an example proving that matter has the property of porosity.

12. Inertia must be overcome in order to stop or start the movement of matter.

    What is required to do this? ______________________________

13. Give an example proving that matter has the property of impenetrability.

11.16
lsn 1; p. 39

14. List three examples of the inertia of objects (balls, aircraft, vehicles) being overcome.

a.
b.
c.

15. List the three states of matter in the blanks below. To the right is a list of characteristics that pertain to these states. Place the number found beside each characteristic under the state of matter to which it pertains. Some characteristics may pertain to more than one state.

a. ________________ b. ________________ c. ________________

(1) Is a fluid.
(2) Will assume the shape of its container.
(3) May be compressed.
(4) Will assume the volume of any container.
(5) Shape is not changed when moved from one container to another.
(6) Particles are more fixed and very close together.

LESSON 1, PART A

MATTER - SELF TEST ANSWERS

1. g, a, h, c, b, d, f, e

2. No

3. c

4. b

5. DENSITY $= \frac{\text{WEIGHT}}{\text{VOLUME}}$

6. $D = \frac{W}{V} = \frac{2400 \text{ lbs}}{24 \text{ cu ft}} = 100 \text{ lbs/cu ft}$

7. STEP 1. $W = D \times V = 5 \text{ lbs/cu ft} \times 10 \text{ cu ft} = 50 \text{ lbs}$
   STEP 2. $D = \frac{W}{V} = \frac{50 \text{ lbs}}{2 \text{ cu ft}} = 25 \text{ lbs/cu ft}$

8. decrease

9. b

10. porosity

11. combining a bucket of sand and one of rocks into a third pail and occupying less volume than the rocks and the sand did previously or any other situation which shows or proves the existance of space in between particles

12. force

13. a nail pushing aside fibers as it goes into wood,
    a pool ball knocking another ball away so it can occupy its space,
    or any other example which shows that two things cannot occupy the same place

14. a. hitting the ball with a bat
    b. the arresting gear on an aircraft carrier stopping aircraft
    c. a car accelerating from a stop

15. a. solid - (5), (6)
    b. liquid - (1), (2),
    c. gas - (1), (2), (3), (4)

GO RIGHT ON TO LESSON 1, PART B-ATOMIC STRUCTURE

11.16
lsn 1; p. 41

44

FUNDAMENTALS OF ELECTRICITY

LESSON 1

PART B

ATOMIC STRUCTURE

OBJECTIVES

1. Given the terms compound, molecule, atom, mixture, ion, nucleus, and a list of the definitions of these terms, match each term to its definition.

2. Given an illustration of an atom, label its three parts.

3. Given an illustration of an atom, give the atomic number and the atomic weight of that atom.

4. Given some illustrations of atoms, label each as having a positive, negative, or neutral charge.

5. State the name given to electrons that have been removed from their orbit about an atom.

6. Compare a conductor and an insulator in relation to the number of free electrons that each contains.

7. State how electrical energy is transferred through a conductor.

8. State the direction the electrons flow when an atom with a negative charge is contacted by an atom with a positive charge.

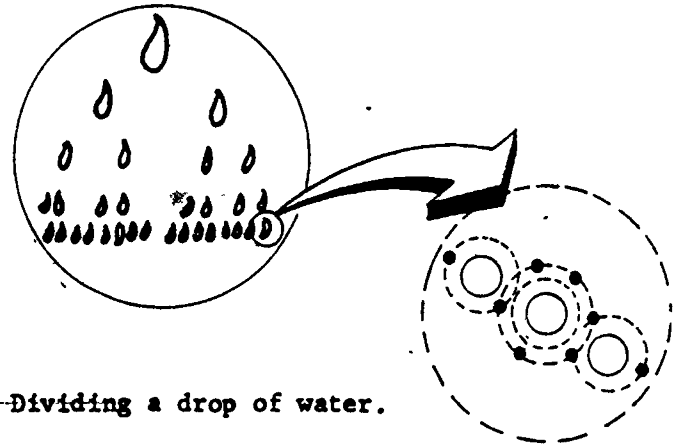
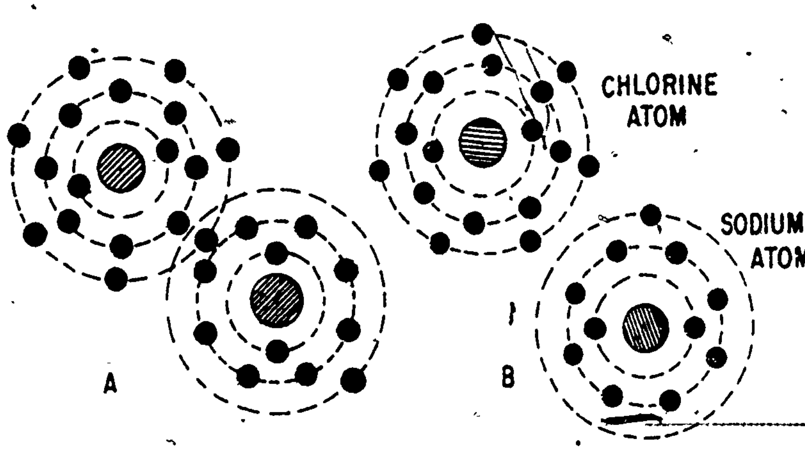
	1. Everything in the universe that has weight and occupies space is matter. Matter can be broken down into elements - substances which cannot be altered by chemical means. NO RESPONSE REQUIRED
	2. There are over 100 known elements. Most are natural; a few are man-made. Some natural elements are oxygen, gold, tin, and carbon. Hydrogen, silver, and lead are also examples of natural ________.
ELEMENTS	3. Matter exists either as a natural element or as a chemical combination of two or more different elements. This combination is called a compound. A compound can be divided into two or more different ________.
ELEMENTS	4. Some familiar examples of compounds are water, a combination of hydrogen and oxygen, and salt, a combination of sodium and chlorine. Because water and salt can be divided into different elements, they are ________.
COMPOUNDS	5. When compounds are chemically changed to form new compounds or when they are broken down into their original elements, the action is called chemical action. When sweet milk is chemically changed to sour milk, the action is called ________ ________.
CHEMICAL ACTION	6. When sulfuric acid, a compound, reacts with the compound lead peroxide in a battery, lead sulfate is formed. This action between two compounds to form a new compound is called ________ ________.
CHEMICAL ACTION	7. The elements hydrogen and oxygen are gases. When properly combined chemically, these elements will form the compound water. Water is a ________. (liquid/gas)

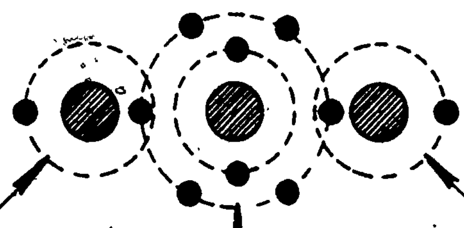
11.16
lsn 1; p. 43

LIQUID	8. A compound will possess properties different from the properties of the elements used to make the compound. When two or more elements are combined chemically, a compound is formed which has different ________________ than its elements.
PROPERTIES	9. Sodium, an element, will ignite on contact with water, while the element chlorine is poisonous. A chemical combination of sodium and chlorine forms the compound salt, which neither ignites upon contact with water nor is it poisonous. This is an example showing that a compound has ____________ different than the properties of the individual __________ making up that compound.
PROPERTIES ELEMENTS	10. The properties of a compound will depend on the chemical combination of its elements. Some examples are as follows: a. Two parts hydrogen and one part oxygen form the compound <u>water</u> (H_2O). b. Two parts hydrogen and two parts oxygen form the compound <u>hydrogen peroxide</u> (H_2O_2). c. One part hydrogen, one part nitrogen, and three parts oxygen form the compound <u>nitric acid</u> (HNO_3). These three compounds have different properties because of the difference in the chemical combination of their ______________.
ELEMENTS	11. When two or more different elements are chemically combined, a compound is formed. The properties of the compound will depend on the ____________ combination of its elements.
CHEMICAL	12. When the elements hydrogen, sulfur, and oxygen are properly combined chemically, <u>sulfuric acid</u> (H_2SO_4) is formed. A chemical combination of two or more different elements forms a __________

COMPOUND.	13. Select the definition of a compound. a. A combination of elements. b. A chemical combination of two or more different elements. c. A physical combination of two or more different elements.
b.	14. When compounds or elements are combined and no chemical action takes place, a mixture is formed. The compounds water (H_2O) and sulfuric acid (H_2SO_4), as used in a battery, do not chemically combine. Therefore, they form a ____________.
MIXTURE	15. When the elements aluminum, nickel, cobalt, and iron are combined, ALNICO is formed. ALNICO is a mixture; therefore, the elements do not lose their original characteristics. ALNICO is used to make magnets, and is a mixture composed of different ____________.
ELEMENTS	16. When the compounds salt and fresh water are mixed, the result is salt water. By distillation, they can easily be separated and once again become salt and fresh water. By this example, we can see that compounds, when mixed, ____________ (retain/lose) their original characteristics.
RETAIN	17. ALNICO is a mixture of elements, while salt water is a mixture of compounds. A mixture can be composed of ____________ or ____________.
ELEMENTS COMPOUNDS	18. A mixture is a combination of elements or compounds in which the elements or compounds do not lose their original characteristics. ALNICO and salt water can be separated and their elements or compounds will not lose their ____________ ____________________.

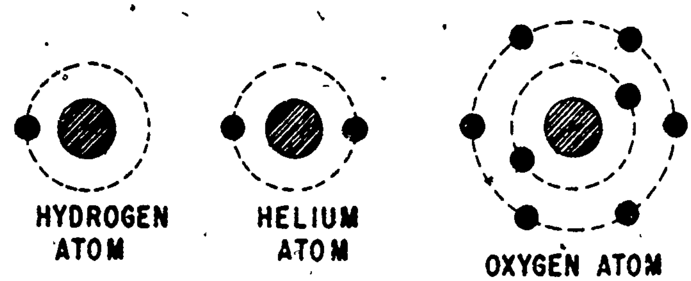
11.16
lsn 1; p. 45

ORIGINAL CHARACTERISTICS	19.  Dividing a drop of water. A molecule. By taking one drop of the compound water and dividing it into smaller and smaller parts, as shown, the smallest part of water we can reduce it to is a ________________.
MOLECULE	20. The smallest particle of a compound, which has all the properties of that compound, is a molecule. The smallest particle that the paper on which you are writing could be broken down to and still be paper is a ________________.
MOLECULE	21. The smallest particle of a compound, which has all the properties of that compound, is a molecule.  Illustration A shows a molecule of salt. Illustration B shows the molecule further divided into atoms. Do the substances in illustration B still have the properties of salt? ________

NO	22. Select the definition of a molecule. a. The smallest particle of a compound. b. The smallest particle of a compound which has all the properties of that compound. c. The smallest particle of any substance.
b.	23.  The illustration above shows that a water molecule is made up of ______ (number) oxygen atom and ______ (number) hydrogen atoms.
ONE TWO	24. A molecule is composed of two or more atoms. If a substance is divided down to a molecule, the molecule will be made up of two or more ______.
ATOMS	25. Atoms are the basic building material of all matter. All matter is made up of ______.
ATOMS	26. The atom is the smallest particle of an element. When an element is reduced to its smallest particle, that particle is an ______.

11.16
lsn 1; p. 47

50

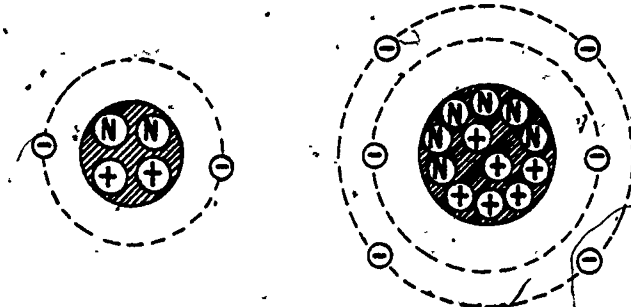
ATOM	27.  Each of the above represents the smallest particle of an ______________.
ELEMENT	28. Match the definitions in column B with their proper terms in column A. Place the number before the definition in the space beside the proper term. **A** a. Compound ____ b. Mixture ____ c. Molecule ____ d. Atom ____ **B** 1. The smallest particle of an element. 2. A chemical combination of two or more different elements. 3. The smallest particle of a compound which has all the properties of that compound. 4. A combination of elements or compounds in which the elements or compounds do not lose their original characteristics.
a. 2 b. 4 c. 3 d. 1	29. The smallest particle of an element is an atom. The atom cannot be seen by the usual microscopic instruments. Although they cannot be seen, we know there are many kinds of ______________.
ATOMS	30. The number of protons, neutrons, and electrons will vary with each kind of atom. The oxygen atom and the helium atom have different numbers of ______________, ______________, and ______________.

11.16
lsn 1; p. 48

PROTONS NEUTRONS ELECTRONS	31.
HELIUM (+) 2 (N) 2 (-) 2 CARBON (+) 6 (N) 6 (-) 6	32.

PROTONS
NEUTRONS
ELECTRONS

31.



Helium. Carbon.

The illustration above is an example showing that the numbers of protons (+), electrons (-), and neutrons (N) vary with the different kinds of atoms. Compare the number of protons (+), electrons (-), and neutrons (N) of the atoms above. Place the number of each in the space provided.

HELIUM		CARBON	
(+) Protons	____	(+) Protons	____
(N) Neutrons	____	(N) Neutrons	____
(-) Electrons	____	(-) Electrons	____

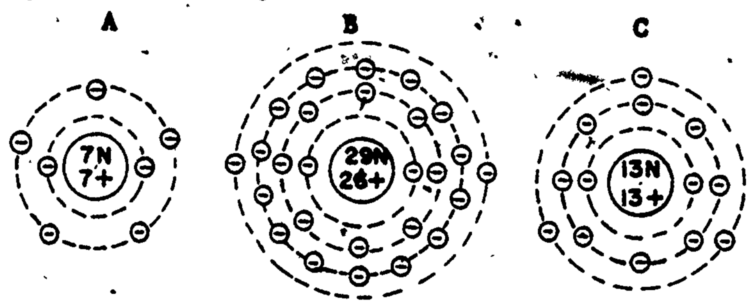
For the remainder of this program, instead of showing each individual neutron and proton in an atom, the total number of each will be shown.

EXAMPLE: (6+) will indicate 6 protons and (6N) will indicate 6 neutrons.

HELIUM
(+) 2
(N) 2
(-) 2

CARBON
(+) 6
(N) 6
(-) 6

32. Each of the different atoms is identified by an atomic number (1 through 103). The number of protons in an atom determines its atomic number.



Nitrogen. Iron. Aluminum.

What is the atomic number of each of the above atoms?

A. ____________ B. ____________ C. ____________

11.16
lsn 1; p. 49

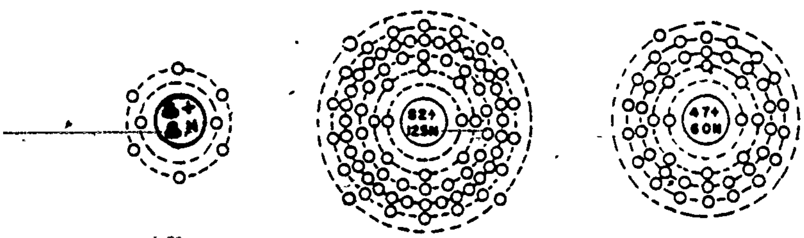
A. 7

B. 26

C. 13

33. Lead is much heavier than oxygen. A lead atom is heavier than an oxygen atom because it contains more protons (+) and neutrons (N).
The atomic weight of an atom is determined by adding the number of protons (+) and neutrons (N) contained in the center (nucleus) of the atom.

A B C



Oxygen. Lead. Silver.

What is the atomic weight of the above atoms?

A. ________ B. ________ C. ________

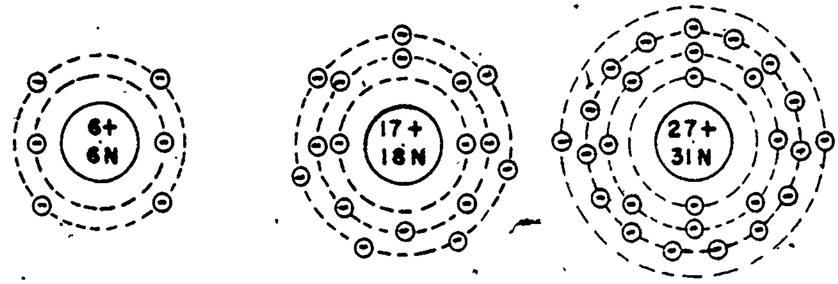
A. 16

B. 207

C. 107

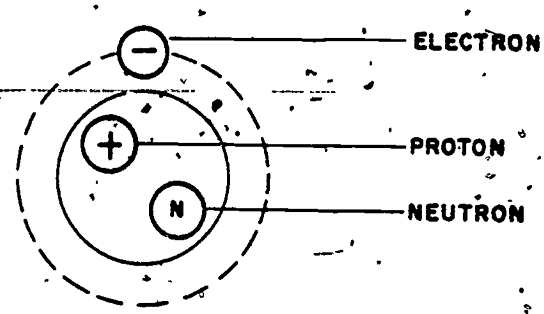
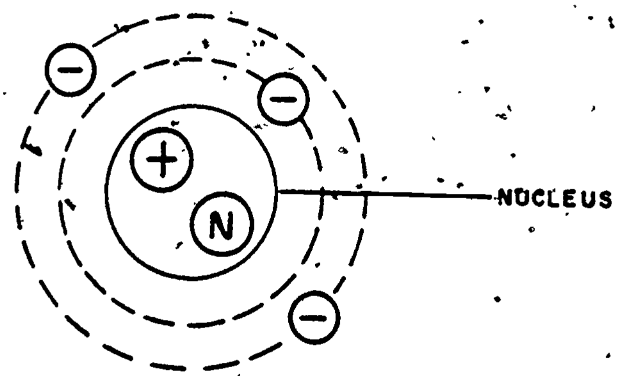
34. What are the atomic number and atomic weight of each atom illustrated below?

A B C

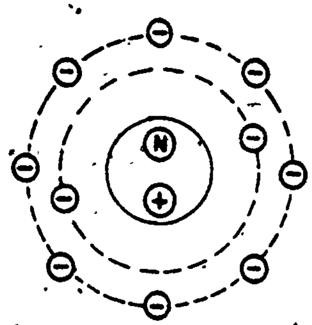
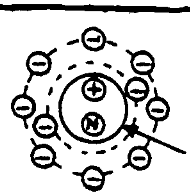


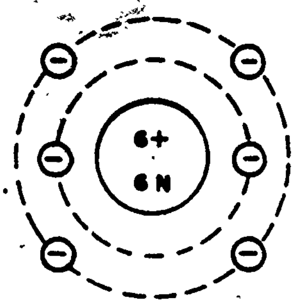
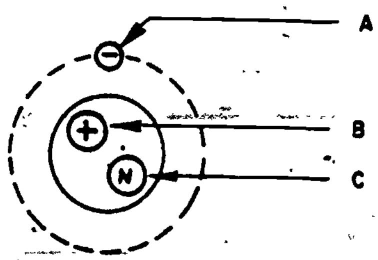
Carbon. Chlorine. Cobalt.

Atomic number ____ Atomic number ____ Atomic number ____
Atomic weight ____ Atomic weight ____ Atomic weight ____

A. 6 12 B. 17 35 C. 27 58	35. How are the atomic number and atomic weight determined? a. Atomic number ____________________ b. Atomic weight ____________________ ____________________
a. THE NUMBER OF PROTONS b. THE NUMBER OF PROTONS AND NEUTRONS	36. The atom is composed of three particles. What are they? ____________, ____________, ____________. 
ELECTRONS PROTONS NEUTRONS	37.  The center of the atom is the ____________.
NUCLEUS	38. The center of the atom, which contains the protons and neutrons, is the ____________.

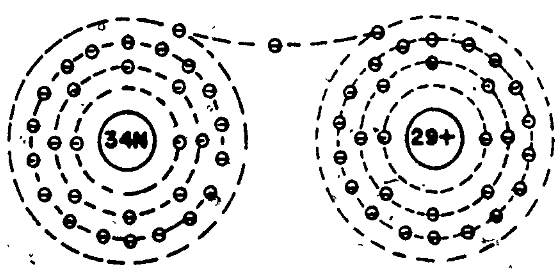
11.16
lsn 1; p. 51

NUCLEUS	39.  Draw an arrow pointing to the nucleus of this atom.
	40. The protons of an atom have a positive charge and are identified by a plus (+) sign. A proton has a ________________ charge.
POSITIVE	41. Protons are identified by a ( ) sign.
(+)	42. The neutrons of an atom have a neutral charge (no charge) and are identified by an (N) sign. A neutron has a ________________ charge.
NEUTRAL	43. Neutrons are identified by an ( ) sign.
(N)	44. The electrons of an atom have a negative charge and are identified by a minus (-) sign. An electron has a ________________ charge.
NEGATIVE	45. Electrons are identified by a ( ) sign.

(-)	46. Electrons are in orbit about the nucleus of an atom, and they can be in different orbital paths. In the atom below, how many electrons are orbiting about the nucleus? ________ 
SIX	47. The electrons are in orbit about the ________ of an atom.
NUCLEUS	48. Label the three particles of the atom below.  A. ________ B. ________ C. ________ The center of an atom is the ________.

11.16

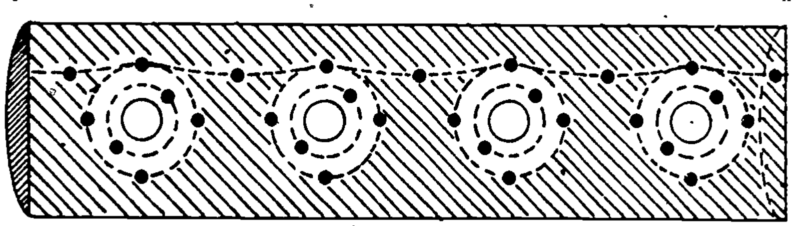
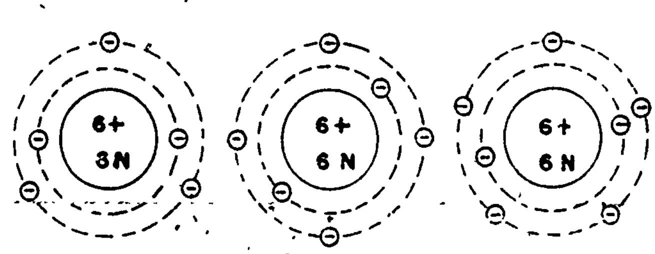
lsn 1; p. 53

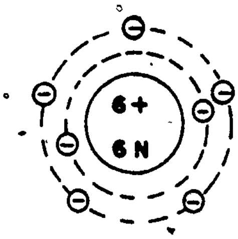
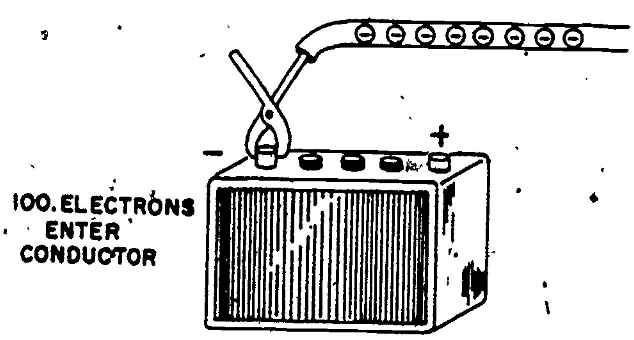
A. ELECTRON B. PROTON C. NEUTRON NUCLEUS	49. The nucleus of an atom has an attractive force for its electrons. The strength of this attractive force will vary with each kind of atom. Between the nucleus and the electrons of an atom, there is an _____________ __________.
ATTRACTIVE FORCE	50. The attractive force between the nucleus of the copper atom, a conductor, and its outer electrons is less than the attractive force between the nucleus of the helium atom, an insulator, and its outer electrons. Which atom, copper or helium, would more readily give up its outer electrons? ______________
COPPER	51. In the atoms of good electrical conductors, silver, copper, and gold, the outer electrons are readily freed from the attractive force of their ______________.
NUCLEUS	52. A good conductor has atoms with loosely held electrons. A copper atom has loosely held ______________.
ELECTRONS	53. Electrons that are loosely bound (held) to an atom can be moved out of orbit easily. Electrons of a gold atom can be moved out of orbit easily because they are _____________ ___________.
LOOSELY BOUND	54. FREE ELECTRON  Copper atoms. When a loosely bound electron is removed from orbit, it is called a _________ ____________ (see illustration).

11.16
lsn 1; p. 54

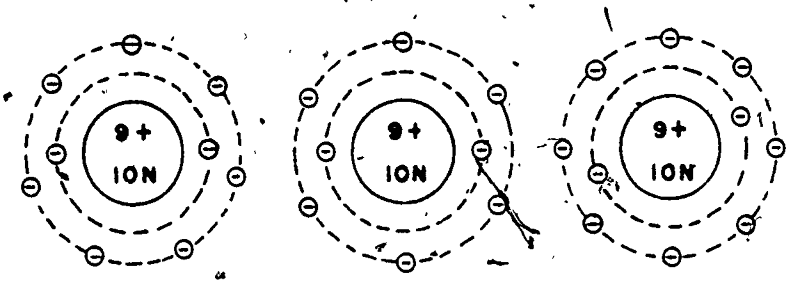
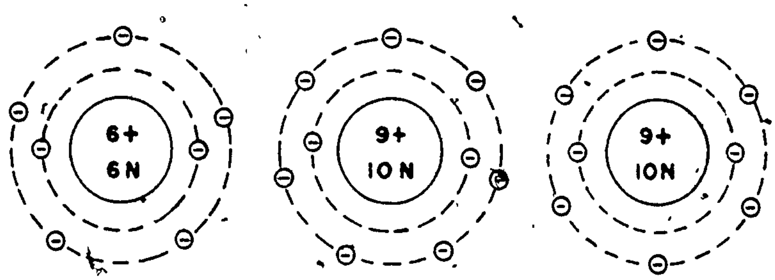
FREE ELECTRON	55. Electrons removed from their orbit about an atom are called ________ ____________.
FREE ELECTRONS	56. An insulator, such as rubber, has very few free electrons and will not conduct electricity. A good insulator contains a small number of ______ ____________.
FREE ELECTRONS	57. Materials with a small number of free electrons are good ____________.
INSULATORS	58. The controlled movement of free electrons through a conductor is electrical current flow. In comparison to an insulator, a conductor has a large number of ________ ____________.
FREE ELECTRONS	59. Materials having a large number of free electrons are good ____________.
CONDUCTORS	60. Electrons removed from their orbit are free electrons. How does a good conductor compare to a good insulator with respect to the number of free electrons in each? a. Conductor ____________. b. Insulator ____________.
a. HAS A LARGE NUMBER b. HAS A SMALL NUMBER	61. Some materials, carbon, germanium, and silicon, are considered semiconductors. This is because they conduct less current than metal conductors but more than insulators. Materials that conduct less current than metal conductors but more current than insulators are ____________.

11.16
lsn 1; p. 55

SEMICONDUCTORS	62. In a conductor, free electrons are continually moving from one atom to another. By controlling the movement of these free electrons in one general direction, electrical energy is transferred through a conductor. Electrical energy is transferred through a conductor by the movement of ________ ________ from atom to ________.
FREE ELECTRONS ATOM	63. Electrical energy is transferred through a conductor when free electrons are moved from ________ to ________.
ATOM ATOM	64.  In the illustration above, the free electrons are moving from atom to atom through the conductor in one general direction. The result of this will be a transfer of e________ e________.
ELECTRICAL ENERGY	65. How is electrical energy transferred through a conductor? ________________ ________________
BY THE MOVEMENT OF FREE ELECTRONS FROM ATOM TO ATOM.	66. The transfer of electrical energy is possible because an atom has a tendency to stay electrically neutral, that is, to have an equal number of protons and electrons. Which atom below is electrically neutral? ________  A B C

B	67. The atoms of a conductor normally stay electrically neutral because of the random movement of free electrons. As an atom gains an electron, it will give off another electron in order to be electrically neutral. How many electrons must this atom give off in order to be electrically neutral? ______ 
ONE	68. An electrically neutral atom is an atom that has an equal number of ________ and ________.
PROTONS ELECTRONS	69. An outside source such as a battery can be used to add additional electrons to a conductor. When these excess electrons are added, a chain reaction of moving electrons through the conductor is set up because the atoms tend to stay electrically ____________.
NEUTRAL	70. If an outside force adds one million electrons to one end of a conductor, then one million electrons must come out the other end of the conductor. The same number of electrons that enter a conductor must leave that conductor. How many electrons must leave the conductor below? ______ 

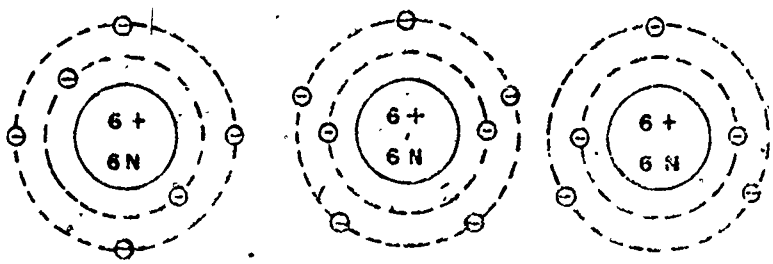
60

100	71. Select the electrically neutral atom. ______  A B C
A	72. An atom that has more electrons than protons has an excess of electrons. An atom with fewer electrons than protons has a deficiency of ________________.
ELECTRONS	73. An atom that has an excess of electrons is an electrically charged atom. An atom that has a deficiency of electrons is also an ____________ charged atom.
ELECTRICALLY	74. An electrically charged atom is known as an ion. An ion has an __________ or a ____________ of electrons.
EXCESS DEFICIENCY	75. Which of these atoms are ions? ______ ______  A B C

A C	76. An ion is an atom having an __________ or a __________ of electrons.
EXCESS DEFICIENCY	77. Match the definitions in column B with their terms in column A. Place the number before the definition in the blank beside the proper term. **A** a. Compound ____ b. Mixture ____ c. Molecule ____ d. Atom ____ e. Nucleus ____ f. Ion ____ **B** 1. The smallest particle of an element. 2. A chemical combination of two or more different elements. 3. An atom having an excess or a deficiency of electrons. 4. A combination of elements or compounds in which the elements or compounds do not lose their original characteristics. 5. The center of the atom which contains the protons and neutrons. 6. The smallest particle of a compound which has all the properties of that compound.
a. 2 b. 4 c. 6 d. 1 e. 5 f. 3	78. Atoms that have more electrons than protons have a negative charge. A negatively charged atom has more __________ than __________.

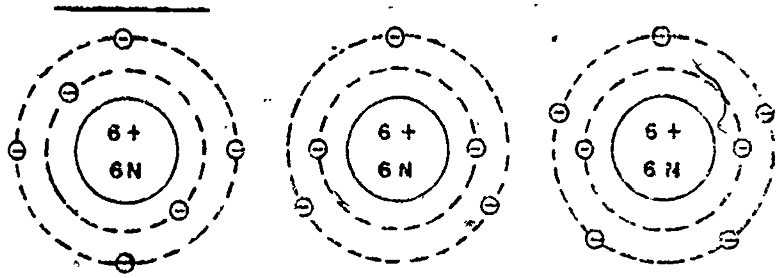
11.16
lsn 1; p. 59

ELECTRONS PROTONS	79. Which of the atoms below has a negative charge? ________



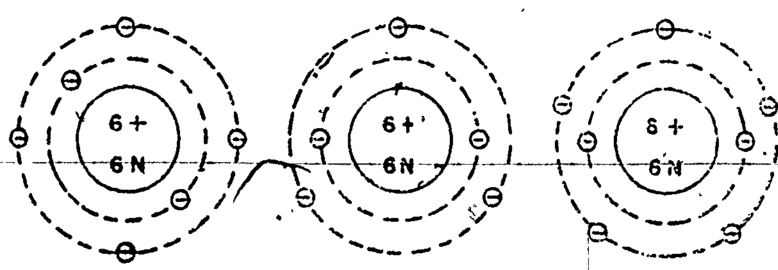
A B C

B	80. An atom that has fewer electrons than protons has a positive charge. A positively charged atom has fewer ________________ than ________________.
ELECTRONS PROTONS	81. Which of the atoms below has a positive charge? ________



A B C

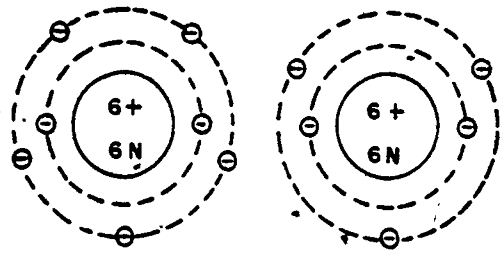
B	82. Label the atoms below as having a positive, negative, or neutral charge.



A B C

__________ __________ __________

11.16
lsn 1; p. 60

A. NEUTRAL B. POSITIVE C. NEGATIVE	83. When a negatively charged atom is contacted by a positively charged atom, the electrons flow from the negative atom to the positive atom. When two atoms of opposite charges contact each other, the electron flow is from ______________ to ________________.
NEGATIVE POSITIVE	84. Which direction will the electrons flow between the two atoms below? ________ a. From atom 1 to atom 2. b. From atom 2 to atom 1.  1 2
a.	85. When a negatively charged atom is contacted by a positively charged atom, electrons will flow from the ______________ atom to the ________________ atom.
NEGATIVE POSITIVE	

FUNDAMENTALS OF ELECTRICITY

LESSON 1

PART B

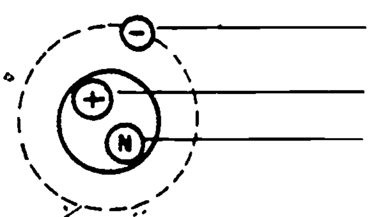
ATOMIC STRUCTURE

SELF-TEST

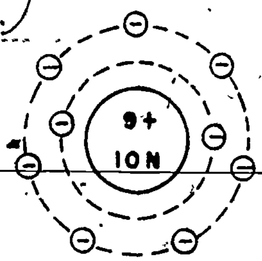
1. Match the definitions in column B with their terms in column A. Place the number before the definition in the blank space beside the proper term.

A		B
a. Compound	____	1. The smallest particle of an element.
b. Mixture	____	2. A chemical combination of two or more different elements.
c. Molecule	____	3. An atom having an excess or a deficiency of electrons.
d. Atom	____	4. A combination of elements or compounds in which the elements or compounds do not lose their original characteristics.
e. Nucleus	____	5. The center of an atom which contains the protons and neutrons.
f. Ion	____	6. The smallest particle of a compound which has all the properties of that compound.

2. Label the three particles of the atom below.



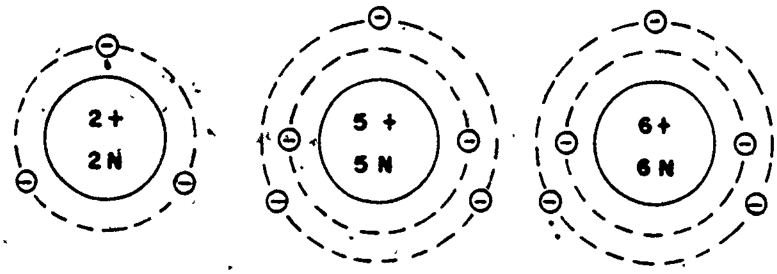
3. What are the atomic number and the atomic weight of the atom below?



Atomic number ____________

Atomic weight ____________

4. Label these atoms as having a positive, negative, or neutral charge.



A B C

________ ________ ________

5. Electrons removed from their orbit about an atom are called ________ ________.

6. How does a good conductor compare to a good insulator with respect to the number of free electrons in each?

Conductor ________________.
Insulator ________________.

7. How is electrical energy transferred through a conductor?

____

8. When a negatively charged atom is contacted by a positively charged atom, electrons will flow from the ________ atom to the ________ atom.

LESSON 1, PART B

ATOMIC STRUCTURE-SELF TEST ANSWERS

1. a 2
   b 4
   c 6
   d 1
   e 5
   f 3

2. Electron
   Proton
   Neutron

3. Atomic number 9
   Atomic weight 19

4. (a) Negative
   (b) Neutral
   (c) Positive

5. Free electrons

6. Conductor - more free electrons
   Insulator - fewer free electrons

7. By the movement of free electrons from atom to atom

8. . . . negative . . . positive

END OF LESSON 1, GO ON TO LESSON 2

* * *

67

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11.16a

FUNDAMENTALS OF ELECTRICITY

LESSON 2

3-3

INTRODUCTION TO ELECTRICITY
AND
ELECTRICAL SYMBOLS

This is a programmed lesson. It is designed to teach, not to test. You will need only this booklet, a pencil, and some time to complete this lesson. If there is something in the program you do not understand, ask your instructor or supervisor for assistance.

- REMEMBER -

This lesson has been written so that the amount of reading necessary is minimal and yet most meaningful. Therefore, it is very important that you follow these instructions.

- **Read each page carefully.**
- **Fill in each blank.**
- **Keep the answer to the frame on which you are working covered with a slip of paper until you have written your answer.**
- **Correct all errors you make.**
- **Follow all directions given in the program.**

SUGGESTED READING TIME
180 MINUTES

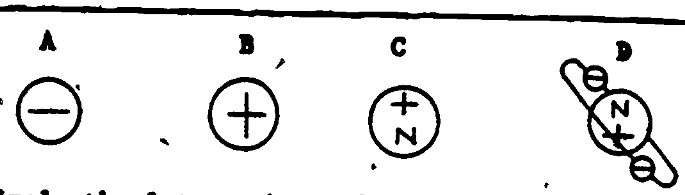
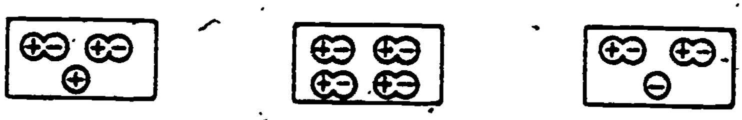
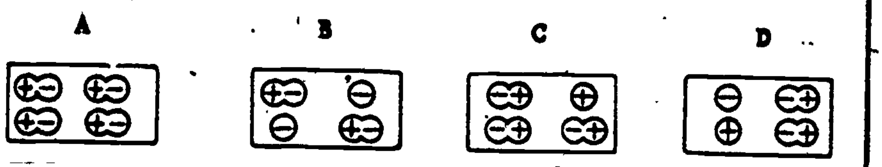
LESSON 2

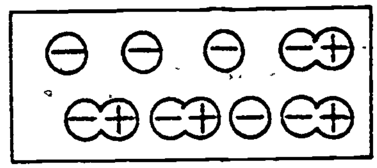
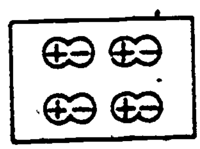
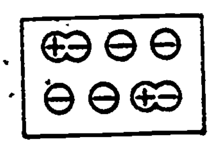
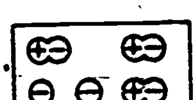
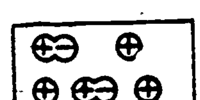
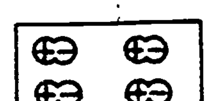
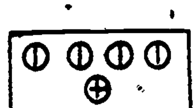
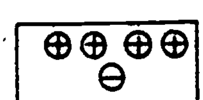
PART A

INTRODUCTION TO ELECTRICITY

OBJECTIVES

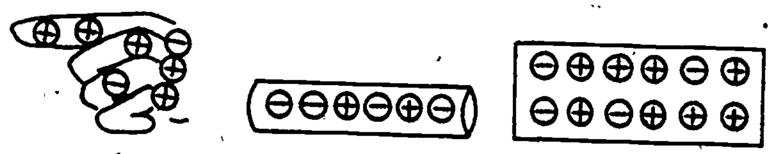
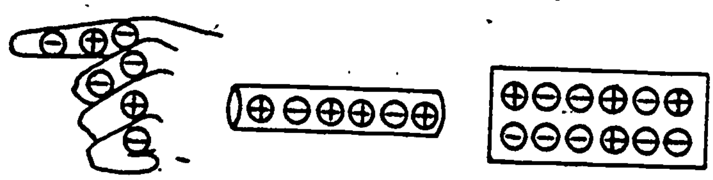
1. State the source of the electrical energy found in all matter.
2. Given illustrations of different bodies, label each as being negatively or positively charged.
3. State the condition of two bodies when the electrons have been physically removed from one and attached to the other.
4. State the primary cause of static electricity.
5. Select from a given list of statements the one correctly describing what occurs when two unequally charged bodies contact each other.
6. State the hazard produced by the electron flow between two separated bodies.
7. List two means used in aviation to prevent the buildup of static electricity.
8. State what must be overcome by the potential difference in order to have current flow.
9. Select from a list of terms two terms that mean the same as potential difference.
10. List the three primary methods of producing electromotive force.
11. Name the correct units of measurement for measuring electromotive force, current, and resistance.
12. Select from a list of instruments the ones used to measure electromotive force, resistance, and current.
13. List two types of current flow.
14. State the term used to identify materials that offer low resistance to current.
15. State the term used to identify materials that offer high resistance to current.
16. State whether the resistance of a conductor or an insulator increases or decreases when its temperature or dimension is varied.
17. State what effect an increase in voltage or resistance will have on current.
18. Using the mathematical formula for Ohm's law, solve three given electrical problems.
19. Given the terms static electricity, charged body, current flow, potential difference, Ohm's law, and resistance, match them with their respective definitions.

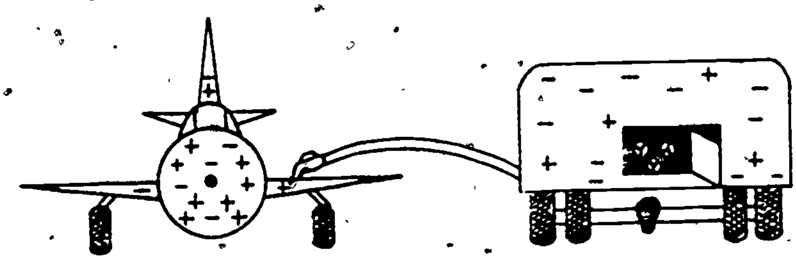
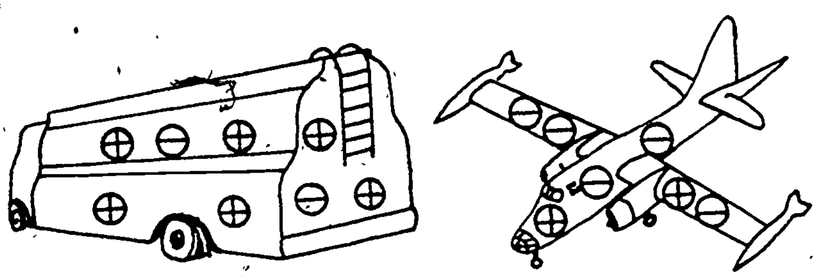
	1. From studying the program on atomic structure, you know that electrical energy is the movement of free electrons through a conductor. Since these free electrons are part of the atom, you can see that the actual source of electrical energy is the ________.
ATOM	2.  Circle the letter above the illustration that represents the source of all electrical energy.
D	3. The source of the electrical energy found in all matter is the ____________.
ATOM	4. Since all matter is made up of atoms, any body of matter is a source of ______________ energy.
ELECTRICAL	5. A body of matter in a normal or balanced state will have one electron for each proton. Electrons can be removed from one body and attached to another body. When this is done, one body will have more electrons than normal and the other body will have less electrons than normal. Label the bodies as having a balance of electrons and protons, an excess of electrons, or a deficiency of electrons.  A. ________ B. __________ C. __________
A. DEFICIENT B. BALANCED C. EXCESS	6. When electrons are removed from one body and attached to another body, one body will have an excess of electrons while the other body will have a shortage of electrons. These unequal charges at rest on two bodies are known as static electricity. Select the two bodies that have a static-electrical charge. 

B C	7. Count the number of electrons (-) and protons (+) on the body below.  a. Number of electrons: _____ b. Number of protons: _____
a. 8 b. 4	8. There were eight electrons and four protons. This means that the body had an excess of electrons; therefore, it has a negative charge. These electrical charges at rest on a body are ________ electricity.
STATIC	9. A charged body is one having more or less than its normal number of electrons (-). Which of these bodies is charged? A  B 
B	10. If a body has more or less than its normal amount of electrons, it is known as a ________ body.
CHARGED	11. Circle the letter above the charged bodies. A  B  C  D  E 

11.16
lsn 2; p. 4

71

A B D E	12. A body which has had some of its electrons removed will have a positive charge. Select the illustrations below that represent a body with a positive charge.  A B C
A C	13. Circle the letter beside the true statement. a. A body having fewer protons than electrons is positively charged. b. A body having fewer electrons than protons is positively charged. c. A body having an equal number of electrons and protons is positively charged.
b.	14. A body that has more electrons than protons has a <u>negative</u> charge. Select the items that have a <u>negative</u> charge.  A B C
A C	15. Select the true statement. a. A positively charged body is one having fewer protons than electrons. b. A negatively charged body is one having more electrons than protons. c. A negatively charged body is one having more protons than electrons.

b.	16. Label the items below as having a positive or negative charge.  A. __________ B. __________  C. __________ D. __________
A. POSITIVE B. NEGATIVE C. POSITIVE D. NEGATIVE	17. You have studied the electron and the meaning of positive and negative charges. Now you are ready to find out how these charges are produced. The primary cause of static electricity is friction. If you rub two different materials together, electrons may be removed from their orbit in one material and captured by the atoms in the other material. This is producing static electricity by ________________.

FRICTION

18. When a hard rubber rod is rubbed with fur, the fur loses electrons to the rod. The rod becomes negatively charged, and the fur becomes positively charged. Friction is one way of producing static electricity. Refer to the illustrations to complete the statements below.

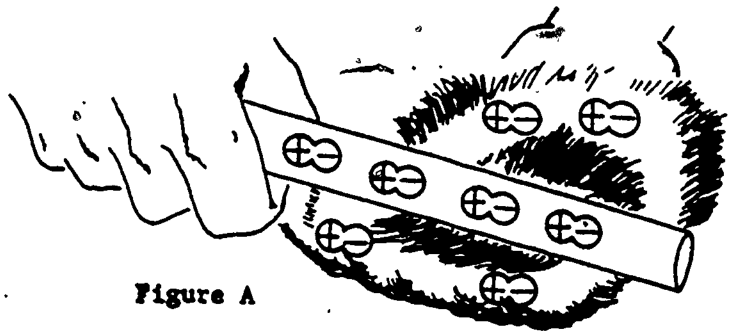


Figure A

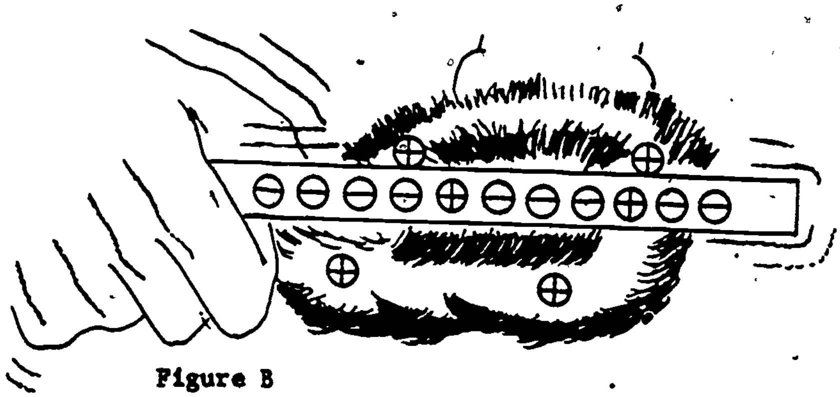


Figure B

a. In figure A, the two bodies contain an __________ amount of electrons.
(equal/unequal)

b. After the two bodies in figure B have been rubbed together, their charges will be __________.
(equal/unequal)

c. The unequal charges that exist on the two bodies in figure B are ________ electricity.

d. One way of causing electrons to leave one body and be transferred to another body is by ____________________.

74

a. EQUAL
b. UNEQUAL
c. STATIC
d. FRICTION

19. Friction between two bodies will cause both bodies to become charged-- one positively and one negatively. Therefore, these two bodies will have an attraction for each other. For example, when you run a comb through your hair several times, the comb and the hair develop unlike charges because of the friction involved. Now, if you hold the comb over your hair, your hair will be attracted to the comb.

From the information above, we are given one of the laws pertaining to charged bodies. This law states that bodies with unlike charges will ______________ each other.

ATTRACT

20.

Select the law that correctly explains why the man's hair is attracted to the comb.

a. Like charges attract.
b. Unlike charges repel.
c. Like charges repel.
d. Unlike charges attract.

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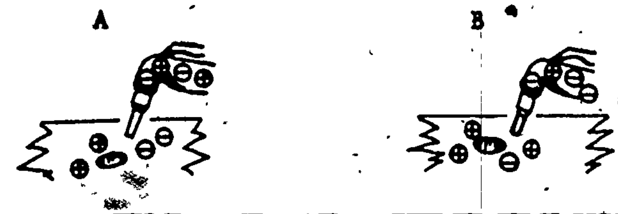
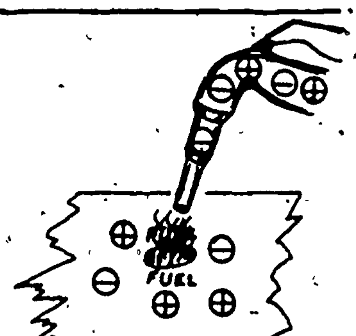
d.

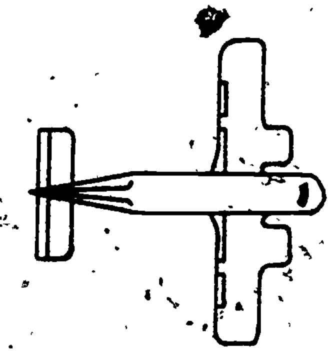
21. If two unlike-charged bodies, one negative and one positive, are brought together, they will attract each other.

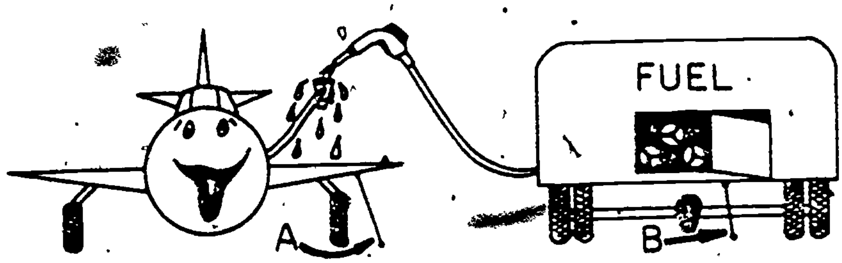
Select the two bodies that will attract each other.

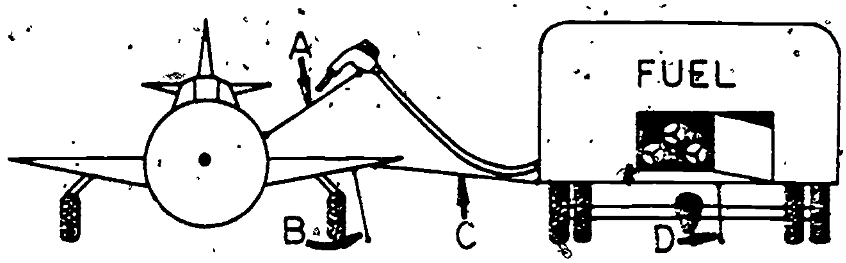
A	B	C
⊕ ⊖	⊕ ⊕	⊖ ⊖

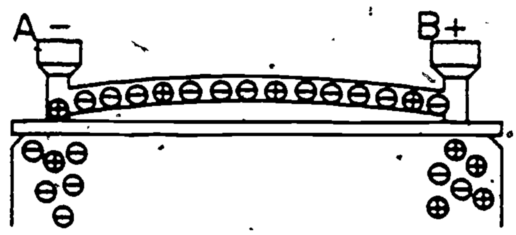
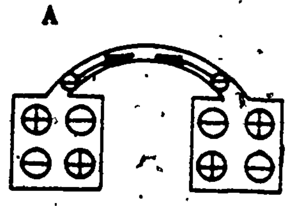
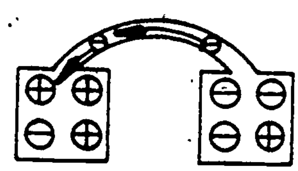
A	22. The law of charges states that unlike charges will ____________ each other.
ATTRACT	23. The law of charges states that if two like-charged bodies are brought together, they will repel (move away) from each other. Circle the letter above the bodies that will repel each other. A: $\ominus \oplus$ B: $\ominus \oplus$ C: $\oplus \oplus$
C	24. Circle the letter above the bodies that will repel each other. A: $\ominus \ominus$ B: $\ominus \oplus$ C: $\oplus \ominus$
A	25. The law of charges states that like charges will ____________.
REPEL	26. The law of charges states that ____________ charges repel and ____________ charges attract.
LIKE UNLIKE	27. A body that is positively charged has a lack of electrons. This body could then be subject to gaining electrons. It would get these electrons from a body that is negatively charged or has an excess of electrons. Therefore, a. a body that is positively charged is subject to electrons flowing ____________ it. b. a body that is negatively charged is subject to electrons flowing ____________ it.
a. INTO b. FROM	28. If bodies with unequal charges contact each other, the electrons will leave the negative-charged body and flow into the ____________-charged body until their charges are equal.

POSITIVE	29. Unequally charged bodies in contact will equalize their charges by a flow of ____________ between them.
ELECTRONS	30. Select the statement that correctly describes what occurs when two unequally charged bodies contact each other. a. The electrons flow from positive to negative until the bodies equalize their charges. b. The electrons flow from negative to positive until the bodies equalize their charges. c. There is no flow of electrons because unlike charges repel each other. d. The electrons flow from one body to the other as long as they are in contact.
b.	31. When two opposite charged bodies are brought near each other and the difference in their charges is great enough, there will also be an electron flow between them. Choose the illustration in which the electron flow would most likely occur. A B 
B	32. The electron flow between two separated bodies will be in the form of a spark. What could be the result of a spark between the two bodies in this illustration? ____________ 

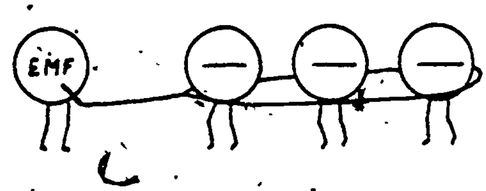
FIRE, EXPLOSION, OR ANY SIMILAR ACTION.	33.  What is created by the electron flow between the separated bodies above? ________
SPARK	34. What is produced that could be hazardous when there is an electron flow between two separated bodies? ________
SPARK	35. Anytime there is friction between bodies of different materials, such as fuel flowing in a hose or an aircraft flying through the air, opposite charges will build up on the bodies. If the charges become great enough, an electron flow will occur in the form of a ________.
SPARK	36. When the difference in charges between two parts on an aircraft is great, there is danger of a spark jumping between the parts. A bonding wire (conductor) is a safety device used to connect these parts on an aircraft. This gives a path for electron flow between the parts. To prevent a spark between various parts on an aircraft, a ________ ________ is used.
BONDING WIRE	37. Various parts of an aircraft are connected by bonding wire to permit a free flow of electrons between them. This flow keeps their charges balanced. To prevent the buildup of static-electrical charges, parts that are insulated or separated from each other are connected by ________ ________.
BONDING WIRE	38. The engines of this aircraft are mounted on rubber shock mounts. However, it does not have a buildup of static electricity because of several of these parts.  The name of this part is a ________ ________. 

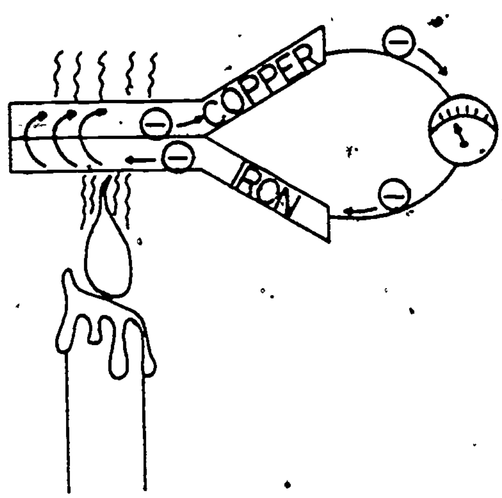
<table>
<tr><td>BONDING WIRE</td><td>39. To connect parts of an aircraft to prevent the buildup of static-electrical charges, a ________ ________ is used.</td></tr>
<tr><td>BONDING WIRE</td><td>40. Another device used to prevent the buildup of static electricity is a ground wire. A ground wire allows a constant dissipation of electrons and prevents a body from becoming charged. The chain hanging from the back of a gasoline truck is an example of a ______________ ________.</td></tr>
<tr><td>GROUND WIRE</td><td>41. A ground wire is used to connect aircraft and fuel trucks to the earth during refueling. Label items A and B below.


______________ ______________</td></tr>
<tr><td>A. GROUND WIRE
B. GROUND WIRE</td><td>42. To maintain a balanced charge between an aircraft and the fueling truck, four grounding connections must be made. Match each letter in the illustration below with the statement which describes that grounding connection.
____ a. Truck to ground
____ b. Fuel nozzle to aircraft
____ c. Truck to aircraft
____ d. Aircraft to ground

</td></tr>
</table>

a. D b. A c. C d. B	43. What are two means used in aviation to prevent the buildup of static electricity? a. ________________ ________ b. ________________ ________
a. BONDING WIRE b. GROUND WIRE	44. Static electricity has no real use to us; we only want to control it. Now let's study about electricity we can use-- dynamic electricity. Select the item that must be moved from one point to another point to produce electricity. a. Proton b. Electron c. Neutron
b.	45. Electrons flow from a point having an excess of electrons to a point having a lack of electrons. Draw an arrow between A and B to indicate the direction the electrons will flow. 
 A B	46. The electrons that are moving are free electrons. These free electrons are in a random movement in a conductor all the time; but when we can get them to drift or move in one direction, we will have current flow. Which illustration represents current flow? A  B 

B	47. A drift or movement of electrons in one direction through a conductor is called _________ ______.
CURRENT FLOW	48. A force is needed to move these electrons in one direction. One term used for this force is <u>potential</u> <u>difference</u>. Potential difference is the difference in the attractive force between unlike charges. Which illustration represents the greater potential difference? A B 
B	49. To have current flow, the potential difference must be great enough to overcome resistance. Resistance is an opposition to current flow. In which illustration will current flow occur? A B 
A	50. Before current can flow, the potential difference must be great enough to overcome __________.
RESISTANCE	51. Since potential difference is forcing or causing current flow, then the greater the potential difference, the greater the _________ ______.

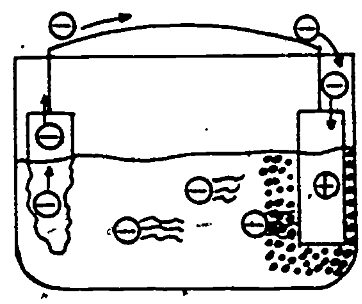
CURRENT FLOW	52. The drift or movement of electrons through a conductor is known as ________ ________.
CURRENT FLOW	53. What must potential difference overcome in order to have current flow? ____________
RESISTANCE	54. The difference in the amount of electrical energy between two bodies is p________ d________.
POTENTIAL DIFFERENCE	55. Potential difference is the force that causes electrons to move from one point to another. Potential difference is also known as electromotive force (EMF). List two names for the force that causes current flow. a. ________ ________ b. ________ ________
a. POTENTIAL DIFFERENCE b. ELECTROMOTIVE FORCE (EITHER ORDER)	56. Another term used for potential difference and electromotive force is voltage.  Mr. Force above is called by three different terms; what are they? a. ____________ b. ____________ c. ____________
a. POTENTIAL DIFFERENCE b. ELECTROMOTIVE FORCE c. VOLTAGE	57. What two terms mean the same as potential difference? a. ____________ b. ____________

a. ELECTROMOTIVE FORCE b. VOLTAGE	58. The common term used for potential difference and electromotive force is ________________.
VOLTAGE	59. There are several methods of producing electromotive force (EMF). We shall only concern ourselves with three of the methods: thermal, chemical, and mechanical. Thermal, chemical, and mechanical are three ways to produce ________________________.
ELECTROMOTIVE FORCE OR EMF	60. One of the methods of producing electromotive force (EMF) is the thermal (heat) method. When a metal, such as copper, is heated, the electrons tend to move away from the heated end towards the cool end. In other metals, such as iron, the opposite is true. The electrons move from the cool end to the heated end. If these two metals are connected at the heated end, the flowing electrons will cross at the junction point.  The method used to produce EMF in the illustration above is the ______________ method.

11.16.
lsn 2; p. 16

THERMAL
(HEAT)

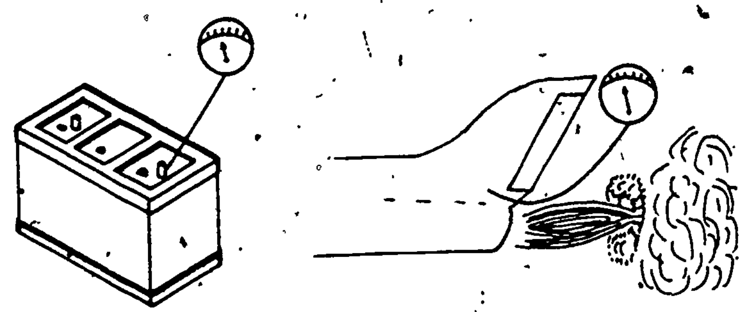
61. Another method of producing electromotive force (EMF) is the chemical method. When the molecules of a substance are altered, the action is referred to as chemical. For instance, when the molecules of air come in contact with bare iron, they combine and form rust. In some cases, the loss or gaining of electrons in this manner produces EMF.



The method of producing EMF illustrated above is the ________________ method.

CHEMICAL

62. Shown below are two methods of producing EMF. Wha method of producing EMF is shown in each illustration?

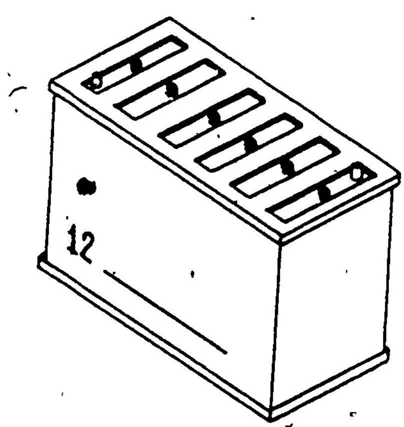


A. ________________ B. ________________

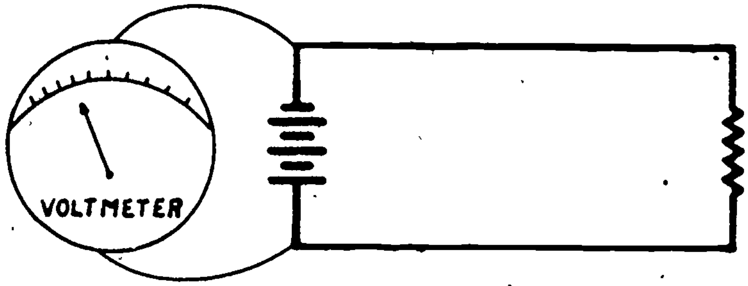
A. CHEMICAL

B. THERMAL

63. So far you have learned two methods of producing EMF-- thermal and chemical. Now, let's learn a little about a third method of producing EMF-- the mechanical method. Anytime you move a conductor in a magnetic field, you are producing EMF. Producing EMF in this manner is an example of the __________ method.

MECHANICAL	64. Generators and magnetos produce EMF by rotating a large number of conductors in a magnetic field. This is an example of producing EMF by the ________________ method.
MECHANICAL	65. List the three primary methods of producing EMF. a. ________________ b. ________________ c. ________________
a. CHEMICAL b. THERMAL c. MECHANICAL	66. The EMF produced by each of ~~the methods~~ must be known, or measured, so that it can be used to full advantage. The volt(V) is the unit of measurement of ______.
EMF	67. The EMF produced by some methods is extremely weak; however, in all cases the EMF can be measured. The unit of measurement for EMF is the volt(V). Write the unit of measurement for EMF in the space below. 

11.16
lsn 2; p. 18

VOLTS	68. To measure the EMF, an instrument which indicates volts is used. As shown in the illustration, this instrument is called a ________________. 
VOLTMETER	69. The unit of measurement for EMF is the __________ The instrument used to measure EMF is the ________________.
VOLT VOLTMETER	70. The number of electrons the voltage can move past a point in a period of time is a measure of current flow. One volt moving a given number of electrons in one second past a point having one ohm of resistance is one ampere (amp.) of ____________
CURRENT	71. Measuring the number of electrons one volt can cause to flow through one ohm of resistance in one second is the method used to determine one ampere of ________________.
CURRENT	72. Because the electron is too small a unit to use in measuring the amperage, a larger unit is used. This larger unit is the coulomb (6,280,000,000,000,000,000 electrons). The coulomb is used as the unit which one volt must cause to flow in one second to obtain a current flow of one ______________.

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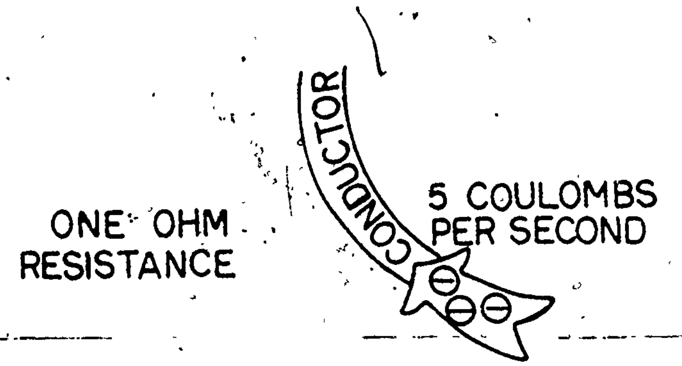
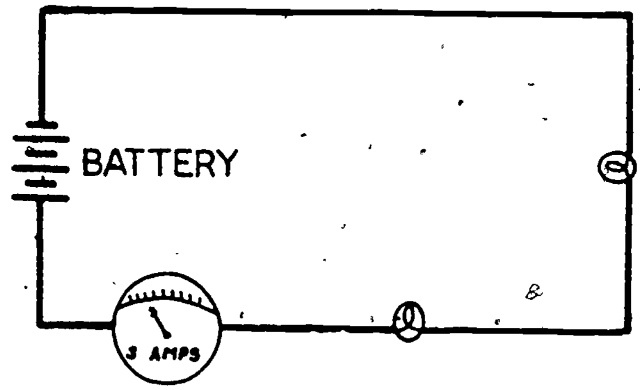
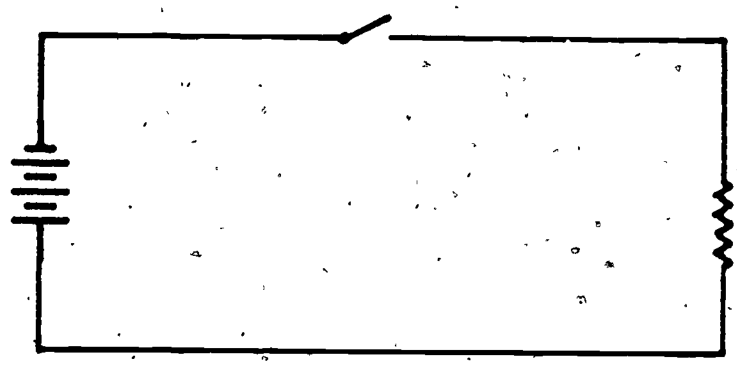
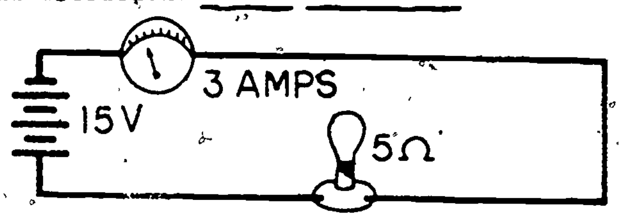
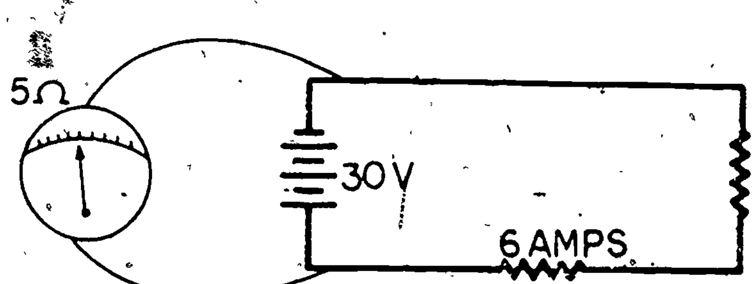
AMPERE (AMP.)	73. By increasing the number of coulombs per second, current flow (amps.) will increase; two coulombs = two amps, three coulombs = three amps. How many amps are flowing in this illustration? ______ 
FIVE	74. What must occur to have one ampere of current flow? ______________________________ ______________________________
ONE VOLT MUST MOVE ONE COULOMB THROUGH ONE OHM OF RESISTANCE IN ONE SECOND.	75. Since such a large number of electrons are moved to obtain only one amp, an instrument must be used to measure current flow. An ammeter is the instrument used to measure __________ __________.
CURRENT FLOW	76. Current flow in a circuit may be measured by using an ______________.
AMMETER	77. The unit of measurement for current flow is the ______________. The instrument used to measure current flow is the ______________.
AMPERE (AMP.) AMMETER	78. There are two types of current flow. One type is current flow produced by a battery. This type flows in only one direction. This type is usually referred to as D.C. or direct ______________.

CURRENT	79. What type of current flow would the circuit in the illustration have? ____________________ 
DIRECT CURRENT (D.C.)	80. A modified type of direct current, in which the current flow is interrupted periodically, causing it to pulsate, is called P.D.C. or pulsating __________ ______________.
DIRECT CURRENT	81. The ignition system of cars and some aircraft uses breaker points to interrupt the current flow. This type of ignition system produces a ____________ __________ current.
PULSATING DIRECT	82. If the switch in the illustration were opened and closed rapidly, the direct current of the circuit would then be ______________ ____________ ______________. 
PULSATING DIRECT CURRENT (P.D.C.)	83. The second type of current flow is the type which alternates its direction of flow. The type of current which flows first in one direction and then in the opposite direction is A.C. or ____________ ______________.

ALTERNATING CURRENT (A.C.)	84. D.C. flows in only one direction; A.C. periodically changes its ______________ of flow.
DIRECTION	85. What are the two types of current flow? a. ______________________ b. ______________________
a. DIRECT CURRENT (D.C.) b. ALTERNATING CURRENT (A.C.) (ANY ORDER)	86. Symbols are used extensively in electricity, usually to represent a component in a circuit. However, the symbol Ω (the Greek letter Omega) is used to represent ohms. As an example, 10 Ω is read as _______ _______
TEN OHMS	87. The ohm is the electrical unit of resistance; it is represented by this symbol: ___________.
Ω	88. What is the resistance of the light bulb in the illustration? _____ _______ 
5 OHMS	89. If the resistance of a circuit or an electrical device is unknown, it can be measured with an ohmmeter. An instrument that is used to determine the resistance of a circuit is the ___________.
OHMMETER	90. What is the resistance of the circuit below? _____ _______ The instrument used to measure this resistance is called an _______________. 

5 OHMS OHMMETER	91. To have current flow, voltage must overcome resistance. The resistance of a material indicates its degree (high or low) of opposition to ________ flow.
CURRENT	92. All materials have some resistance to current flow, and they may be divided into two basic classes, depending on whether they have high or low ____________.
RESISTANCE	93. Conductors are materials that offer little opposition to current flow and are classed as materials having low ____________.
RESISTANCE	94. Some materials that have low resistance to current flow are silver, copper, and aluminum. These materials are all good ____________.
CONDUCTORS	95. The resistance of conductors, in general, is affected by three factors: type of material, size of material, and temperature of material. Silver is the best conductor, since it has the least resistance. Copper is next, since it offers slightly more resistance. Conductors made of silver and copper have different resistances because they are made from different ________ ____________.
TYPES OF MATERIAL	96. Silver, because of its cost, has a limited use as a conductor. Copper is readily available and is the type of material usually used as a ________.
CONDUCTOR	97. The type of material is one factor affecting resistance. The size (length and diameter) of the material is another factor. The greater the distance the current must travel, the greater the voltage must be. This indicates that as the length of the conductor increases, its resistance ________.

11.16
lsn 2; p. 23

INCREASES	98. Which conductor below has the greatest resistance? 
C	99. The resistance of a conductor increases as its length increases. However, an increase in its diameter has the opposite effect. As the diameter is increased, the resistance will ______________.
DECREASE	100. When the length of a conductor is increased, its resistance ______________; when its diameter is increased, its resistance ______________.
INCREASES DECREASES	101. Temperature, the third factor, has the same effect as length. An increase in the temperature of a conductor will ______________ its resistance.
INCREASE	102. List the three factors affecting the resistance of conductors. a. ______________ b. ______________ c. ______________
TYPE OF MATERIAL SIZE (LENGTH AND DIAMETER) TEMPERATURE (ANY ORDER)	103. Conductors are materials that have low resistance. Insulators are materials that have ______________ ______________.
HIGH RESISTANCE	104. Materials which have high resistance and are often used to shield conductors are ______________.

91

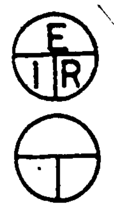
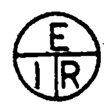
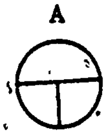
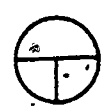
INSULATORS	105. The purpose of an insulator is to oppose current flow. The best type of material for an insulator would be a material having ______ resistance.
HIGH	106. Some materials make better insulators than others. One factor that affects an insulator's resistance is the type of ______.
MATERIAL	107. One factor to be considerad in selecting an insulator is the ______ ______ ______.
TYPE OF MATERIAL	108. The size (thickness) of an insulator will affect its resistance. If the insulation on a conductor allows current to flow through it, it indicates the size (thickness) of the insulation should be ______.
INCREASED	109. Increasing the size of an insulator will ______ its resistance.
INCREASE	110. Temperature will also affect the resistance of an insulator. Glass, an insulator, when heated will conduct electricity. This indicates that an increase in temperature will cause an insulator's resistance to ______.
DECREASE	111. What would be the effect on the resistance of an insulator if its a. size were increased? ______ b. temperature were increased? ______
a. INCREASE b. DECREASE	112. The factors affecting the resistance of a conductor also affect its relationship with current flow. The relationship between resistance, current flow, and electromotive force is explained by Ohm's law. There is a close connection between resistance, current flow, and electromotive force which can be found in ______ law.

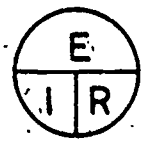
11.16
lsn 2; p. 25

OHM'S	113. Ohm's law shows the close ties between ____________, ____________, and ____________.
ELECTROMOTIVE FORCE CURRENT FLOW RESISTANCE (ANY ORDER)	114. Part of Ohm's law states that current flow is directly proportional to EMF. As you increase the voltage or EMF, you will also increase current flow an equal or proportionate amount. Select the statement below that is correct. a. If voltage is increased by 1/2, current decreases by 1/2. b. If voltage is increased by 1/2, current increases by 1/2. c. If voltage is increased by 1/2, current remains unchanged. d. None of these is correct.
b.	115. When EMF increases, current flow also increases. This fact shows that the current flow is directly proportional to ________.
EMF	116. If current flow will increase as EMF is increased, a decrease in EMF will produce a ____________ in current flow.
DECREASE	117. The first part of Ohm's law shows how current flow and EMF are related. The second part of it shows how current flow and resistance are related. It says that current flow is inversely proportional to resistance. This means that a change in resistance, either higher or lower, will produce the opposite change in current flow. Select the correct statement below. a. As resistance increases, current flow decreases. b. As resistance increases, current flow increases. c. As resistance increases, current flow remains unchanged.
a.	118. As resistance increases, current flow decreases. This means that current flow is inversely proportional with ____________.

11.16
lsn 2, p. 28

RESISTANCE	119. Current flow is inversely proportional with resistance. This means that as resistance is decreased, current flow will ________.
INCREASE	120. Ohm's law states that current flow is ________ proportional to EMF and ________ proportional to resistance.
DIRECTLY INVERSELY	121. Complete the statements below. a. When resistance is increased, current flow will ________. b. When voltage is increased, current flow will ________.
a. DECREASE b. INCREASE	122. Ohm's law in the mathematical formula looks like this, E I R. The horizontal bar in the circle, , means to divide. In order to find I, you ________ E by R.
DIVIDE	123. The horizontal bar, , means to ________.
DIVIDE	124. The vertical bar in the circle, , means to multiply. If you must determine E by the Ohm's law-mathematic formula E I R, you ________ I by R.
MULTIPLY	125. The vertical bar in the circle, , means to ________.

MULTIPLY	126. Now, when given some information, you can insert the known values in place of the letters in the circle and perform the indicated mathematics to solve for the unknown value. Solve the problem given below by using the Ohm's law formula.  I = 2 amps. R = 6 ohms E = ? E = ________ volts
E = 12 VOLTS	127. In order to find E, you must ________ I by R.
MULTIPLY	128. Solve for the unknown in the problems below.  A  E = 12 volts I = 3 amps. R = ____ ohms B  E = 24 volts R = 6 ohms I = ____ amps.
A. R = 4 OHMS B. I = 4 AMPS.	129. In order to solve for either I or R, you must ________.
DIVIDE	130. Draw the mathematical formula for Ohm's law.



131. In using the mathematical formula for Ohm's law, you probably noticed that letters are used to represent the various values. The letter E represents voltage. The letter R represents resistance, and the letter I represents the intensity or rate of current flow. Match the letter with the item it represents. Place the letter in the proper space beside its true meaning.

R ________ a. Electromotive force

E ________ b. Amperage

I ________ c. Resistance

---

a. E

b. I

c. R

132. Solve for the unknown value in figure 2.

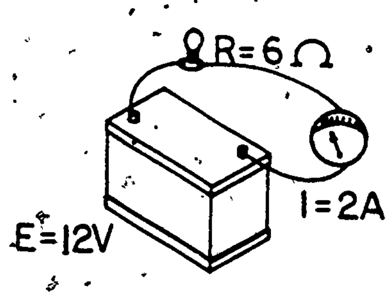


Figure A

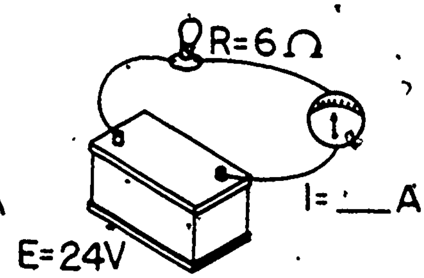


Figure B

The comparison between figures A and B proves that as voltage increases, current flow ________.

4

INCREASES

11.16
lsn 2, p. 29

FUNDAMENTALS OF ELECTRICITY

LESSON 2

PART A

INTRODUCTION TO ELECTRICITY

SELF-TEST

1. What is the source of the electrical energy found in all matter?

____

2. Label the illustrations below as being positively or negatively charged bodies.

A. __________ B. __________ C. __________ D. __________

3. If electrons are removed from one body and attached to another body, the two bodies would be in a __________ condition.

4. What is the primary cause of static electricity?

____

5. Select the statement that correctly describes what occurs when two unequally charged bodies contact each other.

   a. The electrons will flow from positive to negative until the bodies equalize their charges.

   b. The electrons will flow from negative to positive until the bodies equalize their charges.

   c. There will be no flow of electrons because unlike charges repel each other.

   d. The electrons will flow from one body to the other as long as they are in contact.

6. What is produced that could be hazardous when there is an electron flow between two separated bodies?

____

7. What are two means used in aviation to prevent the buildup of static electricity between two bodies or objects?

   a. _______________

   b. _______________

8. What must potential difference overcome in order to have current flow?

____

9. Select two terms that mean the same as potential difference.

a. Resistance
b. Electromotive force
c. Current flow
d. Voltage
e. Static electricity

10. What are the three primary methods of producing electromotive force?

a. ________________
b. ________________
c. ________________

11. List the correct unit of measurement for:

ELECTROMOTIVE FORCE (EMF) ______________

CURRENT FLOW ______________

RESISTANCE ______________

12. Select the correct instrument used to measure:

ELECTROMOTIVE FORCE ________

CURRENT FLOW ________

RESISTANCE ________

INSTRUMENTS
a. OHMMETER
b. VOLTMETER
c. AMMETER

13. List two types of current flow.

a. ________________

b. ________________

14. What are materials called that offer low resistance to current flow?

____

11.16
lsn 2; p. 31

15. What are materials called that offer high resistance to current flow?

____

16. What effect (increase/decrease) does the following have upon the resistance of a <u>conductor</u>?

Increase its length, and its resistance _____________.

Increase its diameter, and its resistance ____________.

Increase its temperature, and its resistance __________.

17. What effect (increase/decrease) does the following have upon the resistance of an <u>insulator</u>?

Increase its thickness, and its resistance ___________.

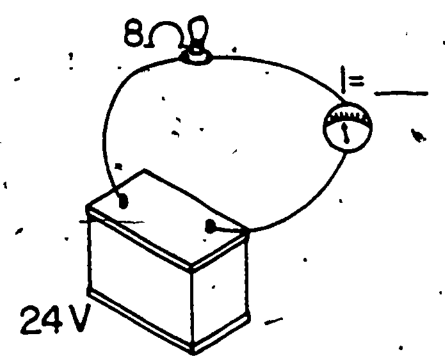
Increase the temperature, and its resistance __________.

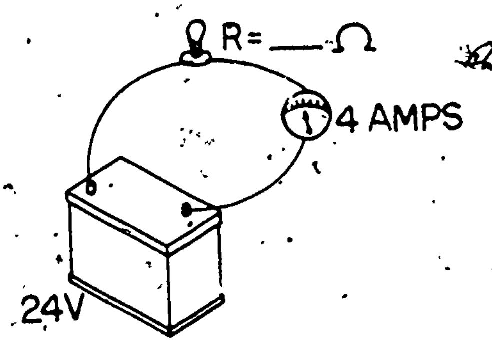
18. Complete these statements about Ohm's law.

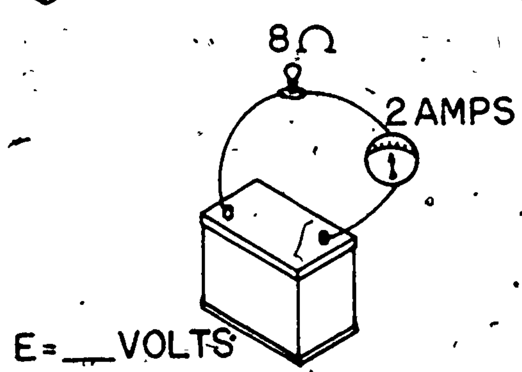
When resistance is increased, current flow will ____________.

When voltage is increased, current flow will ______________.

19. Using the mathematical formula for Ohm's law, solve these problems.







20. Match each electrical term below with its correct definition.

ELECTRICAL TERMS

a. Current flow
b. Static electricity
c. Resistance
d. A charged body
e. Potential difference
f. Ohm's law

DEFINITIONS

_____ 1. Electrical charges at rest.
_____ 2. One having more or less than its normal number of electrons.
_____ 3. The drift or movement of electrons through a conductor.
_____ 4. The difference in the amount of electrical energy of two bodies.
_____ 5. The opposition to current flow.
_____ 6. Current is directly proportional to the EMF and inversely proportional to the resistance.

11.16
lsn 2; p. 33

LESSON 2, PART A
INTRODUCTION TO ELECTRICITY-SELF TEST ANSWERS

1. The atom

2. (a) Positive
   (b) Negative
   (c) Positive
   (d) Negative

3. Charged

4. Friction

5. b

6. A spark

7. (a) Bonding wire
   (b) Ground wire

8. Resistance

9. b, d

10. Chemical, thermal, mechanical

11. Volts
    Amperes
    Ohms

12. b
    c
    a

13. (a) a.c.
    (b) d.c.

14. Conductors

15. Insulators

16. Increases
    Decreases
    Increases

17. Increases
    Decrease

18. Decrease
    Increase

19. $I = \frac{E}{R} = \frac{24v}{8\Omega} = 3 \text{ amps}$

    $R = \frac{E}{I} = \frac{24v}{4A} = 6 \text{ ohms}$

    $E = IR = (2A)\ (8\Omega) = 16 \text{ volts}$

20. b 1
    d 2
    a 3
    e 4
    c 5
    f 6

GO RIGHT ON TO LESSON 2,
PART B - ELECTRICAL SYMBOLS

11.16
lsn 2; p. 34

FUNDAMENTALS OF ELECTRICITY

LESSON 2.

PART B

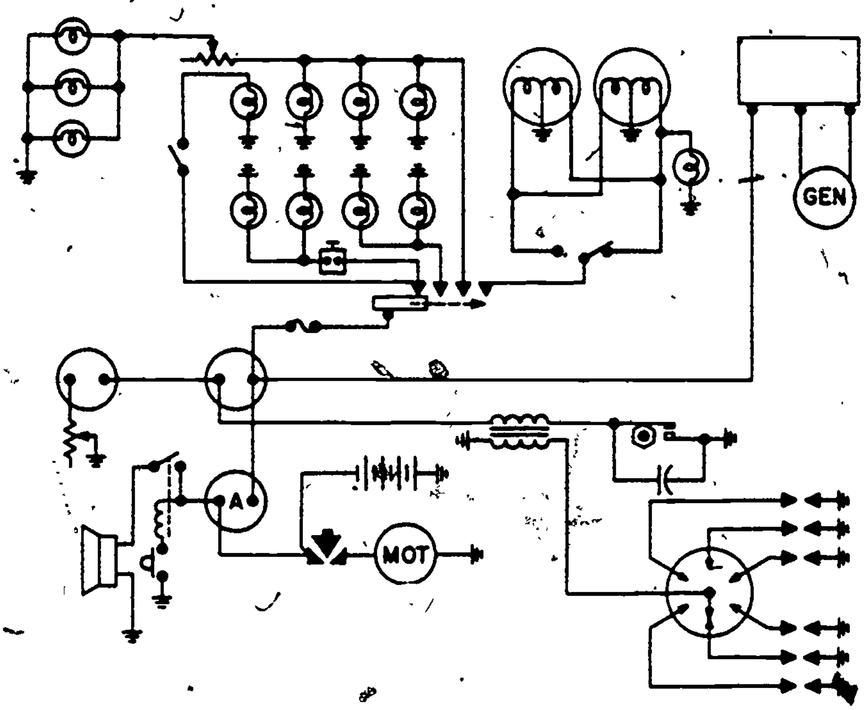
ELECTRICAL SYMBOLS

OBJECTIVES

1. **Given a list of electrical symbols and a list of electrical components, match the components to their respective symbols.**

2. **Given a list of statements pertaining to schematics, select the statement that describes a schematic diagram.**

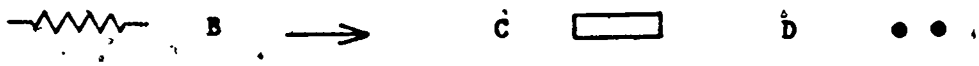
11,16
lsn. 2; p. 35

	1. Whether you are in OF11 or OF13, a knowledge of electrical diagrams is necessary. The diagram used the most is the schematic diagram. The schematic uses symbols to represent the parts of the circuit, and a single line to represent the connecting wires. This is a typical schematic diagram.  Parts are illustrated in a schematic by ________.
SYMBOLS	2. The arrangement of the parts in a schematic is by electrical priority. This is to say, the parts appear in the order in which they receive electrical power. The schematic diagram is arranged by a. electrical location of parts. b. physical location of parts. c. neither A nor B. d. both A and B.
a.	3. In schematic diagrams, the parts are represented by ________, and they are arranged in ________ order.

SYMBOLS
ELECTRICAL

4. To be able to read a schematic, you must first know what the symbols used in them represent. Below are eight basic shapes. From these shapes, or a combination of them, most electrical symbols are constructed.
Study these basic shapes; then proceed to the next frame.

A B C D



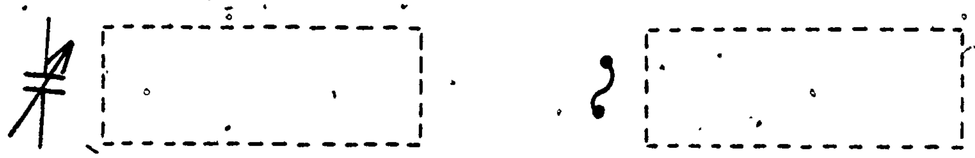
E F G H

These basic shapes may appear at different angles when used in combination with others, and straight-line shapes may appear with a bend in them.

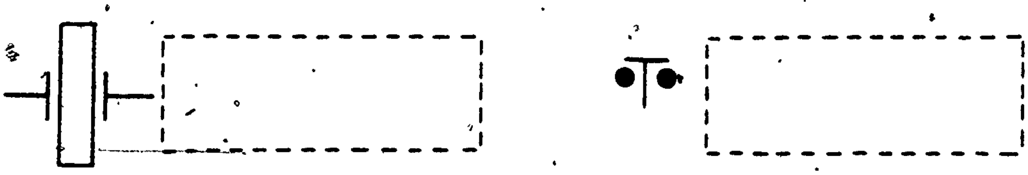
EXAMPLE:

5. The symbols below are made up of basic shapes. Break each symbol down into its basic shapes by drawing its basic shapes in the dotted boxes. Do not just recopy the symbol.

EXAMPLE:

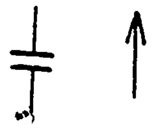


A B

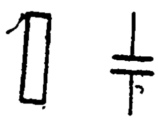


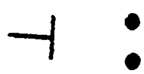
C D

11.16
lsn 2; p. 37

A 

B 

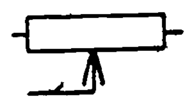
C 

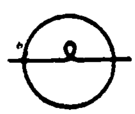
D 

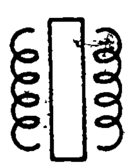
6. **NOW, DO THE SAME WITH THESE SYMBOLS.**

A 

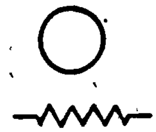
B 

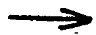
C 

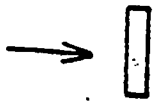
D 

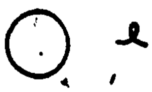
E 

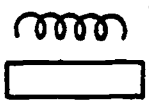
You may be wondering why you should know these basic shapes; they are the starting point for learning the symbols which they make up.

A 

B 

C 

D 

E 

7. There are two groups of electrical symbols that are shaped somewhat alike.

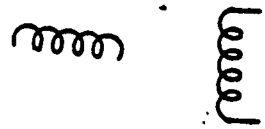
The two groups are:

RESISTORS AND COILS (or INDUCTORS)

Notice that the lines in the resistor form a zigzag.

Remember this symbol by thinking, "The zigzag lines in the resistor symbol look like mountains, and mountains resist travel."

The lines in both of these types of coil symbols are coiled.



The symbols show how a coil is made up of coiled wire.

Now, label these symbols.

A. ________ B. ________ C. ________

A. COIL
B. RESISTOR
C. COIL

8. a. Lines in a resistor symbol form a ________.

b. Lines in a coil symbol are usually ________.

c. Coils are made up of ________ wire.

d. Label the symbols below.

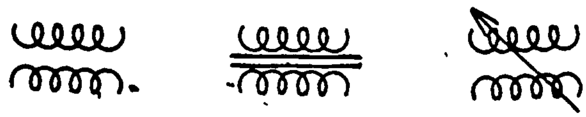
(1) ________ (2) ________

11.16
lsn 2; p. 39

a. ZIGZAG
b. COILED
c. COILED
d. (1) RESISTOR
(2) COIL

9. A transformer is used either to step up or to step down voltage. Since a transformer is constructed with coils of wire, it seems reasonable that a symbol for a transformer should contain the coil shape.

Below are some symbols for transformers.



Air-core transformer. Iron-core transformer. Variable transformer.

a. Which transformer symbol has an arrow running through it? ______________

b. Which transformer symbol has nothing between the coils? ______________

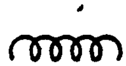
c. Which transformer symbol has heavy lines between the coils? ______________

The heavy lines between the coils represent an iron core. The iron core is simply a piece of iron around which the coils are wrapped. An arrow running through the coils of a transformer or through a resistor means the transformer or resistor is variable.

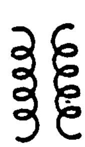
Label the symbols below.

A. ______________

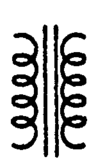
B. ______________



C. ______________



D. ______________



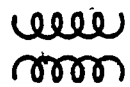
E. ______________

a. VARIABLE
b. AIR-CORE
c. IRON-CORE
A. RESISTOR
B. COIL
C. COIL
D. AIR-CORE TRANSFORMER
E. IRON-CORE TRANSFORMER

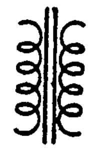
10. Label the symbols below as coils, transformers, resistors, variable resistors, or variable transformers.

A. ____________

B. ____________

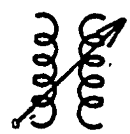


C. ____________



E. ____________

D. ____________



F. ____________

G. ____________

A. COIL
B. VARIABLE RESISTOR
C. AIR-CORE TRANSFORMER
D. COIL
E. IRON-CORE TRANSFORMER
F. VARIABLE TRANSFORMER
G. RESISTOR

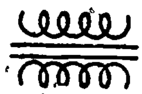
11. Draw the symbols for these parts.

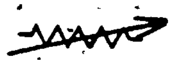
a. Iron-core transformer

b. Variable resistor

c. Coil

11.16
lsn 2; p. 41

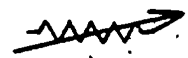
a. 

b. 

c. 

12. Perhaps some explanation of the term variable resistor should be given. The term variable simply means the resistance of a resistor can be varied. The <u>rheostat</u> is a good example of a variable resistor.

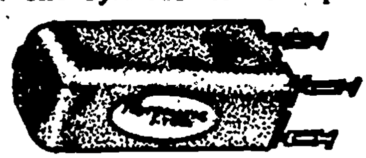
Variable resistor or rheostat.



There is another symbol which looks similar to the rheostat-- the <u>potentiometer</u>. The main difference between the symbols is the number of terminals (shown as dots) which lead from each one. The rheostat will have two and the potentiometer will have three dots in the symbol.

Potentiometer symbol.

Draw the symbols for the parts illustrated below.

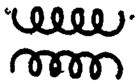


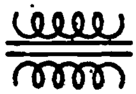
a. Air-core transformer

b. Iron-core transformer

c. Resistor

d. An arrow through a resistor symbol or a transformer symbol indicates that it is a ______________ resistor or transformer.

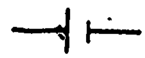
a. 

b. 

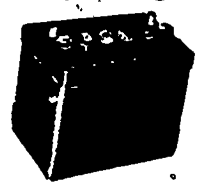
c. 

d. VARIABLE

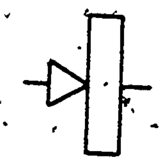
13. Now, some symbols that use ⟶ and ⊢ shapes. The simplest is the single cell.



The battery is merely a combination of cells; so the symbol for a battery is a series of cell symbols put together as shown below.



A rectifier is a device that changes alternating current to direct current. Below are two symbols for the rectifier. Either of these symbols may be used.



What do these symbols represent?

A. ______ B. ______ C. ______ D. ______ E. ______

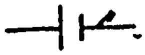
A. CELL
B. BATTERY
C. RECTIFIER
D. BATTERY
E. RECTIFIER

14. Using the shapes ⟶ and ⊢ , draw the symbols for these parts.

a. Cell

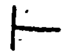
b. Battery

c. Rectifier

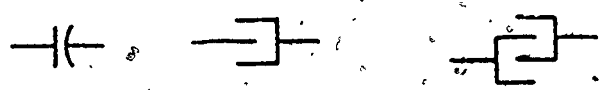
a. 

b. 

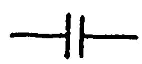
c. 

15. Here are some more symbols using the shapes →
and 

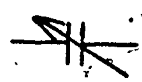
These three are capecitors.



THIS SYMBOL

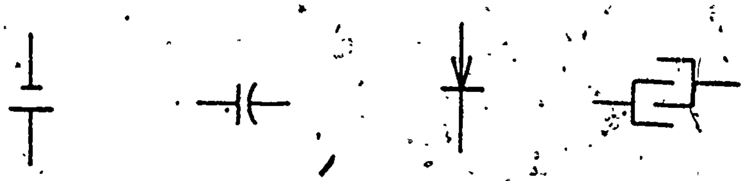


with an arrow through it means
a variable capacitor.

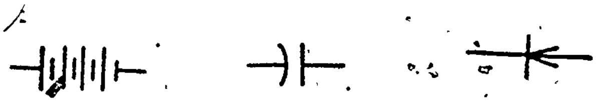


Variable capacitor.

Label the symbols below.



A. ________ B. ________ C. ________ D. ________



E. ________ F. ________ G. ________

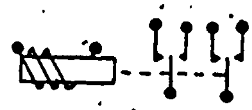
111

A. CELL
B. CAPACITOR
C. RECTIFIER
D. CAPACITOR
E. BATTERY
F. CAPACITOR
G. RECTIFIER

16. Contacts may be illustrated by the symbols below.

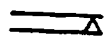
When the symbols above are used, you will usually see the symbol for an electromagnet used with them-- indicating a <u>relay</u>.

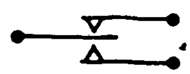
Electromagnet.



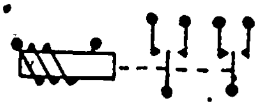
Relay.

a. Label the symbols below.





(1) ____________ (2) ____________ (3) ____________

(4) ____________ (5) ____________

b. Draw the symbol for the following:

(1) Battery

(2) Capacitor

(3) Contacts

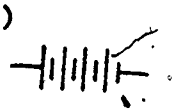
(4) Electromagnet

(5) Relay

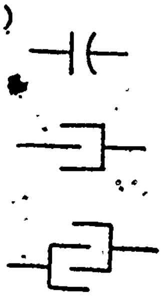
a.
(1) CONTACTS
(2) VARIABLE CAPACITOR
(3) CONTACTS
(4) ELECTRO-MAGNET
(5) RELAY

b.

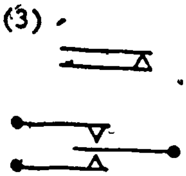
(1)



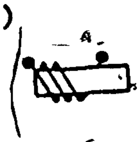
(2)



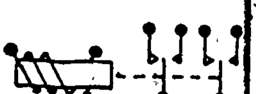
(3)



(4)

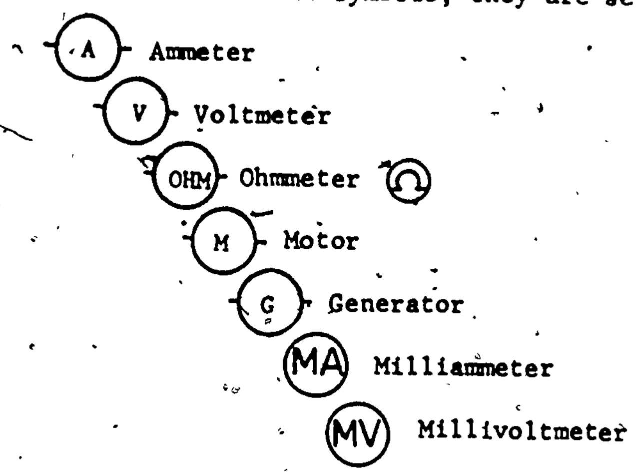


(5)



17. Now, let's look at some symbols using the  shape. These should be no problem to remember. Look for the letter within the circle.

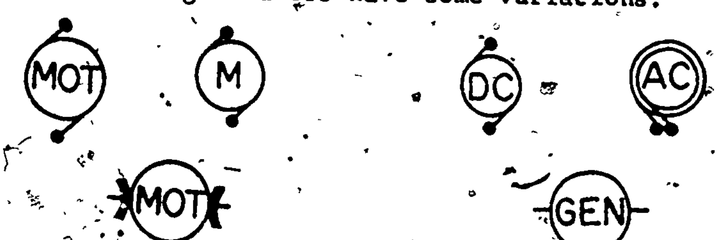
Below are several symbols; they are self-explanatory.



As you can see, the letter is the identifying mark. The symbol for the lamp is the exception.

Lamp symbols.

Motors and generators have some variations.



Motor symbols. Generator symbols.

Draw the symbol for the following:

a. Ohmmeter

b. Ammeter

c. Voltmeter

d. Lamp

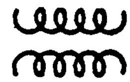
a. 

b. 

c. 

d. 

18. Match each component with its respective symbol.

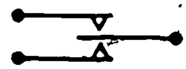
A. ______  1. Voltmeter

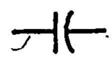
B. ______  2. Relay

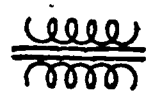
C. ______  3. Cell

D. ______ 

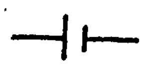
4. Resistor

E. ______  5. Electromagnet

F. ______  6. Rectifier

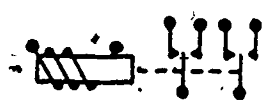
G. ______  7. Capacitor

H. ______  8. Battery

I. ______  9. Contacts

J. ______ 

10. Rheostat

K. ______  11. Iron-core transformer

L. ______  12. Air-core transformer

M. ______  13. Ammeter

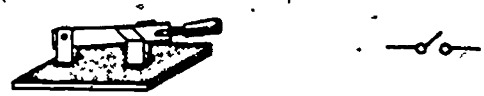
11.16
lsn 2; p. 47

A.	12
B.	5
C.	8
D.	1
E.	9
F.	7
G.	11
H.	6
I.	3
J.	13
K.	2
L.	4
M.	10

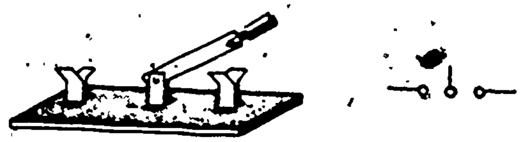
19. Let's study switches next. Since an electrical circuit is a pathway for current to flow through, a break in this pathway would stop current flow. Switches are simply ways to break this pathway or to control the flow of current.

Below are some symbols for switches...

SINGLE-POLE, SINGLE-THROW SWITCH

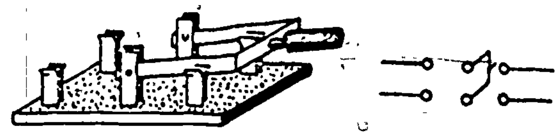


SINGLE-POLE, DOUBLE-THROW SWITCH



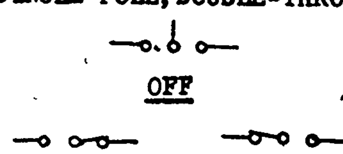
DOUBLE-POLE, SINGLE-THROW SWITCH

DOUBLE-POLE, DOUBLE-THROW SWITCH



To remember these switches, think of the number of poles as the number of wires coming to either side of the switch. The throws can be thought of as the number of on positions.

Example:

SINGLE-POLE, SINGLE-THROW	SINGLE-POLE, DOUBLE-THROW
	
OFF ON	OFF ON ON
ONE WIRE, ONE ON POSITION	ONE WIRE, TWO ON POSITIONS

a. The number of wires coming to each side of a double-pole switch is ____________.
b. The number of on positions a double-pole, single-throw switch has is ____________.
c. The number of on positions a double-pole, double-throw switch has is ____________.

a. TWO

b. ONE

c. TWO

20. From the descriptions below, name the switch and draw the symbol for it.

EXAMPLE: Has one wire connected to each side of the switch and has one on position.

single-pole, single-throw 

NAME — SYMBOL

a. Has one wire connected to each side of the switch and has two on positions.

__________ __________

b. Has two wires connected to each side of the switch and has one on position.

__________ __________

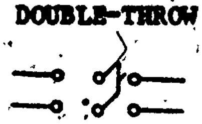
c. Has two wires connected to each side of the switch and has two on positions.

__________ __________

a. SINGLE-POLE, DOUBLE-THROW

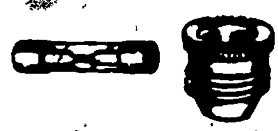
b. DOUBLE-POLE, SINGLE-THROW

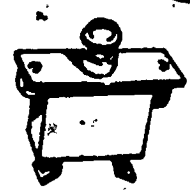
c. DOUBLE-POLE, DOUBLE-THROW



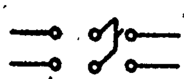
21. Two other devices which can control current flow in a circuit are circuit breakers and fuses. Both of these are safety devices. A circuit breaker amounts to nothing more then a fuse that can be reset.

Below are the fuse and circuit breaker and the symbol for each.

FUSE  

CIRCUIT BREAKER  

Both of these devices protect the circuit by breaking the pathway for current flow. Label these symbols.

A. ________ B. ________ C. ________

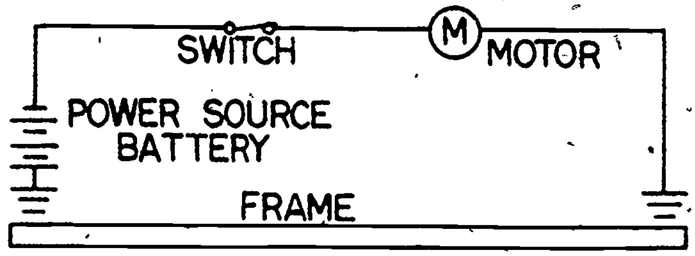
A. DOUBLE-POLE, DOUBLE-THROW SWITCH

B. FUSE

C. CIRCUIT BREAKER

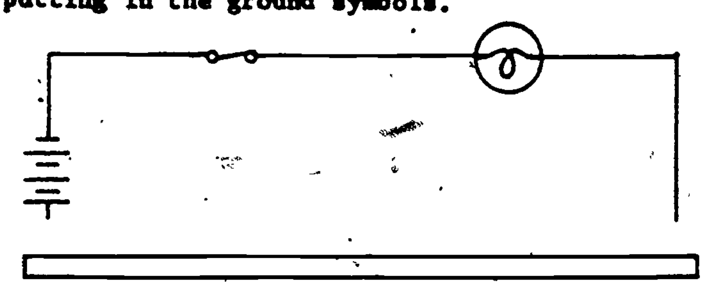
22. The ground symbol is the most often used symbol in electrical diagrams. This is the symbol for ground.

In an aircraft, as in your car, some components are grounded to the frame. This type of installation is known as a grounded circuit. This means that the ground (frame) is the return line for current back to the power source. Let's look at a grounded circuit.

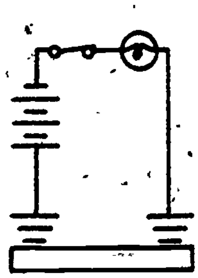


In the circuit above, current flows from the battery, through the switch, to the motor, and then to ground. Since both the battery and the motor are grounded to the frame, there is a complete circuit.

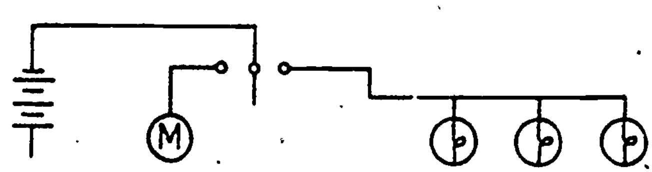
Make the circuit below a complete circuit by putting in the ground symbols.

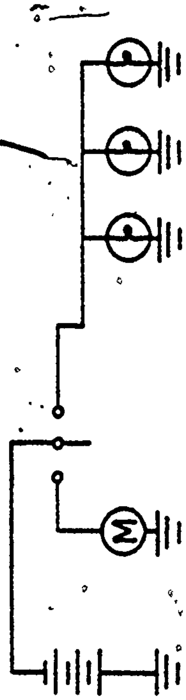


The only thing shown in an electrical diagram is the ground symbol. The ground (frame) is assumed to be there.



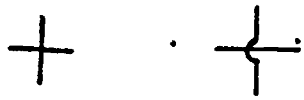
23. Place a ground symbol wherever it is needed in the diagram below.





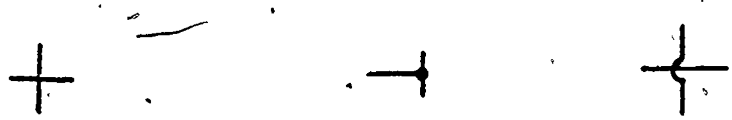
24. **Connection symbols represent permanent connections such as soldered connections or connections to terminals (screws and lugs). Below are some connection symbols you may see.**

You will notice that each of the illustrations above has dots at the intersection of the lines. The dot is the actual connection of the wires. Shown below are symbols known as "no connection." In other words, these illustrations merely show wires that cross each other but are not connected.

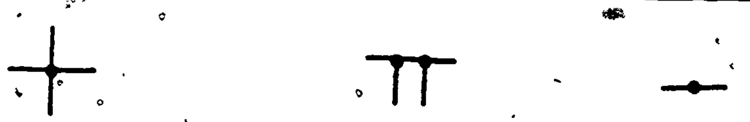


NOTICE NO DOT.

Label the symbols below as "connection" or "no connection."



A. ________ **B.** ________ **C.** ________



D. ________ **E.** ________ **F.** ________

A. NO CONNECTION
B. CONNECTION
C. NO CONNECTION
D. CONNECTION
E. CONNECTION
F. CONNECTION

25. **Draw the symbol for each of these components.**

a. Circuit breaker **b. Fuse** **c. Single-pole, single-throw switch**

d. Connection **e. No connection** **f. Ground**

118

a. 

b. 

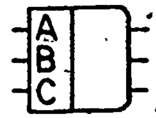
c. 

d. 

e. 

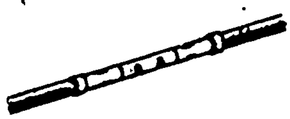
f. 

26. Below are two more symbols for connections. These symbols represent connections which are frequently connected or disconnected. The first is called the <u>connector</u> (cannon plug).



Looking at the symbol for the connector, you can easily see its use. The connector is used for multiwire installations. The letters identify the wires.

The next symbol represents the <u>disconnect</u>.



Again, the symbol shows how it is used. The disconnect is for single-wire installations. You have probably seen this type on your car.

Label the symbols below.

A. ____________

B. ____________

C. ____________

D. ____________

E. ____________

F. ____________

G. ____________

H. ____________

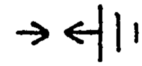
I. ____________

A. CONNECTION
B. NO CONNECTION
C. DISCONNECT
D. BATTERY
E. GROUND
F. FUSE
G. DISCONNECT
H. RECTIFIER
I. CELL

27. The last two symbols are the spark plug, as used in your car, and the spark igniter, as used in a jet engine. First the spark plug. This symbol is composed of the ground symbol and two arrows facing each other. Below is the spark plug symbol.

As you can see below, the spark igniter uses the ground symbol also, but it has a circle and cross in place of the two arrows.

Label the symbols below.

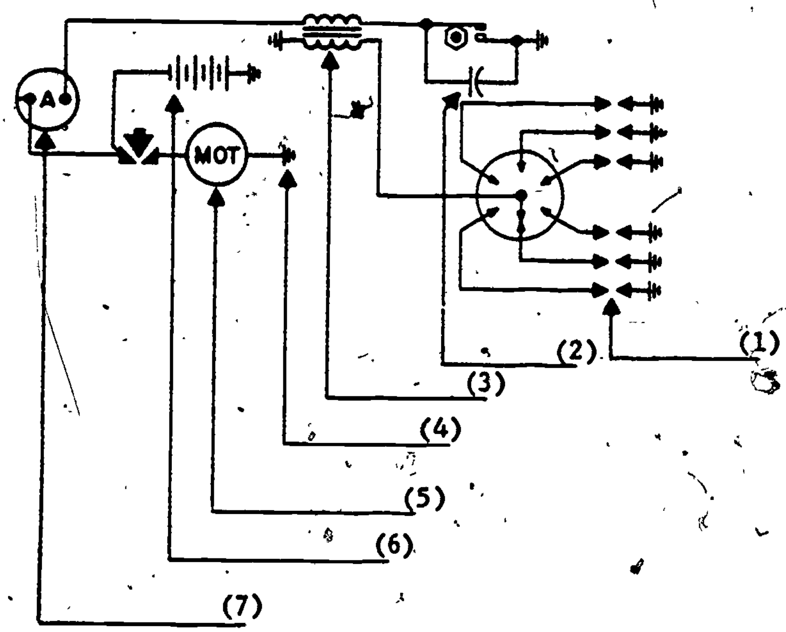
a.  ______ b.  ______

c.  ______

a. CIRCUIT BREAKER
b. SPARK PLUG
c. SPARK IGNITER

28. You have seen a lot of symbols separately. Now, let's put them in a schematic and see if you can identify them.

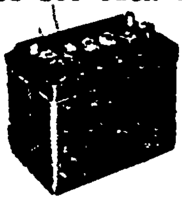
Label the numbered symbols in the schematic below.



11.16
lsn 2; p. 53

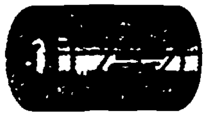
(1) SPARK PLUG
(2) CAPACITOR
(3) IRON-CORE TRANSFORMER
(4) GROUND
(5) MOTOR
(6) BATTERY
(7) AMMETER

29. Draw the symbol for each of the components below.

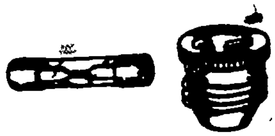


a. Battery ____________

b. Lamp ____________

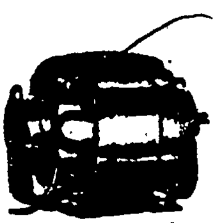


c. Cell ____________



d. Fuse ____________

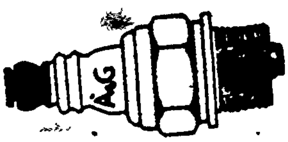
e. Generator ____________



f. Motor ____________

g. Resistor ____________

h. Disconnect ____________



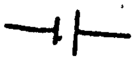
i. Spark plug ____________

11.16
lsn 2; p. 54

101

a. 

b. 

c. 

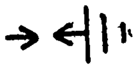
d. 

e. 

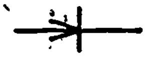
f. 

g. 

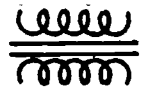
h. 

i. 

30. Label each symbol shown below.



A. ____________

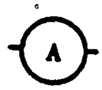


B. ____________

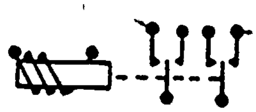
C. ____________

D. ____________

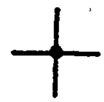
E. ____________



F. ____________



G. ____________



H. ____________

I. ____________

11.16
lan 2, p. 55

A. RECTIFIER

B. IRON-CORE TRANSFORMER

C. PUSH-PULL CIRCUIT BREAKER

D. OHMMETER

E. SINGLE-POLE, SINGLE-THROW SWITCH

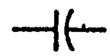
F. AMMETER

G. RELAY

H. CONNECTION

I. GROUND

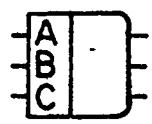
31. Label each symbol shown below.



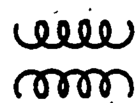
A. ____________

B. ____________

C. ____________



D. ____________



E. ____________

F. ____________

G. ____________

H. ____________

A. CAPACITOR

B. RHEOSTAT

C. SPARK IGNITER

D. CONNECTOR

E. AIR-CORE TRANSFORMER

F. SINGLE-POLE, DOUBLE-THROW SWITCH

G. VOLTMETER

H. NO CONNECTION

11.16
lsn 2; p. 56

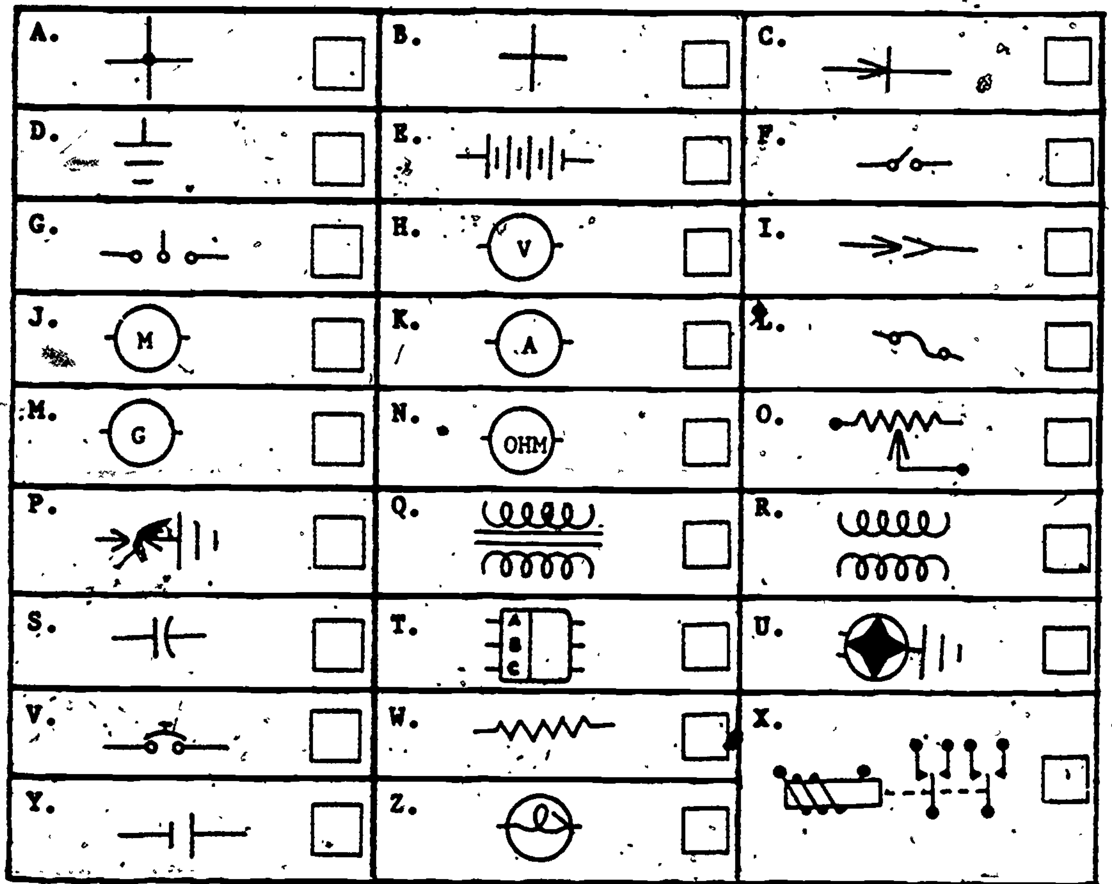
FUNDAMENTALS OF ELECTRICITY

LESSON 2, PART B

ELECTRICAL SYMBOLS

SELF-TEST

1. **Match the name of each component with its respective symbol by placing the number before the component in the box beside its respective symbol.**



1. **Ground**
2. **Lamp**
3. **Connection**
4. **No connection**
5. **Cell**
6. **Battery**
7. **Fuse**
8. **Generator**
9. **Motor**
10. **Resistor**
11. **Rheostat**
12. **Voltmeter**
13. **Ammeter**
14. **Ohmmeter**
15. **Disconnect**
16. **Single-pole,single-throw switch**
17. **Single-pole,double-throw switch**
18. **Push-pull circuit breaker**
19. **Capacitor**
20. **Air-core transformer**
21. **Iron-core transformer**
22. **Relay**
23. **Rectifier**
24. **Spark ignitor**
25. **Spark plug**
26. **Connector (cannon plug)**

2. Which statement describes a schematic diagram?

a. Parts are illustrated with pictures and are arranged by their physical location.

b. Parts are illustrated with pictures and are arranged in the order in which they receive electrical power.

c. Parts are represented by symbols and are arranged in the order in which they receive electrical power.

11.16
lsn 2; p. 58

LESSON 2, PART B
ELECTRICAL SYMBOLS-SELF TEST ANSWERS

1.	A	3	J	9	S	19
	B	4	K	13	T	26
	C	23	L	7	U	24
	D	1	M	8	V	18
	E	6	N	14	W	10
	F	16	O	11	X	22
	G	17	P	25	Y	5
	H	12	Q	21	Z	2
	I	15	R	20		

2. c

END OF LESSON 2, GO-ON TO LESSON 3

* * *

11.16
lsn 2, p. 59

126

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11.16a

FUNDAMENTALS OF ELECTRICITY

LESSON 3

SERIES CIRCUITS

AND

PARALLEL CIRCUITS

33

INSTRUCTIONS

This is a programmed lesson. It is designed to teach, not to test. You will need only this booklet, a pencil, and some time to complete this lesson. If there is something in the program you do not understand, ask your instructor or supervisor for assistance.

- REMEMBER -

This lesson has been written so that the amount of reading necessary is minimal and yet most meaningful. Therefore, it is very important that you follow these instructions.

- Read each page carefully.
- Fill in each blank.
- Keep the answer to the frame on which you are working covered with a slip of paper until you have written your answer.
- Correct all errors you make.
- Follow all directions given in the program.

SUGGESTED READING TIME
180 MINUTES

LESSON 3

PART A

SERIES CIRCUITS

OBJECTIVES

1. From a list of statements pertaining to electrical circuits, select the statement that correctly describes an electrical circuit.

2. From a list of statements pertaining to electrical circuits, select the statements that correctly describe a series circuit.

3. Solve series-circuit problems for the following:

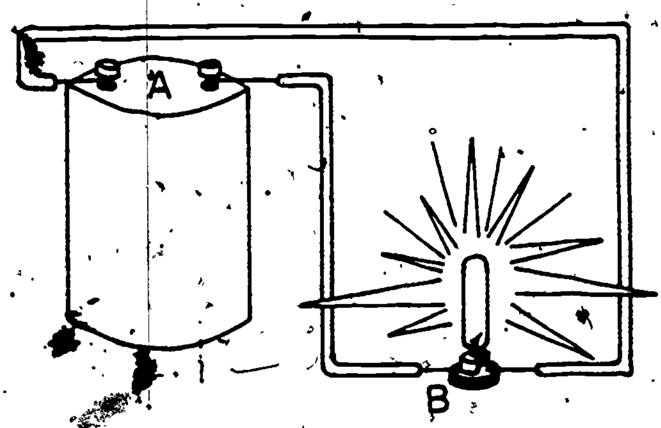
   a. Current
   b. Voltage drop across an individual component
   c. Resistance of an individual component
   d. Total resistance
   e. Total voltage

4. From a list of statements pertaining to source voltage, select the statements that are correct concerning source voltage in a series circuit.

5. Given a list of statements concerning the ohmmeter, ammeter, and voltmeter, match each statement with the meter to which it applies.

6. From a list of statements pertaining to circuits, select the statements that apply to a short circuit.

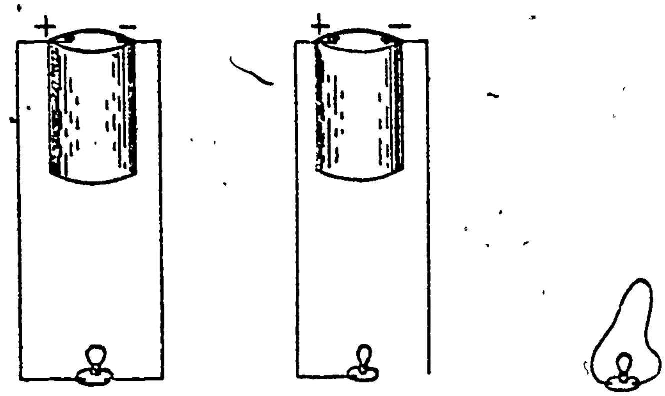
7. From a list of statements pertaining to circuits, select the statements that apply to an open circuit.

	1. There are three configurations (types) of circuits used in electrical work. If you were building a complex electrical device, how many different types of electrical circuits could you possibly use?
THREE	2. One of the three types of circuits is the series circuit. In electrical work, one type of circuit you can use is the __________ circuit.
SERIES	3. Electric current must have a means of getting from its source to the point where it is to be used and back again. This is accomplished with a circuit. A circuit provides a continuous electrical pathway for __________.
CURRENT	4. The illustration below represents a circuit because it has a continuous pathway for current to flow from the source, through the light bulb, and back to the source.  If the wire between points A and B is disconnected, will the light continue to burn? __________

11.16
lsn 3; p. 3

NO

5. Circle the letter under the illustration that correctly represents an electrical circuit.



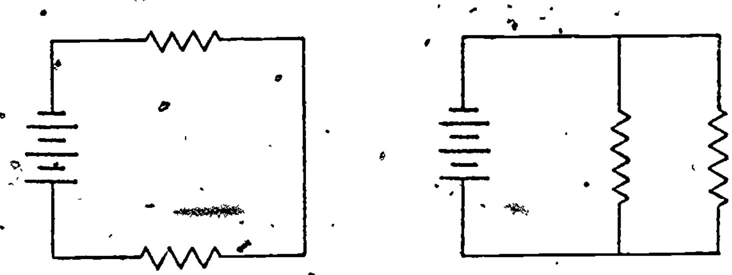
A B C

A

6. A series circuit has only one continuous pathway through which current may flow. Other types of circuits have more than one pathway. A circuit that has only one path for current is known as a __________ circuit.

SERIES

7. A series circuit is a circuit having only one pathway for current.



A B

Circle the letter below the illustration that represents a series circuit.

A.

8. Select the correct answer.

A series circuit has

a. at least two paths for current.

b. any number of continuous electrical pathways for current.

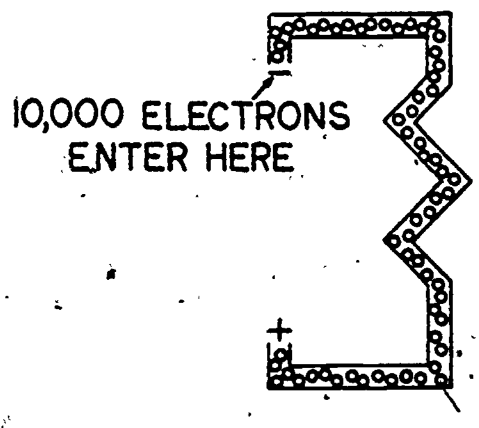
c. only one path for current..

c.

9. In a series circuit, there is only one path for current; therefore, current is the same any place in the circuit. Current at any point in a series circuit will be ______________________.

THE SAME (CONSTANT)

10. Current in a series circuit is constant throughout. Current is the movement of electrons.



If it were possible to count the electrons in a series circuit, the same number of electrons would be flowing across any point in the circuit.

How many electrons would leave the positive side of the circuit illustrated above?

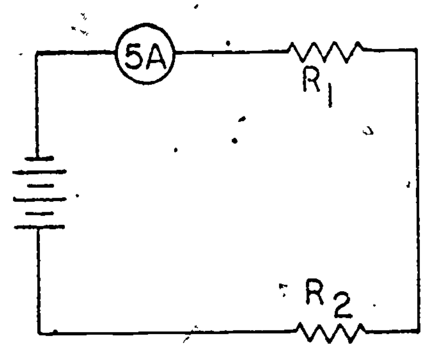
a. 10,000.
b. Less than 10,000.
c. More than 10,000.
d. None.

11.16
lsn 3; p. 5

a.

11. The law of current states that the current in any part of a series circuit is equal to the current in any other part of the same circuit ($I_t = I_1 = I_2 = I_3$ ....).

NOTE: GO TO PAGE 39, UNFOLD THE FOLDOUT SHEET, READ, AND KEEP OPEN FOR REFERENCE.



What will the current be across R_1 and R_2 in the circuit above?

R_1: ______________

R_2: ______________

R_1 : 5 AMPS.

R_2 : 5 AMPS

12. Select the correct answer.

An electrical circuit is a

a. continuous electrical pathway for voltage flow.

b. minimum of two pathways for current.

c. continuous electrical pathway for current.

c.

13. Select the two correct answers.

A series circuit has

a. only one pathway for current.

b. more than one pathway for current.

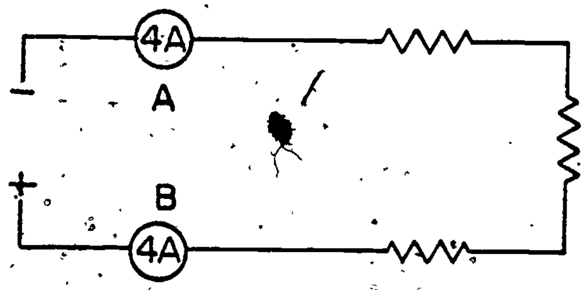
c. current that will vary throughout the circuit.

d. constant current throughout the circuit.

a

d.

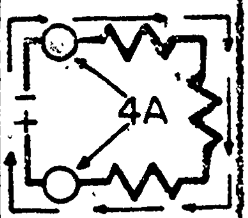
14. In a series circuit, there is only one path for current, and the current is constant. The current will flow from the negative side of the power source, through the circuit, and back to the positive side of the power source. The amount of current is measured with an ammeter. An ammeter indicates amperes.



a. Draw arrows in the illustration above to indicate the direction of current.

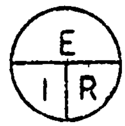
b. What type of meter is represented by items A and B in the illustration above? ______________

a.



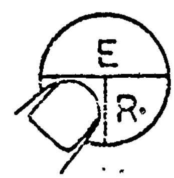
b. AMMETER

15. Current can be measured by an ammeter, or it can be determined mathematically by using Ohm's law. The formula for Ohm's law is illustrated in the magic circle.

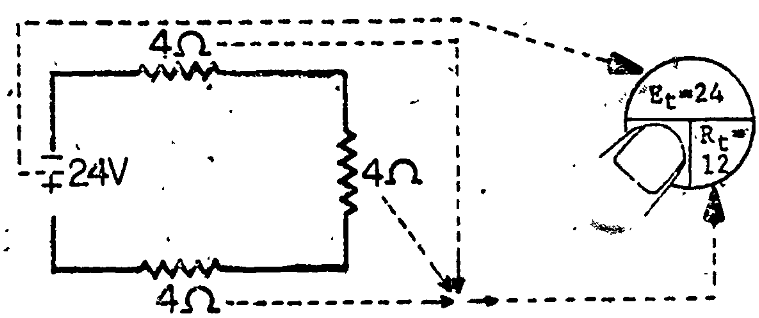


The letters in the magic circle represent specific factors: E = voltage, I = current, and R = resistance. To use the magic circle, simply cover the unknown factor with your finger and you can see what you need to do to find the unknown. Example: To find current, cover the I,  , and you can see that you divide E by R. One way of determining current in a series circuit is by using the total values. The total voltage (source voltage) divided by the total resistance will give you current. Complete the steps below and determine the current.

Step 1



Step 2



Step 3 24 ÷ 12 = I

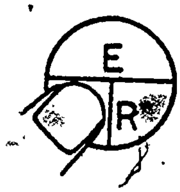
I = ______ amps.

2 AMPS.

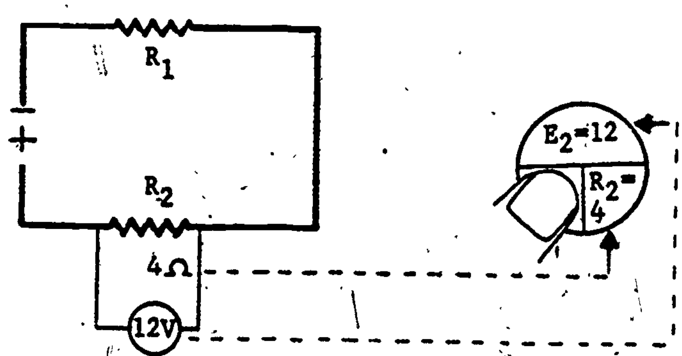
16. Current in a series circuit can be found when total values are not known. When the amount of voltage drop across an individual component is known and the resistance of that component is known, we can divide the voltage drop by the resistance and find the current. Remember, this value will be for the entire circuit, because current is constant.
In the illustration below, you will notice there are no total values given; however, the voltage drop across R_2 and the resistance of R_2 are given. Using these values, we can find current.

Complete the steps below.

Step 1



Step 2



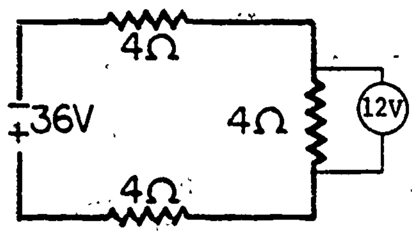
Step 3 $12 \div 4 = I$

I = ____ amps.

3 AMPS.

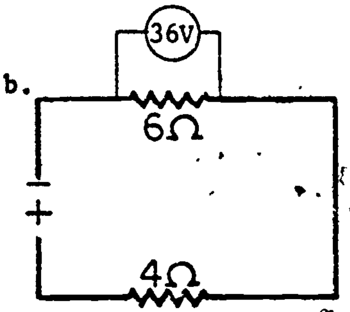
17. Find the current in the series circuits below.

a.



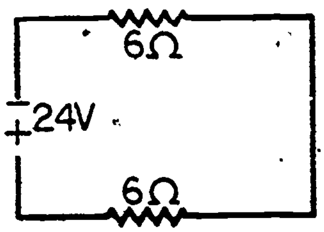
I = ______ amps

b.



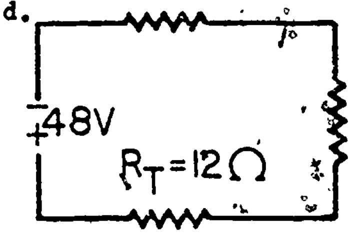
I = ______ amps

c.



I = ______ amps

d.



I = ______ amps

---

a. 3

b. 6

c. 2

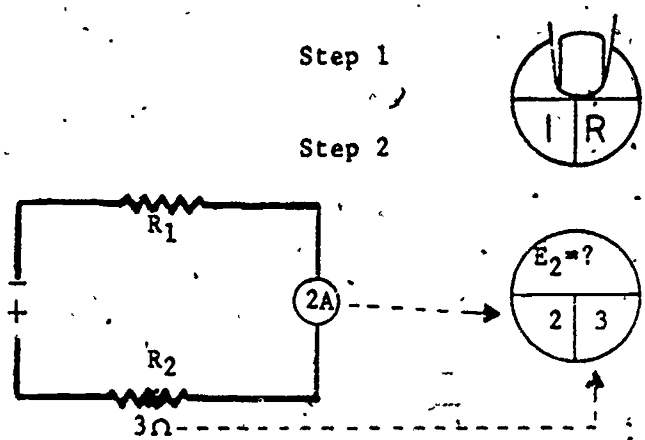
d. 4

18. You previously found current by dividing the voltage drop across a component by the resistance of that component. Now, let's see how this voltage drop is found. To find the voltage drop across an individual component, multiply the resistance of that component by the current through it.

Follow the steps in the illustration below and find E_2 (voltage drop across resistance number two).

Step 1

Step 2



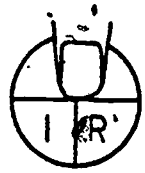
Step 3 $2 \times 3 = E_2$

E_2 = ____ volts

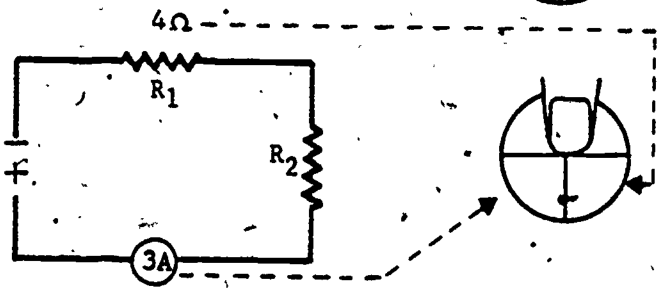
6 VOLTS

19. Using the information in the illustration below, complete the steps and find E_1 (the voltage drop across resistance number one).

Step 1



Step 2

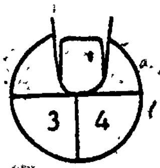


Step 3

___ × ___ = ____ volts

E_2 = ____ volts

STEP 2

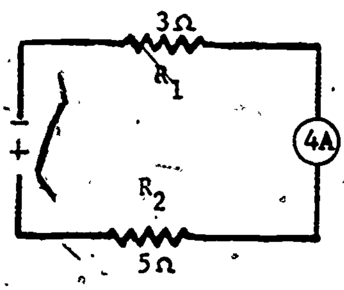


STEP 3

3 × 4 = 12 VOLTS

E_1 = 12 VOLTS

20. Solve for voltage drops E_1 and E_2.



E_1 = __________ volts

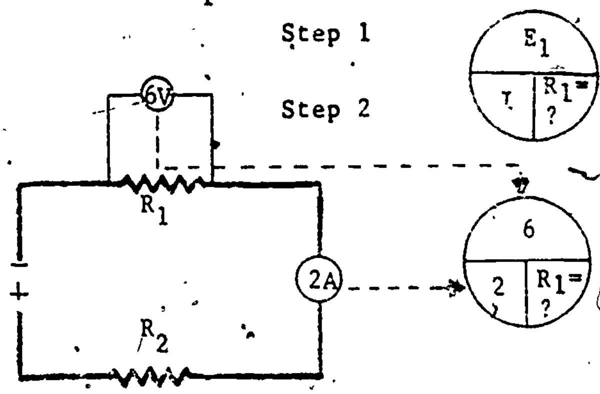
E_2 = __________ volts

E_1 = 12 VOLTS

E_2 = 20 VOLTS

21. Now that you know how to find a voltage drop across a component, let's use this voltage drop to find the resistance of a component. To find this resistance, divide the voltage drop across the component by the current through it.

Follow the steps in the illustration below, and find the resistance of R_1.

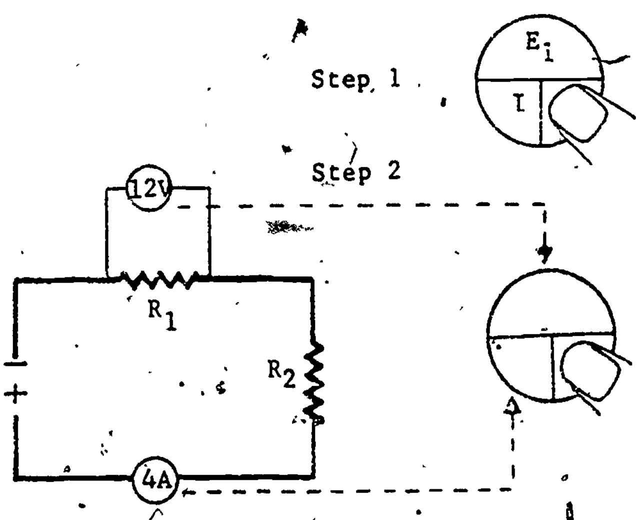


Step 3 $6 \div 2 = R_1$

R_1 = ____ ohms

R_1 = 3 OHMS

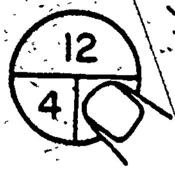
22. Complete the steps and find the resistance of R_1.



Step 3 ___ + ___ = R_1

R_1 = ____ ohms

STEP 2.

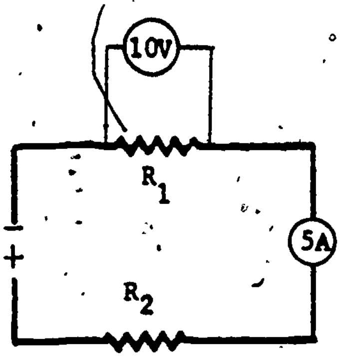


STEP 3

$12 \div 4 = R_1$

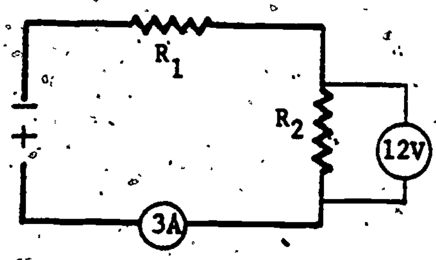
$R_1 = 3$ OHMS

23. Solve for the resistance of R_1.



R_1 = ____ ohms

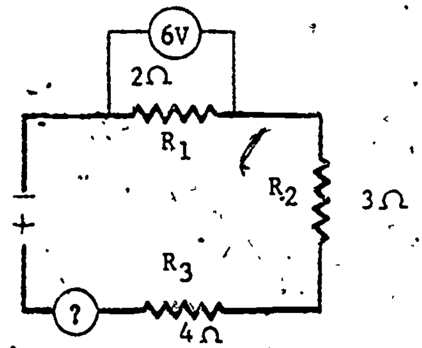
Solve for the resistance of R_2.



R_2 = ____ ohms

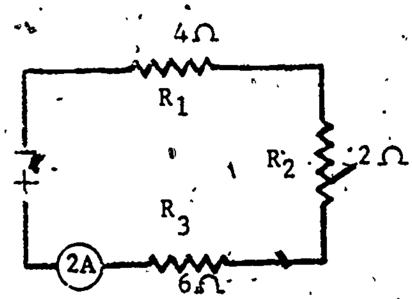
R_1 = 2 OHMS R_2 = 4 OHMS	24. Solve for the unknown.

a.



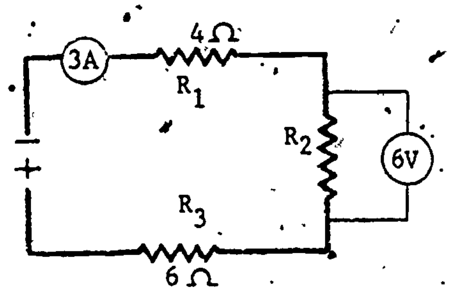
I_t = ______ amps.

b.

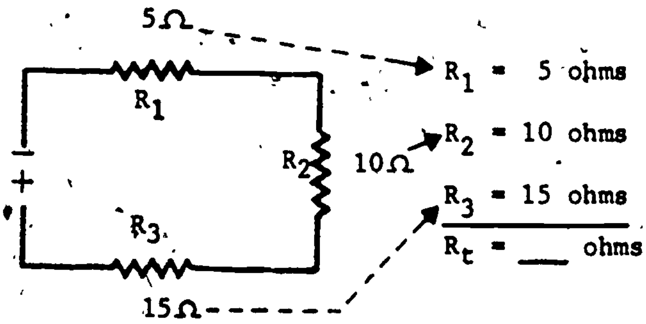
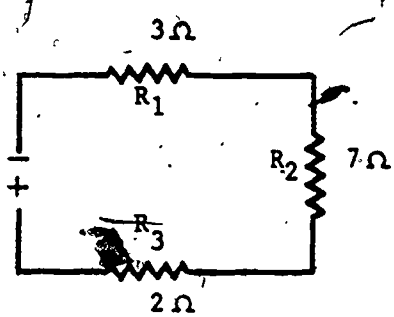
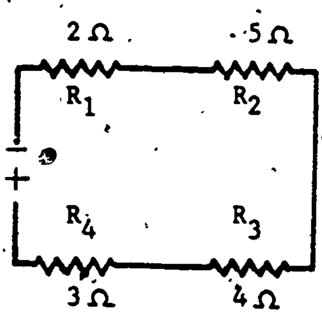


E_3 = ______ volts

c.



R_2 = ______ ohms

a. 3 AMPS. b. 12 VOLTS c. 2 OHMS	25. After determining the resistance of the individual components, it is a simple task to find the total resistance of a series circuit. The law of resistance states: The total resistance of a series circuit is equal to the sum of the individual resistances of the circuit ($R_t = R_1 + R_2 + R_3 \ldots$). Complete the following example. 
R_t = 30 OHMS	26. Total resistance (R_t) of a series circuit is found by ____________ the individual resistances. Find the total resistance (R_t) of the following circuits. a.  R_t = ___ ohms b.  R_t = ___ ohms

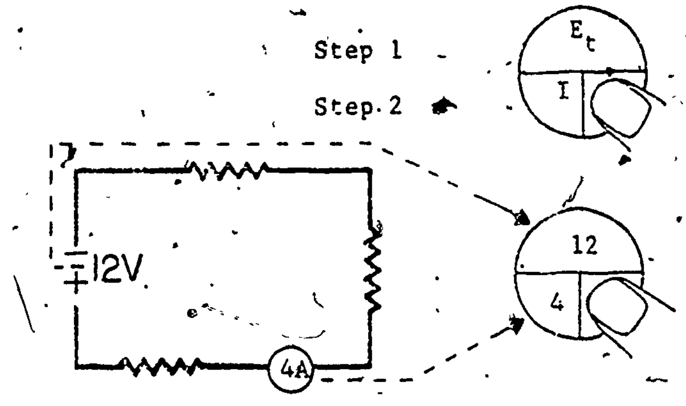
11.16
lsn 3; p. 15

ADDING

a. 12 OHMS

b. 14 OHMS

27. Previously, you added individual resistances to find the total resistance of a series circuit; however, this is not the only way it can be found. When total voltage and current are known, we can divide total voltage (E_t) by current to determine total resistance (R_t). Complete the following example.

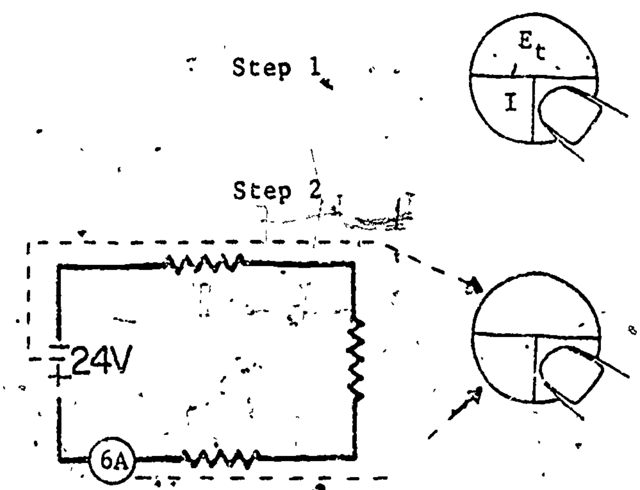


Step 3 $12 \div 4 = R_t$

R_t = ____ ohms

R_t = 3 OHMS

28. Complete the steps and find the total resistance (R_t).



Step 3 ____ $\div$ ____ = R_t

R_t = ____ ohms

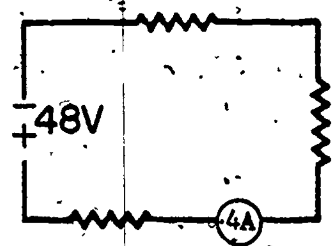
STEP 2 --

STEP 3 --

$24 \div 6 = R_t$

$R_t = 4$ OHMS

29. Solve for the total resistance (R_t).

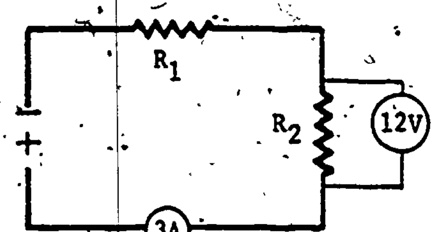


R_t = ______ ohms

$R_t = 12$ OHMS

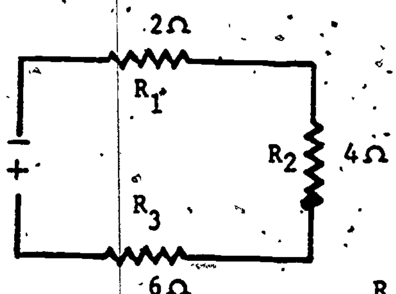
30. Solve for the unknown.

a.



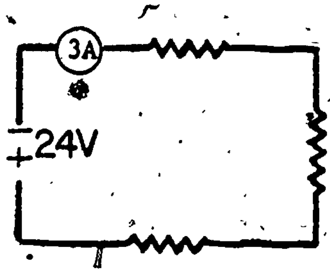
R_2 = ______ ohms

b.



R_t = ______ ohms

c.



R_t = ______ ohms

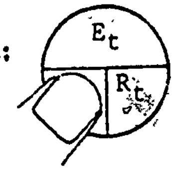
a. 4 OHMS

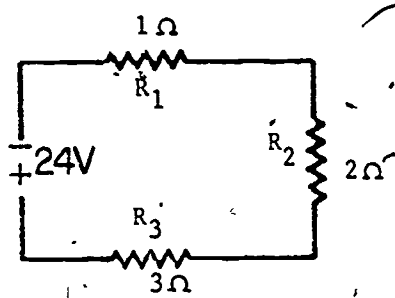
b. 12 OHMS

c. 8 OHMS

31. By now, you should have a good understanding of how to find resistance in a series circuit. A little review of current is in order at this point. Remember, current can be found by dividing total voltage by total resistance.

In the magic circle, it looks like this:
Solve for current in the circuit below.





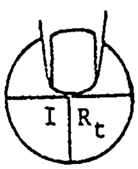
I = ________ amps.

I = 4 AMPS.

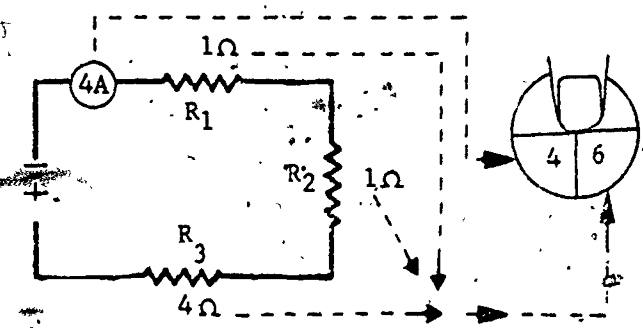
32. In order to work with series circuits, you must know how to determine total voltage. You can determine total voltage (E_t) by multiplying current by total resistance (R_t).

Complete the example below.

Step 1



Step 2



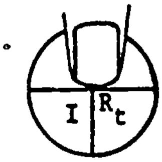
Step 3 $4 \times 6 = E_t$

E_t = ____ volts

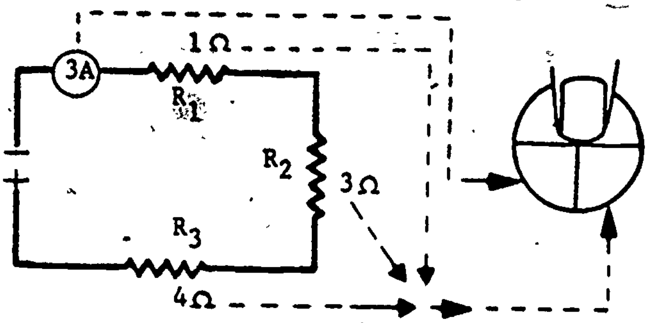
E_t = 24 VOLTS

33. Using the information in the illustration below, complete the steps and determine the total voltage (E_t).

Step 1



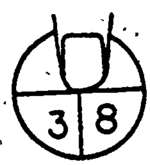
Step 2



Step 3 ____ × ____ = E_t

E_t = ____ volts

STEP 2 --

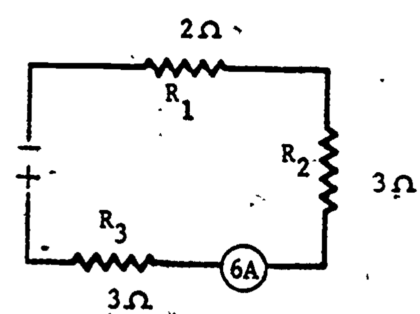


STEP 3 --

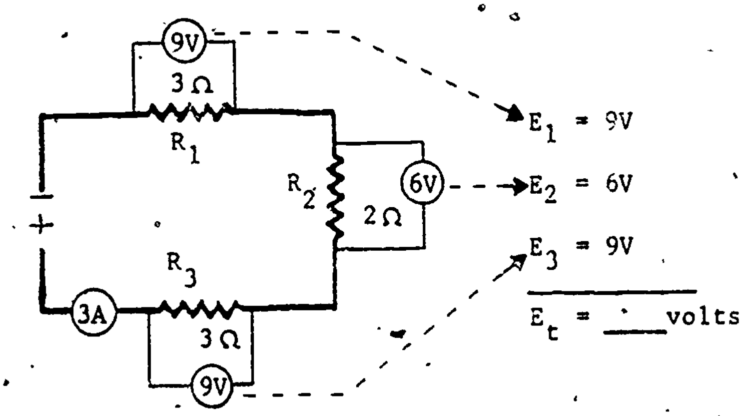
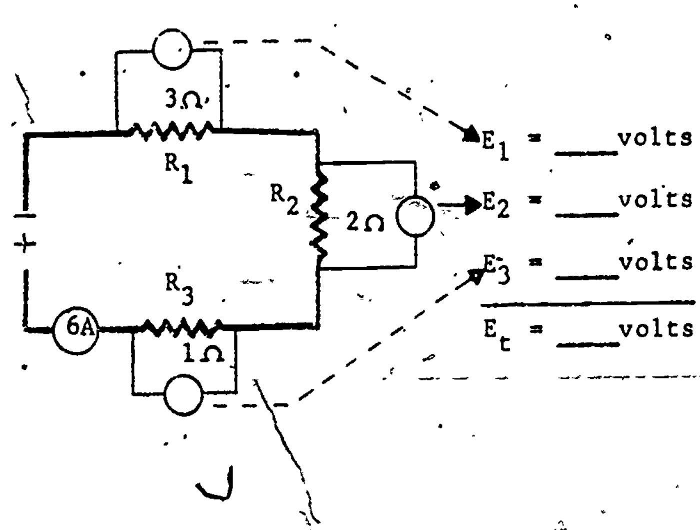
$3 \times 8 = E_t$

E_t = 24 VOLTS

34. Solve for total voltage (E_t).



E_t = ____ volts

E_t = 48 VOLTS	35. Previously, you found the voltage drop of an individual component by multiplying the resistance of the component by the current through it. The law of voltage states: The total voltage of a series circuit is equal to the sum of the individual voltage drops of the circuit ($E_t = E_1 + E_2 + E_3 \ldots$). This total voltage is equal to the source voltage. Complete the example below. 
E_t = 24 VOLTS	36. Find each individual voltage drop and the total voltage in the circuit below. 

E_1 = 18 VOLTS

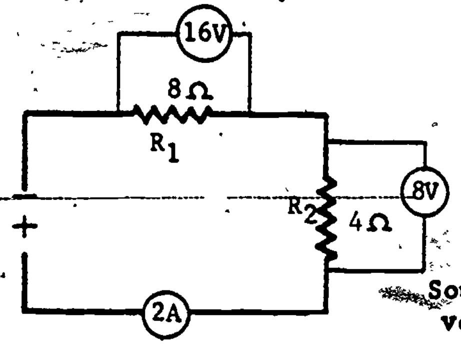
E_2 = 12 VOLTS

E_3 = 6 VOLTS

E_t = 36 VOLTS

37. In a series circuit, the sum of the individual voltage drops is total voltage (E_t). The total voltage (E_t) is equal to the source voltage. It should be understood that the source voltage and the total voltage in a series circuit have the same value. Source voltage is the voltage of the battery or other source potential; total voltage is the sum of the voltage drops in the circuit and equals the value of the source.

Complete the example below.



E_1 = ______ volts

E_2 = ______ volts

E_t = ______ volts

Source voltage = ______ volts

E_1 = 16 VOLTS

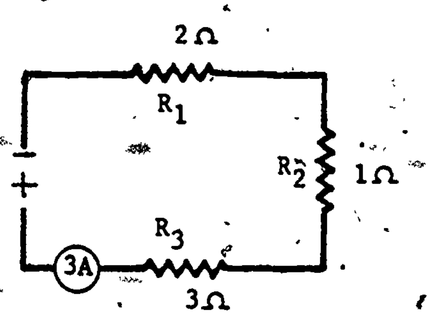
E_2 = 8 VOLTS

E_t = 24 VOLTS

SOURCE VOLTAGE = 24 VOLTS

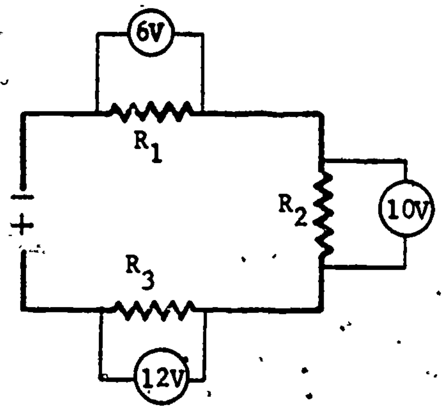
38. Solve for unknowns in the circuits below.

a.



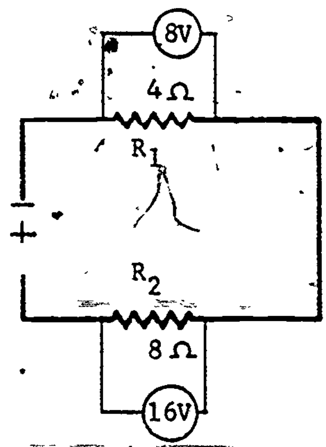
E_t = ______ volts

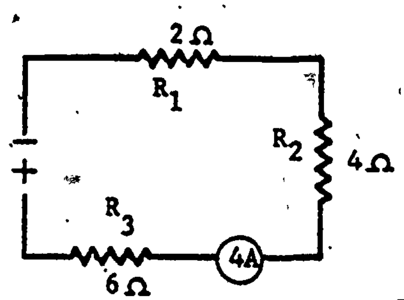
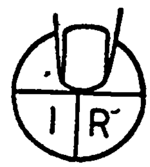
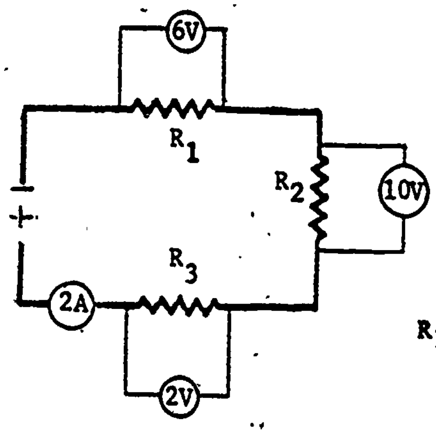
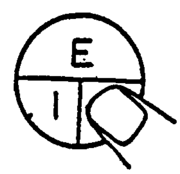
b.



E_t = ______ volts

11.16
lsn 3; p. 21

a. 18 VOLTS b. 28 VOLTS	39. The values of source voltage and total voltage are equal. The value of source voltage will diminish as you progress through a series circuit. Each component will cause a certain amount of source voltage to be used because there is resistance to current within it. This is voltage drop. Source voltage will be expended by moving the current through the circuit. In moving current through a series circuit, the source voltage will be completely ________.
EXPENDED (USED UP)	40. Source voltage will be totally expended while moving current through a series circuit, but only a portion of the source voltage will be expended moving current through each component, as shown in the illustration below.  a. What is the total amount of voltage expended by moving current through R_1 and R_2 above? ______ volts b. What is the source voltage of the circuit above? ______ volts

a. 24 VOLTS b. 24 VOLTS	41. As you now know, there is a certain amount of source voltage expended or used at each component in the circuit. The amount of source voltage expended at each component is known as the voltage drop across that individual component. The voltage expended at a component is known as ______________.
VOLTAGE DROP	42. Voltage drop, resistance of a component, and current through a component can all be used in the formula for Ohm's law. You can find the voltage drop of a component by multiplying its resistance by the current through it. Find the voltage drop (E_1) in the circuit below.  E_1 = __________ volts
E_1 = 8 VOLTS	43. To find the resistance of a component, divide its voltage drop by the current through it. Find the resistance of R_1 in the circuit below.  R_1 = __________ ohms

11.16
lsn 3; p. 23

R_1 = 3 OHMS

44. Label the statements below true or false.

_____ a. All of the source voltage will be expended by moving current through a circuit.

_____ b. All of the source voltage will be expended across each resistance in a circuit having three resistances.

_____ c. Total voltage is equal to the source voltage.

_____ d. Source voltage and total voltage are not equal.

_____ e. Only a portion of source voltage will be expended by moving current through the circuit.

_____ f. Voltage drop is the amount of voltage expended by moving current through a resistance.

T a.

F b.

T c.

F d.

F e.

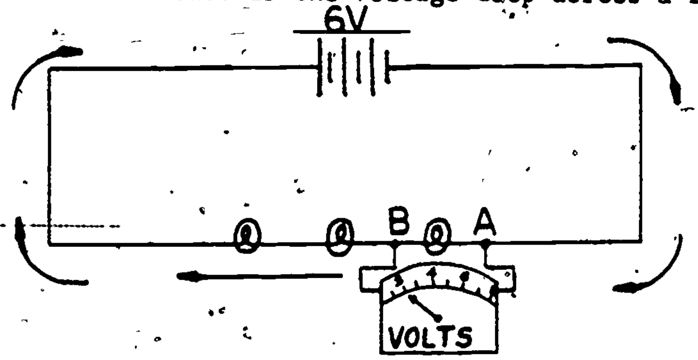
T f.

11.16
lsn 3; p. 24

150

NOTE: THE CORRECT ANSWERS FOR THE REMAINDER OF THIS PROGRAM ARE FOUND ON PAGE 33.

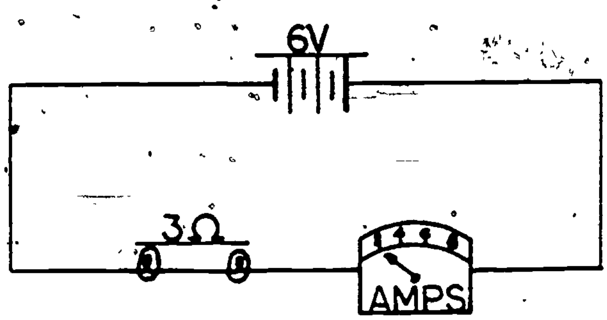
45. If you work around electrical circuits, you will be using various meters. You need to know how to connect these meters in a circuit and know what each meter measures after it is connected. A voltmeter is connected parallel with a circuit. A voltmeter is used to measure the potential difference between two points. This potential difference is the voltage drop across a resistance.



Using the information and the illustration above, answer these questions.

a. The potential difference (voltage drop) is measured in ________.
b. A voltmeter is connected ________ with a circuit.
c. If 6 volts are available at point A, how many volts would be available at point B? ________
d. A voltmeter measures the p__________ d__________ between two points.

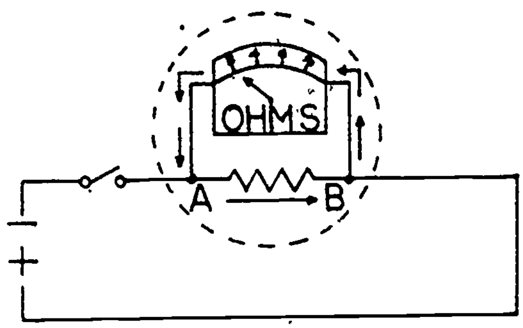
46. An ammeter is connected in series in a circuit and measures the current in the circuit. All current in a series circuit must go through the ammeter.



a. Current is measured in ________.
b. An ammeter is connected in ________ in a circuit.
c. An ammeter measures the ________ in a circuit.

11.16
lsn 3; p. 25

47. An ohmmeter is a meter used to measure the resistance between any two points. The ohmmeter has its own power source and is connected in series with the component to be measured. Since the ohmmeter has its own power source, the circuit power must be off while testing a circuit with an ohmmeter. Failure to turn off circuit power could result in damage to the ohmmeter.

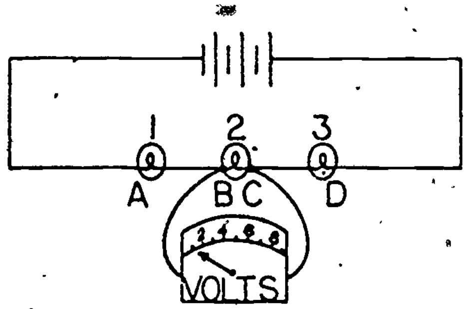


Ohmmeter in series with the component to be checked. Current flows from the ohmmeter through the part of the circuit to be checked and back to the ohmmeter. The ohmmeter is measuring the resistance between point A and point B.

Using the information above, answer these questions.

a. An ohmmeter measures the ____________ between two points.
b. An ohmmeter is connected in ________ with the circuit to be measured.
c. An ohmmeter has its own ____________ source.
d. What must be off when testing a circuit with an ohmmeter? __________________

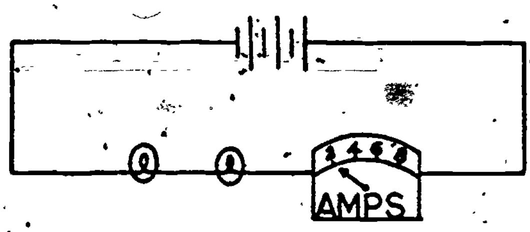
48.



a. The voltmeter above is indicating the potential difference between what two points? __________
b. The voltmeter above shows a voltage drop of 1 volt across the number ______ bulb.
c. How is a voltmeter connected with a circuit? ____________

152

49.

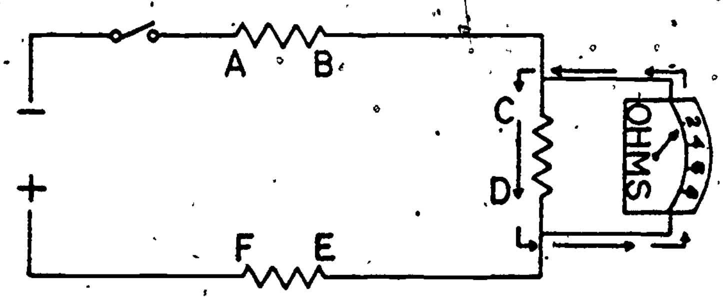


a. In the illustration above, current is being measured with an ____________.

b. The current in the circuit above is ________ amps.

c. An ammeter is connected in ________ in a circuit.

50.



a. The ohmmeter above is measuring the resistance between what two points? ________

b. What must be done with circuit power when testing a circuit with an ohmmeter? ________________

c. An ohmmeter has its own ________ source.

d. An ohmmeter is connected in ________ with the circuit to be measured.

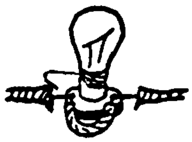
e. What two meters are connected in series? ________________ ________________

51. Match each meter in column A with the statement(s) in column B. Place the letter beside the meter in the blank beside the appropriate statement. A statement may apply to more than one meter.

A	B
a. Ammeter	______ 1. Measures potential difference between two points.
b. Ohmmeter	______ 2. Connected in parallel.
c. Voltmeter	______ 3. Connected in series.
	______ 4. Circuit power must be off when using.
	______ 5. Has its own power source.
	______ 6. Measures resistance between two points.
	______ 7. Measures current.

11.16
lsn 3; p. 28

52. A circuit condition frequently encountered around electrical equipment is a short circuit. A short circuit occurs when current takes a path short of its intended circuit. Illustrated below are two examples of a short circuit.



Improper wiring.

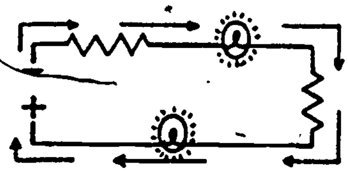
Bare wires touching.

Ohm's law states that when resistance decreases, current increases. In a short circuit, the current takes the path of least resistance; therefore, a short circuit will result in greater than normal current. Fuses and circuit breakers are examples of safety devices to protect against short circuits.

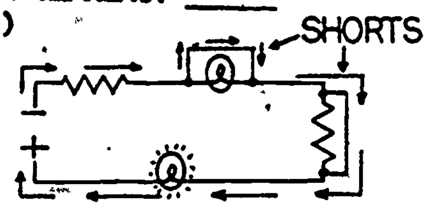
Using the previous information, answer the following.

a. Which of the circuits below indicates current taking a path of least resistance because of short circuits? _____

(1)

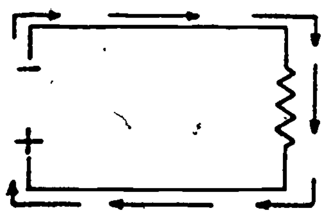


(2)

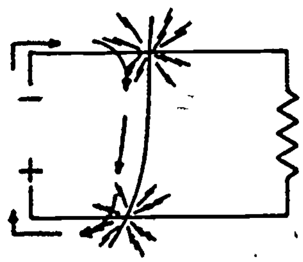


b. Which of the following circuits illustrates the current taking a path short of its intended circuit? _____

(1)

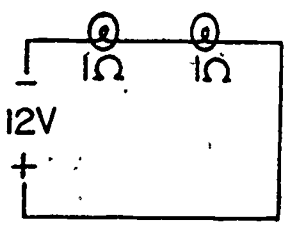


(2)

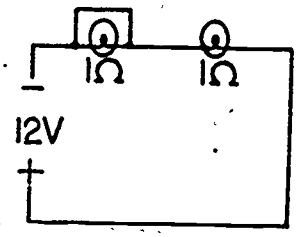


c. Which of the following circuits will have the greater amount of current? _____

(1)



(2)



11.16
lsn 3; p. 29

53. Complete the following.

a. In a short circuit, the current will take the path of least __________.

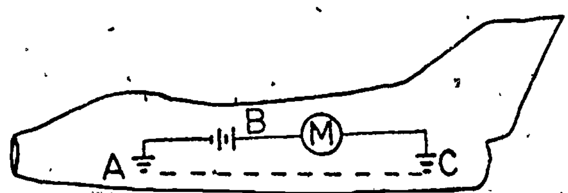
b. In a short circuit, the current will take a path short of its __________ circuit.

c. In a short circuit, the current will be __________ than normal.

54. Select the statements that apply to a short circuit.

a. Current will take a path short of it's intended circuit.
b. ~~It is~~ a form of an open circuit.
c. It results in greater than normal current.
d. Current will take the path of greatest resistance.

55. A grounded circuit is a circuit that uses something other than a wire as part of the circuit. We can form a grounded circuit by using the fuselage of an aircraft as one part or one path of the circuit. One side of the power source would be connected to the fuselage, while the other side would be connected to the equipment to be operated. The equipment would also be connected to the fuselage. The current path will be from the power source via a wire conductor to the equipment and back to the source via the metal framework (ground). The metal framework acts as a conductor.

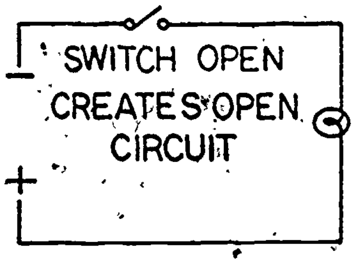


In the illustration above, the path formed by ground is from points

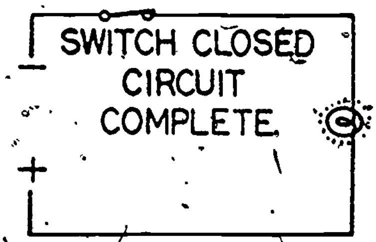
a. A to B.
b. B to C.
c. C to A.

56. The last circuit condition is the open circuit. An open circuit is an opening or break in an electrical circuit.

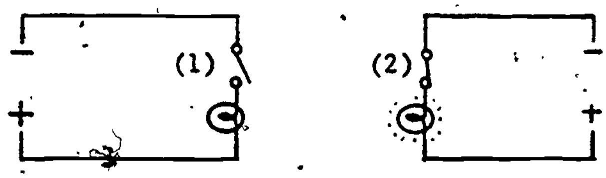
(1)



(2)



a. Which of the illustrations above shows an open circuit? ______ The open circuit can be intentional, such as in the case of the light switch above, or it can be unintentional. A broken wire in a circuit is an unintentional open circuit as long as the broken end does not touch another conductor. An open in a series circuit will affect the entire circuit, since there is only one path for current.



b. Which circuit above contains an open circuit? ______

57. Using the previous information, complete the following.

a. An opening or break in an electrical circuit is an example of an ______________ circuit.

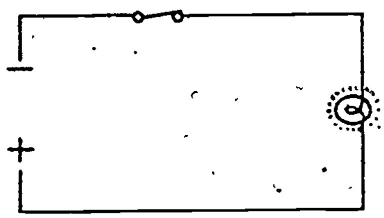
b. An open circuit created by opening a switch is an example of what type of open circuit? ______________

c. An open circuit created by a broken wire is an example of what type of open circuit? ______________

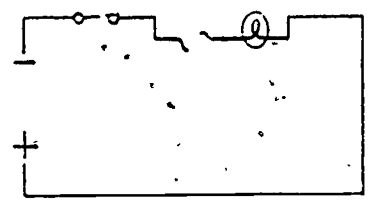
d. An open in a series circuit will affect the ________ circuit.

e. What circuit arrangement is involved when an open circuit affects all the branches? __________

58. **Which of the following illustrates an open circuit? ________**

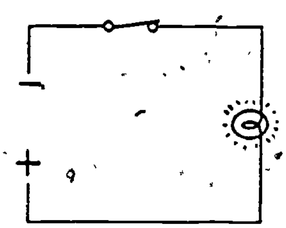


A



B

C



D

59. **Select the statements that apply to an open circuit.**

a. **It will affect the entire series circuit.**
b. It will affect all the branches in a series circuit.
c. It will not affect the entire series circuit.
d. Current will take a path short of its intended circuit.
e. It is a form of short circuit.

ANSWER PAGE

FRAME NUMBER:

45. a. VOLTS
    b. PARALLEL
    c. 4 VOLTS
    d. POTENTIAL DIFFERENCE

46. a. AMPS
    b. SERIES
    c. CURRENT

47. a. RESISTANCE
    b. SERIES
    c. POWER
    d. CIRCUIT POWER

48. a. POINTS B AND C
    b. 2
    c. PARALLEL

49. a. AMMETER
    b. 2
    c. SERIES

50. a. POINTS C AND D.
    b. TURN IT OFF.
    c. POWER
    d. SERIES
    e. AMMETER AND OHMMETER

51. c. 1.
    c. 2.
    a.-b. 3.
    b. 4.
    b. 5.
    b. 6.
    a. 7.

52. a. (2)
    b. (2)
    c. (2)

53. a. RESISTANCE
    b. INTENDED
    c. GREATER

54. a.
    c.

55. c.

56. a. (1)
    b. (1)

57. a. OPEN.
    b. INTENTIONAL
    c. UNINTENTIONAL
    d. ENTIRE
    e. SERIES CIRCUIT

58. B
    C

59. a.
    b.

11.16
lsn 3; p. 33

FUNDAMENTALS OF ELECTRICITY

LESSON 3

PART A

SERIES CIRCUITS

SELF-TEST

1. An electrical circuit is a

   a. pathway formed by a conductor between two resistances.

   b. complete electrical pathway for current.

   c. continuous electrical pathway for voltage.

2. A series circuit has (select two)

   a. two or more paths for current.

   b. constant voltage throughout the circuit.

   c. only one pathway for current.

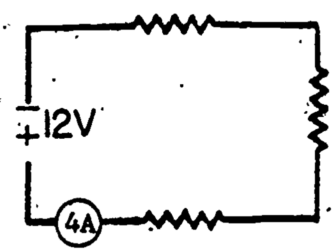
   d. constant current throughout the circuit.

   e. constant resistance throughout the circuit.

   f. current that will vary throughout the circuit.

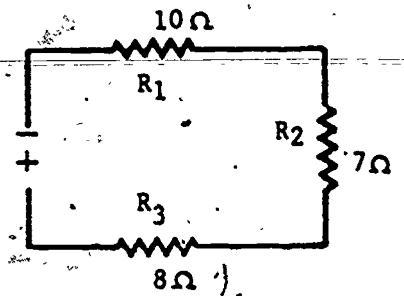
3. Solve for the unknowns in the problems below.

   a.



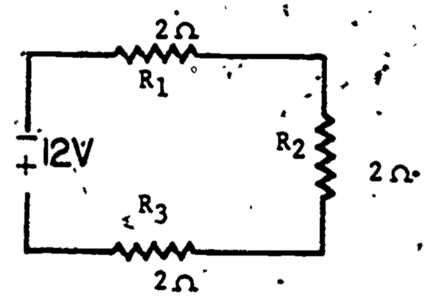
Total resistance = ______ ohms

b.



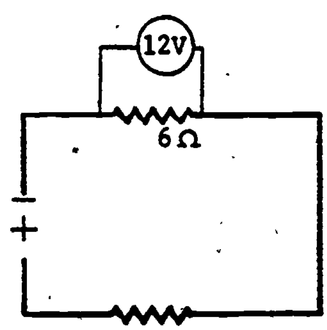
Total resistance = ___ohms

c.



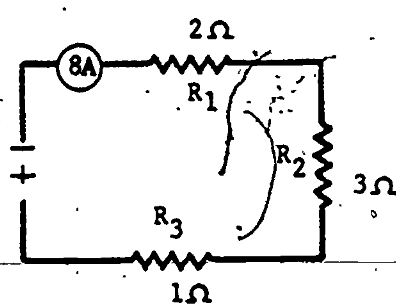
Current = ________ amps.

d.



Current = ________ amps.

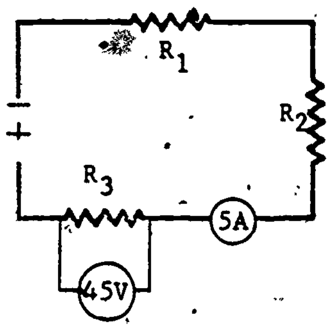
e.



Voltage drop across R_2 = ________ volts

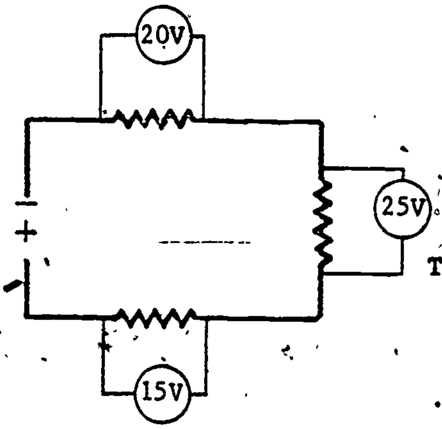
11.16
lsn 3; p. 35

f.



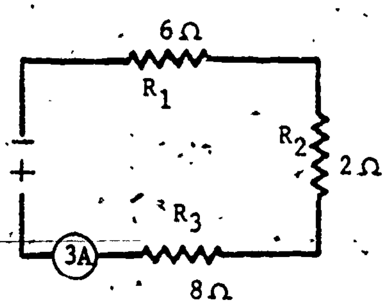
Resistance of R_3 = ______ ohms

g.



Total voltage = ________ volts

h.



Total voltage = ________ volts

4. Which statements below are correct concerning source voltage in a series circuit?

   a. All the source voltage will be expended moving current through a circuit.

   b. Only a portion of source voltage will be expended moving current through the circuit.

   c. Total voltage is equal to the source voltage.

   d. Source voltage and total voltage are not equal.

   e. All the source voltage will be expended across each resistance in a circuit having three resistances.

5. Match each meter in column A with the statement(s) in column B. Place the letter found beside each meter in the blank beside the appropriate statement. A statement may apply to more than one meter.

A	B
a. Ammeter	_____ 1. Measures potential difference between two points.
b. Ohmmeter	_____ 2. Connected in parallel.
c. Voltmeter	_____ 3. Connected in series.
	_____ 4. Circuit power must be off when using.
	_____ 5. Has its own power source.
	_____ 6. Measures resistance between two points.
	_____ 7. Measures current.

6. Which statements apply to a short circuit?

    a. Current will take a path short of its intended circuit.

    b. It is a form of an open circuit.

    c. It will result in greater than normal current.

    d. Current will take the path of greatest resistance.

7. Which statements apply to an open circuit?

    a. It will affect the entire series circuit.

    b. Current will take a path short of its intended circuit.

    c. It is a form of short circuit.

11.16
lsn 3; p. 38

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 in the circuits. This will be done by using capital letters and subscripts. The subscripts will consist of numbers or lower-case letters.

The capital letters will be E (voltage), I (current), and R (resistance).

Any time you see one of the designations, say the full meaning of it to yourself. Example: If you see the designation E_1, say to yourself, voltage drop across resistance number one. This will get you used to the designations, and you will learn them a lot faster. Study the examples below.

E_t = Total voltage of a circuit.

I_t = Total current in a circuit.

R_t = Total resistance in a circuit.

E_1 = Voltage drop across resistance number one.

E_2 = Voltage drop across resistance number two.

R_1 = Resistance of component number one.

R_2 = Resistance of component number two.

I_1 = Current through resistance number one.

I_2 = Current through resistance number two.

If more than two resistances are in a circuit, the subscript numbers or letters will be in numerical or alphabetical order. Examples below.

E_1 , E_2 , E_3 , E_4 , etc.

R_1 , R_2 , R_3 , R_4 , etc.

E_a , E_b , E_c , E_d , etc.

11.16
lsn 3; p. 39

LESSON 3, PART A
SERIES CIRCUITS - SELF TEST ANSWERS

1. b

2. c, d

3.
a. $R_T = \frac{V}{I} = \frac{12}{4} = 3$ ohms

b. $R_T = R_1 + R_2 + R_3 = 10 + 7 + 8 = 25$ ohms

c. Step 1. $R_T = R_1 + R_2 + R_3 = 2 + 2 + 2 = 6$ ohms

Step 2. $I = \frac{V}{R_T} = \frac{12}{6} = 2$ amps

d. $I = \frac{V}{R} = \frac{12}{6} = 2$ amps

Note: Current is the same throughout a series circuit.

e. $V_2 = IR_2 = (8)(3) = 24$ volts

f. $R_3 = \frac{V_3}{I} = \frac{45}{5} = 9$ ohms

g. $V_T = V_1 + V_2 + V_3 = 20 + 25 + 15 = 60$ volts

h. Step 1. $V_T = V_1 + V_2 + V_3$

Step 2. $V_1 = IR_1 = (3)(6) = 18$

$V_2 = IR_2 = (3)(2) = 6$

$V_3 = IR_3 = (3)(8) = 24$

$VT = 18 + 6 + 24 = 48$ volts

4. a, c

11.16.
lsn 3; p. 41

166

5. c 1
   c 2
   ab 3
   b 4
   b 5
   b 6
   a 7

6. a, c

7. a, c

GO RIGHT ON TO LESSON 3, PART B - PARALLEL CIRCUITS

FUNDAMENTALS OF ELECTRICITY

LESSON 3

PART B

PARALLEL CIRCUITS

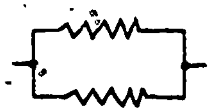
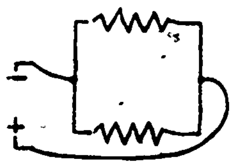
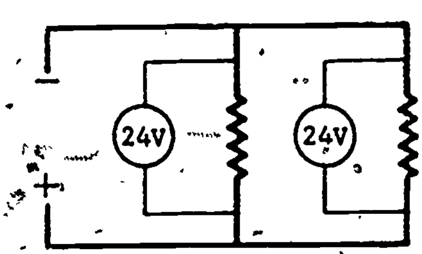
OBJECTIVES

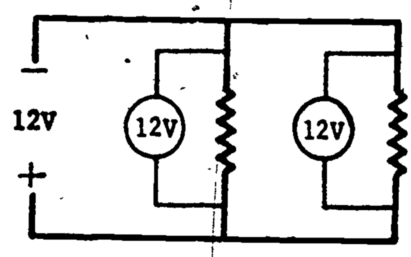
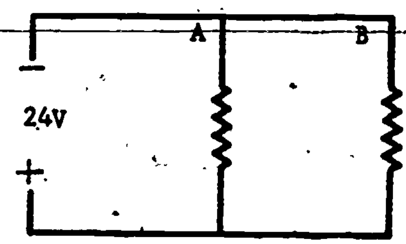
1. From a list of statements pertaining to circuits, select the statements which apply to parallel circuits.

2. Solve problems in parallel circuits for the following:

   a. Total resistance
   b. Resistance of an individual branch
   c. Total current
   d. Current flow of an individual branch
   e. Total voltage

3. Given a list of numbers, determine the reciprocal of each.

	1. Resistances side by side and with their ends connected  are parallel-connected. If the resistances in a circuit are so connected,  the circuit is known as a ________ circuit.
PARALLEL	2. The resistances in a parallel circuit are connected parallel to each other. Each of these resistances will be a branch. If a twelve-volt battery was the source voltage of a parallel circuit, the voltage in each branch of that parallel circuit would also equal twelve volts. The voltage of each branch of a parallel circuit equals the __________ voltage.
SOURCE	3. The voltage in each branch of a parallel circuit will equal source voltage. 
	What is the source voltage in the circuit above? ______ volts

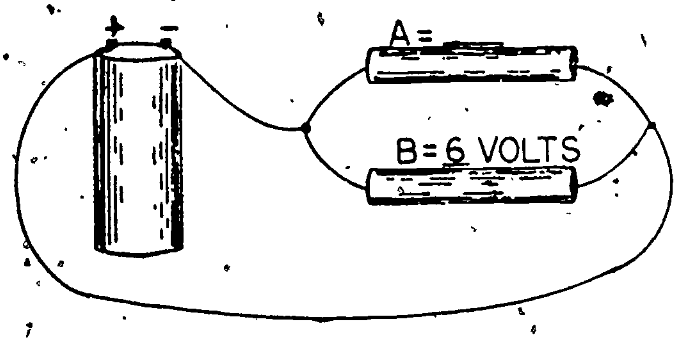
24 VOLTS	4.  **PARALLEL CIRCUIT LAW FOR TOTAL VOLTAGE** $E_t = E_1 = E_2 = E_3 \ldots$ In the illustration above, the source voltage and branch voltages are ________ (equal/unequal).
EQUAL	5. Put the ×, ÷, +, or = sign in the parentheses to make the statement correct. Since source voltage (total voltage) and branch voltages are equal, the parallel circuit law for total voltage is $E_t(\ )\ E_1(\ )\ E_2(\ )\ E_3(\ )$, etc.
$E_t=E_1=E_2=E_3$	6. The voltage is the same across each branch of a parallel circuit, and the voltage of each branch equals source voltage.  What is the voltage in branch A and what is the voltage in branch B above? A. ________ B. ________

11.16
lsn 3; p. 45

A. 24 VOLTS

B. 24 VOLTS

7.



a. What is the voltage in branch A? ____________

b. What is the source voltage? ____________

a. 6 VOLTS

b. 6 VOLTS

8. Now that you know that all the branch voltages and the source voltage are equal in a parallel circuit, you will find that solving for total (source) voltage is relatively easy. You can determine total voltage (source voltage) in a parallel circuit by applying Ohm's law. If you multiply the current of a branch by the resistance of that branch, you will determine the ____________.

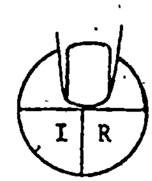
SOURCE VOLTAGE
OR
TOTAL VOLTAGE
OR
BRANCH VOLTAGE

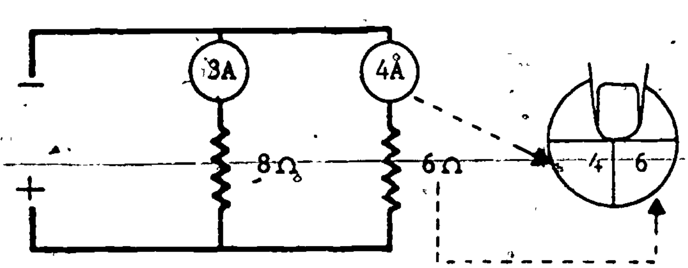
(THEY ARE ALL EQUAL.)

9. Total voltage in a parallel circuit can be determined by multiplying the current of a branch by the resistance of the same branch. Complete the example below.

Step 1 ---

Step 2 ---





Step 3 --- ____ × ____ = E_t

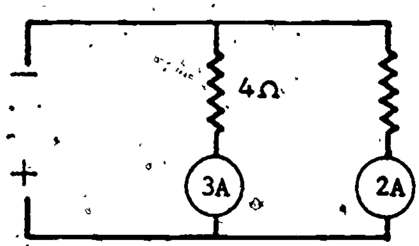
E_t = ____ volts

STEP 3

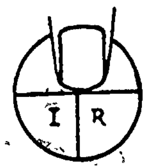
$4 \times 6 = E_t$

$E_t = 24$ VOLTS

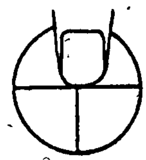
10. Using the information in the illustration below, complete the steps and find total voltage (E_t).



Step 1 ---



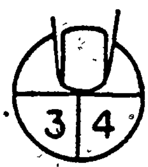
Step 2 ---



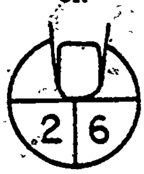
Step 3 --- ____ × ____ = E_t

E_t = ____ volts

STEP 2



OR



STEP 3

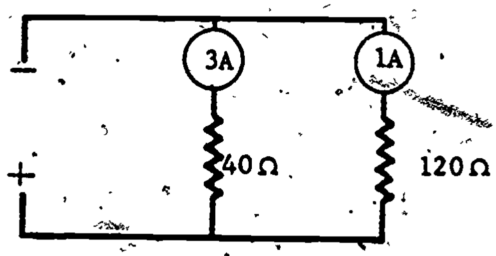
$3 \times 4 = E_t$

OR

$2 \times 6 = E_t$

$E_t = 12$ VOLTS

11. Solve for total voltage in the parallel circuit below.



E_t = ________ volts

120 VOLTS

12. As you probably have noticed in this program, the difference between a parallel circuit and a series circuit is that a parallel circuit has two or more paths for current. Knowing this, you can now understand why an open in a parallel circuit only affects the branch or branches in which the open occurs.

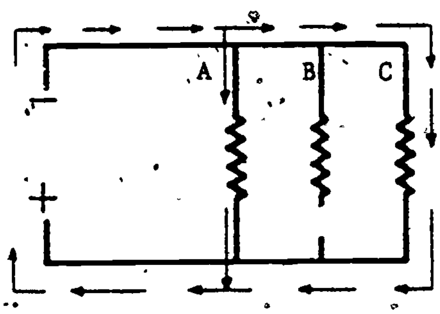


Figure 1

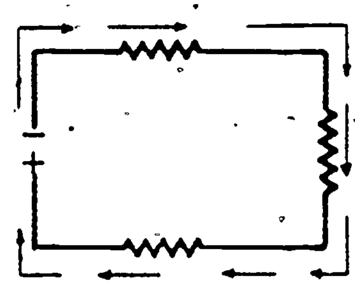


Figure 2

a. Which of the illustrations above shows a parallel circuit? ______________

b. A parallel circuit has __________ or __________ paths for current.

c. Which branch of the parallel circuit above contains an open? ______________

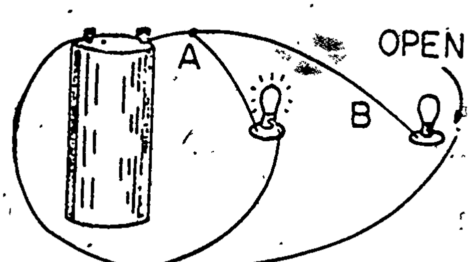
---

a. FIGURE 1

b. TWO OR MORE

c. BRANCH B

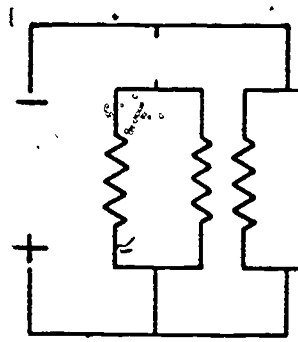
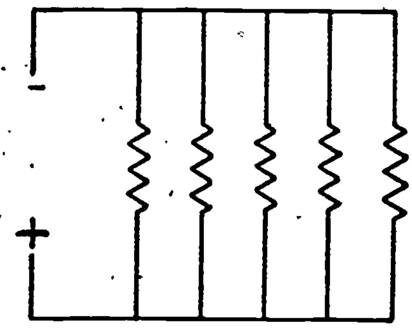
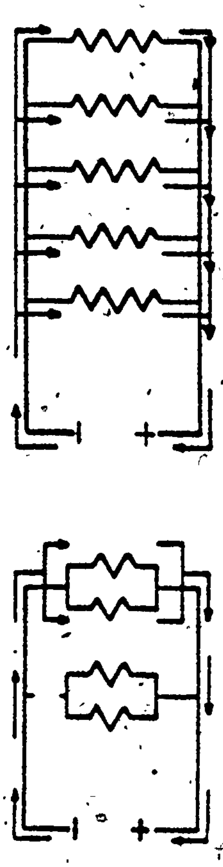
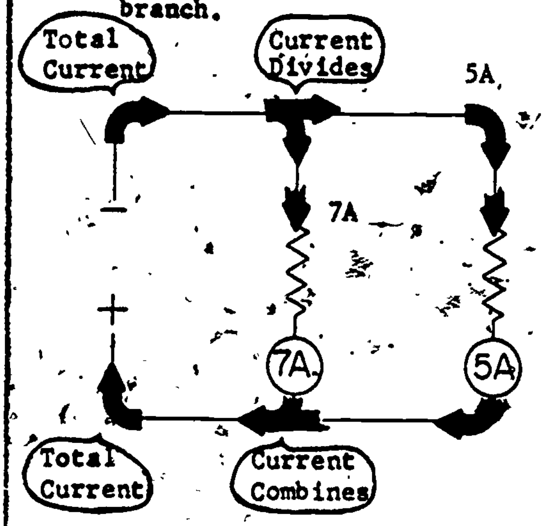
13. What effect will the open in branch B have on the light bulb in branch A?



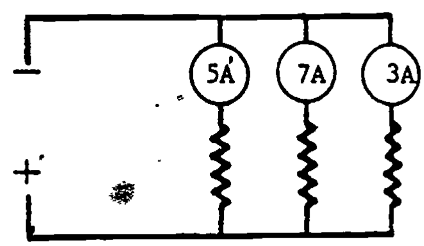
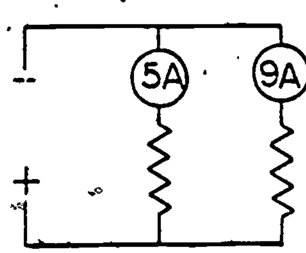
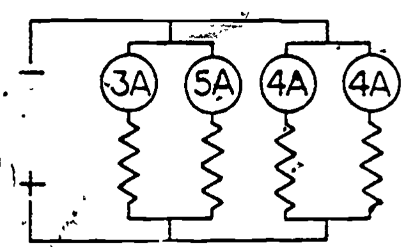
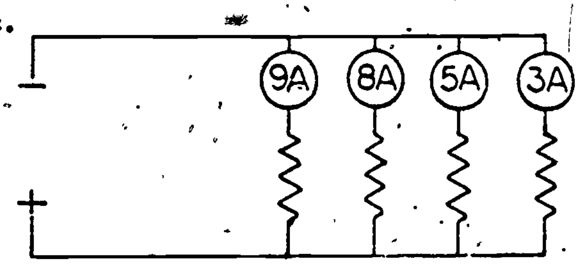
a. The bulb will burn brighter.

b. The bulb will get dimmer.

c. No effect.

c.	14. The reason the open has no effect on the bulb in branch A is that an open in a parallel circuit affects only the ____________ or ____________ in which the open occurs.
BRANCH OR BRANCHES	15. Draw arrows to indicate the path of current flow in the parallel circuits below.  
	16. Since a parallel circuit has two or more paths for current flow, the amount of current in each branch may be different. To find the total current (I_t) in a parallel circuit, add the current of each branch.  **PARALLEL CIRCUIT LAW FOR TOTAL CURRENT** $I_t = I_1 + I_2 + I_3 \ldots$ a. To find total current (I_t) in a parallel circuit, the current of all the branches should be ____________. b. Find the total current (I_t) in the circuit above. I_t = ____________ amps.

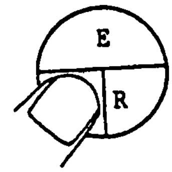
11.16
lsn 3; p. 49

a. ADDED b. I_t = 12 AMPS.	17. If current in each individual branch is known, total current (I_t) in a parallel circuit can be determined by __________ the current of the individual branches.
ADDING	18. What is the total current for the parallel circuit below? I_t = __________ amps. 
I_t = 15 AMPS.	19. Find the total current in the circuits below. a.  I_t = __________ amps b.  I_t = __________ amps. c.  I_t = __________ amps.

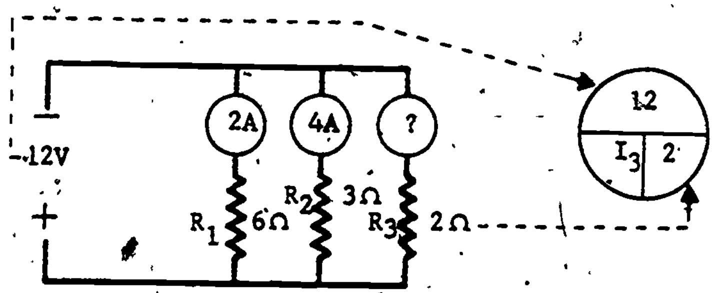
175

a. I_t = 14 AMPS. b. I_t = 16 AMPS. c. I_t = 25 AMPS.	20. There may be times when branch current is unknown in a parallel circuit. Determining branch current is a simple application of Ohm's law. If you divide the applied voltage by the resistance of a branch, you will determine the branch ________.
CURRENT	21. In order to find the current of a branch, divide the applied voltage by the resistance of that branch. Complete the steps below and determine the current for branch 3 (I_3).

Step 1 ---



Step 2 ---



Step 3 --- ____ ÷ ____ = I_3

I_3 = ______ amps.

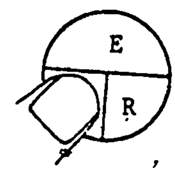
STEP 3

$12 \div 2 = I_3$

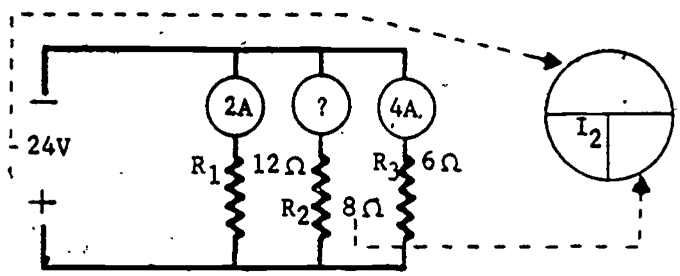
$I_3 = 6$ AMPS.

22. Using the information in the illustration below, determine the current for branch 2 (I_2).

Step 1 ---



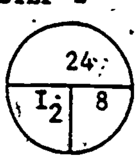
Step 2 ---



Step 3 --- ____ ÷ ____ = I_2

I_2 = ____ amps.

STEP 2

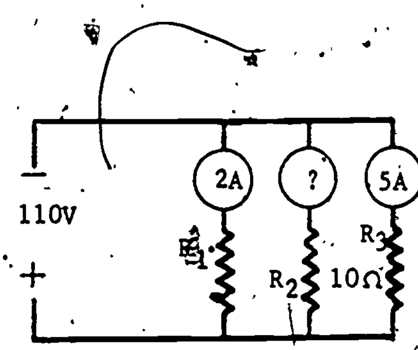


STEP 3

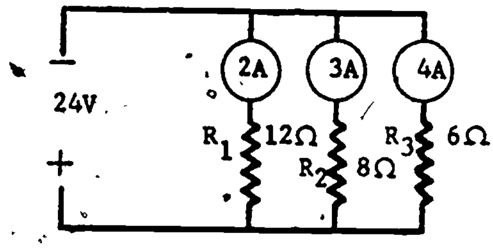
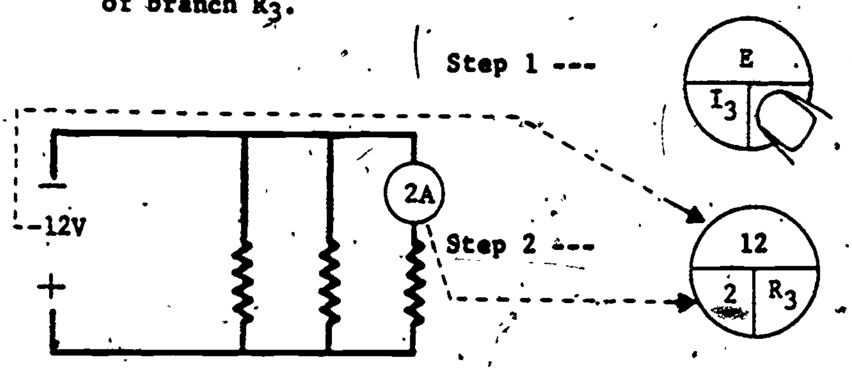
$24 \div 8 = I_2$

$I_2 = 3$ AMPS.

23. Find I_2 in the circuit below.



I_2 = ______ amps.

I_2 = 11 AMPS.	24. You have been solving for current in the preceding frames by dividing the applied voltage by the resistance. Look at the illustration below and study the relationship between current and resistance in each branch.  You can readily see that as resistance becomes larger, current becomes smaller. As resistance decreases, current __________.
INCREASES	25. Current in each branch of a parallel circuit depends on the __________ in that branch.
RESISTANCE	26. Finding the resistance of a branch in a parallel circuit is similar to finding current. When you divide the applied voltage by the current of a branch, you determine the __________ of that branch.
RESISTANCE	27. In order to determine the resistance of a branch in a parallel circuit, divide the applied voltage by the current in that branch. Complete the steps in the example below, and determine the resistance of branch R_3.  Step 3 --- ____ ÷ ____ = R_3 R_3 = _____ ohms

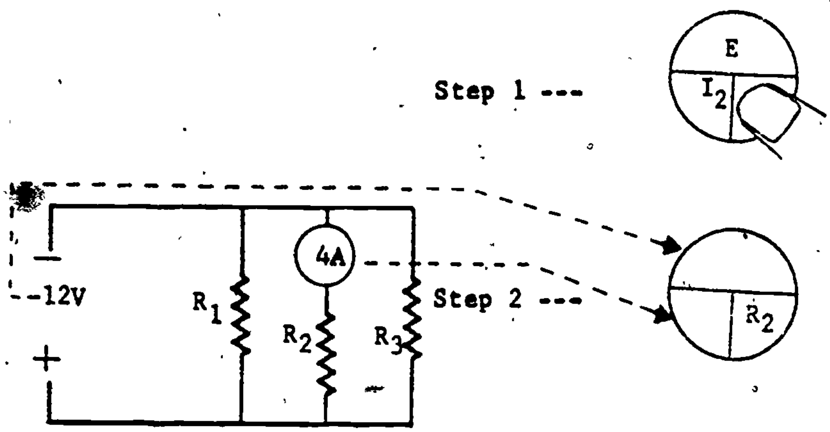
11.16
lsn 3; p. 53

STEP 3

$12 \div 2 = R_3$

$R_3 = 6$ OHMS

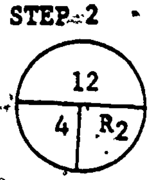
28. From the information given below, complete the steps and find R_2.



Step 3 --- ____ + ____ = R_2

R_2 = ______ ohms

STEP 2

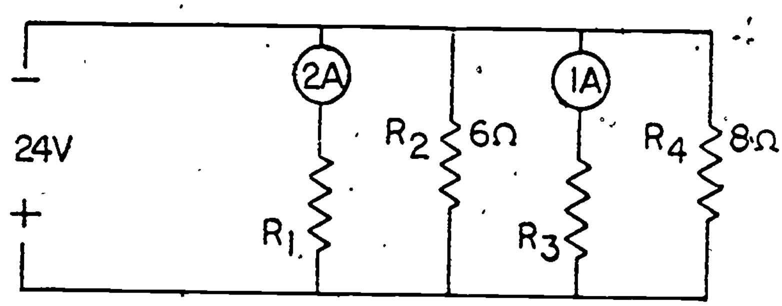


STEP 3

$12 \div 4 = R_2$

$R_2 = 3$ OHMS

29. Using the current, voltage, and resistance laws you have learned thus far, determine the values for the circuit below.



R_1 = ______ ohms I_4 = ______ amps.

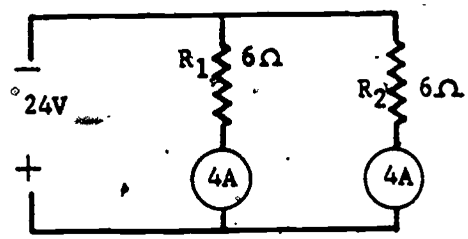
R_3 = ______ ohms E_4 = ______ volts

I_2 = ______ amps. I_t = ______ amps.

179

R_1 = 12 OHMS
R_3 = 24 OHMS
I_2 = 4 AMPS.
I_4 = 3 AMPS.
E_4 = 24 VOLTS
I_t = 10 AMPS.

30. Before we start finding the total resistance of a parallel circuit, here is something to remember. <u>The total resistance of a parallel circuit will always be less than the smallest branch resistance</u> of the circuit.



The total resistance of the circuit above will be

a. 6 ohms.
b. 12 ohms.
c. less than 6 ohms.
d. more than 6 ohms.

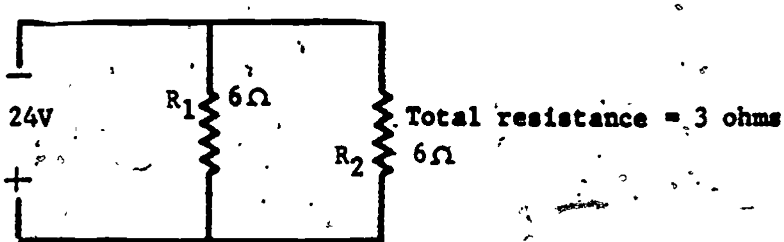
---

c.

31. Resistances in parallel are like water pipes in parallel. In each case, when the total size is increased, then the <u>total resistance</u> to current flow is decreased. Two water pipes of equal size placed side by side carry twice as much water as a single pipe of the same size; and equal resistances connected side by side pass twice as much current as a single resistance. This greater current flow in a parallel circuit indicates that total resistance is ____________ than that of a single resistance.

LESS
(SMALLER)

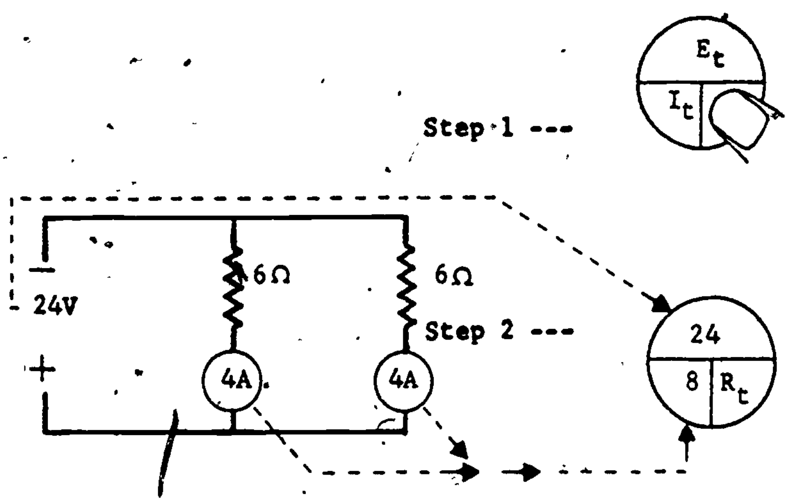
32. When you figure the resistance values in a parallel circuit, you will find that total resistance is always smaller than the resistance of the smallest branch.



In the illustration above, the total resistance is ____________ than the smallest branch resistance.

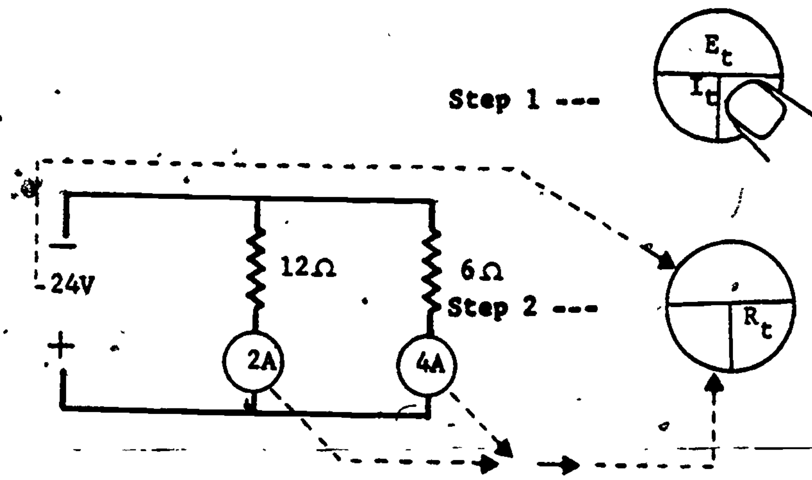
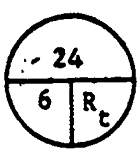
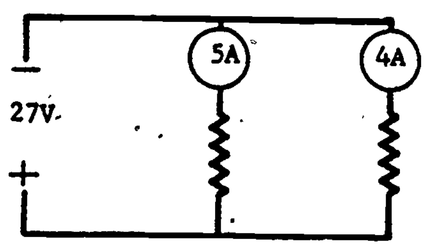
11.16
lsn 3; p. 55

SMALLER (LESS)	33. Since you now know that total resistance in a parallel circuit is less than the resistance of the smallest branch, it is easy to see that you <u>cannot</u> add individual resistances to find total resistance. Finding total resistance is another application of Ohm's law. If you were to divide total voltage (E_t) by the total amperage (I_t), you would determine ________________.
TOTAL RESISTANCE	34. One way of finding the total resistance (R_t) of a parallel circuit is to divide the total voltage (E_t) by the total current (I_t). Complete the steps below to determine total resistance (R_t).



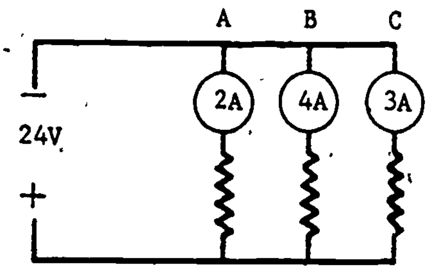
Step 3 --- ____ + ____ = R_t

R_t = ______ ohms

STEP 3 $24 + 8 = R_t$ R_t = 3 OHMS	**35. Using the information in the illustration below, find the total resistance (R_t) of the circuit.**  **Step 3 --- ____ + ____ = R_t** **R_t = ______ ohms**
STEP 2  **STEP 3** $24 + 6 = R_t$ R_t = 4 OHMS	**36. Find the total resistance (R_t) of the circuit below.**  **R_t = ______ ohms**

R_t = 3 OHMS

37. Select the statements that are true if branch C of the circuit below develops an open.



a. Total resistance will increase.
b. Total resistance will decrease.
c. Total current will increase.
d. Total current will decrease.

---

a.

d.

38. Let's review some things we have learned about parallel circuits. Select the statements below that are correct concerning parallel circuits.

a. Voltage is the same across each branch of a parallel circuit.
b. Source voltage and branch voltage are never equal in a parallel circuit.
c. A parallel circuit has two or more paths for current.
d. The total resistance of a parallel circuit is the sum of all the branch resistances.
e. Total resistance of a parallel circuit is always less than the resistance of any branch.

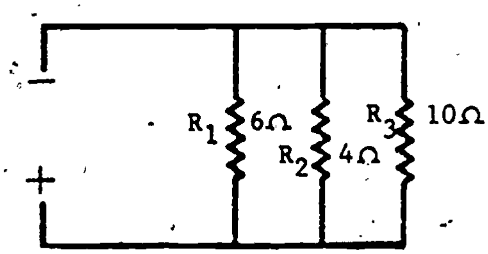
---

a.

c.

e.

39. When the only values known in a parallel circuit are the branches' resistances, total resistance can be determined by the reciprocal method.



What method can be used to determine R_t in the circuit above? ________________

RECIPROCAL	40. In order to find total resistance in a parallel circuit by the reciprocal method, you must first understand what is meant by reciprocal. The reciprocal of a number is that number divided into one. Example: Find the reciprocal of 2. Step 1 --- Set up the problem to divide the number into 1. $\frac{1}{1} \div \frac{2}{1}$ Step 2 --- Invert the divisor and change division sign to a multiplication sign. $\frac{1}{1} \times \frac{1}{2}$ Step 3 --- Multiply. $\frac{1}{1} \times \frac{1}{2} = \frac{1}{2}$ $\frac{1}{2}$ = the reciprocal of 2 Find the reciprocal of 4 by dividing it into 1. ____ = the reciprocal of 4
$\frac{1}{4}$	41. The easiest way to find the reciprocal of a whole number is to make it a fraction by giving it a numerator of one. When you do this, you have the reciprocal without performing a division process. Example: Find the reciprocal of 4. Give the whole number a numerator of 1. $\frac{1}{4}$ numerator / denominator $\frac{1}{4}$ = the reciprocal of 4 Find the reciprocal for the following numbers: a. 6 ________ b. 8 ________ c. 10 ________

11.16
lsn 3; p. 59

a. $\frac{1}{6}$ b. $\frac{1}{8}$ c. $\frac{1}{10}$	42. Giving a whole number a numerator of one gives the ____________ for that whole number.
RECIPROCAL	43. Find the reciprocal of these whole numbers. a. 7 ________ e. 88 ________ b. 9 ________ f. 12 ________ c. 15 ________ g. 3 ________ d. 40 ________ h. 5 ________ i. 6 ________
a. $\frac{1}{7}$ b. $\frac{1}{9}$ c. $\frac{1}{15}$ d. $\frac{1}{40}$ e. $\frac{1}{88}$ f. $\frac{1}{12}$ g. $\frac{1}{3}$ h. $\frac{1}{5}$ i. $\frac{1}{6}$	44. To find the reciprocal of a fraction, simply invert the fraction and reduce to its lowest term. Example: $\frac{1}{2}$ inverted becomes $\frac{2}{1}$. Reduced to its lowest term it becomes 2. Then, 2 is the reciprocal of $\frac{1}{2}$. Example: $\frac{2}{3}$ inverted becomes $\frac{3}{2}$. Reduced to its lowest term it becomes $1\frac{1}{2}$. Then, $1\frac{1}{2}$ is the reciprocal of $\frac{2}{3}$. Find the reciprocal of the following fractions. a. $\frac{3}{5}$ ________ b. $\frac{2}{10}$ ________ c. $\frac{1}{12}$ ________

a. $1\frac{2}{3}$ b. 5 c. 12	45. The reciprocal of a fraction will be a ________ number or a mixed number. The reciprocal of a whole number will be a ________.
WHOLE FRACTION	46. Find the reciprocal of these fractions. a. $\frac{1}{3}$ ________ d. $\frac{1}{6}$ ________ b. $\frac{2}{7}$ ________ e. $\frac{1}{9}$ ________ c. $\frac{3}{8}$ ________ f. $\frac{4}{9}$ ________
a. 3 b. $3\frac{1}{2}$ c. $2\frac{2}{3}$ d. 6 e. 9 f. $2\frac{1}{4}$	47. To find the total resistance (R_t) of a parallel circuit when the only known values are the resistances of the branches, use the ________ method.

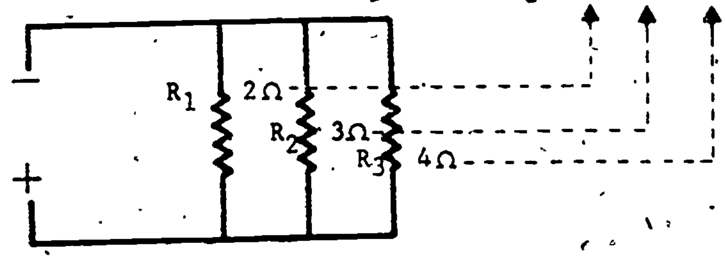
11.16
lsn 3; p. 61

RECIPROCAL

48. Now, let's use the reciprocal method to find the total resistance (R_t) of a parallel circuit by following the steps below.

Parallel circuit law for total resistance: $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Step 1 --- $\frac{1}{R_t} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4}$



Step 2 --- Find the lowest common denominator and add.

$$\frac{1}{R_t} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4}$$

$$\frac{1}{R_t} = \frac{6}{12} + \frac{4}{12} + \frac{3}{12}$$

$$\frac{1}{R_t} = \frac{13}{12}$$

Step 3 --- The sum of the resistances is the reciprocal of R_t and it must be inverted.

$$\frac{1}{R_t} = \frac{13}{12}$$

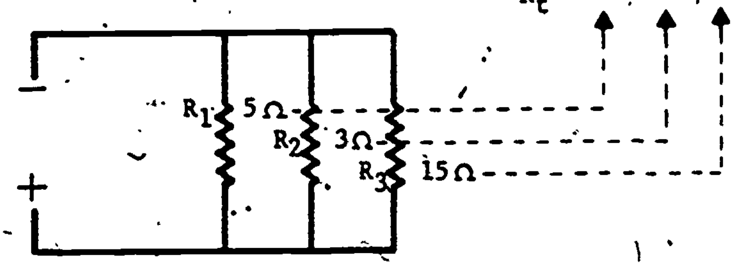
R_t = ______ ohms

11.16
lsn 3; p. 62

$R_t = \frac{12}{13}$ OHMS	49. Find the total resistance (R_t) of the parallel circuit below by completing the steps.

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Step 1 --- $\frac{1}{R_t} = \frac{1}{\_} + \frac{1}{\_} + \frac{1}{\_}$



Step 2 --- Find the lowest common denominator and add.

$\frac{1}{R_t} = \_\_ + \_\_ + \_\_$

Step 3 --- The sum of the resistances is the reciprocal of R_t, and it must be inverted.

R_t = ________ ohms

11.16
lsn 3; p. 63

STEP 1

$\frac{1}{R_t} = \frac{1}{5} + \frac{1}{3} + \frac{1}{15}$

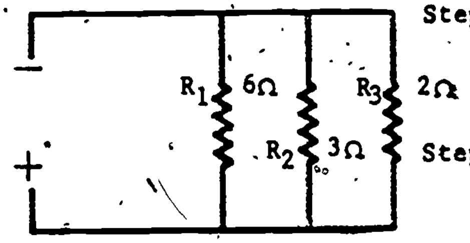
STEP 2

$\frac{1}{R_t} = \frac{3}{15} + \frac{5}{15} + \frac{1}{15}$

STEP 3

$R_t = 1\frac{2}{3}$ OHMS

50. Find the total resistance of the parallel circuit below by completing the steps.



Step 1 --- $\frac{1}{R_t}$ = ___ + ___ + ___

Step 2 --- $\frac{1}{R_t}$ = ___ + ___ + ___

Step 3 --- R_t = ______ ohms

STEP 1

$\frac{1}{R_t} = \frac{1}{6} + \frac{1}{3} + \frac{1}{2}$

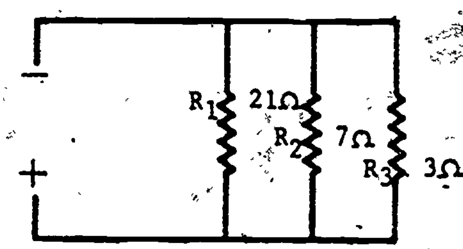
STEP 2

$\frac{1}{R_t} = \frac{1}{6} + \frac{2}{6} + \frac{3}{6}$

STEP 3

$R_t = 1$ OHM

51. Find the total resistance of the parallel circuit below.



R_t = ______ ohms

$R_t = 1\frac{10}{11}$ OHMS

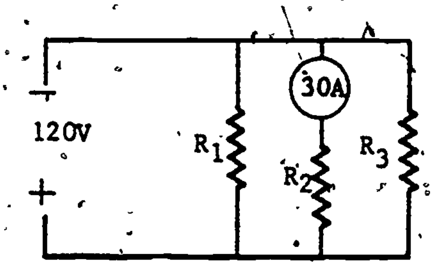
FUNDAMENTALS OF ELECTRICITY
LESSON 3
PART B
PARALLEL CIRCUITS
SELF-TEST

1. A parallel circuit has (select three)

   a. only one path for current.
   b. voltage that is the same across each branch.
   c. voltage that varies between the branches.
   d. two or more paths for current.
   e. a total resistance smaller than the resistance of any branch.
   f. current that is constant throughout.

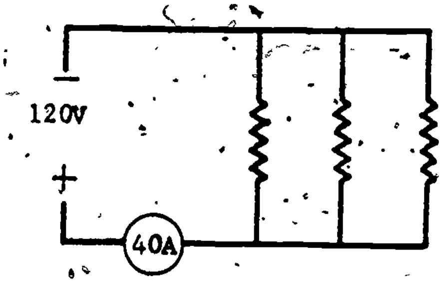
2. Solve for the unknown in each of these problems.

   a.



Resistance of branch 2 = ______ ohms

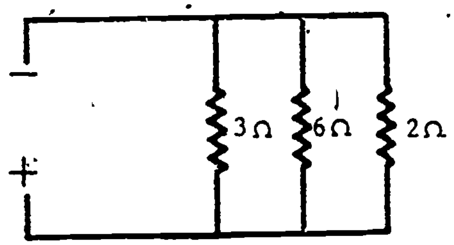
   b.



Total resistance = ______ ohms

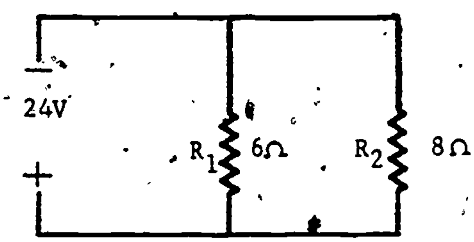
190

c.



Total resistance = _____ ohms

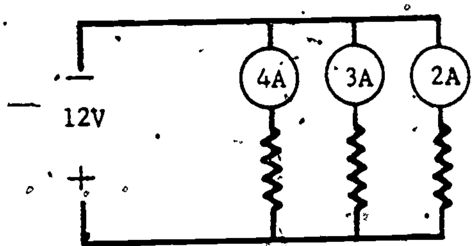
d.



Current through R_1 = ______ amps.

Current through R_2 = ______ amps.

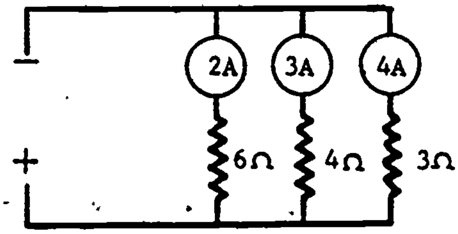
e.



Total current = ____ amps.

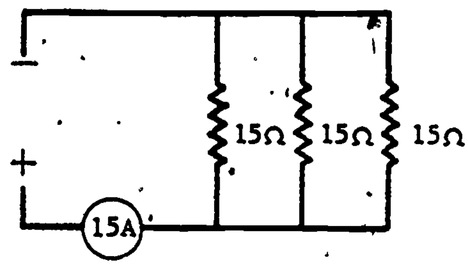
11.16
lsn 3; p. 66

f.



Total voltage = ____ volts

g.



Total voltage = ____ volts

3. Determine the reciprocal of each of these numbers.

5 ________

10 ________

8 ________

1/2 ________

25 ________

1/4 ________

LESSON 3, PART B
PARALLEL CIRCUITS-SELF TEST ANSWERS

1. b, d, e

2. (a) Step 1. Recall voltage is equal to the source voltage across each branch.

Step 2. $R_2 = \frac{V_T}{I_2} = \frac{120}{30} = 4$ ohms

(b) $R_T = \frac{V_T}{I} = \frac{120}{40} = 3$ ohms

(c) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{3} + \frac{1}{6} + \frac{1}{2} = \frac{2}{6} + \frac{1}{6} + \frac{3}{6} = \frac{6}{6}$

$\frac{1}{R_T} = 1$ $\quad R_T = 1$ ohm

(d) $I_1 = \frac{V_T}{R_1} = \frac{24}{6} = 4$ amps

$I_2 = \frac{V_T}{R_2} = \frac{24}{8} = 3$ amps

(e) $I_T = I_1 + I_2 + I_3 = 4 + 3 + 2 = 9$ amps

(f) $V_T = I_1R_1 = I_2R_2 = I_3R_3$
$= (2)(6) = (3)(4) = (4)(3) = 12$ volts

(g) Step 1. $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{15} + \frac{1}{15} + \frac{1}{15}$

$\frac{1}{R_T} = \frac{3}{15} = \frac{1}{5}$ $\quad R_T = 5$

Step 2. $V_T = I_TR_T = (15)(5) = 75$

3.

5	1/5	1/2	2
10	1/10	25	1/25
8	1/8	1/4	4

END OF LESSON 3, GO ON TO LESSON 4

11.16
lsn 3; p. 68

* * *

193

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11.16a

FUNDAMENTALS OF ELECTRICITY

LESSON 4

3-3

SERIES-PARALLEL CIRCUITS AND BATTERIES

INSTRUCTIONS

This is a programmed lesson. It is designed to teach, not to test. You will need only this booklet, a pencil, and some time to complete this lesson. If there is something in the program you do not understand, ask your instructor or supervisor for assistance.

- REMEMBER -

This lesson has been written so that the amount of reading necessary is minimal and yet most meaningful. Therefore, it is very important that you follow these instructions.

- Read each page carefully.
- Fill in each blank.
- Keep the answer to the frame on which you are working covered with a slip of paper until you have written your answer.
- Correct all errors you make.
- Follow all directions given in the program.

SUGGESTED READING TIME
180 MINUTES

LESSON 4

PART A

SERIES-PARALLEL CIRCUITS

OBJECTIVES

1. From a list of statements pertaining to electrical circuits, select those pertaining to series-parallel circuits.

2. Given a battery and four resistances, draw in connecting lines to form two series circuits connected in parallel.

3. Given problems with series circuits connected in parallel, solve for the unknown values of resistance, current, and voltage.

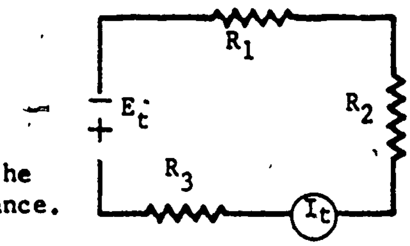
4. Given a battery and four resistances, draw in connecting lines to form two parallel circuits connected in series.

5. Given problems with parallel circuits connected in series, solve for the unknown values of resistance, current, and voltage.

1. A series-parallel circuit may consist of series circuits connected in parallel or it may consist of parallel circuits connected in series. You have had the necessary laws and formulas needed to solve series-parallel circuit problems. The important thing to remember is that when working with resistances connected in series, use series-circuit laws; and when working with resistances connected in parallel, use parallel-circuit laws.

The following formulas are based on the laws of series circuits.

Total resistance equals the sum of the individual resistances.
$R_t = R_1 + R_2 + R_3 \ldots\ldots$

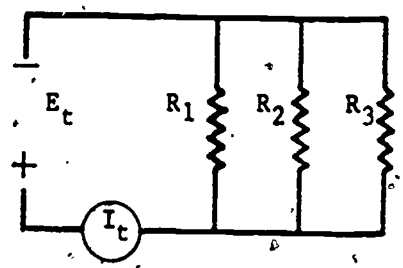


Current flow is the same across each resistance.
$I_t = I_1 = I_2 = I_3 \ldots\ldots$

Total voltage equals the sum of the voltage drops across each resistance.
$E_t = E_1 + E_2 + E_3 \ldots\ldots$

The following formulas are based on the laws of parallel circuits.

Total resistance is determined by the reciprocal method.
$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots\ldots$



Total current is equal to the sum of the current of each branch.
$I_t = I_1 + I_2 + I_3 \ldots\ldots$

Total voltage is equal to the voltage of each branch.
$E_t = E_1 = E_2 = E_3 \ldots\ldots$

a. A series-parallel circuit is a combination of __________ and __________ circuits.

b. A series-parallel circuit may consist of __________ circuits connected in parallel.

c. A series-parallel circuit may consist of __________ circuits connected in series.

d. When working with the portion of series-parallel circuits having resistances connected in series, use __________-circuit laws.

e. When working with the portion of series-parallel circuits having resistances connected in parallel, use __________-circuit laws.

a. SERIES
PARALLEL
b. SERIES
c. PARALLEL
d. SERIES
e. PARALLEL

2. The circuit in figure A consists of two series circuits connected in parallel across a battery.

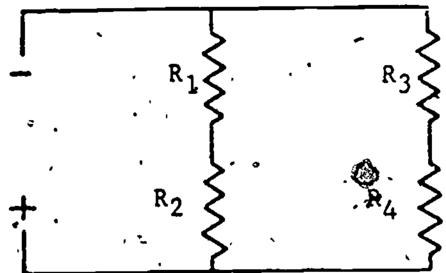


Figure A

Figure B shows resistances R_1 and R_2 connected in series with each other to form one path for current from the battery.

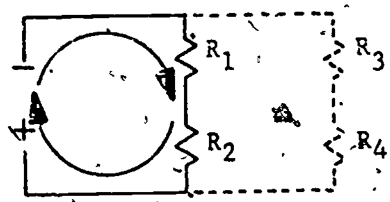


Figure B

Figure C shows resistances R_3 and R_4 connected in series to form a second path for current from the battery.

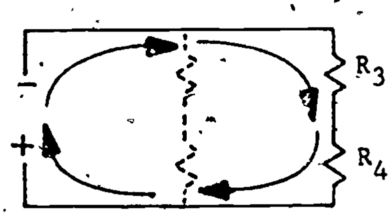


Figure C

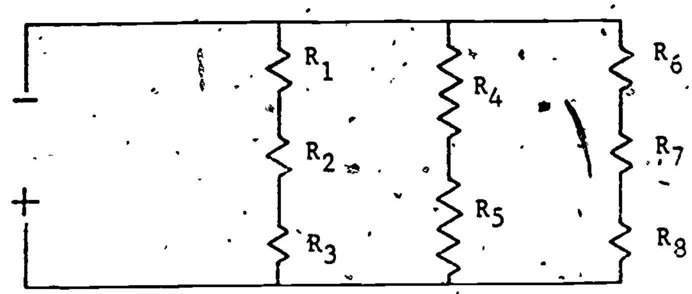


Figure D

Refer to figure D.

a. How many series circuits are in this circuit? ____

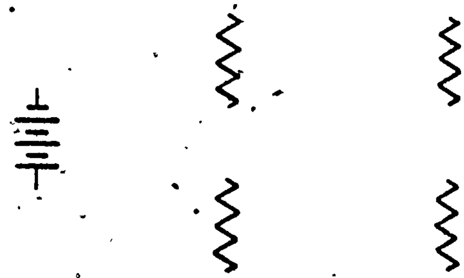
b. How many paths are there for current? ____

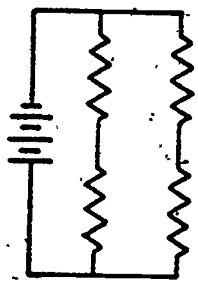
c. How are these series circuits connected?

____

a. THREE
b. THREE
c. PARALLEL

3. Draw connecting lines between the following components to form two series circuits connected in parallel.





4. No new formulas are needed to find the values of series-parallel circuits. Instead, a simplified circuit is made of the original series-parallel circuit, and the necessary circuit laws are used for the simplified circuit.
The circuit in figure A below is electrically the same as the circuit in figure B.

ORIGINAL CIRCUIT

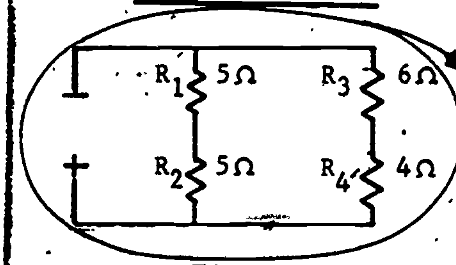


Figure A

THE SAME CIRCUIT DRAWN AS A SIMPLIFIED CIRCUIT

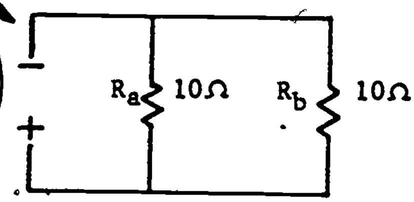


Figure B

In figure A, the circuit has two paths for current; each path (branch) has a total of 10 ohms resistance. $R_1 + R_2$ gives the total resistance of the first branch. $R_3 + R_4$ gives the total resistance of the second branch.
Figure B is the simplified circuit of the circuit in figure A. To solve for R_t in figure B, use

__________________-circuit laws.
(series/parallel)

R_t = ________ ohms

PARALLEL

5 OHMS

5. Simplified circuits are very useful when solving series-parallel circuit problems.

Draw and use simplified circuits when solving the problems in this program.

Figure B is the simplified drawing of the circuit in figure A. To solve for the total resistance of the circuit below, first, solve for the combined resistance of the series network R_1, R_2, and R_3. This combined value is represented in the simplified circuit as R_a. Second, solve for the combined value of R_4 and R_5. This combined value is represented in the simplified circuit as R_b.

ORIGINAL CIRCUIT

SIMPLIFIED CIRCUIT

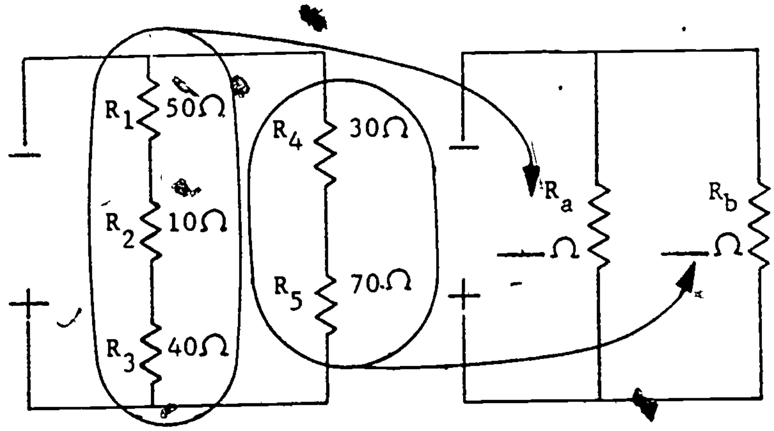


Figure A

Figure B

a. The circuit in figure A consists of ________ series circuits connected in parallel.

b. R_a in figure B represents which resistances in figure A? ____________

c. R_b in figure B represents which resistances in figure A? ____________

d. What is the value of R_a? ________

e. What is the value of R_b? ________

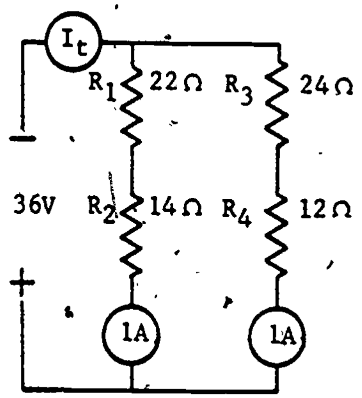
f. R_t = ________ ohms.

a. TWO
b. R_1, R_2, R_3
c. R_4, R_5
d. 100 OHMS
e. 100 OHMS
f. 50 OHMS

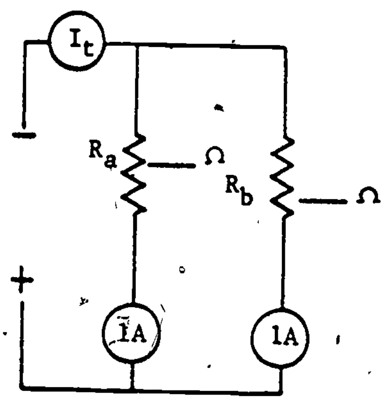
6. The total current (I_t) in series circuits connected in parallel is equal to total voltage (E_t) divided by total resistance (R_t).

Total current is also equal to the sum of the branch currents.

ORIGINAL CIRCUIT



SIMPLIFIED CIRCUIT



Using the illustrations above, solve for:

R_a = ________ ohms

R_b = ________ ohms

R_t = ________ ohms

I_t = ________ amps.

R_a = 36 OHMS R_b = 36 OHMS R_t = 18 OHMS I_t = 2 AMPS.	7. a. Complete the simplified circuit. b. Label the two branches in the simplified circuit as R_a and R_b. c. Use the completed simplified circuit to solve for I_t.

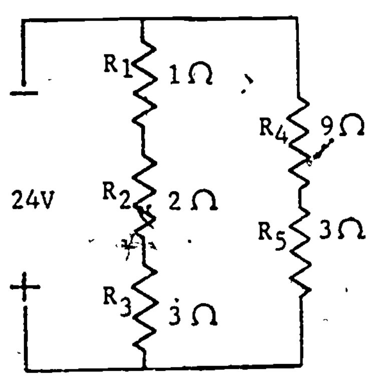
Remember, the current through each branch of a parallel network is equal to the voltage across the branch divided by the total resistance of the branch.

$$I_a = \frac{E_a}{R_a}$$

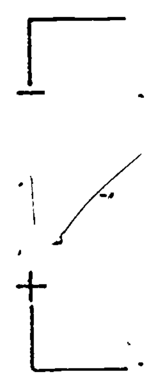
$$I_b = \frac{E_b}{R_b}$$

$$I_t = I_a + I_b$$

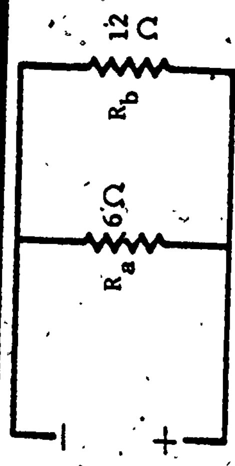
ORIGINAL CIRCUIT



SIMPLIFIED CIRCUIT

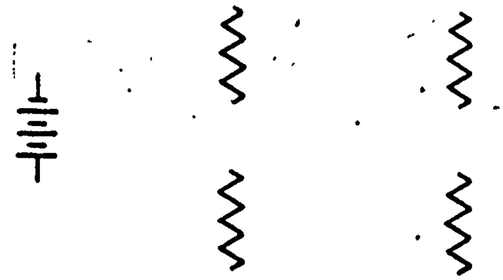


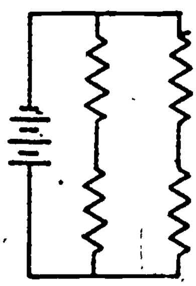
I_t = ______ amps.



I_t = 6 AMPS.

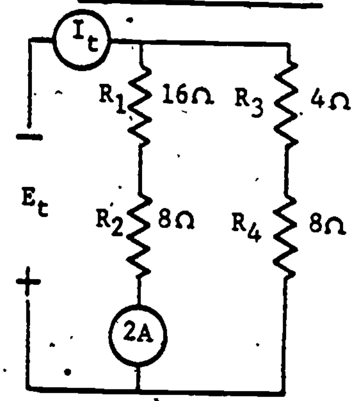
8. Draw connecting lines between the following components to form two series circuits connected in parallel.



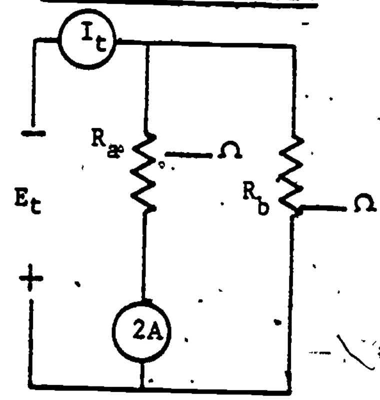


9. The total voltage (E_t) applied to series circuits connected in parallel is equal to I_t times R_t. E_t is also equal to the voltage across <u>either</u> of the parallel branches:

ORIGINAL CIRCUIT



SIMPLIFIED CIRCUIT



The simplified circuit shows two resistances in parallel; the voltage across either parallel branch is equal to the applied voltage (parallel voltage law).

$E_t = E_a$ $\quad\quad$ $E_a = I_a \times R_a$

I_a = ________ amps.

R_a = ________ ohms

E_a = ________ volts

E_t = ________ volts

11.16
lsn 4; p. 9

I_a = 2 AMPS.

R_a = 24 OHMS

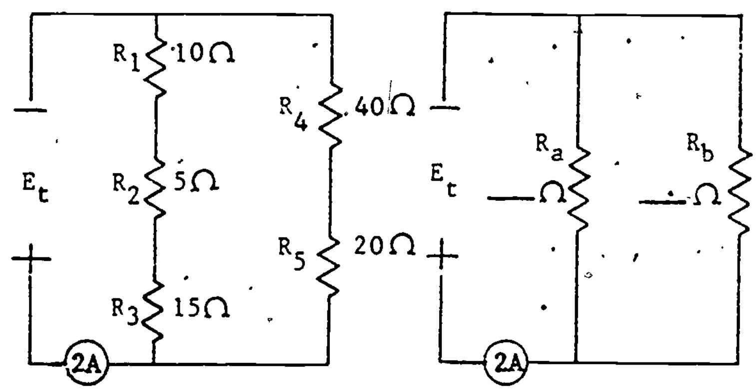
E_a = 48 VOLTS

E_t = 48 VOLTS

10. The ammeter in the circuit below indicates the total current in the circuit. Complete the simplified circuit and solve for the values listed below.

ORIGINAL CIRCUIT

SIMPLIFIED CIRCUIT



Ohm's law: $E_t = I_t \times R_t$

R_a = ________ ohms

R_b = ________ ohms

R_t = ________ ohms

I_t = ________ amps.

E_t = ________ volts

R_a = 30 OHMS

R_b = 60 OHMS

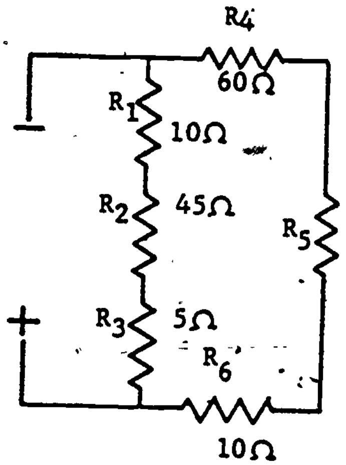
R_t = 20 OHMS

I_t = 2 AMPS.

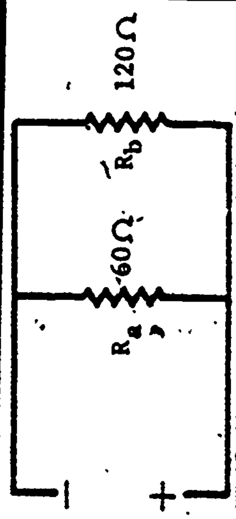
E_t = 40 VOLTS

11. Draw a simplified circuit of this circuit, and solve for R_t.

ORIGINAL CIRCUIT — SIMPLIFIED CIRCUIT

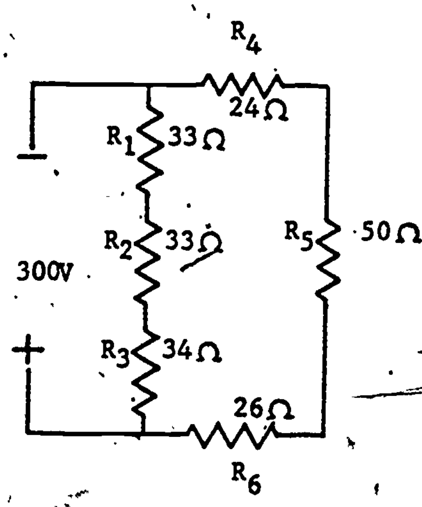


R_t = ______ ohms



R_t = 40 OHMS

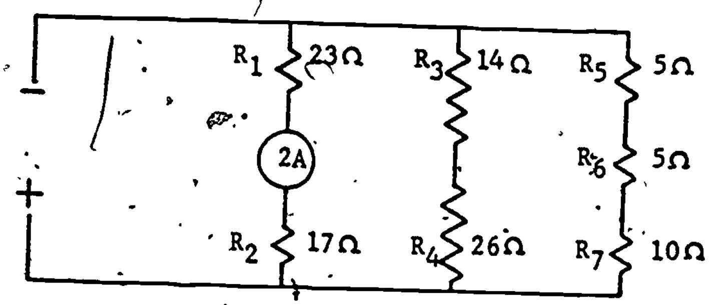
12. Solve for the value of I_t.



I_t = ______ amps.

I_t = 6 AMPS.

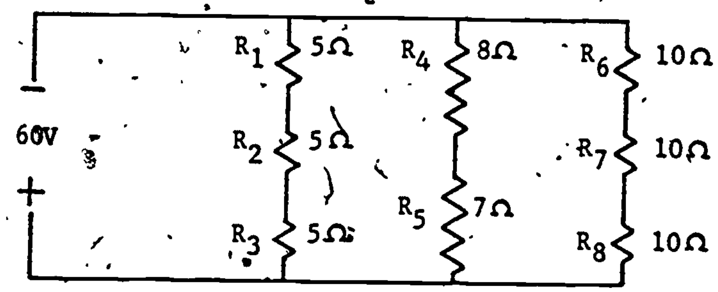
13. Solve for the value of E_t.



E_t = ______ volts

E_t = 80 VOLTS

14. Solve for the value of I_t.



I_t = ______ amps.

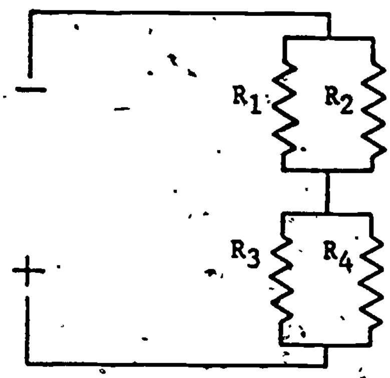
I_t = 10 AMPS.

15. a. A series-parallel circuit is a combination of ________ and ________ circuits.
b. A series-parallel circuit may consist of ________ circuits connected in parallel.
c. A series-parallel circuit may consist of ________ circuits connected in series.
d. When working with the portion of a series-parallel circuit having resistances connected in series, use ________-circuit laws.
e. When working with the portion of a series-parallel circuit having resistances connected in parallel, use ________-circuit laws.

a. SERIES
PARALLEL
b. SERIES
c. PARALLEL
d. SERIES
e. PARALLEL

You have completed the section on series circuits connected in parallel. Next we will cover parallel circuits connected in series.

16. The circuit below consists of <u>two parallel circuits</u> connected in series.



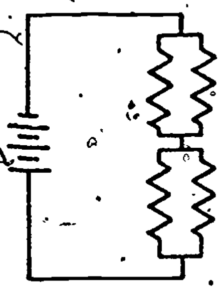
Resistances R_1 and R_2 form one parallel network.

Resistances R_3 and R_4 form one parallel network.

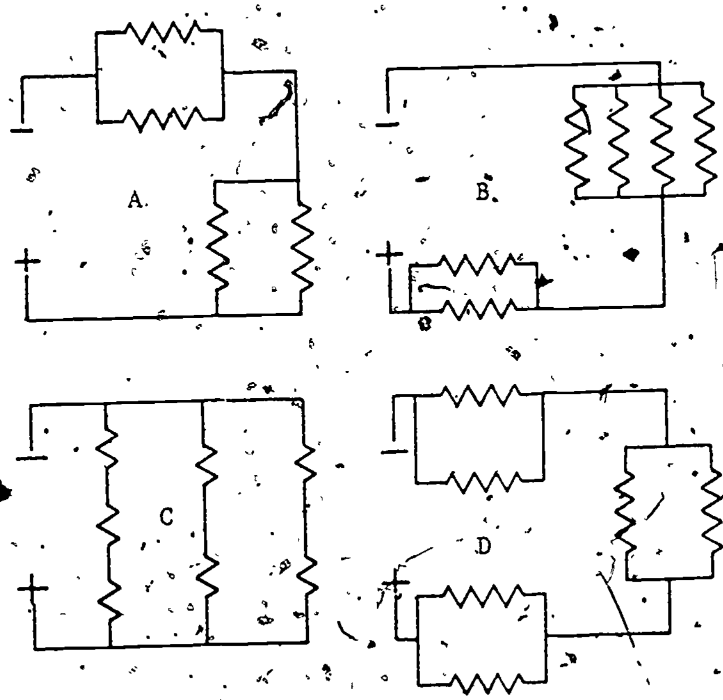
The parallel network R_1 and R_2 and the parallel network R_3 and R_4 are connected in ____________.

SERIES

17. Draw connecting lines between the following components to form two parallel circuits connected in series.



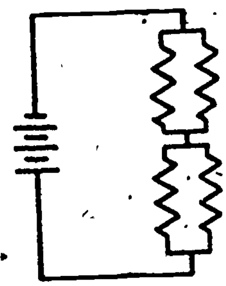
18. There are many combinations of parallel circuits connected in series.



Which of the circuits above are combinations of parallel circuits connected in series? ________

A
B
D

19. Draw connecting lines between the following components to form <u>two</u> parallel circuits connected in series.



20. Solving problems with parallel circuits connected in series is made easier by drawing simplified circuits.
Remember, when working with resistances connected in parallel, use parallel-circuit laws; and when working with resistances connected in series, use series-circuit laws.

ORIGINAL CIRCUIT   SIMPLIFIED CIRCUIT

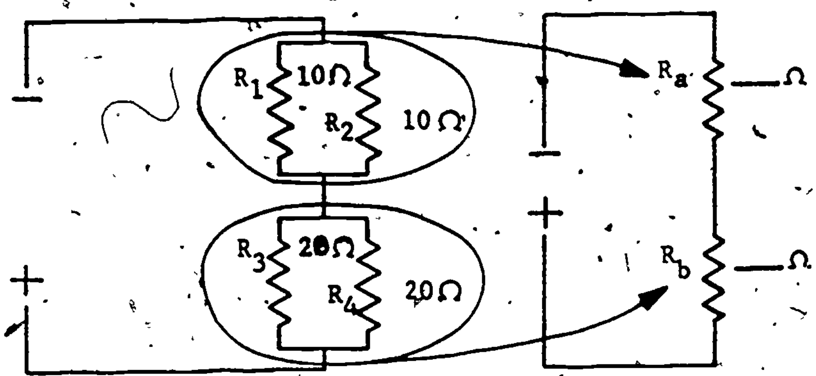


Figure A   Figure B

NOTE: The simplified circuit is a series circuit; therefore, R_t is found by adding the values of R_a and R_b (series-circuit law for total resistance).

a. The circuit in figure A consists of ________ parallel circuits connected in series.

b. R_a (figure B) represents the combined value of the parallel network of which resistances?

____

c. R_b (figure B) represents the combined value of the parallel network of which resistances?

____

d. What is the value of R_a? ________

e. What is the value of R_b? ________

f. R_t = ______ ohms

a. TWO
b. R_1, R_2
c. R_3; R_4
d. 5 OHMS
e. 10 OHMS
f. 15 OHMS

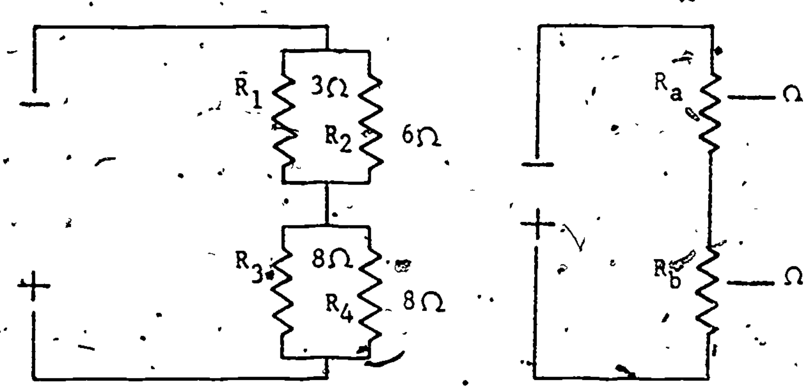
21. Find the total resistance of the original circuit below by:

a. Finding the total resistance of the parallel network of R_1 and R_2. Represent this in the simplified circuit as R_a.

b. Finding total resistance of the parallel network of R_3 and R_4. Represent this in the simplified circuit as R_b.

c. Totaling the values of R_a and R_b to get R_t.

ORIGINAL CIRCUIT — SIMPLIFIED CIRCUIT



R_a = ______ ohms

R_b = ______ ohms

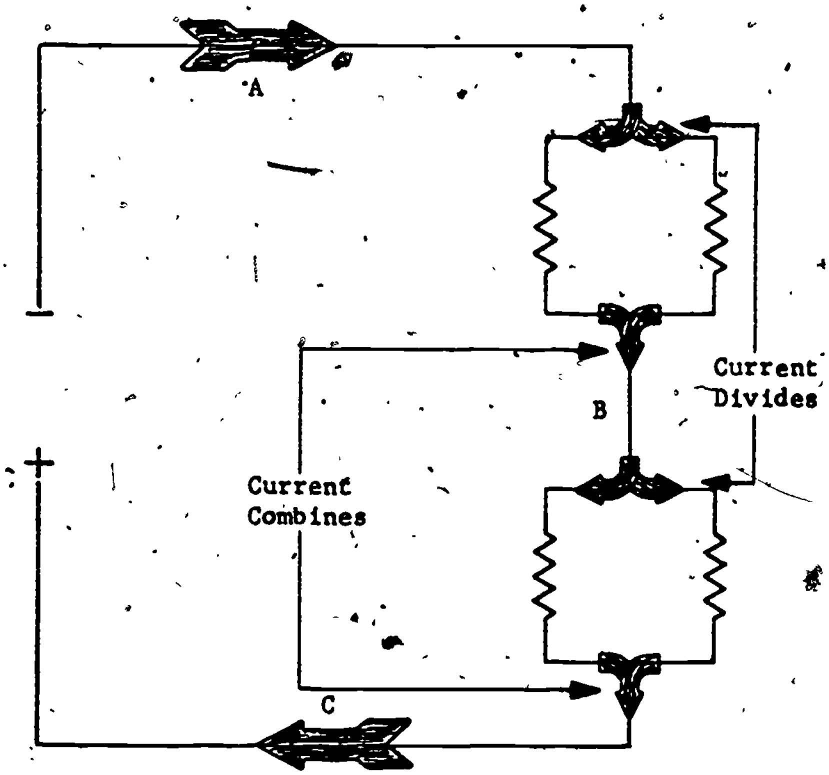
R_t = ______ ohms

R_a = 2 OHMS

R_b = 4 OHMS

R_t = 6 OHMS

22. This illustration shows current flow through a parallel circuit connected in series.



At what points can total current be measured in the circuit above?

a. Points A and B only.

b. Points A and C only.

c. Points C and B only.

d. Points A, B, and C.

11.16
lsn 4; p. 17

d.

23. Total current is equal to the total voltage divided by the total resistance. To solve for I_t in the circuit below:

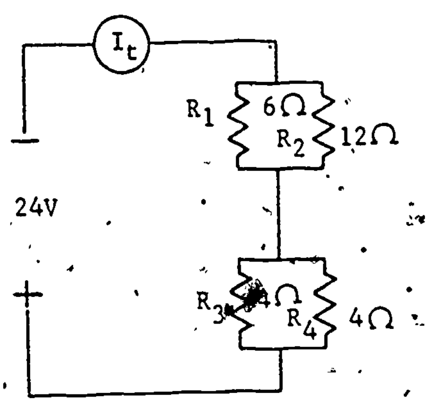
a. Solve for the value of R_a and R_b.

b. Solve for R_t.

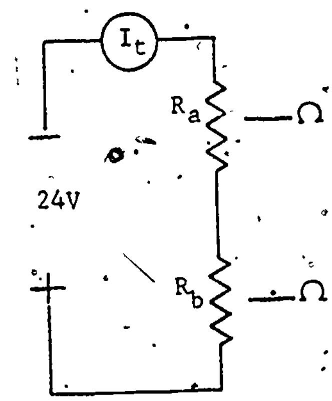
c. Divide E_t by R_t to get I_t.

E_t is the source voltage.

ORIGINAL CIRCUIT



SIMPLIFIED CIRCUIT



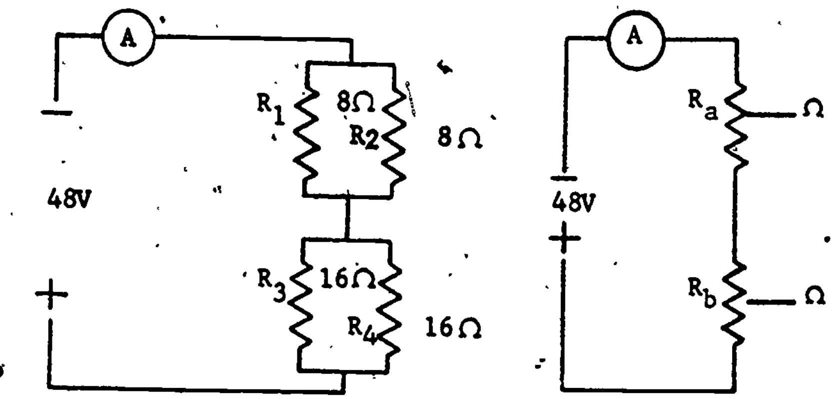
R_t = ________ ohms

I_t = ________ amps.

R_t = 6 OHMS

I_t = 4 AMPS.

24. Solve for the values of R_t and I_t.



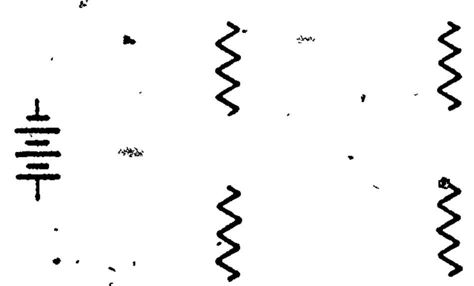
R_t = ________ ohms

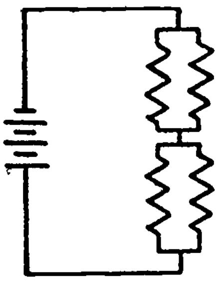
I_t = ________ amps.

R_t = 12 OHMS

I_t = 4 AMPS.

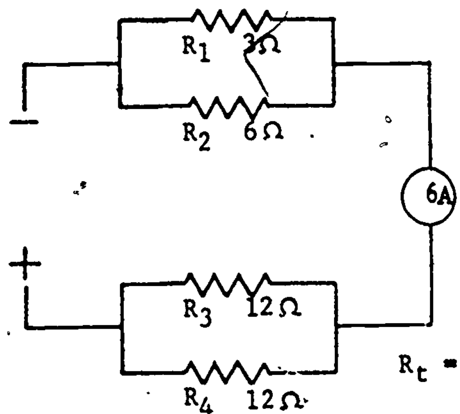
25. Draw connecting lines between the following components to form two parallel circuits connected in series.





26. The total voltage in a circuit is equal to total current multiplied by total resistance ($E_t = I_t \times R_t$).

In the circuit below, I_t equals 6 amps. Find total resistance (R_t) and source voltage (E_t).



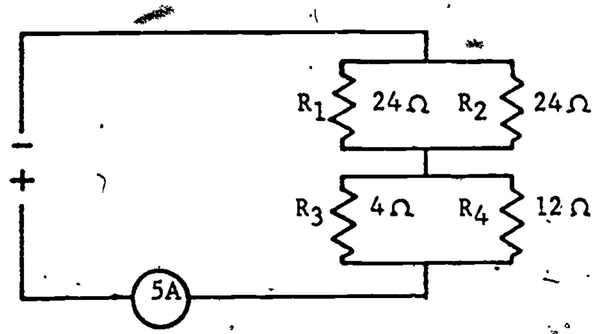
R_t = ________ ohms

E_t = ________ volts

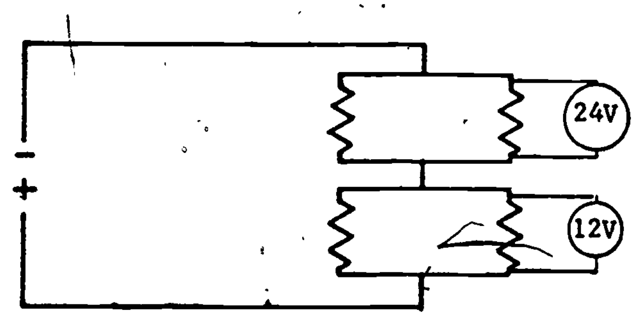
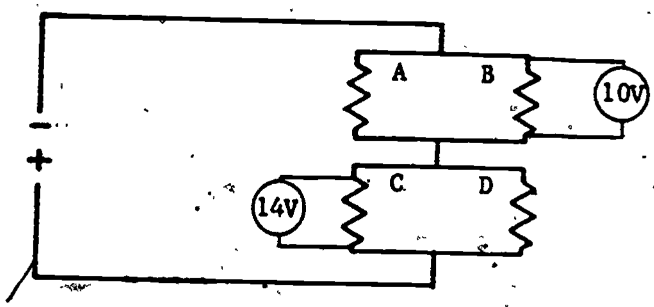
R_t = 8 OHMS

E_t = 48 VOLTS

27. Solve for the value of E_t in the circuit below.

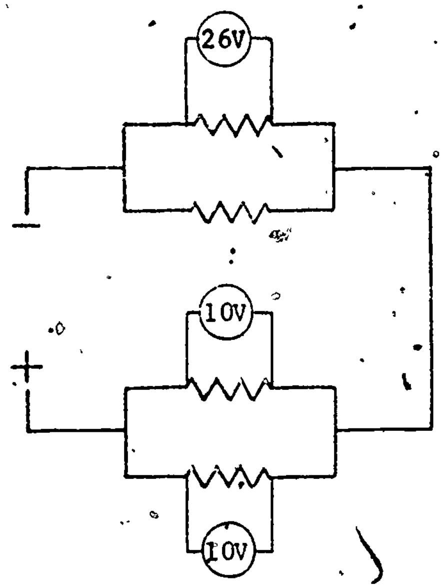


E_t = ________ volts

E_t = 75 VOLTS	28. In a series-parallel circuit with the parallel circuits connected in series, total voltage (E_t) is equal to the sum of the voltage drops across each parallel network.  The total voltage (E_t) of the circuit above is ______ volts.
36	29. The voltage across each branch of a parallel network is the same.  In the illustration above, a. voltage across branch A is ______ volts. b. voltage across branch D is ______ volts. c. total voltage is ______ volts.

11.16
lsn 4; p. 21

214

a. 10 VOLTS b. 14 VOLTS c. 24 VOLTS	30. Determine the total voltage of the circuit below.  E_t = ______ volts
E_t = 36 VOLTS	

11.16
lsn 4; p. 22

FUNDAMENTALS OF ELECTRICITY

LESSON 4

PART A

SERIES-PARALLEL CIRCUITS

SELF-TEST

1. Circle the letter beside the statements that pertain to series-parallel circuits.

   a. When working with the portion of the circuit having the resistances connected in parallel, use parallel-circuit laws.

   b. The total values can be determined by multiplying the sum of the series portion by the sum of the parallel portion.

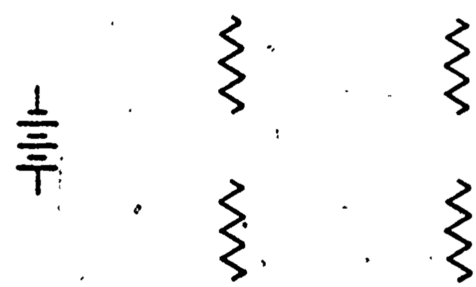
   c. When working with the portion of the circuit having the resistances connected in series, use series-circuit laws.

   d. A series-parallel circuit is a combination of series and parallel circuits.

   e. The total values can be determined by dividing the sum of the series portion of the circuit by the sum of the parallel portion of the circuit.

   f. You may use either series-circuit laws or parallel-circuit laws, regardless of how the resistances are connected.

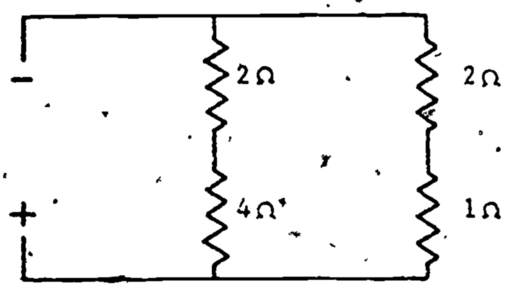
2. Draw connecting lines between the following components to form two series circuits connected in parallel.



11.16
lsn 4; p. 23

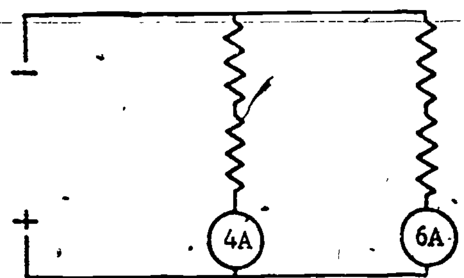
3. Solve for the unknown in each of these problems.

a.



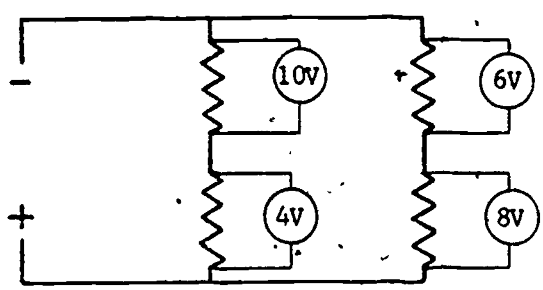
Total resistance = ____ ohms

b.



Total current = _____ amps.

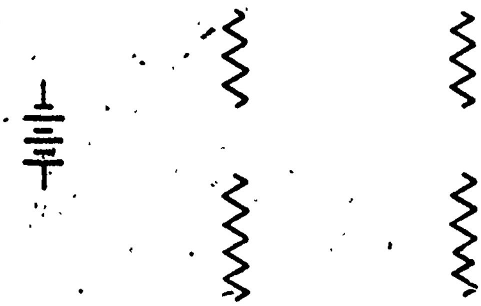
c.



Total voltage = _____ volts

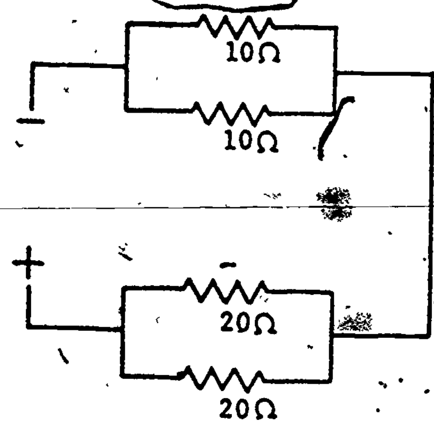
217

4. Draw connecting lines between the following components to form two parallel circuits connected in series.



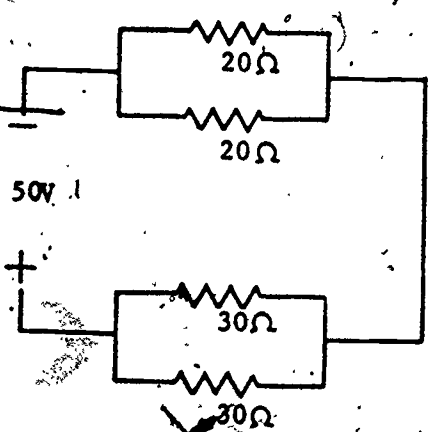
5. Solve for the unknown in the following problems.

a.



Total resistance = _____ ohms

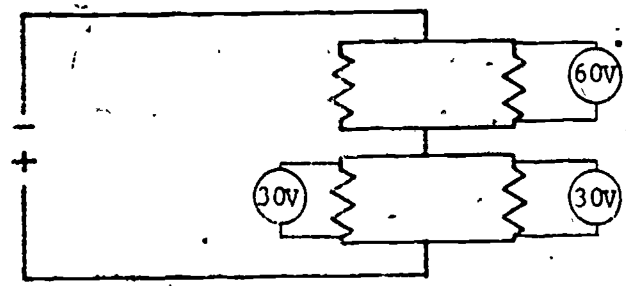
b.



Total current = _____ amps.

11.16
lsn 4; p. 25

c.



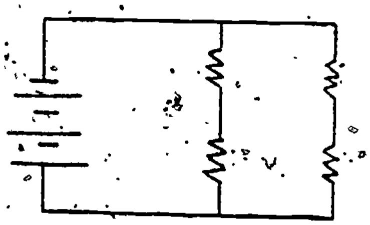
Total voltage = _____ volts

11.16
lsn 4; p. 26

LESSON 4, PART A
SERIES-PARALLEL CIRCUITS-SELF TEST ANSWERS

1. a, c, d

2.



3. (a) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2+4} + \frac{1}{2+1}$

$\frac{1}{R_T} = \frac{1}{6} + \frac{1}{3} = \frac{3}{6}$

$\frac{1}{R_T} = \frac{1}{2}$ $R_T = 2$

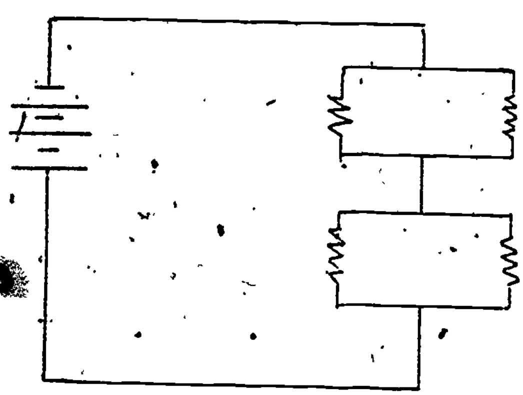
(b) $I_T = I_1 + I_2 = 4 + 6 = 10$ amps

(c) Remember: 1. Add voltages together when they are in series
2. Voltage is the same over parallel branches

$V_T = V_1 + V_2 = V_3 + V_4$

$= 10 + 4 = 6 + 8 = 14$ volts

4.



11.16
lsn 4; p. 27

5. (a) $R_T = R_{1,2} + R_{3,4}$

$$\frac{1}{R_{1,2}} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10} = \frac{1}{5}$$

$$R_{1,2} = 5$$

$$\frac{1}{R_{3,4}} = \frac{1}{20} + \frac{1}{20} = \frac{2}{20} = \frac{1}{10}$$

$$R_{3,4} = 10$$

$$R_T = R_{1,2} + R_{3,4}$$

$$5 + 10 = 15 \text{ ohms}$$

(b) Step 1. $I_T = \frac{V}{R_T}$

Step 2. $R_T = R_{1,2} + R_{3,4}$

$$\frac{1}{R_{1,2}} = \frac{1}{20} + \frac{1}{20} = \frac{2}{20} = \frac{1}{10}$$

$$R_{1,2} = 10$$

$$\frac{1}{R_{3,4}} = \frac{1}{30} + \frac{1}{30} = \frac{2}{30} = \frac{1}{15}$$

$$R_{3,4} = 15$$

$$R_T = 10 + 15 = 25$$

$$I_T = \frac{V}{R_T} \quad \frac{50}{25} = 2 \text{ amps}$$

(c) Remember: (1) That voltage is the same over branches of a circuit.
(2) That voltage over a series circuit is the sum of all voltages around it.

$V_T = V_1 + V_2 = 60 + 30 = 90$ volts

GO RIGHT ON TO LESSON 4, PART B - BATTERIES

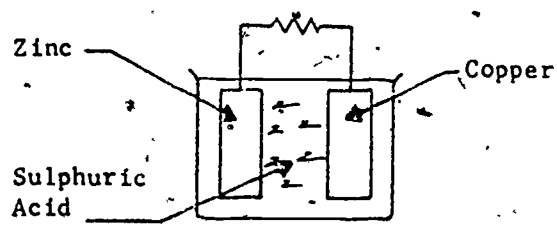
LESSON 4

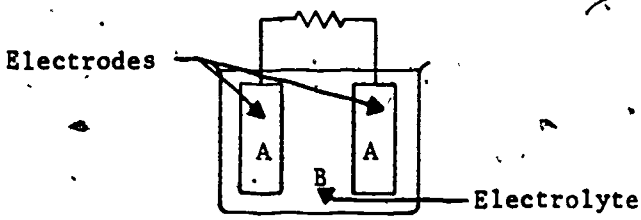
PART B

BATTERIES

OBJECTIVES

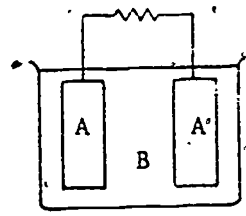
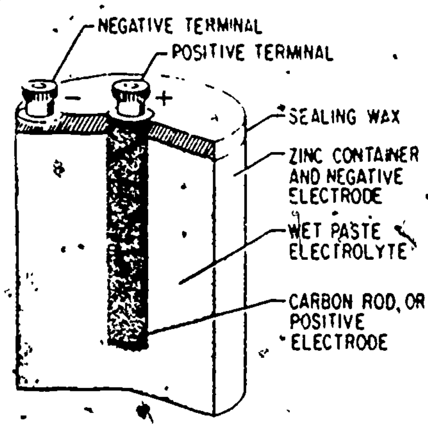
1. Define a cell.
2. Given a diagram of a cell, label its two basic parts.
3. State the difference between a primary cell and a secondary cell.
4. State what determines the amount of current a cell will produce.
5. State how a cell is charged.
6. Name the instrument used to determine the condition of a cell's electrolyte.
7. State the reason a discharged lead-acid cell will freeze if exposed to subfreezing temperatures.
8. Define a battery.
9. State how cells are connected to produce maximum voltage.
10. State how cells are connected to produce maximum current.
11. State the damage that will result from spilling battery acid on aircraft metals.
12. State how battery terminals and cable clamps can be protected from corrosion.
13. State the measures to be taken when battery acid comes in contact with the skin, eyes, and clothing.
14. State two safety precautions to observe when working with or near batteries.

	1. If a piece of metal is suspended in acid, a chemical action will take place. The acid will attack the metal. A piece of zinc dropped in a certain acid will cause a __________ action.
CHEMICAL	2. Chemical energy is released when an acid attacks metal. By utilizing this energy, an electric current can be generated. Chemical energy can be changed into __________ energy.
ELECTRICAL	3. Any device which changes chemical energy into electrical energy is called a cell. A flashlight cell changes __________ energy into __________ energy.
CHEMICAL ELECTRICAL	4. A piece of zinc and a strip of copper immersed in a solution of sulfuric acid will cause a chemical action to take place. The acid will start eating the zinc and an electric current will be produced. This device which is changing chemical energy into electrical energy is called a __________. 
CELL	5. A device which changes __________ energy into __________ energy is called a __________.
CHEMICAL ELECTRICAL CELL	6. Define a cell. __________

A DEVICE WHICH CHANGES CHEMICAL ENERGY INTO ELECTRICAL ENERGY.	7. Here is a diagram of a simple cell. Two metal plates are suspended in a solution of water and acid. The metal plates are called electrodes. The solution is called electrolyte.  The metal plates A ~~are~~ called ________________. The acid solution B is called ________________.
ELECTRODES ELECTROLYTE	8. An electrolyte is a chemical compound, such as an acid solution, which will conduct an electric current. A mixture of sulfuric acid and water is commonly used as an ________________.
ELECTROLYTE	9. When mixing a fresh electrolytic solution of sulfuric acid and distilled water, do not pour the water into the acid, since this may cause excessive heating and splashing of the mixture. To mix properly an electrolytic solution, pour the ______ into the ________. (HINT: A before W.)
ACID WATER	10. To produce an electric current, a cell must have two or more electrodes suspended in the electrolyte. An electrode is one of the plates or poles of the cell. Lead plates are commonly used as __________.
ELECTRODES	11. The chemical energy created by the electrolyte attacking the electrodes is changed into ________________ energy.
ELECTRICAL	12. If either the electrodes or the electrolyte becomes exhausted (used up), the cell will no longer produce a current. The two basic parts of a cell are the ________________ and the ________________.

11.16

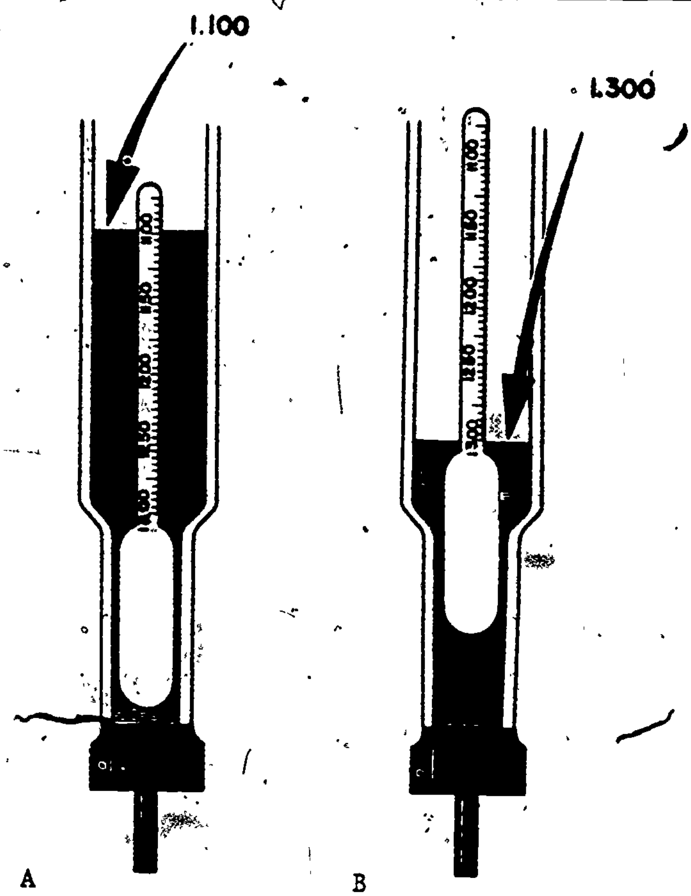
lsn 4; p. 31

ELECTRODES ELECTROLYTE	13. From this diagram, identify the two basic parts of a cell. a. ____________ b. ____________ 
a. ELECTRODES b. ELECTROLYTE	14. A common flashlight cell, rated at 1.5 volts, is known as a primary cell. Primary (dry) cells are normally <u>not</u> rechargeable, but sometimes heating will increase their output for a short period of time. Therefore, common flashlight cells, rated at _____ volts, for all practicable purposes, cannot be ______________.
1.5 RECHARGED	15. This is a cutaway drawing of a ________ cell. The negative electrode is made of ______________. The positive electrode is made of ________. The electrolyte is a ______ ________. 
PRIMARY (OR DRY) ZINC CARBON WET PASTE	16. The chemical action that takes place between the electrodes and the electrolyte continues to produce a current until the zinc electrode is exhausted, or until the electrolyte becomes dry. After the zinc case has been eaten away, the cell is not capable of producing any more current and <u>cannot</u> normally be recharged. Primary cells cannot be ______________.
RECHARGED	17. Secondary cells (wet cells), the type used in automobile batteries, are constructed with materials that make recharging possible. Secondary cells <u>can</u> be recharged, while __________ cells <u>cannot</u> normally be recharged.

PRIMARY	18. The common lead-acid cell, the type found in automobile batteries, consists of an electrolyte composed of sulfuric acid diluted with water and electrodes made of lead. The common lead-acid type of cell can be recharged. It is, therefore, a ________ cell.
SECONDARY	19. The main difference in primary and secondary cells is that one type cannot normally be recharged while the other type can be recharged. The type of cell that <u>can</u> <u>be</u> <u>recharged</u> is the ________ cell.
SECONDARY	20. What is the major difference between a secondary cell and a primary cell? ________
SECONDARY CELLS CAN BE RECHARGED. PRIMARY CELLS CANNOT NORMALLY BE RECHARGED.	21. The <u>amount</u> <u>of</u> <u>current</u> (amperes) a cell will produce and the <u>length</u> <u>of</u> <u>time</u> it will produce that current are expressed in <u>ampere-hours</u>. A flow of <u>one</u> <u>ampere</u> for <u>one</u> <u>hour</u> is <u>one</u> <u>ampere-hour</u>. Two amperes of current flowing for one hour would be ________ ampere-hours.
TWO	22. The amount of current (ampere-hours) a cell delivers depends on its size. The larger the cell, the more current it will produce. The total amount of current a cell will deliver depends on its ________.
SIZE	23. The size of a cell has no effect on the voltage but does have an effect on the amount of ________ it will deliver.
CURRENT	24. The voltage of a cell depends on the composition of the electrodes and electrolyte. The amount of current a cell will produce is determined by its ________.
SIZE	25. What determines the total amount of current a cell will produce? ________

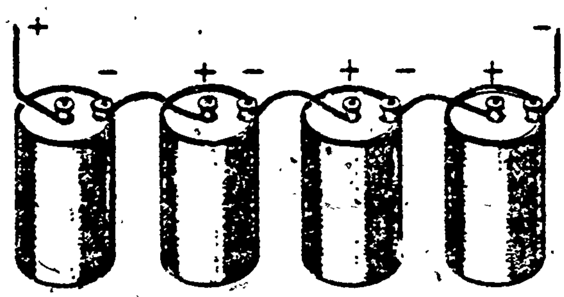
11.16
lsn 4; p. 33

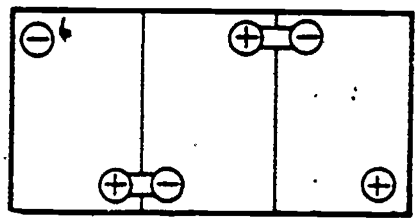
THE AMOUNT OF CURRENT A CELL WILL PRODUCE IS DETERMINED BY ITS SIZE.	26. To recharge a secondary cell, a current is forced through the cell in a reverse direction. Forcing current through a cell in a reverse direction ________________ the cell.
CHARGES (RECHARGES)	27. Charging a cell reverses the chemical action. Forcing a current through in a reverse direction restores the chemicals to their original form. Forcing a current through a cell in a reverse direction reverses the ____________ __________.
CHEMICAL ACTION	28. The recharging process changes the water back to acid and changes the composition of the lead plates to their original condition. Recharging a cell changes the electrolyte from ____________ to __________.
WATER TO ACID	29. How is a cell recharged? ____________________ ____________________ ____________________
BY FORCING CURRENT THROUGH THE BATTERY IN A REVERSE DIRECTION.	30. If the electrolyte in a cell is strong with acid, it indicates the cell is charged. If the electrolyte through chemical action is reduced to water, the cell is considered discharged. The condition of a cell can be determined by the condition of the ________________.
ELECTROLYTE	31. The most convenient method for determining the charge of a cell is by using a <u>hydrometer</u>. The specific gravity of a cell's electrolyte is determined with a ________________.
HYDROMETER	32. The specific gravity of a liquid is an indication of its density. A water-acid solution is denser than water. A fully charged battery contains approximately 27 percent sulfuric acid and 73 percent water. A fully discharged battery is practically all water. Therefore, the bulb of a hydrometer will sink in the solution from a discharged battery, but in the solution from a fully charged battery, it will __________ higher.

FLOAT	33. The strength of the acid solution of the electrolyte in a cell determines its specific gravity. The specific gravity can be determined by using a ________________.
HYDROMETER	34. The hydrometer reading of a fully charged cell is about 1.300. The electrolyte in a discharged cell will read about 1.100. If the hydrometer reading of a cell is 1.100 or less, it indicates the cell is ________________.
DISCHARGED (DEAD)	35. The operation of a cell depends on the chemical action the electrolyte produces within the cell. The chemical action of the cell depends on the acid content, or strength, of the ________________.
ELECTROLYTE	36. Since the acid content of the electrolyte determines the amount of chemical action within the cells, the condition of a cell's electrolyte is best determined by using a ________________.
HYDROMETER	37.  Which hydrometer shows a charged cell? ________ Which hydrometer shows a discharged cell? ________

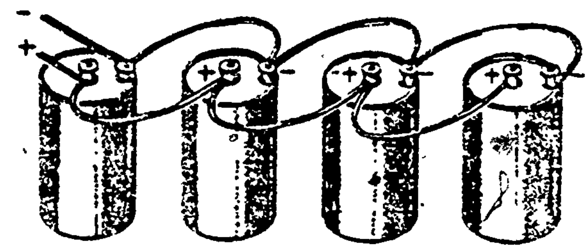
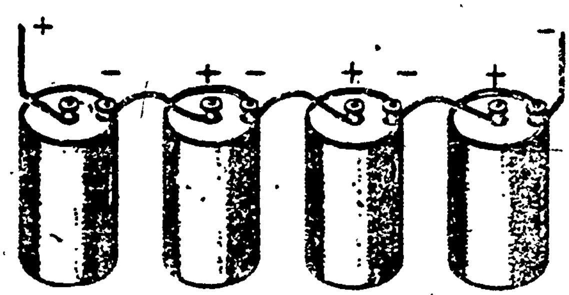
11.16

lsn 4; p. 35

CHARGED B DISCHARGED A	38. What instrument is used to determine the condition of a cell's electrolyte? ____________________
HYDROMETER	39. The chemical action, which accounts for the current in a lead-acid cell, causes an exhaustion of both the lead plates and the acid. A chemically inactive cell is not capable of producing an electric _______________.
CURRENT	40. As a lead-acid cell discharges, the acid gradually changes to water. The electrolyte in a discharged cell is practically all _______________.
WATER	41. A discharged cell will freeze if subjected to low temperatures because the electrolyte has changed from ____________ to ____________.
ACID WATER	42. A discharged lead-acid cell will freeze if exposed to subfreezing temperatures because ____________ ____.
THE ELECTROLYTE HAS TURNED TO WATER	43. A battery consists of two or more cells connected together.  The illustration above shows a ________________ with _________ cells. (number)
BATTERY FOUR	44. The difference between a cell and a battery is that a battery consists of __________ or more _______________.

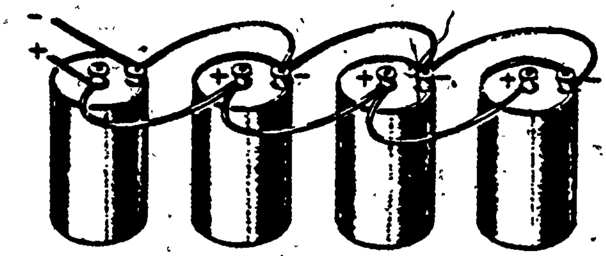
TWO CELLS	45. Two or more cells connected together make up a ________.
BATTERY	46. Define a battery. ________________________________ ________________________________
A GROUP OF TWO OR MORE CELLS CONNECTED TOGETHER.	47. This diagram represents an automobile battery consisting of three cells connected in series.  If the cells are connected so that the positive (+) terminal of one is connected to the ________ terminal of the next, etc., the cells are connected in ________.
NEGATIVE (-) SERIES	48. The cells in an automobile battery are connected in series to get maximum voltage output. To get the most voltage from a group of cells, they should be connected in ________.
SERIES	49. A secondary cell is rated at two volts. An automobile battery with three secondary cells connected in series would be rated at ________ volts.
SIX	50. A 12-volt automobile battery has how many cells? ________

11.16
lsn 4, p. 37

SIX	51. The cells in illustration A are connected in parallel. The cells in illustration B are connected in ____________.  A  B Which set of cells has the greater voltage output, A or B? (Underline one.)
SERIES B	52. Connecting a group of cells in series will give a maximum output of amperage, voltage, resistance. (Circle the correct answer.)
VOLTAGE	53. How can a group of cells be connected to get maximum voltage? ____________

CELLS CONNECTED IN SERIES WILL GIVE MAXIMUM VOLTAGE OUTPUT.

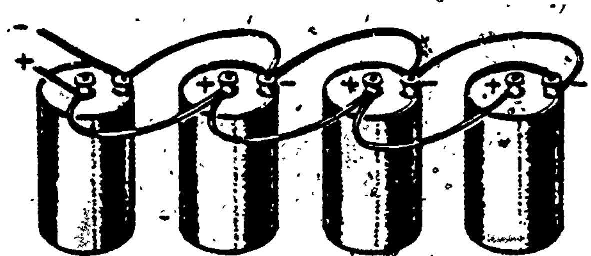
54. The cells in the diagram below are connected in parallel.



By connecting positive terminals together and by connecting negative terminals together, a maximum output of current will be supplied. To get maximum current output from two or more cells, they must be connected in ______________.

PARALLEL

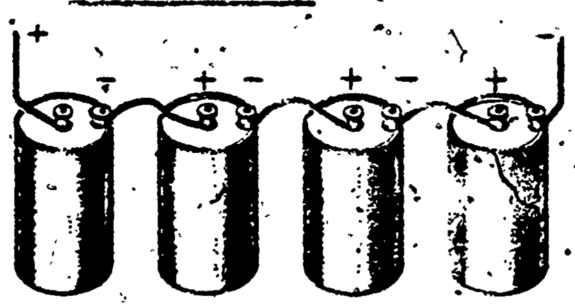
55. These cells are connected in ______________ for maximum ______________ output.



PARALLEL

CURRENT

56. These cells are connected in ______________ for maximum ______________ output.



SERIES

VOLTAGE

57. To get maximum current from a battery, the cells should be connected in ______________.

PARALLEL	58. How should a group of cells be connected for maximum current output? ____________
IN PARALLEL.	59. Sulfuric acid spillage from aircraft batteries is highly corrosive to metals and should be removed as soon as possible. Flushing the affected area with a solution of sodium bicarbonate and fresh water will prevent ____________ action from taking place.
CORROSIVE	60. Acid spilled from a battery onto metal surfaces will cause corrosion. Therefore, spilled acid should be removed as soon as possible by flushing with a mixture of ________ ____________ and ________ ________.
SODIUM BICARBONATE FRESH WATER	61. Frequent cleaning of battery acid spillage areas will prevent excessive ____________.
CORROSION	62. Spilling battery acid on aircraft metal surfaces will cause ____________.
CORROSION	63. Battery terminals and cable clamps will corrode unless some method is used to prevent it. Periodic maintenance is therefore necessary to prevent ____________.
CORROSION	64. Corrosion of terminals and cable clamps can be prevented by first cleaning and then coating them with petroleum jelly. Coating terminals and cable clamps with petroleum jelly will help prevent ____________.
CORROSION	65. How can battery terminals and cable clamps be protected from corrosion? ____________ ____________ ____________

CLEANING AND COATING WITH PETROLEUM JELLY.	66. Periodic maintenance of aircraft batteries also includes checking the level of the electrolyte in each cell. When the level of the electrolyte is below the top of the plates (electrodes), distilled water should be added. When necessary, the electrolyte level can be brought to normal (approximately 3/8" above the plates) with the addition of _______________ _____________.
DISTILLED WATER	67. When handling electrolyte (battery acid), wear protective clothing, such as face shields, gloves, footwear, and aprons. To avoid splashing or spilling electrolyte on the skin, personnel shall wear _______________ _______________.
PROTECTIVE CLOTHING	68. This man used the correct rubber bucket to carry the electrolyte, but he forgot to wear any protective clothing. He could have saved those fingers if he had remembered to wear his chemically resistant _____________. 

GLOVES	69. In case of personal contact with battery acid, there are certain basic first-aid measures that must be followed to prevent permanent injury. If acid comes in contact with the skin, flush the affected area with plenty of fresh water, apply vaseline, boric acid, or zinc ointment, and report to sick bay. If acid comes in contact with the eyes, flush immediately with plenty of fresh water and report directly to sick bay. Occasions may arise when acid will be spilled on clothing. It may be neutralized (counteracted) by flushing with a solution of baking soda and water. This will prevent deterioration of the cloth. In order to counteract any possible acid injury, certain ____________ measures must be taken.
FIRST-AID	70. The first-aid procedures to follow when acid comes in contact with the skin is to flush with plenty of fresh ________, apply ________________, and report to ______________.
WATER VASELINE, BORIC ACID, OR ZINC OINTMENT SICK BAY	71. If battery acid were to come in contact with the eyes, immediately ________ with ________ ________ and report directly to ________ ________.
FLUSH FRESH WATER SICK BAY	72. To prevent deterioration of clothing if battery acid should be spilled on them, immediately flush or soak the affected area with a solution of ________________ and ________.

BAKING SODA AND WATER	73. Match the measures to be taken, column B, to the conditions listed in column A. A: a. Acid on clothing ____ b. Acid on the skin ____ c. Acid in the eyes ____ B: (1) Flush with fresh water and report to sick bay. (2) Flush with fresh water, apply a medication, and report to sick bay. (3) Flush with baking soda and report to sick bay. (4) Flush with baking soda and water.
a. (4) b. (2) c. (1)	74. What measures are to be taken when battery acid comes in contact with the following? a. The eyes: __________ b. The skin: __________ c. Clothing: __________
a. FLUSH WITH FRESH WATER AND REPORT TO SICK BAY b. FLUSH WITH FRESH WATER, APPLY A MEDICATION, AND REPORT TO SICK BAY c. FLUSH WITH A SOLUTION OF BAKING SODA AND WATER	75. Extreme care must be taken to avoid creating sparks in the vicinity of aircraft batteries; naturally, smoking is not permitted around them. Even with good ventilation, the hydrogen and oxygen gases produced by the acid will concentrate above the cells in explosive amounts. When working with or near aircraft batteries, the safety precautions that must be observed are: do not create any __________, and observe the NO __________ rule.

11.16
lsn 4; p. 43

SPARKS SMOKING	76. "Avoiding the creation of sparks" and "NO SMOKING" are the two major safety precautions that must be observed when working with or near aircraft batteries. Failure to observe these safety precautions could result in an ______________ of the hydrogen gases present.
EXPLOSION	77. What are the two safety precautions that must be observed when working with or near aircraft batteries? a. ____________________ b. ____________________
a. AVOID THE CREATION OF SPARKS. b. NO SMOKING. (ANY ORDER)	

FUNDAMENTALS OF ELECTRICTY

LESSON 4

PART B

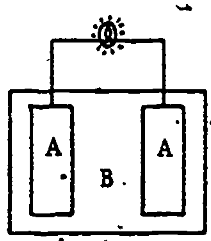
BATTERIES

SELF-TEST

1. What is the definition of a cell? ______________________

____

2. Label the two essential parts of the cell.



A. ______________________

B. ______________________

3. What is the difference between a primary cell and a secondary cell?

____

____

4. What determines the amount of current a cell will produce?

____

5. How is a battery charged?

____

____

6. What is the name of the instrument used to determine the condition of a cell's electrolyte?

____

7. Why will a discharged lead-acid cell freeze if exposed to sub-freezing temperatures?

____

8. What is the definition of a battery?

____

9. How are cells connected to get maximum voltage output?

____

10. How are cells connected to get maximum current output?

____

11. What damage may result from spilling battery acid on aircraft metals?

____

12. How can battery terminals and cable clamps be protected from corrosion?

____

13. What are the measures to be taken when battery acid comes in contact with the following?

a. The eyes: ______________________________

____

b. The skin: ______________________________

____

c. Clothing: ______________________________

____

14. List two safety precautions that must be observed when working with or near aircraft batteries.

a. ______________________________

b. ______________________________

LESSON 4, PART B

BATTERIES-SELF TEST ANSWERS

1. Cell - A device which changes chemical energy into electrical energy.

2. (a) Electrodes
   (b) Electrolyte

3. Primary cells cannot normally be recharged. Secondary cells can be recharged.

4. Its size

5. A battery is charged by forcing current through a cell in a reverse direction.

6. Hydrometer

7. The electrolyte has turned to water.

8. Battery - A group of 2 or more cells connected together.

9. Series

10. Parallel

11. Corrosion

12. Cleaning and coating with petroleum jelly.

13. (a) The eyes: flush with fresh water and report to sick bay
    (b) The skin: flush with fresh water, apply a medication and report to sick bay
    (c) Clothing: flush with a solution of baking soda and water.

14. (a) Avoid the creation of sparks
    (b) No smoking

END OF LESSON 4, GO ON TO LESSON 5

* * *

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11.16a

FUNDAMENTALS OF ELECTRICITY

3-3

LESSON 5

MAGNETISM AND

ELECTROMAGNETISM AND ELECTROMAGNETIC INDUCTION

INSTRUCTIONS

This is a programmed lesson. It is designed to teach, not to test. You will need only this booklet, a pencil, and some time to complete this lesson. If there is something in the program you do not understand, ask your instructor or supervisor for assistance.

- REMEMBER -

This lesson has been written so that the amount of reading necessary is minimal and yet most meaningful. Therefore, it is very important that you follow these instructions.

- Read each page carefully.
- Fill in each blank.
- Keep the answer to the frame on which you are working covered with a slip of paper until you have written your answer.
- Correct all errors you make.
- Follow all directions given in the program.

SUGGESTED READING TIME
170 MINUTES

LESSON 5

PART A

MAGNETISM

OBJECTIVES

1. Given a list of statements pertaining to magnets, state whether each statement applies to a natural magnet or an artificial magnet.

2. Given a list of materials, classify each as being either magnetic or nonmagnetic.

3. Given a list of true and false statements about magnetic lines of flux, select the true statements.

4. Given an illustration of a magnet, with the direction of the flux lines shown, label the poles of the magnet.

5. Given illustrations of magnets, select the one that shows where the greatest concentration of flux lines occurs.

6. State the laws of polarity.

7. Given illustrations showing different molecular arrangements in a magnetic material, label each as being unmagnetized, partially magnetized, or saturated.

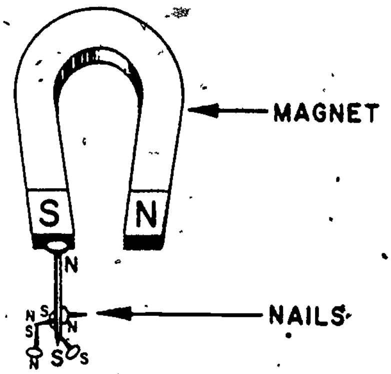
8. Given the terms residual magnetism, magnetism, retentivity, permeability, transparency, saturated, induced magnetism, and a list of their definitions, match each term with its definition.

9. List three ways of magnetizing an iron bar.

10. State whether the permeability is high or low and whether the retentivity is high or low for metals used to make permanent magnets.

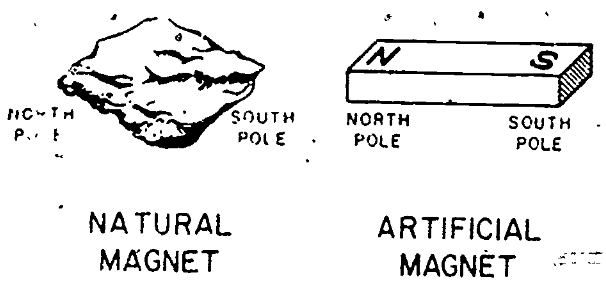
11. State whether the permeability is high or low and whether the retentivity is high or low for metals used to make temporary magnets.

12. Given a list of metals, select the one(s) used to make permanent magnets and the one(s) used to make temporary magnets.

	1. When a metal attracts a magnetic material, that metal is said to have magnetism. Magnetism can be defined as having the ability to ________ magnetic materials.
ATTRACT	2.  Because the magnet in the illustration attracts the nails, it is said to have ____________.
MAGNETISM	3. Magnetism is defined as having the ability to ________ ________ ________.
ATTRACT MAGNETIC MATERIALS	4. Everyday magnetism affects us in some way. The large generators which provide electricity for lighting our cities and homes and the small motors of some model cars use a magnet. These very practical magnets are artificial magnets. Motors, generators, and magnetos use ____________ magnets.
ARTIFICIAL	5. Artificial magnets have many practical uses and they are man-made. The magnets used in electrical motors and magnetos are artificial; they are produced by ________.
MAN	6. Since these magnets are used in various applications, they must be made in different shapes and sizes; and because these practical magnets are produced by man, they are called ____________ ____________.

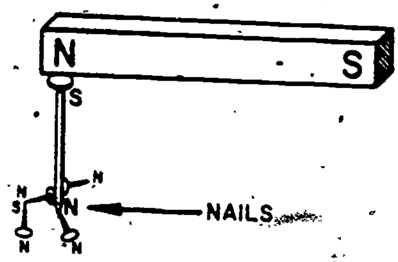
II.16
lsn 5; p. 3

ARTIFICIAL MAGNETS	7. There are two kinds of magnets: a. An artificial magnet which is produced by man. b. A magnet found in a natural magnetic condition. This magnet is called a ________ magnet.
NATURAL	8. What are the two kinds of magnets? a. ____________ b. ____________
a. ARTIFICIAL b. NATURAL	9. Magnetite is a material found in a magnetic condition. Since magnetite is found in a magnetic condition, it is a __________ magnet.
NATURAL	10. Although magnetite is found in a magnetic condition, it has no practical use. Would magnetite be used as the magnet in a motor or generator? _____
NO	11. Because of the difficulty in obtaining desired sizes and shapes from magnetite, it has no practical use as a __________.
MAGNET	12. Magnetite is the only type of iron ore found in a magnetic condition. It has no practical use in motors or generators, but it was used in ancient times as a crude compass. Select the correct statement. _____ a. Magnetite is a type of iron ore. b. Magnetite was used as a crude compass. c. Neither A nor B is true. d. Both A and B are true.
d.	13. Because magnetite was used as a compass, it is called lodestone. Lodestone means leading stone. From its early use as a compass, magnetite is often referred to as ____________.

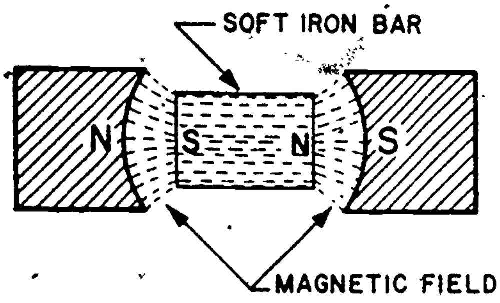
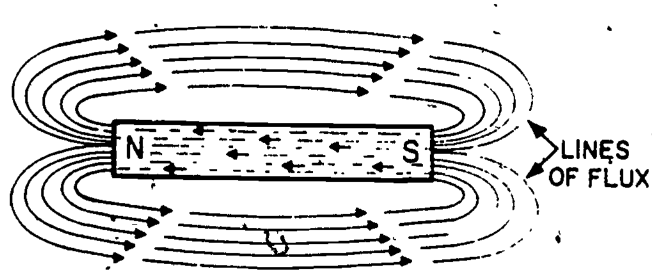
LODESTONE	14. Select the names which apply to the type of iron ore that is a natural magnet. ______ a. Magnesium b. Lodestone c. Manganese d. Magnetite e. Magneto
b. d.	15. What is the only type of iron ore found in a magnetic condition? ______________
MAGNETITE (LODESTONE)	16. There are many materials which can be made into artificial magnets. There is only one that is a natural magnet; it is called ______________.
MAGNETITE (LODESTONE)	17. Circle the letter beside each statement that pertains to an <u>artificial</u> magnet. a. It is called lodestone. b. It is a magnet produced by man. c. It has the greater application. d. It is the magnet with the least practical use. e. It is the most practical magnet.
b. c. e.	18.  All magnets, whether they are artificial or natural, have a __________ and __________ pole.

11.16
lsn 5; p. 5

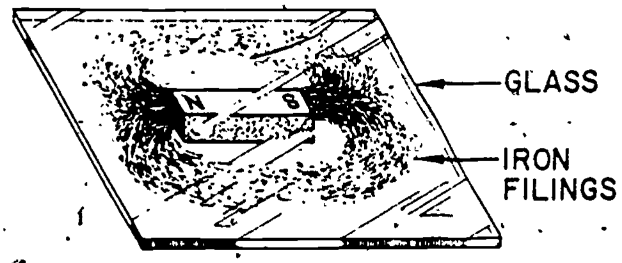
NORTH SOUTH	19. All magnets have two poles— a ________ and a ________ pole.
NORTH SOUTH	20. Some materials are not affected by magnetism. These materials are classified as nonmagnetic. Brass, aluminum, copper, and magnesium are some of these materials, and they would be classified as ________________.
NONMAGNETIC	21. Any material that cannot be magnetized is classified as nonmagnetic. Brass and copper cannot be used as magnets and are classified as ________.
NONMAGNETIC	22. Aircraft parts made of aluminum or magnesium are not affected by a magnet, and ____________ (are/are not) classified as nonmagnetic.
ARE	23. Materials are classified as being either magnetic or nonmagnetic. Those materials affected by a magnet are classified as ______________.
MAGNETIC	24. Magnets have an attraction for magnetic materials. Alnico and iron are attracted by a magnet and are classified as ____________ materials.
MAGNETIC	25. Cobalt and permalloy are magnetic materials. What is the effect on these materials by a magnet? ______________________________
THEY ARE ATTRACTED.	26. Circle the letter beside the materials that are classified as nonmagnetic. a. Aluminum e. Alnico b. Permalloy f. Cobalt c. Iron g. Copper d. Brass h. Magnesium

a. d. g. h.	27. Circle the letter beside the materials that are classified as magnetic. a. Copper e. Permalloy b. Cobalt f. Brass c. Magnesium g. Aluminum d. Iron h. Alnico
b. d. e. h.	28. Magnetic materials, when attracted to or even near a magnet, will become magnetized. This indicates that materials affected by magnetism are easily ________________.
MAGNETIZED	29.  In the illustration above, the objects attracted by the magnet become ________________.
MAGNETIZED	30. Magnetism produced in a material by the presence of a magnet is <u>induced</u> magnetism. If you were wearing a watch near a strong magnet and it became magnetized, the magnetism in the watch would be ____________ ________________.

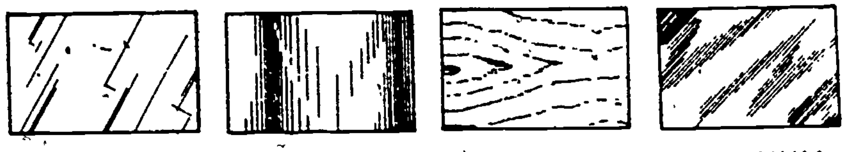
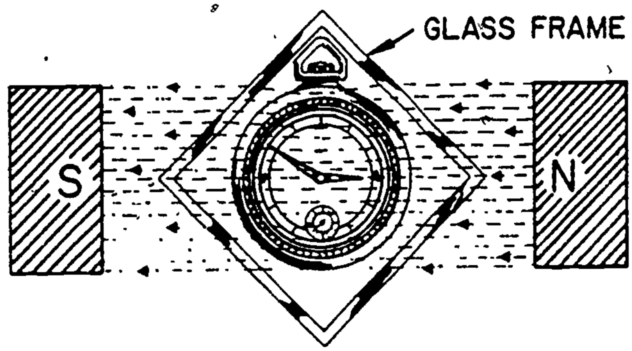
11.16
lsn 5; p. 7

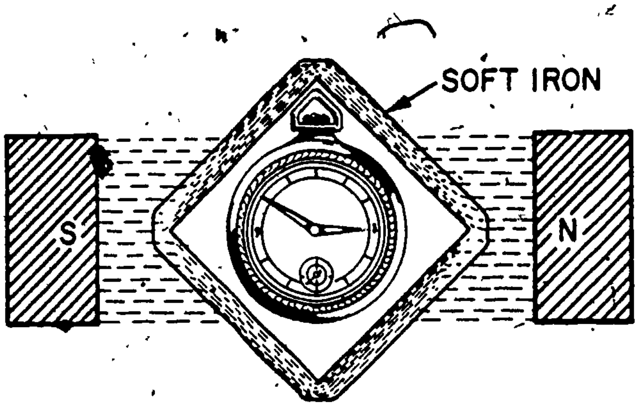
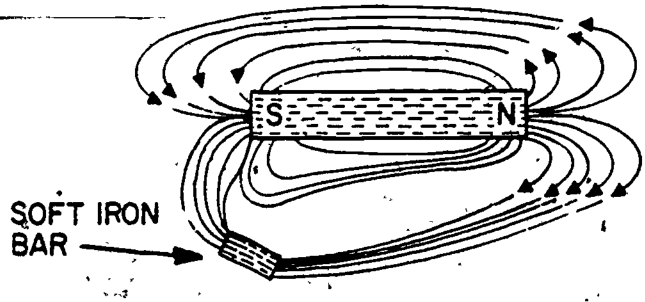
INDUCED MAGNETISM	31.  Magnetism induced in the iron bar by the magnetic field is ________ ____________.
INDUCED MAGNETISM	32. Magnetism induced in a material by the presence of the magnetic field of a magnet is ____________ ____________.
INDUCED MAGNETISM	33.  In the illustration, the magnetic field, which produces induced magnetism, is made up of ________ of ________.
LINES OF FLUX	34. All magnets have a magnetic field; therefore, all magnets have ________ of ________.

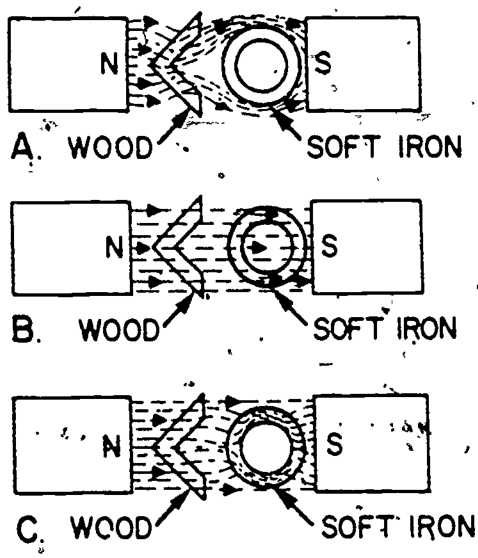
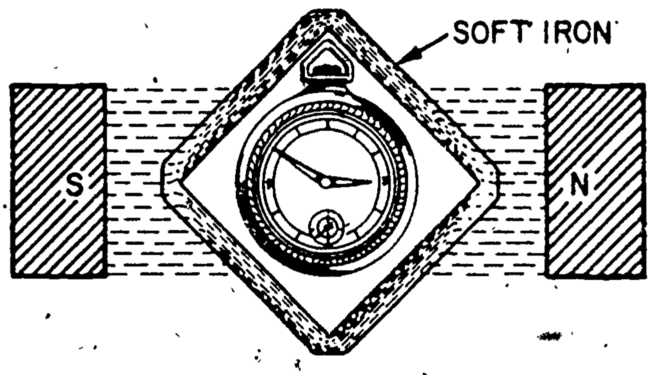
11.16
lsn 5; p. 8

LINES OF FLUX	35. The magnetic field cannot be seen; however, a visual representation of this magnetic field around a magnet can be obtained by placing a sheet of glass over a magnet and sprinkling iron filings on the glass as illustrated below.  What do the iron filings in the illustration represent? ________________________________
MAGNETIC FIELD (LINES OF FLUX)	36. The lines of flux, which make up the magnetic field, were not affected by the sheet of glass because it is a nonmagnetic material. A non-magnetic material is said to have the property of transparency because it does not affect the ________ of ________.
LINES OF FLUX	37. Just as glass is transparent to light and allows light rays to pass through it, a nonmagnetic material is transparent to lines of flux and allows the flux lines to pass through it. A material that has no effect on the lines of flux has the property of ______________.
TRANSPARENCY	38. Transparency is a property of all ____________ materials.
NONMAGNETIC	39. Because the flux lines are not affected by nonmagnetic materials, they cannot be insulated. Lines of flux readily pass through all nonmagnetic materials; for this reason, flux lines cannot be ______________.

11.16
lsn 5, p. 9

INSULATED	40.  Will any of the materials above insulate lines of flux? ______
NO	41.  Why will the watch in the illustration become magnetized by the lines of flux? ______________ ______________
LINES OF FLUX CANNOT BE INSULATED.	42. Which of the following statements are true? a. Lines of flux cannot be insulated. b. Lines of flux are not affected by nonmagnetic materials. c. Neither A nor B is true. d. Both A and B are true.

d.	43. Although the lines of flux cannot be insulated, equipment can be shielded by using a magnetic material to direct the lines of flux.  In the illustration above, the soft iron acts as a __________.
SHIELD	44. Lines of flux traveling outside the magnet will seek the path of least resistance. If two paths exist, one air and one magnetic material, the flux lines will travel through the magnetic material, even though it may be the longer route. This shows that magnetic material offers the path of ________ ____________.
LEAST RESISTANCE	45.  Why do the lower flux lines travel the path shown? ______________________________ ______________________________________

FLUX LINES SEEK THE PATH OF LEAST RESISTANCE.	46.  Which illustration shows the path the lines of flux will travel through magnetic and nonmagnetic materials? ________
C.	47.  Why is the watch not affected by the lines of flux? ____________________________ ____________________________________

THE WATCH IS SHIELDED BY THE SOFT-IRON MATERIAL. LINES OF FLUX TAKE THE PATH OF LEAST RESISTANCE.

48. Select the statement that states how to protect an instrument from lines of flux.

a. Insulate the instrument with a nonmagnetic material.

b. The instrument cannot be protected from lines of flux.

c. Use a shield of magnetic material.

d. Protection is obtained by the use of a glass face.

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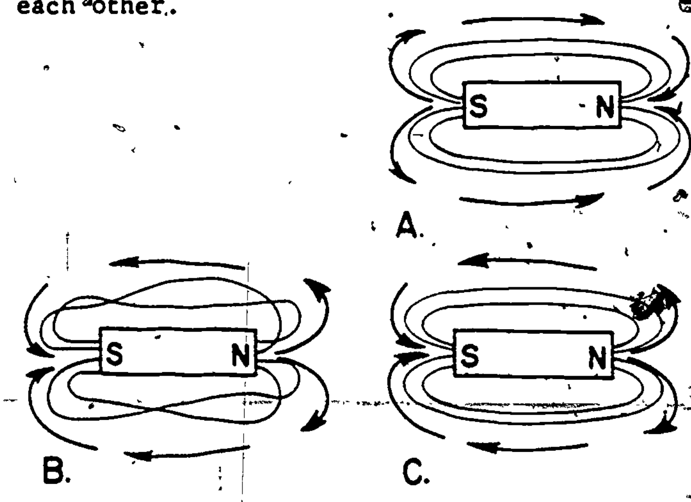
c.

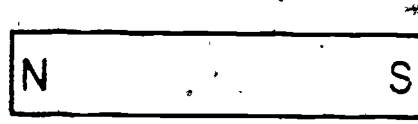
49. The lines of flux travel outside the magnet from the north pole to the south pole and never cross each other.



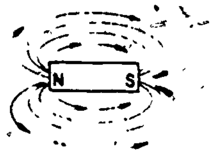
Which illustration correctly shows how the flux lines travel outside the magnet? _____

C.

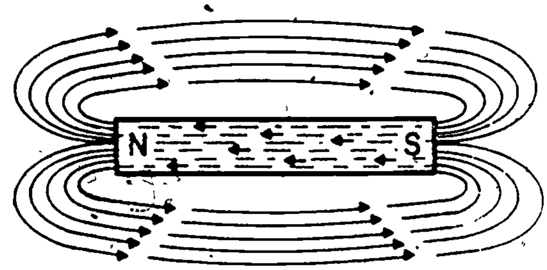
50. Complete the illustration below by drawing the lines of flux. Use arrows to indicate the direction of travel; remember, lines of flux never cross.

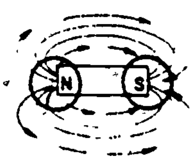


11.16
lsn 5; p. 13



51. Although the magnetic field surrounds the magnet, the greatest concentration of flux lines is at the poles. Circle the area(s) where the greatest concentration of flux lines occurs.

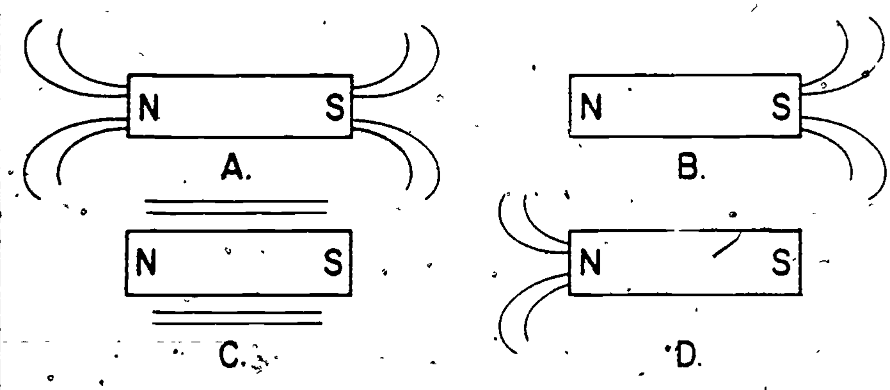




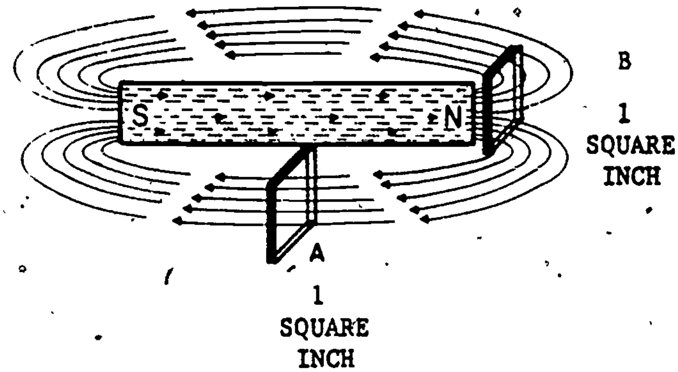
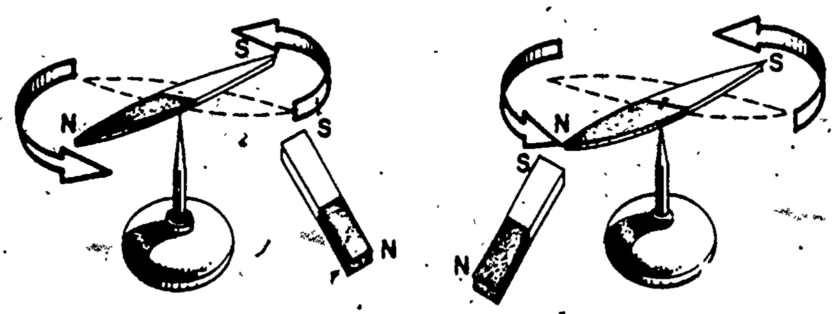
52. Because the poles have the greatest concentration of flux lines, the greatest strength of the magnet is at the ________.

POLES

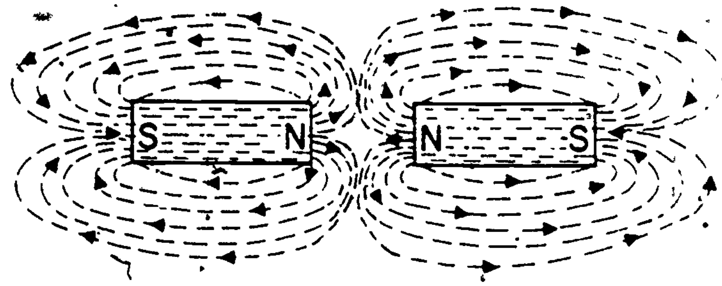
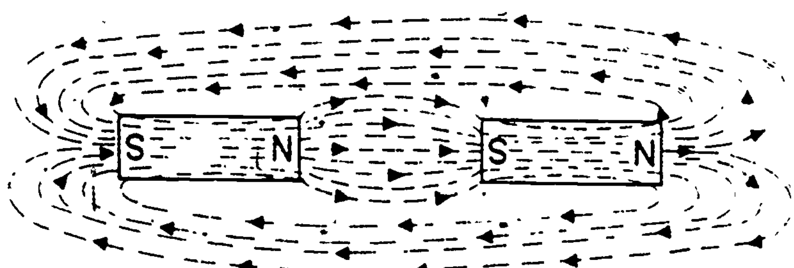
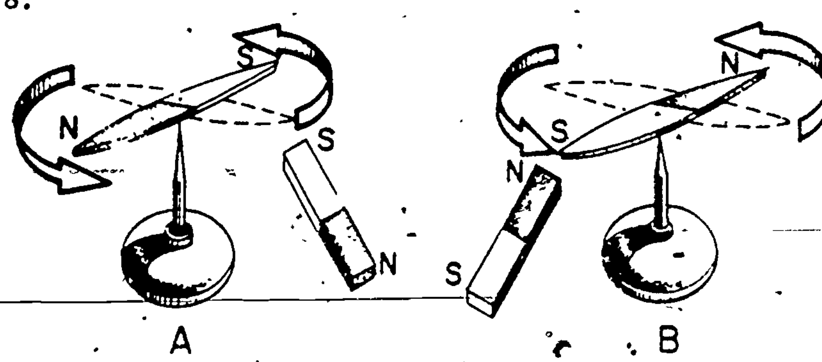
53.

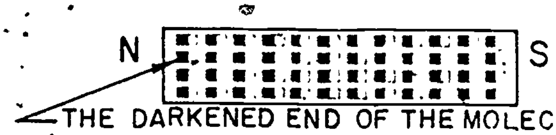


The illustration which correctly shows where the greatest concentration of flux lines occurs is ________.

A.	54. The greater the concentration or intensity of flux lines in a given area, the greater the strength of the magnetic field. Which area has the stronger magnetic field, A or B? ______ 
B	55. We know that both natural and artificial magnets have a north and south pole. There are two laws of polarity concerning these poles. a. Like poles repel (north repels north and south repels south). b. Unlike poles attract (north attracts south and south attracts north). Place the letter representing the law (a or b) under the illustration to which it applies.  (1)________ (2)________

11:16
lsn 5; p. 15

(1) a. (2) b.	56.  This illustration demonstrates one of the laws of polarity. This law states that __________ poles __________.
LIKE REPEL	57. When the unlike poles of two magnets are brought near each other, flux lines join and cause an attraction between them.  The illustration above shows the other law of polarity. This law states that __________ __________ __________.
UNLIKE POLES ATTRACT	58.  In illustration A, the south pole will __________ the south pole. In illustration B, the north pole will __________ the south pole.

REPEL ATTRACT	59. State the laws of polarity. a. ______________________ b. ______________________
a. LIKE POLES REPEL. b. UNLIKE POLES ATTRACT. (ANY ORDER)	60.  The molecular theory of magnetism is based on the theory that each molecule of a magnetic material is a magnet. In the illustration, each molecule is a ____________.
MAGNET	61. When the molecules are not aligned, the material is said to be unmagnetized.  A B Which illustration shows a material that is not magnetized? ______ The reason is (circle the letter beside the correct statement) a. the molecules are aligned. b. the molecules are not aligned.

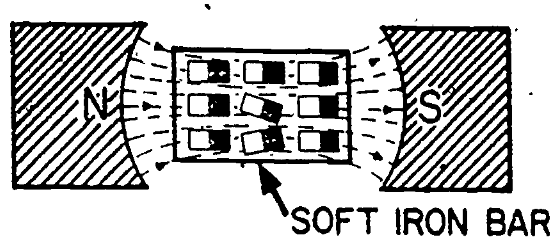
A

b.

62. There are three ways of aligning the molecules of a material and making it a magnet.

These are:

a. Stroking the material with a magnet.
b. Placing the material in a direct-current coil.
c. Placing the material in a magnetic field.



Which method is being used to align the molecules in the soft iron bar? ____

7

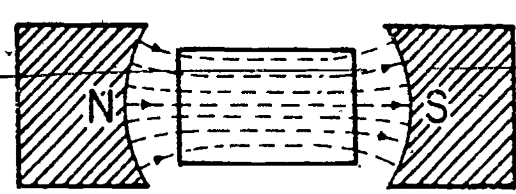
c.

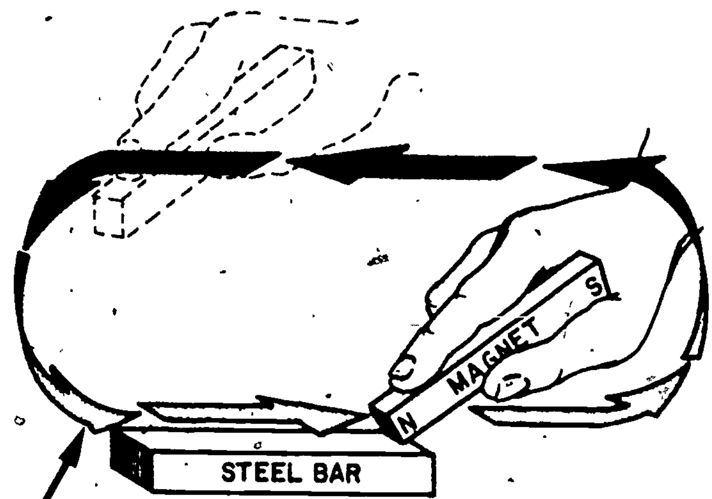
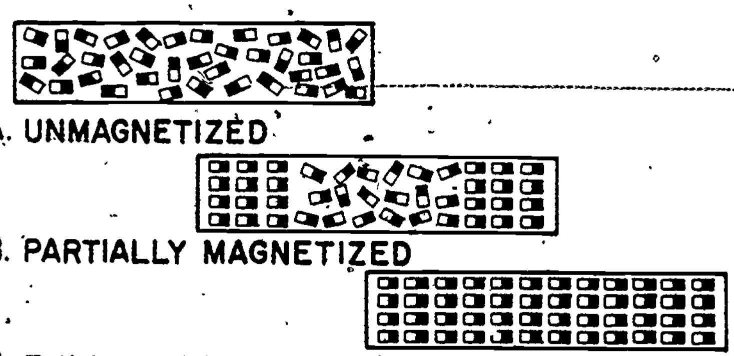
63. A material can be magnetized by a magnetic field. This causes the molecules to be aligned with their north poles in one direction and their south poles in the opposite direction. Magnetism is induced in a material when the molecules are caused to be aligned by a __________ __________.

MAGNETIC FIELD

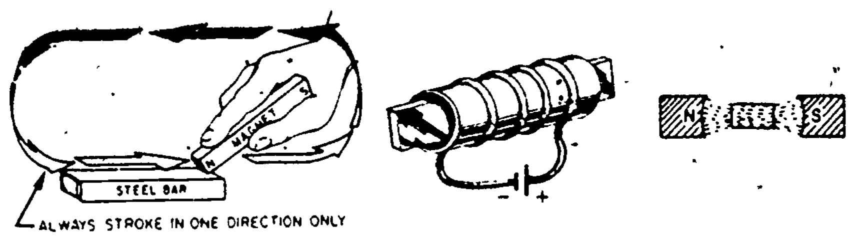
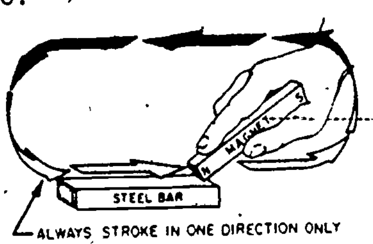
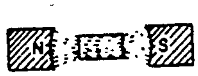
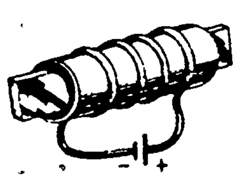
64. By placing a material in a magnetic field, we induce magnetism. This will align the molecules of the material.

Draw the arrangement of the molecules in the soft iron bar.



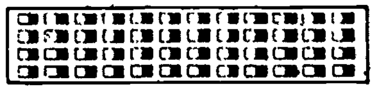
	65.  The method of aligning molecules by stroking is shown in the illustration. What does the illustration show that must be remembered when using this method? ______________________
ALWAYS STROKE IN ONE DIRECTION ONLY.	66.  Stroking a material in one direction with a magnet will align the molecules as in illustration C. During the stroking procedure, prior to reaching a saturated (fully magnetized) condition, the material will be in a ______________________ ______________________ condition.

11.16
lsn 5; p. 19

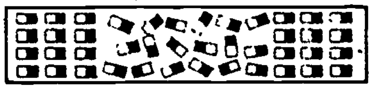
PARTIALLY MAGNETIZED	67. The best method of obtaining a saturated condition in a material is by placing the material in a coil carrying a direct current. Which illustration shows the best method of fully magnetizing a material? ______  A B C
B	68.  A. ____________________ ____________________  B. ____________________ ____________________  C. ____________________ ____________________ Label each illustration as to the method being used to magnetize the material.
A. STROKING WITH A MAGNET B. PLACING IN A MAGNETIC FIELD C. PLACING IN A COIL WITH DIRECT CURRENT	69. When a material is saturated, which means it has been fully magnetized by one of the three methods, all its molecules are aligned. A material, when fully magnetized, with all its molecules aligned is said to be ______________.

SATURATED

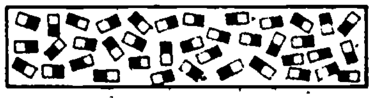
70\. A material when saturated is fully magnetized, and the strength of the magnet cannot be increased.



A. ____________________



B. ____________________



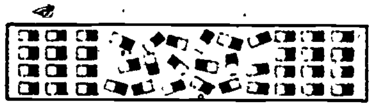
C. ____________________

Write the word saturated by the material that is fully magnetized.

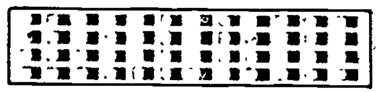
A. SATURATED

71\. A material that is unmagnetized has its molecules disarranged. As the material becomes partially magnetized, the molecules align themselves near the ends of the material, causing the magnetic poles to develop.

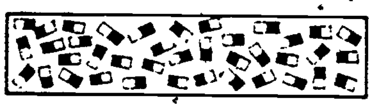
A



C



B



The material in illustration A is

____
(saturated/unmagnetized/partially magnetized)

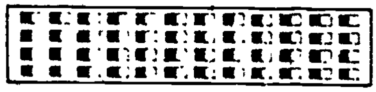
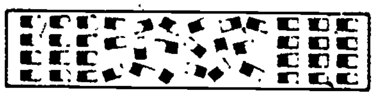
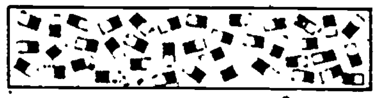
The material in illustration B is

____
(partially magnetized/unmagnetized/saturated)

The material in illustration C is

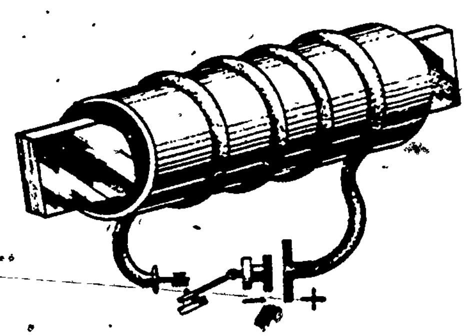
____
(unmagnetized/saturated/partially magnetized)

11.16
lsn 5; p. 21

A PARTIALLY MAGNETIZED B UNMAGNETIZED C SATURATED	72.  A. ______  B. ______  C. ______ Label the magnetic condition of the materials as being unmagnetized, partially magnetized, or saturated.
A. SATURATED B. PARTIALLY MAGNETIZED C. UNMAGNETIZED	73. What are three ways of producing a magnet? a. ______ b. ______ c. ______
a. STROKING WITH A MAGNET. b. PLACING IN A MAGNETIC FIELD. c. PLACING IN A COIL CARRYING A DIRECT CURRENT.	74. There are also three ways a magnet can be demagnetized. Since aligning the molecules of a material causes it to become magnetized, disarranging the alignment of the molecules would cause the material to become ______.
DEMAGNETIZED	75. Three ways a magnet can become demagnetized are: a. By dropping or jarring. b. By heating. c. By using a coil carrying alternating current. Which one of the three ways of demagnetization could result from careless handling? ______

a.	76. Instruments such as an ohmmeter or a voltmeter depend on a small magnet for their accurate operation. By dropping or jarring these instruments, their accuracy could be affected by the magnet becoming ________________.
DEMAGNETIZED	77. When a magnet is exposed to extreme heat, such as a welding torch flame, the magnet will become ______________.
DEMAGNETIZED	78. Heating will demagnetize a material but may destroy the desired properties of that material. The best way to demagnetize material intentionally is to use a coil carrying alternating current. To demagnetize purposely a material, the best way would be to ____ ____.
USE A COIL CARRYING ALTERNATING CURRENT	79. Three ways a material may be demagnetized are: a. Dropping or jarring. b. Heating. c. Using a coil carrying alternating current. Which of these is the most desirable? _____
c.	80. Residual magnetism is the magnetism that remains after the magnetizing force is removed. A soft iron bar, when removed from a magnet, will attract iron fillings for a short period of time because it contains ____________ magnetism.
RESIDUAL	81. The magnetism remaining in a material after the magnetizing force is removed is called ________ ______________.
RESIDUAL MAGNETISM	82. Some materials retain their magnetism longer than others. Retentivity is the ability of a material to retain its ____________.

MAGNETISM	83. A mixture of ALuminum, NIckel, and CObalt, known as ALNICO, has a high retentivity. The reason is (circle the letter of the correct response) a. it remains magnetized for long periods of time. b. it loses its magnetism easily. c. it does not demagnetize with heat. d. it is not affected by a magnet.
a.	84. The ability of a material to retain its magnetism is ______________.
RETENTIVITY	85. A material that remains magnetized for a long period of time has ________ (high/low) retentivity; however, a material that remains magnetized for a short period of time has ________ (high/low) retentivity.
HIGH LOW	86. Another property of a material is permeability-- the ability of a material to permit or oppose the passage of lines of flux. A material with low retentivity has high permeability. Alnico, nipper mag, and hardened steel have ________ (high/low) retentivity; therefore, they would have ________ (high/low) permeability.
HIGH LOW	87. A material that allows the easy passage of lines of flux has high permeability; however, the material would have ________ (high/low) retentivity.
LOW	88. A magnetic material that does not allow the easy passage of the lines of flux has low permeability, but when magnetized, will retain its magnetism for a ________ period of time.

LONG	89. If we wanted to produce a permanent magnet, we would select a magnetic material with a ________ (high/low) permeability and a ________ (high/low) retentivity.
LOW HIGH	90. Alnico, nipper mag, and hardened steel have high retentivity and low permeability. These materials are used to make ________ magnets.
PERMANENT	91. Which of these metals would be used to make permanent magnets? Place the letter P in the blank beside the metals which would be used to make permanent magnets. a. ______ Permalloy d. ______ Mumetal b. ______ Alnico e. ______ Hardened steel c. ______ Soft iron f. ______ Nipper mag
b. e. f.	92. Where magnetism is required constantly, as in a magneto, a permanent magnet is used. When magnetism is to be used temporarily or turned on and off, like the magnet used in loading scrap iron into railroad cars, the magnet used is a ________ magnet.
TEMPORARY	93. Materials used to make temporary magnets must lose their magnetism quickly. Soft iron and Mumetal make good temporary magnets because of their ________ (high/low) retentivity.
LOW	94.  In the illustration above, the core becomes a temporary magnet when current is flowing through the coil. When the current stops, because the core has low retentivity, it loses its ________.

11.16
lsn 5; p. 25

MAGNETISM	95. Metals such as permalloy, soft iron, and Mumetal are known for their properties of high permeability and low retentivity. Because of these properties, they are used as ______________ magnets.
TEMPORARY	96. The desired properties of metals used to make good temporary magnets are ________ (high/low) permeability and ________ (high/low) retentivity.
HIGH LOW	97. Place the letter P by the metals that are used to make permanent magnets. Place the letter T by the metals that are used to make temporary magnets. a. ______ Permalloy d. ______ Mumetal b. ______ Alnico e. ______ Hardened steel c. ______ Soft iron f. ______ Nipper mag
a. T b. P c. T d. T e. P f. P	

FUNDAMENTALS OF ELECTRICITY

LESSON 5

PART A

MAGNETISM

SELF-TEST

1. Below is a list of statements about magnets. In the blank beside each statement, place the letter N if the statement pertains to a natural magnet or place the letter A if the statement pertains to an artificial magnet.

   a. A magnet produced by man ________

   b. It is also called magnetite. ________

   c. The most practical magnet ________

   d. It is sometimes called lodestone. ________

   e. The magnet with least practical use ________

   f. Has the greater application. ________

2. Label these materials as being either magnetic or nonmagnetic.

   a. Brass ________________

   b. Iron ________________

   c. Aluminum ________________

   d. Alnico ________________

   e. Magnesium ________________

   f. Permalloy ________________

   g. Copper ________________

   h. Cobalt ________________

3. Below are some true and false statements about magnetic lines of flux. Circle the letter beside the true statements.

   a. Lines of flux <u>cannot</u> be shielded.

   b. Lines of flux never cross each other.

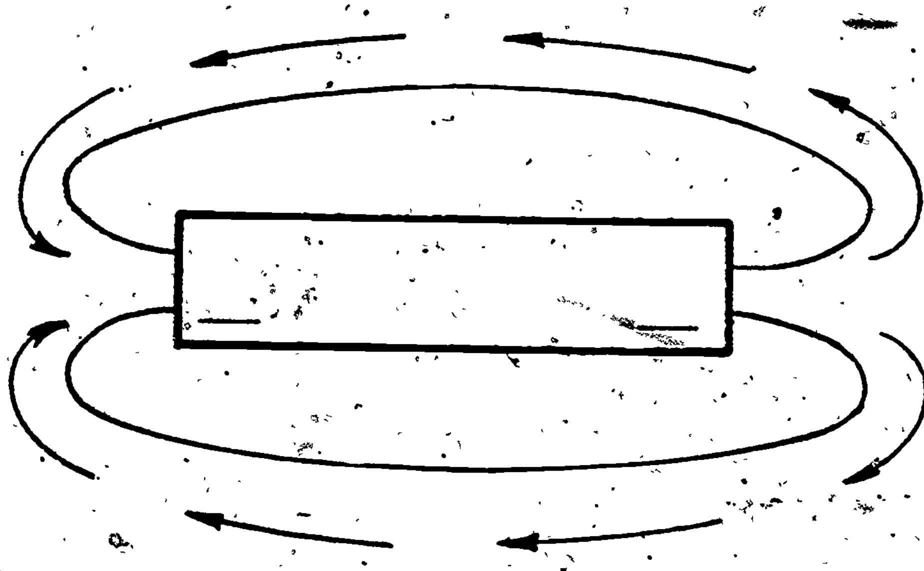
   c. Lines of flux create a magnetic field.

   d. Lines of flux can be insulated.

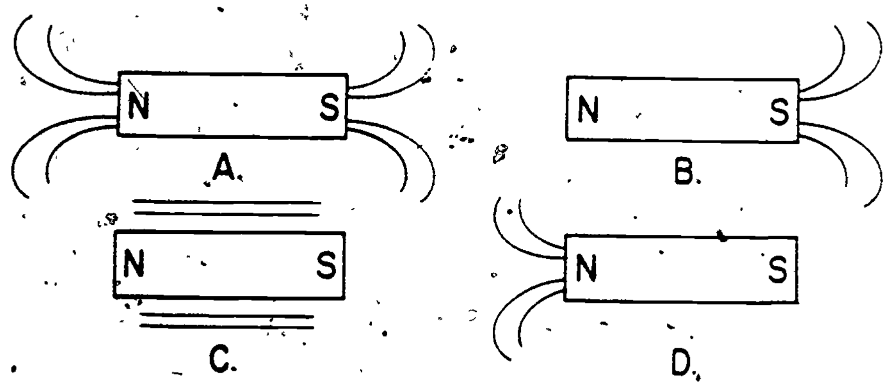
   e. Lines of flux travel outside the magnet from north to south.

   f. Lines of flux are affected by nonmagnetic materials.

4. Label the poles of this magnet.



5. Which illustration correctly shows the concentration of flux lines?

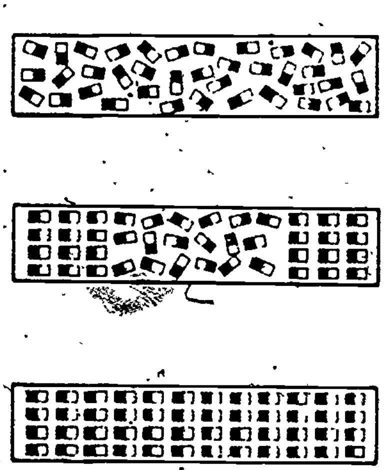


6. State the laws of polarity.

a. ______________________________

b. ______________________________

7. Label the materials below as being unmagnetized, partially magnetized, or saturated.



11.16
lsn 5; p. 29

8. Match the terms in column A with their correct definition in column B. Place the letter beside the term in the space provided beside its definition.

A		B
a. Residual magnetism	_____	(1) The property of nonmagnetic materials to have no effect on lines of flux.
b. Retentivity	_____	(2) Magnetism that remains after the magnetizing force has been removed.
c. Permeability	_____	(3) The ability of a material to permit or oppose the passage of lines of flux.
d. Transparency	_____	(4) The ability of a material to remain magnetized.
e. Saturated	_____	(5) Magnetism produced in a material by a magnetic field.
f. Induced magnetism	_____	(6) The condition of material that is fully magnetized.
g. Magnetism	_____	(7) Has the ability to attract magnetic materials.

9. What are three ways of magnetizing an iron bar?

a. ______________________________

b. ______________________________

c. ______________________________

10. The required properties of metals used to make good permanent magnets are ________ permeability and ________ retentivity.

11. The required properties of metals used to make good temporary magnets are ________ permeability and ________ retentivity.

12. State whether the metals below are used to make temporary magnets or permanent magnets. Write temporary or permanent in the space provided.

a. Permalloy ________________

b. Alnico ________________

c. Soft iron ________________

d. Mumetal ________________

e. Hardened steel ________________

f. Nipper mag ________________

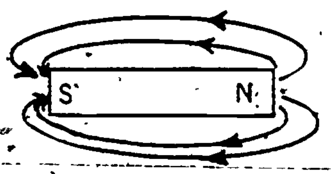
11.16
lsn 5; p. 31

LESSON 5, PART A
MAGNETISM-SELF TEST ANSWERS

1. (a) A
   (b) N
   (c) A
   (d) N
   (e) N
   (f) A

2. (a) N
   (b) M
   (c) N
   (d) M
   (e) N
   (f) M
   (g) N
   (h) M

3. b, c, e.

4. 

5. A

6. (a) Like poles repel
   (b) Unlike poles attract

7. Unmagnetized
   Partially magnetized
   Saturated

8. d (1)
   a (2)
   c (3)
   b (4)
   f (5)
   e (6)
   g (7)

9. (a) Stroking with a magnet
   (b) Placing in a magnetic field
   (c) Placing in a coil carrying a direct current

10. low
    high

11. high
    low

12. (a) T
    (b) P
    (c) T
    (d) T
    (e) P
    (f) P

GO RIGHT ON TO LESSON 5, PART B - ELECTROMAGNETISM AND ELECTROMAGNETIC INDUCTION

FUNDAMENTALS OF ELECTRICITY

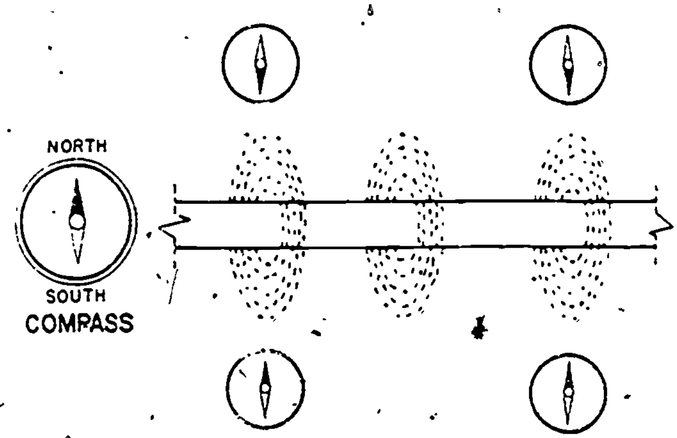
LESSON 5

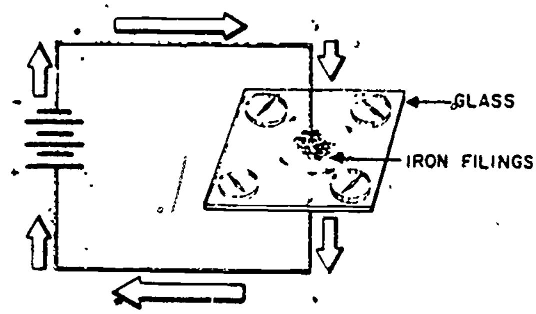
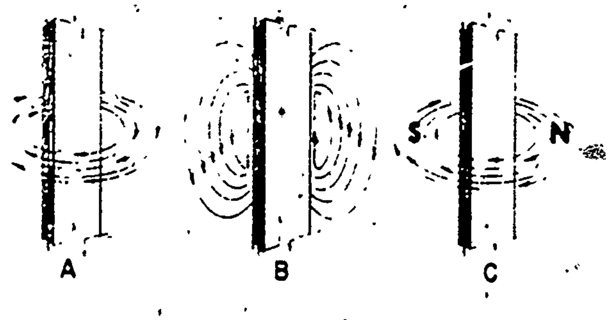
PART B

ELECTROMAGNETISM AND ELECTROMAGNETIC INDUCTION

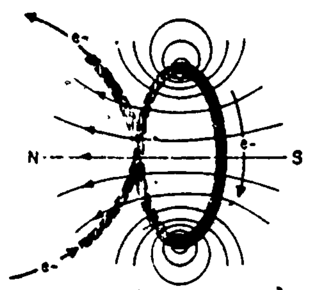
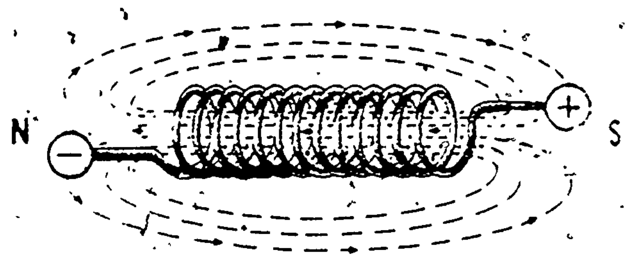
OBJECTIVES

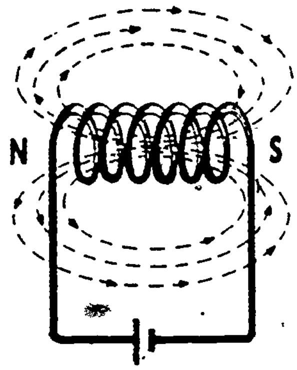
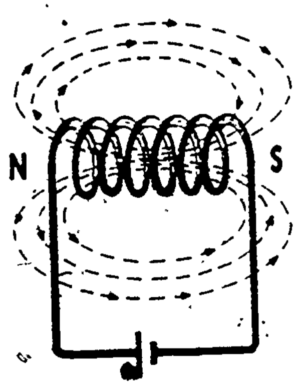
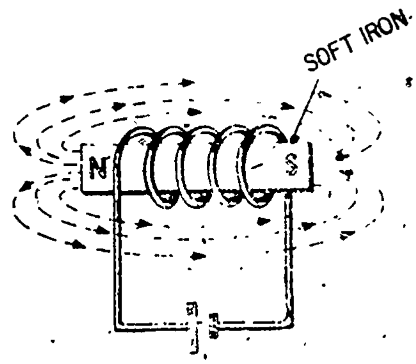
1. Given three illustrations of straight conductors carrying current and three statements describing the illustrations, match the true statement with the correct illustration.
2. Given the terms core, solenoid, relay switch, and electromagnet, and a list of their definitions, match each term to its definition.
3. Given an illustration of a solenoid and an electromagnet, label each illustration as being either a solenoid or an electromagnet.
4. List the three factors that affect the strength of an electromagnet.
5. Given illustrations of two types of relay switches, label them as being either the solenoid and plunger type or the armature type.
6. Define electromagnetic induction.
7. Given illustrations and statements pertaining to induced EMF, match each statement to its correct illustration.
8. List the three requirements for induced EMF.
9. Select, from a list of statements pertaining to lines of flux, the factor(s) that determine(s) the number of flux lines cut per second.
10. Given three illustrations of electrical circuits, select the one having the requirements needed for induced current.
11. Given an illustration of an induction coil, label the components of the coil as being the primary coil, the secondary coil, the interrupter or the core.
12. Given a list of statements about induction coils, select the true statements.
13. Given an illustration of an induction coil and its circuitry, state in your own words how the low input voltage is changed to a high output voltage.
14. Given a list of statements about transformers and induction coils, state whether each statement pertains to transformers, induction coils, or both.

	1. A compass, when near a magnet, is affected by the magnet's magnetic field. A compass is also affected when it is near a straight conductor carrying current. This indicates that a conductor carrying current has a ______________ ____________.
MAGNETIC FIELD	2. The fact that a conductor carrying current is surrounded by a magnetic field may be proved by using a compass. Move the compass around the wire. At any place along the conductor, the needle will be deflected.  As long as current is flowing, the needle of the compass will be deflected at any point along the conductor because of the presence of the ______________ ____________.
MAGNETIC FIELD	3. As shown in the previous frame, the magnetic field ______________ (runs parallel/circles) the straight conductor when ______________ is flowing.

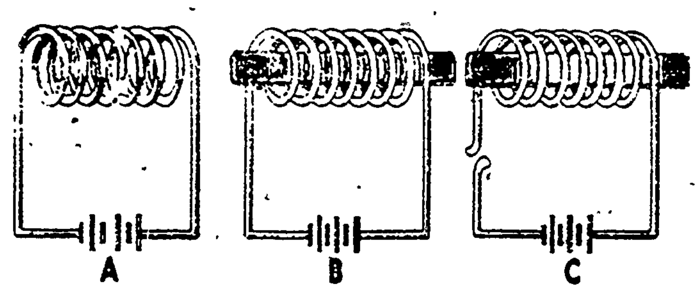
CIRCLES CURRENT	4. The magnetic field around the conductor may be illustrated like this.  The magnetic field about the conductor is in the shape of a ____________.
CIRCLE	5. Although a magnetic field surrounds a current-carrying conductor and will affect a compass, it does not have polarity. This means a. it does not have a north and south pole. b. it does have a north and south pole. c. it has a north pole only. d. it has a south pole only.
a.	6. Which illustration correctly shows the magnetic field about a straight conductor? 

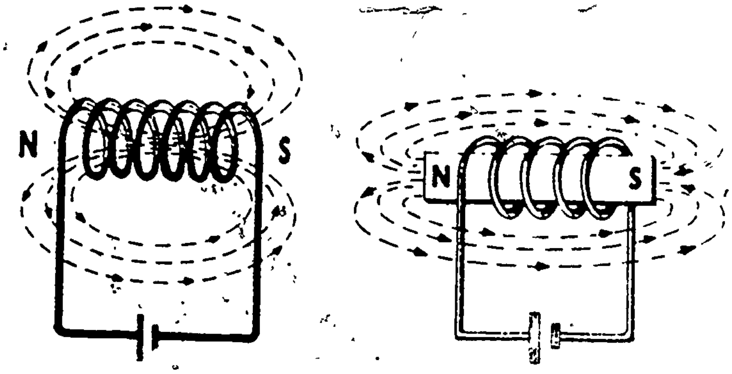
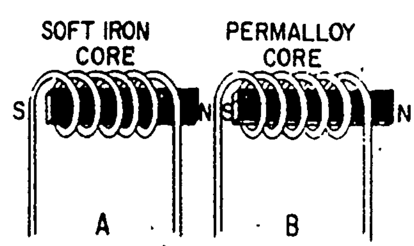
11.16
lsn 5; p. 35

A	7.  The illustration shows that when a loop is formed in a straight conductor, the lines of flux enter at one side of the loop and exit at the other side. This results in a _________ and _________ pole.
NORTH SOUTH (ANY ORDER)	8. Although the loop does have polarity, it has little magnetic strength. If several loops were made in the conductor and a coil were formed, the lines of flux for each loop would join, and the coil would have a greater _____________ _____________.
MAGNETIC STRENGTH	9.  Look at the illustration above. When current flows, the lines of flux join, travel through the center of the coil (core), and form a weak _____________.

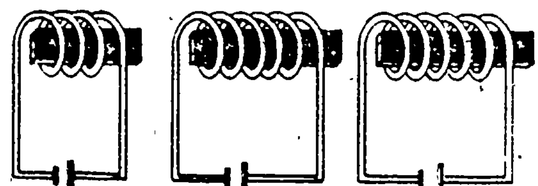
MAGNET	10. Although the coil has greater magnetic strength than the single loop, it's still a weak magnet because its center area or core is composed of air.  Solenoid (current-carrying coil with air core). The center area of the ~~solenoid~~ is known as the ________.
CORE	11. A current-carrying coil with an air core is a ________________.
SOLENOID	12.  A  B Which of the illustrations shows a solenoid? ____

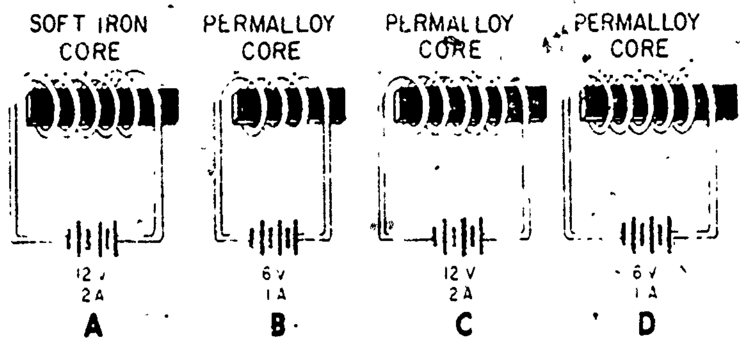
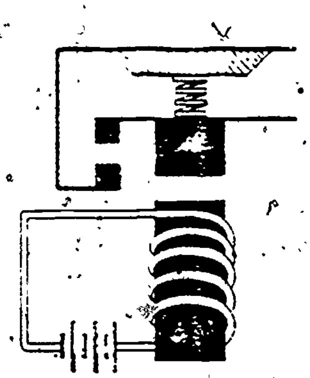
11:16
lsn 5; p. 37

A	13. The lines of flux traveling through the air core of the solenoid are opposed by the air. A core of magnetic material placed in the air space will concentrate and offer an easier path for the ____________ of ____________.
LINES OF FLUX	14. Air, with a low permeability, is an inefficient core. Soft iron is a more efficient core because it has ________ permeability. (high/low)
HIGH	15. The most efficient core is one of ____________ (high/low) ____________________.
HIGH PERMEABILITY	16. A core material of high permeability becomes a temporary magnet when current is flowing.  Which illustration represents the strongest temporary magnet? ______
B	17. When the coil has a core of a magnetic material, it is known as an electromagnet. The difference between a solenoid and an electromagnet is in the substance used for the ________.
CORE	18. The magnetism produced in the soft iron core by the electric current is called electromagnetism. The temporary magnet, a coil with a magnetic core, is called an ________________________.

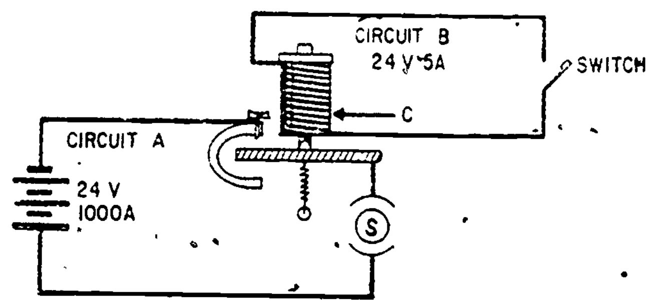
ELECTROMAGNET	19. A coil with an air core is a ____________. An electromagnet has a core of ____________.
SOLENOID SOFT IRON (MAGNETIC MATERIAL)	20. Label the illustrations as representing either a solenoid or an electromagnet.  A. ____________ B. ____________.
A. SOLENOID B. ELECTRO-MAGNET	21. Electromagnets have many uses. They can be very small, such as the ones used by doctors to remove metal splinters from a patient's eyes; or they can be very large and capable of lifting tons of metal. Because of these varied uses, it is necessary to have some means of changing the strength of an ____________.
ELECTROMAGNET	22. The strength of an electromagnet is determined by three factors. One of these factors is the type of material used in the core. An electromagnet with a core of low permeability would not be as strong as an electromagnet with a core of ________ permeability.
HIGH	23. Permalloy has a higher permeability than soft iron. Which electromagnet is stronger? ________ 

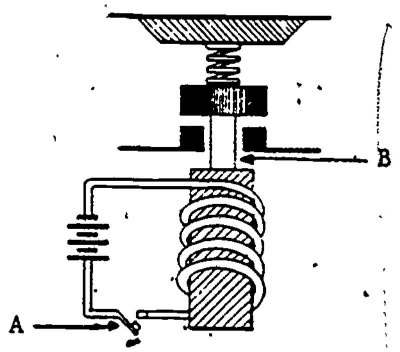
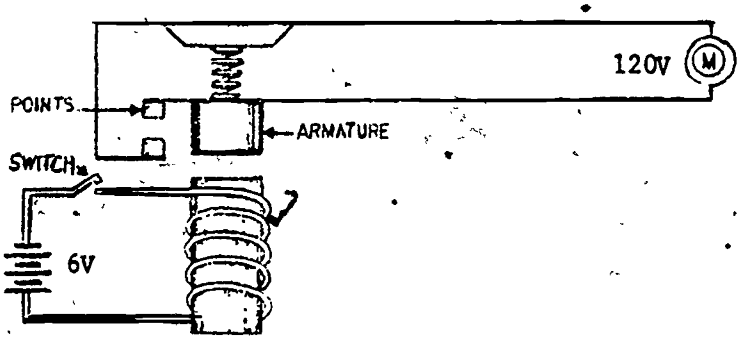
11.16
lsn 5; p. 39

B	24. Another factor that determines the strength of an electromagnet is the number of turns or loops in the conductor-- the more loops or turns, the greater its strength.  Which electromagnet is the weakest? ______ Which electromagnet is the strongest? ______
A WEAKEST B STRONGEST	25. Two of the factors that determine the strength of an electromagnet are: a. ______________________ b. ______________________
a. TYPE OF CORE MATERIAL b. NUMBER OF LOOPS OR TURNS OF THE COIL	26. The third factor that will affect the strength of the electromagnet is the amount of current. The greater the current, the __________ the electromagnet's strength.
GREATER	27. The three factors that affect the strength of an electromagnet are the type of core material, the number of loops or turns of the coil, and the ______________________.

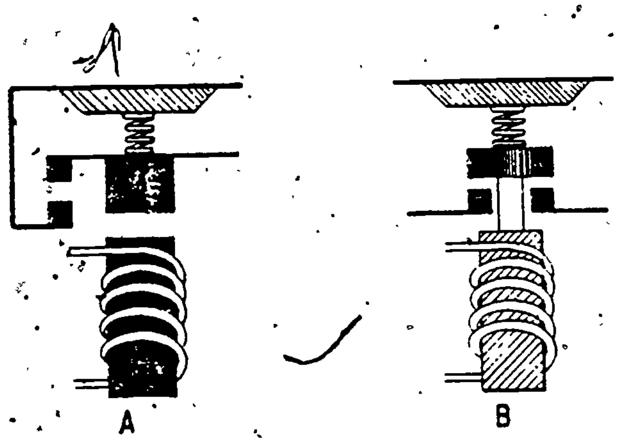
AMOUNT OF CURRENT	28.  a. Which electromagnet is stronger, A or C? ____ Why? ____________ b. Which electromagnet is stronger, B or D? ____ Why? ____________ c. Which electromagnet is weaker, D or C? ____ Why? ____________
a. C BECAUSE OF TYPE OF CORE MATERIAL USED. b. D NUMBER OF TURNS OR LOOPS IS GREATER. c. D HAS LESS CURRENT.	29. The three factors that affect the strength of an electromagnet are: a. ____________ b. ____________ c. ____________
a. TYPE OF CORE MATERIAL b. THE NUMBER OF TURNS OR LOOPS OF THE COIL c. AMOUNT OF CURRENT	30. This is an illustration of a simple relay switch. The illustration shows a common use for an ____________. 

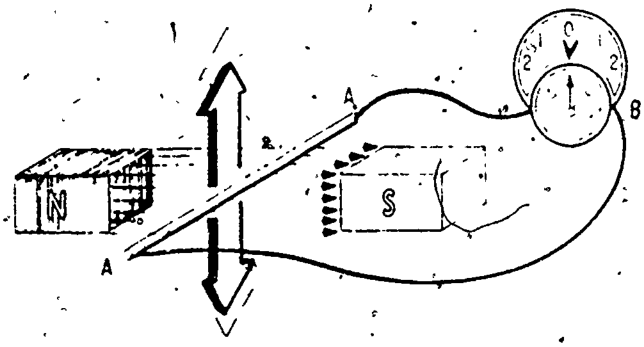
11/16
lsn 5; p. 41

ELECTROMAGNET	31. One of the main uses of electromagnets is in relay switches. The magnetism used to actuate a relay switch is obtained by using an ____________.
ELECTROMAGNET	32. A relay switch is a device used to control remotely an electrical circuit. By using a relay switch, a small amount of current can be used to control a circuit with a large amount of current.  In the illustration above, high amperage is needed for the starter operation. Device C allows circuit B to control circuit A. Device C is a ____________ ____________.
RELAY SWITCH	33. A remote-control device used to control electrical circuits is a ____________ ____________.
RELAY SWITCH	34. There are two basic types of relay switches. The method by which electromagnetism is used to actuate the contact points will identify each type of ____________ ____________.

RELAY SWITCH	35. One type of relay switch is the solenoid and plunger. It has a solenoid with a movable plunger held partially out of the coil. When current flows, the plunger is drawn into the solenoid by the attraction of the magnetism.  Look at the illustration above. When switch A is closed, in which direction will the plunger, B, move? ________
DOWN	36. The type of relay switch in which the plunger is free to move is the ____________ and ____________ type.
SOLENOID AND PLUNGER	37. The second type of relay switch is the armature. The coil of insulated wire is wrapped around the core. The core is not movable; and when current flows, the core becomes magnetized and attracts the armature.  Refer to the illustration above. When the switch is closed, current flows to the coil. The armature moves ________ (up/down) and the points will ________ (close/open).

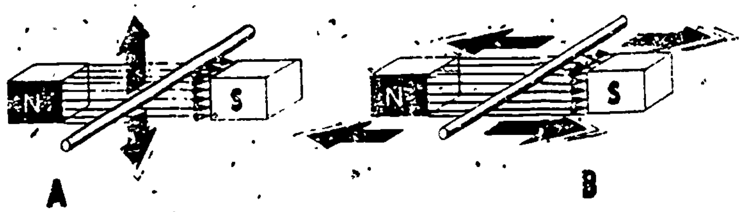
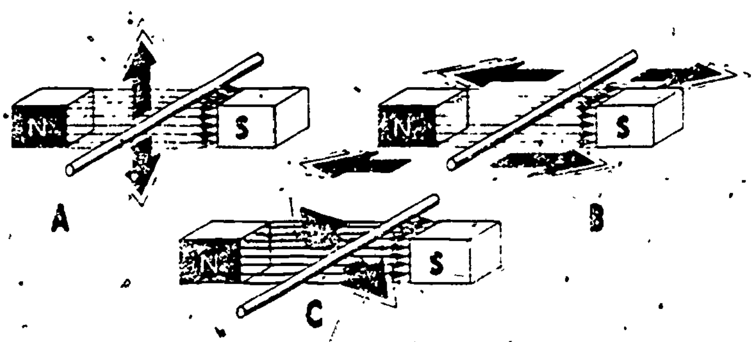
11.16
lsn 5; p. 43

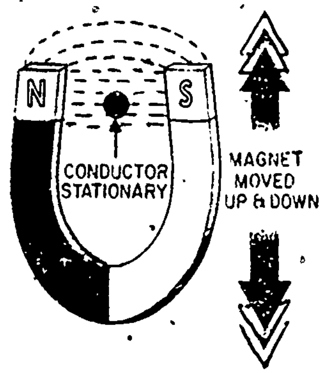
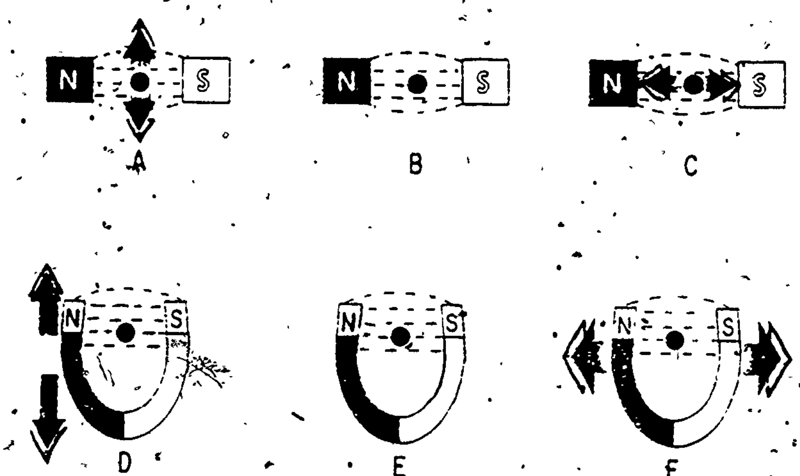
DOWN CLOSE	38. The relay switch with a fixed core is the ____________ type.
ARMATURE	39. The two types of relay switches are: a. ____________ b. ____________
a. SOLENOID AND PLUNGER b. ARMATURE (ANY ORDER)	40.  Illustration A shows an ____________ type of relay switch. Illustration B shows a ____________ and ____________ type of relay switch.

A ARMATURE B SOLENOID AND PLUNGER	41. We have seen how electricity can be used to produce magnetism. This is called electromagnetism. We can do the opposite and use magnetism to produce electricity. To do this, the flux lines must be cut by a conductor through relative motion. This is called electromagnetic induction.  When conductor A is moved rapidly up and down across the magnetic field, meter B will show that electricity is being produced. This action is known as ______ ______.
ELECTROMAGNETIC INDUCTION	42. Electromagnetic induction is the action involved in producing electricity by the use of a ______ field, a ______, and relative ______ between them.
MAGNETIC CONDUCTOR MOTION	43. Producing electricity by using a magnetic field, a conductor, and relative motion is called ______ ______.
ELECTROMAGNETIC INDUCTION	44. Electromagnetic induction is producing electricity by using a ______ ______, a ______, and ______ ______ between them.

11.16
lsn 5; p. 45

285

MAGNETIC FIELD CONDUCTOR RELATIVE MOTION	45. What is electromagnetic induction? ______________________________ ______________________________ ______________________________ ______________________________
ELECTROMAGNETIC INDUCTION IS PRODUCING ELECTRICITY BY THE USE OF A MAGNETIC FIELD, A CONDUCTOR, AND RELATIVE MOTION BETWEEN THEM.	46. An EMF (electromotive force) is induced in the conductor when the relative motion between the conductor and the lines of flux causes the flux lines to be cut. With the conductor moving parallel to the lines of flux, no flux lines are cut and an induced EMF ____________ occur. (will/will not)
WILL NOT	47. In which illustration will induced EMF <u>not</u> be produced in the conductor? ______ 
B	48. An EMF is <u>not</u> produced when the flux lines are <u>not</u> cut by the conductor. For induced EMF, the conductor must move so the ________ ________ are cut.
FLUX LINES	49. To obtain induced EMF in the conductor, the best method to follow is to cut the flux lines at right angles (perpendicular).  Which illustration shows the most efficient method of producing an induced EMF in the conductor? ____

A	50. Relative motion is the motion of the conductor or the magnetic field; that is, the conductor can be moved to cut the flux lines of the magnetic field, or the magnetic field can be moved so that flux lines are cut by the ______.
CONDUCTOR	51. What will result from the action shown in the illustration?  ______ ______ ______
INDUCED EMF IS PRODUCED WHEN A MAGNETIC FIELD MOVES ACROSS THE CONDUCTOR.	52. To have induced EMF, there are three requirements: a magnetic field, a conductor, and relative motion between them. When flux lines are cut by the relative motion between a magnetic field and a conductor, there will be an ______ EMF in the conductor.
INDUCED	53. Which illustrations indicate that EMF will be induced in the conductor? ______ 

<table>
<tr>
<td>A

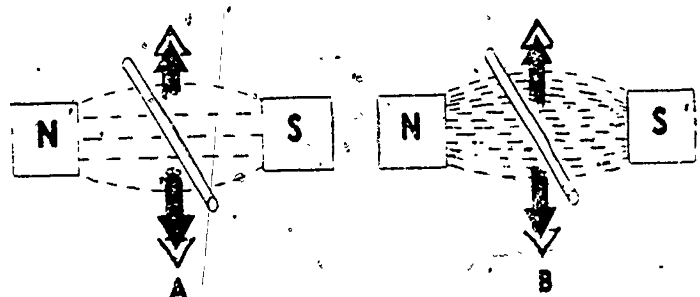
D</td>
<td>54. What are the three requirements for induced EMF?

a. ________________
b. ________________
c. ________________</td>
</tr>
<tr>
<td>a. CONDUCTOR
b. MAGNETIC FIELD
c. RELATIVE MOTION</td>
<td>55. The strength of induced EMF is dependent on the number of flux lines cut per second. When the number of flux lines cut per second is increased, the strength of induced EMF will ________.</td>
</tr>
<tr>
<td>INCREASE</td>
<td>56. There are three factors that will affect the number of flux lines cut per second. One of the three factors is the flux density (number of flux lines per unit area).

Which illustration shows the stronger induced EMF?

______

Why? ________________

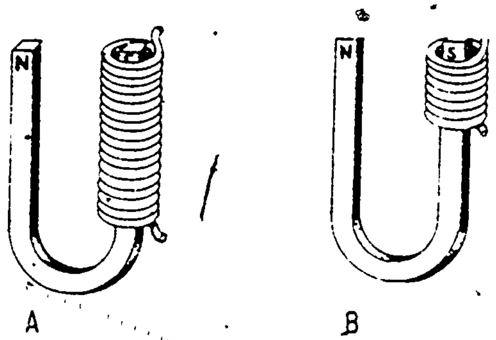


</td>
</tr>
<tr>
<td>B

HAS A GREATER FLUX DENSITY.</td>
<td>57. When the magnet used in a magneto loses part of its strength, the EMF it produces will decrease.

Why does this happen?

____
____
________________</td>
</tr>
</table>

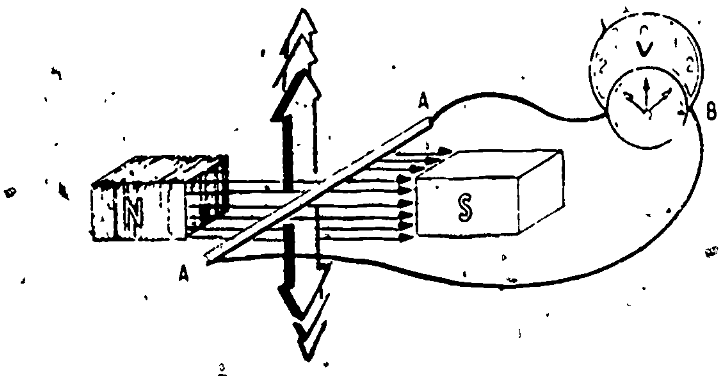
THERE IS A DECREASE IN FLUX DENSITY (NUMBER OF FLUX LINES).	58. The second factor which will affect the number of flux lines cut per second is the number of turns or loops of the conductor. The device in illustration A is capable of producing twice the amount of induced EMF as the device in illustration B. Why? ______________________ ______________________ ______________________ 
THE COIL (CONDUCTOR) IN ILLUSTRATION A HAS TWICE THE AMOUNT OF LOOPS OR TURNS AS THE COIL IN ILLUSTRATION B.	59. Two factors which affect the number of flux lines cut per second are the flux density and the number of loops or __________ of the __________.
TURNS CONDUCTOR (COIL)	60. How can induced EMF be increased without increasing flux density? ______________________ ______________________

11.16
lsn 5; p 49

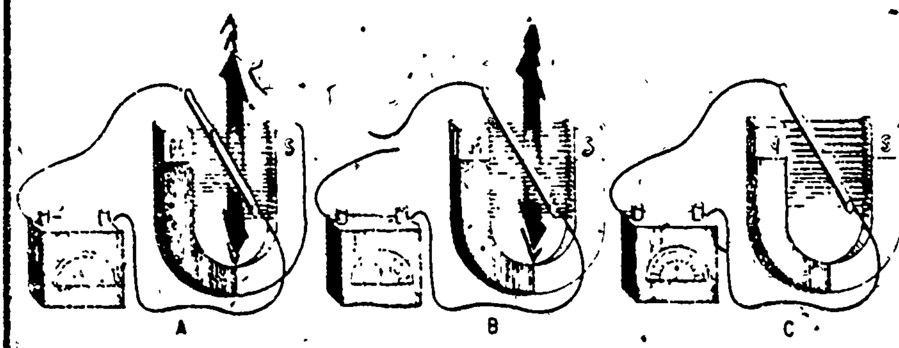
INCREASE THE NUMBER OF TURNS OF THE CONDUCTOR (COIL).	61. Induced EMF is dependent on the number of flux lines cut per second. If one hundred million flux lines are cut in one second, an induced EMF of one volt is produced; but if two hundred million flux lines are cut in one second, an induced EMF of two volts is produced. Other than flux density and number of turns of the conductor, what is the third factor that affects the number of flux lines cut per second? ________________________________
RATE OF SPEED OF CUTTING THE FLUX LINES.	62. The strength of induced EMF is dependent on three factors. They are: a. ____________________________ b. ____________________________ c. ____________________________
FLUX DENSITY NUMBER OF TURNS OF THE CONDUCTOR (COIL) RATE OF SPEED (ANY ORDER)	63. When a conductor is moved through a magnetic field, an EMF is induced; however, there is no induced current (electron flow) unless there is a closed path or circuit. To have induced current, there must be a closed ______________.
CIRCUIT	64. Up to this point, we have only discussed how an EMF is induced. Using this induced EMF, we can get an induced current. You must realize there is a difference between <u>induced EMF</u> and <u>induced current</u>. An induced EMF is potential energy. When the circuit is closed, this potential energy causes electron flow in the circuit, and this electron flow is known as ____________ ____________.
INDUCED CURRENT	65. To have an induced current, two conditions must be met. There must be an ____________, ________ and a ____________________________

29t

INDUCED EMF CLOSED CIRCUIT	66.



When a conductor is moved, cutting the flux lines, an induced EMF is set up in the conductor; and as long as the circuit is closed, an induced current flows, as indicated by the meter.



a. Illustration A will have

(1) induced EMF.
(2) induced current.
(3) both.
(4) neither.

b. Illustration B will have

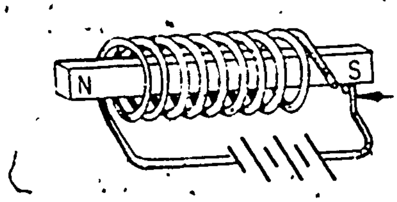
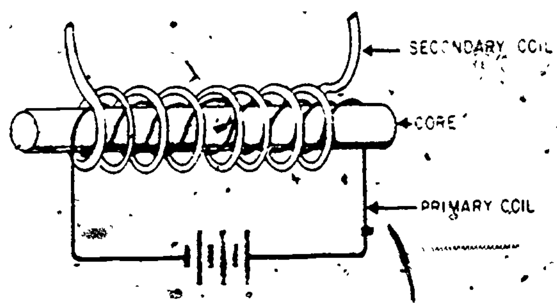
(1) induced EMF.
(2) induced current.
(3) both.
(4) neither.

c. Illustration C will have

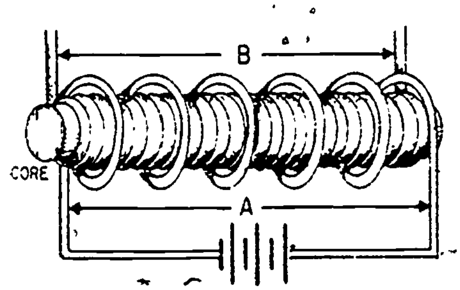
(1) induced EMF.
(2) induced current.
(3) both.
(4) neither.

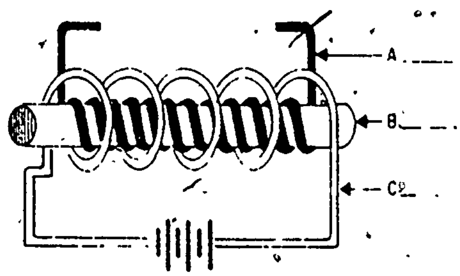
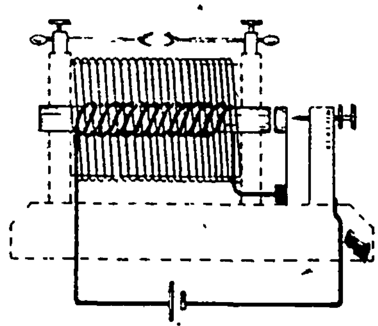
11.16
lsn 5; p. 51

a. (3) b. (1) c. (4)	67. According to Ohm's law, when the voltage (EMF) of a circuit changes (increases or decreases), the current changes in the same direction (increases or decreases). Therefore, the three factors which affect induced EMF will also affect ______ ______.
INDUCED CURRENT	68. A generator in which all three factors are incorporated will produce any desired voltage. However, weight, space, or a system which requires different voltages will limit the design. The electrical system of a car is an example. The lights require only a low voltage; whereas, for the ignition system, the EMF must be greatly increased. This increase in EMF is accomplished by using an <u>induction coil</u> which will greatly ______ EMF.
INCREASE	69. When it is necessary to increase a low source voltage (EMF) to a higher output voltage, the device used to cause the increase is an ______ coil.
INDUCTION	70. The higher induced EMF of the induction coil is caused by a moving magnetic field which is being cut by conductors. The relative motion between the conductors and the magnetic field of an induction coil is obtained by using a moving ______ ______.
MAGNETIC FIELD	71. The moving magnetic field of the induction coil is obtained by using a coiled conductor with a pulsating direct current (P.D.C.). This pulsating direct current is produced by using an interrupter switch. Because the type of direct current used in the induction coil is periodically interrupted, it is called a ______ ______ ______.
PULSATING DIRECT CURRENT	72. A <u>pulsating direct current</u> flowing through a coiled conductor produces a ______ magnetic ______.

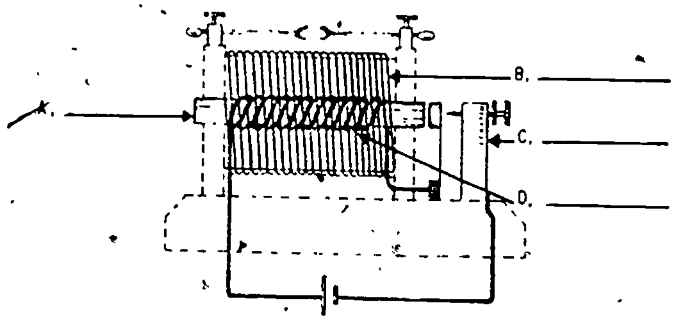
MOVING FIELD	73.  If the switch (interrupter) at point A were opened and closed rapidly, the magnetic field would build up and collapse. This produces a moving ________ ________.
MAGNETIC FIELD	74. An induction coil is made up of a primary coil and a secondary coil. The primary coil receives the low input P.D.C. The other coil, which is the output coil, produces the high induced EMF and is called the ________ ________.
SECONDARY COIL	75. In the basic design of an induction coil, two coils are used; these coils are the ________ coil and the ________ coil.
PRIMARY SECONDARY	76.  Although the primary coil and the secondary coil are separate coils, the illustration above shows they are both wound on a common ________.

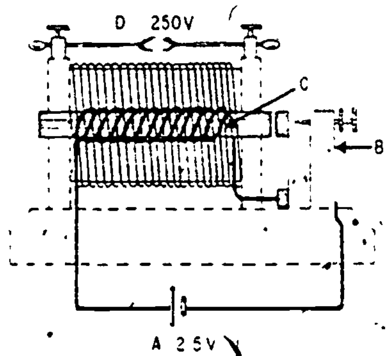
11.16
lsn 5; p. 53

CORE	77. Insulation is used to prevent an electrical connection between the two conductors. An induction coil does not have an electrical connection between the primary coil and the secondary coil, since the primary coil is ________________ from the secondary coil.
INSULATED	78. Each turn or loop of the coil is insulated to prevent an electrical connection between turns. To prevent an electrical connection between the coils, the primary coil and secondary coil are ________________ from each other.
INSULATED	79. In a basic induction coil, the primary coil and the secondary coil are both wound on the same core. To protect the primary coil and secondary coil from having an electrical connection, they must be ________________ from each other.
INSULATED	80. In an induction coil, the primary coil and the secondary coil are both wound on the same core. The primary coil always has fewer turns than the secondary coil.  In the illustration, A is the ________________ (primary/secondary) coil and has __________ (more/less) turns than B.

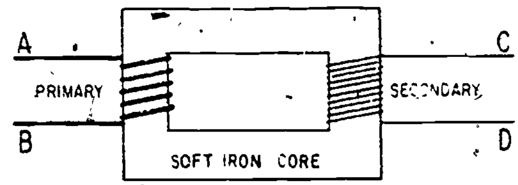
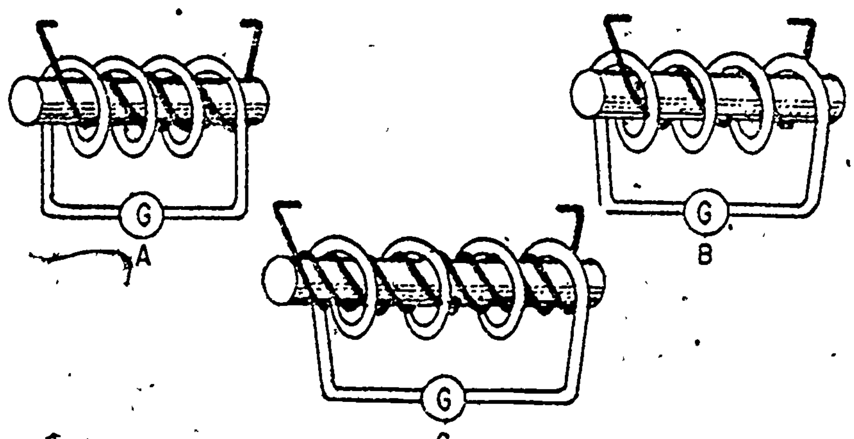
PRIMARY LESS	81. In an induction coil, the coil that always has the greater number of turns is the ______________ coil.
SECONDARY	82. Label the primary coil, the secondary coil, and the core. 
A. SECONDARY B. CORE C. PRIMARY	83.  In the illustration, which coil is receiving the low input voltage? ______________ (primary/secondary)
PRIMARY	84. In an induction coil, the low input voltage is always received by the ______________ coil.

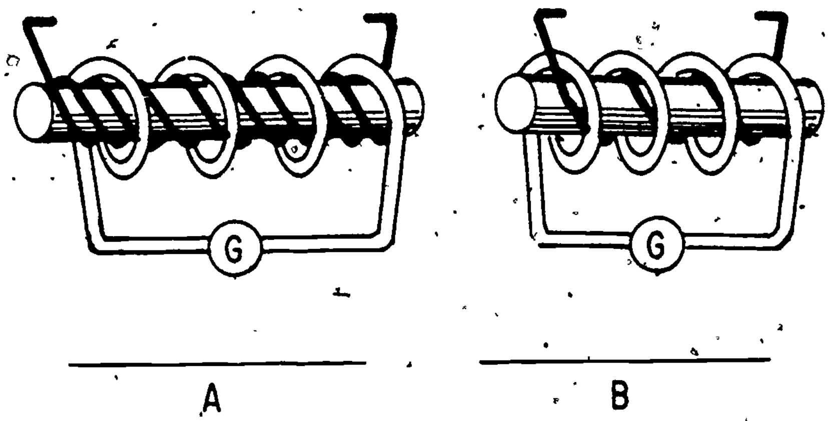
11.16
lsn 5; p. 55

PRIMARY	85. The source voltage for an induction coil is direct current which is changed to pulsating direct current by an <u>interrupter</u> switch. Label the interrupter switch, primary coil, secondary coil, and core. 
A. CORE B. SECONDARY COIL C. INTERRUPTER SWITCH D. PRIMARY COIL	86. The P.D.C. in the primary coil causes a moving magnetic field. This moving magnetic field will be cut by the larger number of turns of the ______ coil.
SECONDARY	87. The purpose of an induction coil is to ______ (decrease/increase) EMF. The increased EMF is induced in the coil that has the greatest number of turns. This is the ______ coil.
INCREASE SECONDARY	88. The secondary coil cuts the moving magnetic field and induces EMF. This induced electromotive force in the secondary coil is increased because the secondary coil has a ______ (greater/lesser) number of turns than the primary coil.

GREATER	89. Relative motion between the moving magnetic field and the turns of the conductor of the secondary coil will cause an increased EMF to be induced in the ________ coil.
SECONDARY	90.  In the illustration above, direct current comes from point A. This low input direct current is changed to P.D.C. at B by the ________. This causes a moving magnetic field around C which is the ________ ________. The relative motion between the increased number of turns of the ________ coil and the moving magnetic field will cause an ________ EMF at D.
INTERRUPTER PRIMARY COIL SECONDARY INCREASED	91. For the operation of the basic induction coil, a P.D.C. was required to produce a moving magnetic field. Alternating current (A.C.), which changes direction constantly, will also cause a moving ________ ________.
MAGNETIC FIELD	92. The type of current that can be used to produce a moving magnetic field and does not need to be interrupted is ________ current.
ALTERNATING	93. A device that uses alternating current to produce a moving magnetic field is the transformer. Since the transformer operates on alternating current (A.C.), there is no need for an ________.

11.16
lsn 5; p. 57

INTERRUPTER	94.  TRANSFORMER The voltage transformer is similar to the induction coil, except the interrupter switch is not required because of the type of current used. As shown in the illustration, the transformer has a ________ coil and a ______________ coil.
PRIMARY SECONDARY	95. Transformers may be used to step up (increase) voltage. Transformers used for this purpose will have more turns (loops) on the secondary coil than on the primary coil. NOTE: The primary coil of a transformer, like the primary coil of an induction coil, will always receive the input voltage.  Which transformer is used to step up voltage? _____

C	96. Transformers may be used to step up (increase) voltage, or they may be used to step down (decrease) voltage; however, when they are used to step down voltage, the primary coil will have more turns than the secondary coil.  Label the illustrations as being either a step-up or a step-down type of transformer.
A STEP-UP B STEP-DOWN	97. The secondary coil of a transformer used to increase (step up) voltage has more turns than the primary coil. A transformer used to decrease (step down) voltage has more turns on the ______________ coil than the ______________ coil.
PRIMARY SECONDARY	98. The basic transformer does not have an electrical connection between coils since the (circle letter beside correct answer) a. primary coil is insulated from the secondary coil. b. primary coil is not insulated from the secondary coil.
a.	99. In a transformer, either step-up or step-down, the EMF is always induced in the secondary coil. Therefore, it is the output voltage coil. The input voltage coil of any transformer is always the ______________ ______________.

11.16
lsn 5; p. 59

PRIMARY COIL	100. In a transformer, the input voltage coil is the __________ __________, and the EMF (output) voltage) is always induced in the __________ __________.
PRIMARY COIL SECONDARY COIL	101. Below are some true and false statements about transformers. Circle the letter beside the true statements. a. Transformers use A.C. b. Transformers may be used to increase or decrease voltage. c. Transformers will have induced EMF in the primary coil. d. Transformers will only be used to step up voltage. e. Transformers always have more loops on the primary coil. f. The secondary coil is always the output coil.
a. b. f.	

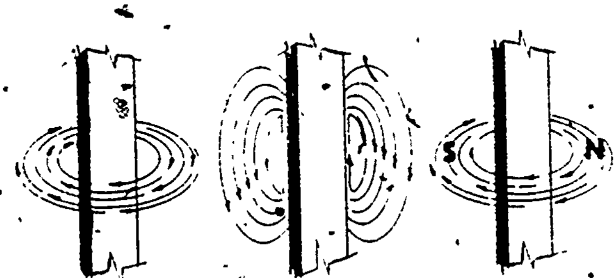
FUNDAMENTALS OF ELECTRICITY
LESSON 5
PART B
ELECTROMAGNETISM
AND
ELECTROMAGNETIC INDUCTION
SELF-TEST

1. Which statement correctly describes the magnetic field about a straight conductor carrying current? Place the number of the correct statement under the illustration that correctly shows this magnetic field.

   a. A magnetic field encircles a current-carrying conductor.

   b. A magnetic field runs parallel to a current-carrying conductor.

   c. A magnetic field surrounding a current-carrying conductor has a definite fixed polarity.



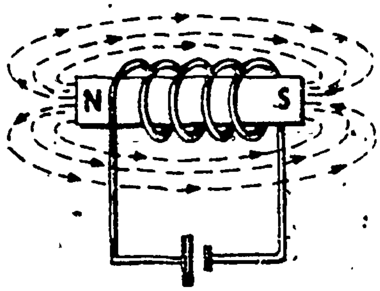
A B C

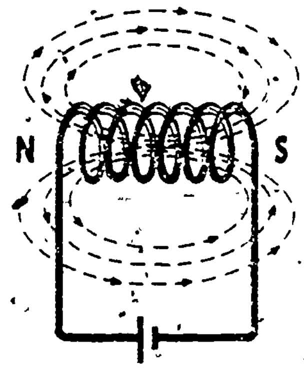
2. Match the terms in column A with their definitions in column B.

   Place the letter from column A in the space provided in column B.

A		B
a. Core	____	(1) A device used to control electrical circuits remotely.
b. Solenoid	____	(2) A coil carrying a current.
c. Relay switch	____	(3) The center area of a coil.
d. Electromagnet	____	(4) Coils of wire wound on a soft iron core.

3. Label the illustrations as being either a solenoid or an electromagnet.





A. ______________ B. ______________

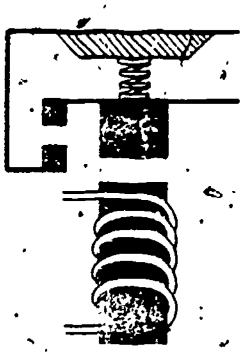
4. List three factors that affect the strength of an electromagnet.

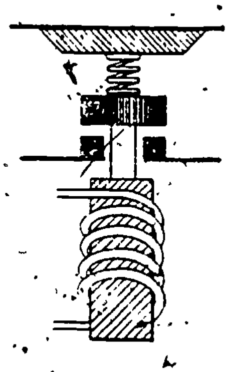
a. ______________

b. ______________

c. ______________

5. Label each illustration as either the solenoid and plunger type of relay switch or the armature type of relay switch.

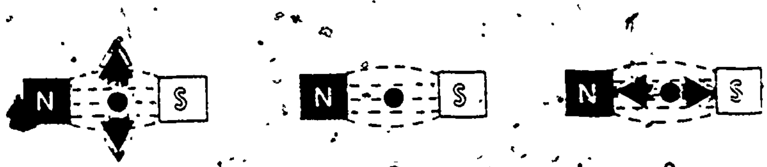




A. ______________ B. ______________

6. Electromagnetic induction is ______________________________
____
____
____
____
____

7. Match each statement to the illustration to which it applies.



A. ____ B. ____ C. ____

a. No induced EMF is produced when the conductor is moving parallel to the lines of flux.

b. No induced EMF is produced when there is no motion of the conductor or the magnetic field.

c. Maximum induced EMF is produced when the conductor is moving perpendicular through the lines of flux.

8. The three requirements for induced EMF are a ____________, a ____________ ____________, and there must be relative ____________ between them.

11.16
lsn 5; p. 63

9. Circle the letter beside the factors which have an effect on the number of flux lines cut per second.

   a. Moving the conductor parallel to the lines of flux

   b. Changing the rate of speed between the magnetic field and the conductor

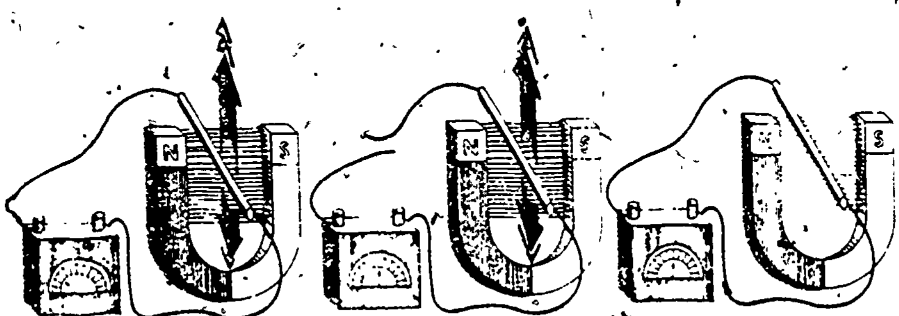
   c. Making a closed circuit

   d. Increasing or decreasing the number of turns of the coil (conductor)

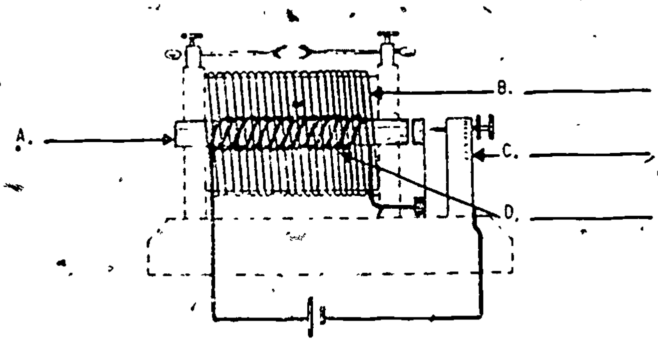
   e. Changing the flux density

10. What would be the effect on induced EMF if the number of flux lines cut per second were increased? ____________

11. Circle the letter under the illustration that shows the requirements for induced current.



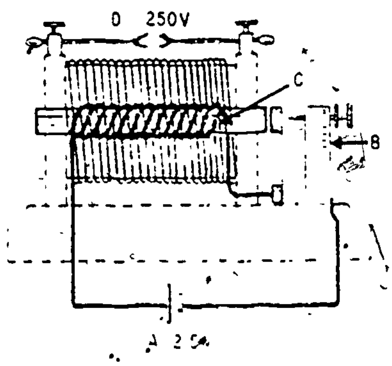
12. Label the primary coil, the secondary coil, the core, and the interrupter.



13. Circle the letter(s) beside the true statement(s) pertaining to induction coils.

a. An induction coil will not increase EMF.
b. A moving magnetic field is used in an induction coil.
c. An induction coil uses a pulsating direct current.
d. An induction coil has a primary and secondary coil.
e. An induction coil uses A.C. only.
f. Input voltage always goes to the primary coil.
g. The secondary coil receives the P.D.C.

14. State in your own words how the low voltage at point A is boosted to a high voltage at point D.



____

____

____

____

15. These statements pertain to transformers and/or induction coils. Place the letter T beside those statements which apply to transformers, the letter I beside those that apply to induction coils, and the letters TI beside those statements which apply to both.

______ a. Has a primary and a secondary coil.
______ b. May be used to increase voltage.
______ c. May be used to decrease voltage.
______ d. May have more turns (loops) on the primary coil than the secondary.
______ e. EMF is always induced in the secondary coil.
______ f. The secondary coil is insulated from the primary coil.
______ g. Uses A.C. only.

11.16
lsn 5; p. 65

LESSON 5, PART B
ELECTROMAGNETISM AND ELECTROMAGNETIC INDUCTION-SELF-TEST ANSWERS

1. Aa

2. c (1)
   b (2)
   a (3)
   d (4)

3. (a) Electromagnet
   (b) Solenoid

4. (a) Type of core material
   (b) Number of turns or loops of the coil
   (c) Amount of current

5. (a) Armature type
   (b) Solenoid and plunger

6. Electromagnetic induction is producing electricity by the use of a magnetic field, a conductor, and relative motion between them.

7. (a) c
   (b) b
   (c) a

8. Conductor
   Magnetic field
   Relative motion

9. b, c (instantaneously only, motion is necessary for a continuous effect), d, e

10. It would increase

11. a.

12. (a) Core
    (b) Secondary coil
    (c) Interrupter switch
    (d) Primary coil

13. b, c, d, f

14. Direct current comes from point A. This is changed to P. D. C. at B by the interrupter. This causes a moving magnetic field, around C which is the primary coil. The relative motion between the increased number of turns of the secondary coil and the moving magnetic field will cause an increased EMF at D.

15. TI a.
TI b.
T c.
T d.
TI e.
TI f.
T g.

END OF LESSON 5. Mail Form Enclosed For Final Exam.

11 16
lsn 5; p 67