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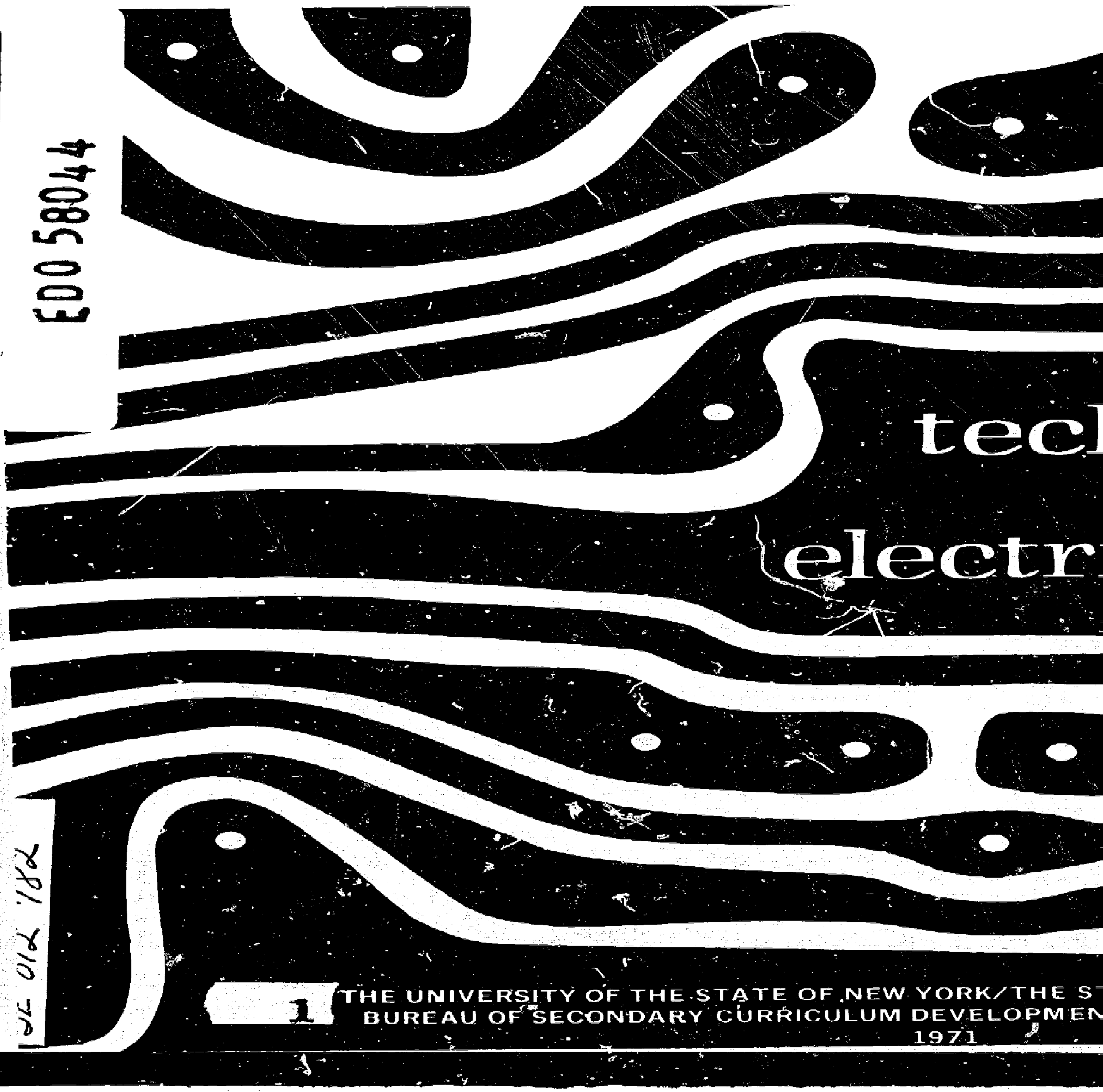
ABSTRACT

This publication is an expanded revision of the 1960 syllabus for the State of New York and has been divided into seven major areas of subject content: Basic Electricity, Basic Electronics, Advanced Electricity option, Advanced Electronics option, Computer Circuitry option, Electrical Construction, and Electrical-Electronic Drafting. Job opportunities in industry have become so diversified that all of this subject content can no longer be taught in all schools. Options are presented that may be selected by individual schools, based on local job opportunities. Objectives of the syllabus and descriptions of the courses are included to serve as an organizational guide to local courses. A suggested scheduling arrangement is outlined for a two or three year pattern. Two columns are included: one identifying content and the other, teaching surgestions. A brief bibliography and resource directory are included. (Author/TS)



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SYLLABUS

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TECHNICAL

ELECTRICITY - ELECTRONICS

The University of the State of New York/The State Education Department
Bureau of Secondary Curriculum Development/Albany/1971

FOREWORD

This publication of Technical Electricity-Electronics is an expanded revision of the 1960 syllabus. A curriculum advisory committee composed of Neil Lash, Technical and Trade Training Center, Nassau County BOCES; Arthur Lefgren, George Westinghouse Vocational and Technical High School, New York City; John Nagi, Hudson Valley Community College; and James Quinn, Brooklyn Technical High School outlined this reorganization of the syllabus.

A curriculum writing committee of Mr. Lash; Rocco Lapenta, Saunders Trade and Technical High School, Yonkers; Stanley Odre, Hutchinson Central Technical High School, Buffalo; and Lloyd Temes, Brooklyn Technical High School prepared an experimental content outline and teaching suggestions, under the guidance of Alfred Davies and Harold Wassmer, Associates, Bureau of Trade and Technical Education. Mr. Edward Kratt, Brooklyn Technical High School joined Mr. Quinn, Mr. Lash, and Mr. Lefgren in evaluating feedback and revising the final copy, which was then prepared for printing by Joseph Messier, Associate in Vocational Curriculum.

The total project was coordinated by G. Earl Hay, Supervisor of Vocational Curriculum.

Gordon E. Van Hooft, *Director*
Division of School Supervision

TO THE TEACHER

This syllabus was developed on the recommendations of an advisory c technical electrical teachers.

The two-column format was suggested by the syllabus writing committ the other teaching suggestions. It is intended that the suggestions wil scope or depth that should be used in presenting the subject content and or teaching order. This aspect is to be developed by each individual te into his own local course of study.

The syllabus has been divided into major areas of subject content t State. Job opportunities in industry have become so diversified that al syllabus can no longer be taught in all schools. In view of this, the s selected by individual schools. This selection should be determined by technical electrical-electronics curriculum is being offered.

The three options of advanced electricity, advanced electronics, an in the 12th year and require two periods per day for a school year.

The subject content of this syllabus will be tested in the comprehe the optional areas.

Decriptions of the courses are included to serve as an organizatio

A suggested scheduling arrangement is outlined to illustrate how th into a 2- or 3-year pattern. The basic diploma requirements for Regents guidance. When this curriculum is offered by a Board of Cooperative Edu matics, and mechanical drawing courses may be taken by the students at t units in Basic Electricity, Basic Electronics, and an advanced option mu diploma requirements.

Robert H. Bielefeld, *Director*
Division of Occupational
Education Instruction

TO THE TEACHER

was developed on the recommendations of an advisory committee composed of industrialists and
l teachers.

format was suggested by the syllabus writing committee. One column identifies content and
suggestions. It is intended that the suggestions will assist teachers in identifying the
should be used in presenting the subject content and the approach or method of presentation
This aspect is to be developed by each individual teacher as he interprets the syllabus
course of study.

as been divided into major areas of subject content that are being taught throughout the
nities in industry have become so diversified that all the subject content appearing in the
ger be taught in all schools. In view of this, the syllabus presents options that may be
ual schools. This selection should be determined by job opportunities in the area where the
l-electronics curriculum is being offered.

ons of advanced electricity, advanced electronics, and computer circuitry should be taught
d require two periods per day for a school year.

ntent of this syllabus will be tested in the comprehensive technical examination including

the courses are included to serve as an organizational guide to local courses.

heduling arrangement is outlined to illustrate how this technical curriculum can be arranged
pattern. The basic diploma requirements for Regents endorsement are also outlined for your
s curriculum is offered by a Board of Cooperative Education Services the science, mathe-
cal drawing courses may be taken by the students at the home schools. A minimum of 4 1/2
tricity, Basic Electronics, and an advanced option must be included in the Group II of the
s.

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CONTENTS

OBJECTIVES

- To provide a thorough grounding in the fundamental principles and practices of electricity and electronics.

- To provide background material sufficient for student entry into industry at a technical or semitechnical level.

- To provide a foundation in technical education from which the student, through further study, may readily advance.

- To aid the student in adapting himself to the environment of technical electricity and electronics.

- To develop by means of the broad technical studies program, an individual whose characteristics will include:

    - An established habit of basing judgments on observed and verified fact
    - An ability to apply known principles to new situations
    - A strong desire to finish assigned work
    - An appreciation of the need for cooperation and loyalty
    - An appreciation of the laws and forces of nature, and their implications
    - A regard for the importance of safety, and a habit of observing proper procedures

DESCRIPTION OF COURSES

BASIC ELECTRICITY - includes all aspects of direct and alternating cu sulating materials, resistance, voltage, current distribution, energy and techniques, magnetism, inductance, and capacitance in alternating as analytical tools. The subject content is applied in student labor tions throughout the course. Throughout all technical courses stress laboratory reports.

BASIC ELECTRONICS - subject content includes elements of electrical c gas tubes (diode, triode, and multielectrodes), power supply systems, trols. Solid state physics is emphasized in order to assist students association with other circuits. Laboratory experiments provide prac through the use of standardized instruments.

ADVANCED ELECTRICITY - the basic power requirements of modern electri ed through generation and distribution of three-phase power. Power m and the instrumentation of transformers is covered through the subjec transformers.

ADVANCED ELECTRONICS - standard procedures used in industry in the de electronic unit are studied. The performance of an electronic syster frequency response is analyzed. Filter coupling, peaking, feedback, to achieve desired performance. The principles learned are applied circuits.

The generation and shaping of pulse and damp waves is also stud applied in the development of TV sweep, radar, and digital circuits.

COMPUTER CIRCUITRY - various number systems including binary and oct systems are analyzed. Problems in computer design stress Boolean al and full-adder, shift register, and counters.

Computers are analyzed through the use of block diagrams and ty explained through the application of the atomic theory of matter and symbols and configurations are integrated into circuit analysis. Tr current gain as it is effected by temperature, is stressed in circui device, and control circuits, as well as input-output devices, is app maintenance.

DESCRIPTION OF COURSES

cludes all aspects of direct and alternating current - the concepts of conductors, in-
sistance, voltage, current distribution, energy, work and power, measuring instruments
ism, inductance, and capacitance in alternating currents, and the uses of these concepts
The subject content is applied in student laboratory experiments and teacher demonstra-
ourse. Throughout all technical courses stress is placed upon proper format in writing

bject content includes elements of electrical circuits, characteristics of vacuum and
de, and multielectrodes), power supply systems, simple amplifiers, and industrial con-
ysics is emphasized in order to assist students in analysis of active devices and their
circuits. Laboratory experiments provide practical application of electronic concepts
ndardized instruments.

the basic power requirements of modern electrical and electronic technology as emphasiz-
and distribution of three-phase power. Power measurements in the three-phase systems
n of transformers is covered through the subject content of three-phase wye and delta

standard procedures used in industry in the design, development, and production of an
udied. The performance of an electronic system with respect to noise, distortion, and
analyzed. Filter coupling, peaking, feedback, and push-pull circuits are developed
formance. The principles learned are applied to AM, FM, TV control, and instrumentation

d shaping of pulse and damp waves is also studied analytically. These principles are
ment of TV sweep, radar, and digital circuits.

arious number systems including binary and octal are studied. Logic diagrams and
Problems in computer design stress Boolean algebra, as well as circuits using half-
register, and counters.

lyzed through the use of block diagrams and typical circuits. Transistor theory is
application of the atomic theory of matter and semiconductor physics. Transistor type
ions are integrated into circuit analysis. Transistor stabilization, in regard to
effected by temperature, is stressed in circuit design. The theory of logic, memory
rcuits, as well as input-output devices, is applied through experiments in computer

ELECTRICAL-ELECTRONIC DRAFTING - can be introduced at the home school throu
that stresses orthographic projection. The Area Center can build on this b
electronic symbols and conventions. Schematic layout diagrams are used to
required laboratory experiments. Emphasis is placed upon development of th
of electrical and electronic equipment.

ELECTRICAL CONSTRUCTION - tools and techniques of the electrical and electr
experimental models directly related to student experiments. Safety and sa
all student activity.

Suggested Scheduling of Technical Electricity and

Two-Year Program

10th	11th
English 10	English 11
Social Studies	Social Studies
Mathematics 10	Mathematics 11
Mechanical Drawing	Chemistry or Physics
	Basic Electricity and Electronics — 3 periods

Three-Year Program

10th	11th
English 10	English 11
Social Studies	Social Studies
Mathematics 10	Mathematics 11
Mechanical Drawing	Chemistry or Physics
Basic Electricity — 2 periods	Basic Electronics — 2 periods

TRONIC DRAFTING - can be introduced at the home school through a standard mechanical drawing course rthographic projection. The Area Center can build on this background by teaching block diagrams and ols and conventions. Schematic layout diagrams are used to explain electrical-electronic theory in tory experiments. Emphasis is placed upon development of the working drawings needed in manufacture nd electronic equipment.

TRUCTION - tools and techniques of the electrical and electronic industry are used in constructing dels directly related to student experiments. Safety and safe procedures are an integral part of ivity.

Suggested Scheduling of Technical Electricity and Electronics

Two-Year Program

	11th	12th
	English 11	English 12
ies	Social Studies	Physics or chemistry
10	Mathematics 11	Health
)rawing	Chemistry or Physics	Basic Electronics and
	Basic Electricity and	Advanced Option — 3 periods
	Electronics — 3 periods	

Three-Year Program

	11th	12th
	English 11	English 12
ies	Social Studies	Physics or Chemistry
10	Mathematics 11	Health
)rawing	Chemistry or Physics	Advanced Option — 2 periods
:icity — 2 periods	Basic Electronics — 2 periods	

ELECTRICITY AND ELECTRONICS

Requirements for Regents Endorsement of a State or Local High School Diploma

		Units
Group I:	Required Constants	
	English	4
	Social Studies (including 1 year of American History)	3
	Science	1
	Mathematics	1
	Health	½
	Total	9 ½
Group II:	Required Technical Subjects	
	Basic Electricity	1 ½
	Basic Electronics	1 ½
	Advanced Electricity, Advanced Electronics, or Computer Circuitry	1 ½
	*Mechanical Drawing Involving Electrical Concepts	½
	*Physics	1
	*Mathematics 10	1
	Total	7
Group III:	Elective Subjects	
	*Mathematics 11 (Recommended)	1
	Open Elective	½
	Total	1 ½

A minimum of 18 units is required for Regents endorsement of a State or local high school diploma.

* May be taught in home school.

BASIC ELECTRICITY

BASIC ELECT

I. Theory of current flow	
A. Construction of atom —— electron flow	Con b
B. Law of action between charges	Dis
C. Concepts of voltage, current, and resistance	Def
	Def
	Def
	Men
D. Conductors, semiconductors, and insulators	Dis i
E. Sources of e.m.f.	Dis
1. Electromagnetic induction	
2. Chemical	
3. Thermal	
4. Piezoelectric	
5. Photovoltaic	
6. Static	
7. Other	

Note: Topics labeled *General Treatment* are to be covered prehensive examination.

Both theory and laboratory instruction is required

BASIC ELECTRICITY

current flow	
tion of atom —— electron flow	Concept of simple atoms. Discuss valence and conduction bands.
ction between charges	Discuss law of charges and electrostatic field concept.
of voltage, current, and ance	Define voltage as a difference of potential.
	Define current as a flow of electrons.
	Define resistance as the opposition to current flow.
	Mention units of current, voltage, and resistance.
rs, semiconductors, and tors	Discuss the nature of conductors, semiconductors, and insulators. List ex mples.
of e.m.f.	Discuss qualitatively the various sources of e.m.f.
tromagnetic induction	
ical	
nal	
oelectric	
ovoltaic	
ic	
r	

ibeled *General Treatment* are to be covered in class but shall not be tested on the com-
sive examination.

ory and laboratory instruction is required.

II. Circuits	
A. Ohm's law	Discuss Ohm's l
B. Series	State the princ give illustra
C. Parallel	
D. Series/parallel	Solve problems circuits.
E. Kirchhoff's current and voltage laws	Make statement
III. Measurements, standards, and tolerances	
A. Current	
1. Ammeter	Show how ammete precautions i
2. Shunt calculations	
B. Voltage	
1. Voltmeter	Show how a volt
2. Multiplier calculations	Calculations of
3. Meter sensitivity and loading	Quantitative tr
C. Resistance	
1. Voltmeter-ammeter method	Demonstrate res Emphasize tha properly loca

Discuss Ohm's law. Solve problems.

State the principles of series and parallel circuits and give illustrated examples.

Solve problems involving combinations of series/parallel circuits.

nt and Make statement of laws with simple, illustrated examples.

ards, and

Show how ammeter is connected in a circuit. Explain precautions in using an ammeter.

ons

Show how a voltmeter is used in a circuit.

ulations Calculations of sensitivity required.

ty and loading Quantitative treatment of voltmeter loading is required.

er method Demonstrate resistance measurement by the V-A method. Emphasize that accurate resistance readings depend on properly locating the meters in the circuit.

2. Ohmmeter

Discuss the si
required.

a. Uses

Discuss precau

b. Circuitry

3. Wheatstone bridge

Discuss the th
several of i
accuracy. W

D. Power

Define power.

1. Units —— watts to horsepower

State that pow
the voltage

2. Voltmeter-ammeter method

Using Ohm's La

$W=I^2R$ and $W=\frac{E}{R}$

3. Wattmeter

Discuss the me

E. Energy

Define electri
multiplied b

IV. Conductors

A. Factors affecting resistance

Discuss the ef
cross-sectio
constant.

B. Resistivity

Solve problems

C. Wire size

a. Permissible voltage drops

Line drop calc
Underwriter'
also be made

Discuss the simple series ohmmeter. Calculations are required.
Discuss precautions in use of the ohmmeter.

Discuss the theory of the Wheatstone Bridge. Describe several of its applications and discuss its superior accuracy. Work simple problems with formula.

Define power. Convert watts to horsepower.

State that power can be determined from the product of the voltage across, and the current through, a circuit.

Using Ohm's Law show that power can be expressed as

$W=I^2R$ and $W=\frac{E^2}{R}$

Discuss the method of connecting a wattmeter in a circuit.

Define electrical energy. Explain that energy is power multiplied by time. Specify energy unit (Kilowatthours).

Discuss the effect of material composition, length, and cross-sectional area on resistance, temperature being constant.

Solve problems using $R = \frac{KL}{d^2}$

Line drop calculations should use National Board of Fire Underwriter's standards. However, reference should also be made to local ordinances as required.

b. Use of wire size

c. Calculation of wire size

D. Temperature effect calculations

V. Magnetism

A. Permanent magnets

1. Properties

a. Laws of interaction
b. Lines of force
c. Permeability and saturation

2. Molecular Theory

3. Materials

B. Electromagnets

1. Direction and distribution of magnetic fields about current carrying conductors and coils

BASIC ELECTRICITY

Use wire tables as sources of information about electrical conductors. Demonstrate use of wire gauge and micrometer.

Determine minimum circular mil area of copper conductor which will satisfy line drop specifications. Use wire tables to select available wire size.

Calculate the effect of temperature on resistance. General treatment of materials having a negative coefficient of resistivity.

Discuss the basic concepts of magnetism and magnetic fields.

Use simple molecular theory to explain permeability, saturation, residual magnetism, permanent magnets. Discuss magnetizing, demagnetizing, and shielding.

Describe distinction between ferromagnetic, diamagnetic, and paramagnetic materials.

Discuss magnetic fields associated with straight conductor and with coil. Use current rules for straight wire and coil.

2. Factors affecting strength

a. Ampere turns

b. Permeability

VI. Electromagnetic induction

A. Faraday's law

B. Lenz's law

C. Induction coils

1. Self-induction

2. Mutual-induction

D. Inductance

E. Voltage of induction

VII. Motor action

A. Principle of operation

1. Force on a conductor

Discuss effect on magnet strength of varying the turns, current, and core material.

Define permeability.

Point out the factors which determine the magnitude of induced e.m.f.

Discuss the polarity of induced self-e.m.f.

Define self-induction and discuss the factors which affect it.

Define mutual-induction and discuss the factors which affect it. Mention some applications.

Discuss inductance qualitatively in terms of number of turns, core permeability, and core shape.

The voltage across the inductance depends on the magnitude of the inductance and the rate of change of current.

Discuss the force on a conductor carrying a current in an electromagnetic field.

2. Relative directions

B. Applications

1. DC motors

2. D'Arsonval meter movement

VIII. Overload protection

A. Fuse

B. Circuit breaker

IX. Alternating current

A. Basic concepts

1. Sine wave development

2. Frequency

3. Maximum value

Show the magnetic field formation of a conductor carrying current, held in a magnetic field. Explain the Left Hand Motor Rule to show the direction of motion of a current-carrying conductor in a magnetic field.

Introduce concept of counter e.m.f. at this point, to be reinforced at a later date.

Describe how force on a conductor acts against a pair of precision springs. Mention that this type of meter is inherently an average-reading device.

Give general description of low-voltage plug and cartridge fuses, indicating voltage and current ranges. Discuss briefly time-delay fuses, both plug and cartridge types.

Introduce the general idea of thermal and electromagnetic circuit breakers, including principle of operation, and uses in preference to fuses.

Discuss and illustrate the generation of a sine wave. Express the function in terms of both degrees and radians.

Define frequency and periodic function. Relate frequency and period.

Define maximum and peak-to-peak values.

4. Effective value

5. Average value

6. Instantaneous value

7. Effective resistance

8. Power (watts)

9. Reactive volt-amperes (vars)

10. Volt-amperes (va)

11. Power factor

B. Inductive circuits

1. Calculation of inductive reactance

2. Phase relationships

3. Mutual inductance

Define effective value (R.M.S.) in terms of heating effect. Describe the relationship between effective and maximum values for sine waves.

Define average value. Illustrate for sine wave.

Define instantaneous value and illustrate with problems.

Discuss the difference between DC resistance and effective resistance.

Define power as the product of voltage, current, and power factor.

Define reactive power as the product of voltage and the reactive component of the current.

Define as the product of volts and amperes.

Define power factor as the relationship between watts and volt-amperes. Relate the power factor to the cosine of the phase angle of the circuit.

State that inductive reactance represents the opposition to current flow in a circuit.

Discuss the concept of phase relationship. Explain the phase lag of current behind voltage in an inductive circuit.

Discuss coefficient of coupling.

C. Capacitive Circuits

1. Basic concepts

2. Factors affecting capacitance

3. Voltage across a capacitor

4. Calculation of capacitive reactance

5. Phase relationships

X. Single-phase circuits

A. Series circuits involving R, L, and C

1. Voltage, current, and power calculations

2. Phasor diagrams

Explain capacitance in terms of:
- the opposition to voltage change
- the storage of charge

Define capacitor. Discuss action of capacitor charging and discharging.

Discuss qualitatively the dependence of capacitance on the physical construction of the unit. Consider the effect of connecting capacitors in series and in parallel.

Explain that the voltage across a capacitor varies directly as the charge and inversely as the capacitance.

State that capacitive reactance represents the opposition offered to current flow by a capacitor in a circuit.

Discuss the effect of capacitance on the phase relationship between circuit voltage and current.

Introduce the concept of impedance as the total circuit opposition to current flow. Present both analytical and graphical solution for impedance (phasor diagram). Thoroughly develop the concepts of power, voltamperes, reactive voltamperes, and power factor.

Develop phasor diagrams both for impedance and for voltage.

B. Parallel circuits involving R, L, and C

1. Voltage, current, and power calculations

2. Phasor diagrams

C. Resonance

1. Series

2. Parallel

D. R-C time constants

XI. Basic instruments

A. D'Arsonval

B. D'Arsonval with rectifier

C. Iron vane

D. Electrodynamometer

Consider pure components only, and branches containing only single elements. Calculations of impedance, current, voltage, power, and power factor required.

Develop phasor diagrams for current.

Define series resonance. Discuss characteristics of series resonant circuits and curves of impedance and current, versus frequency.

Define parallel resonance. Discuss characteristics of parallel resonant circuits and curves of impedance and current, versus frequency.

Discuss the rise and decay of current through, and voltage across, all components in basic R-C circuits to which a voltage is applied.

Discuss construction and basic operation of instruments. Note applications, considering relative precision desired, measured frequency, and sensitivity.

E. Use of ——

1. Watthour meter
2. Oscilloscope
3. Frequency meter
4. VOM
5. VTVM
6. Digital readout meters

XII. DC generators

A. Construction and basic theory

1. Separately excited

2. Self-excited (shunt)

B. Voltage control

XIII. DC motors

A. Theory

B. Characteristics

XIV. Three-phase systems

A. Voltage, current, and power

1. Wye

2. Delta

BASIC ELECTRICITY

Stress use rather than theory of operation. Consider accuracy, frequency response, and loading effect.

Describe armature construction and the basic concepts underlying the generation of a voltage in the armature. Consider the action of the commutator.

Discuss method for controlling the terminal voltage of DC generators.

Discuss the basic concepts underlying the development of torque in DC motor. Consider the generation of a counter electromotive force.

Discuss the operating characteristics of the DC series and shunt motors. Discuss methods of reversing direction of rotation.

Discuss the advantages of polyphase systems. Show the current and voltage relationships in both connections.

B. Three-phase, four-wire transmission and distribution system

XV. Alternators

General principles of operation (general treatment)

XVI. Transformer principles

A. Transformer action

B. Current and voltage

C. Special types: the autotransformer

XVII. Alternating current motors

A. Three-phase induction

B. Single-phase

XVIII. Grounding

Discuss this type connection as applied to generators and transformers.

Discuss the generation of e.m.f. and show the effects on frequency of the speed and number of poles.

Discuss how the power input adjusts to changes in power output.

Define the term volt/turn. Explain that the voltages are directly proportional to turns ratio, and that currents are inversely proportional to the turns ratio.

Discuss construction and basic principles. Include diagrams illustrating current distribution and voltages in both step-up and step-down connections.

Briefly discuss the general principle of operation.

Demonstrate the discuss briefly the common types: universal, split-phase, shaded-pole, capacitor-start, and synchronous.

Discuss grounding as a safety and protective feature in electrical circuits. Consider methods for minimizing possible injury when working in electrical circuits. Consider use of ground as a point of reference.

XIX. Batteries (general treatment)

A. Types

B. Characteristics and care

BASIC ELECTRICITY

Demonstrate factors necessary for simple voltaic action — dissimilar metals and electrolyte.

Display different sizes of common dry cells (carbon/zinc, mercuric oxide/zinc). Discuss series and parallel combinations of cells.

Display common storage cells (nickel/iron, nickel/cadmium, lead/acid).

Compare batteries as to applications, cell voltage, electrolyte, charge and discharge rates, and general maintenance. Demonstrate and discuss the care, maintenance, and safety considerations in the use of lead/acid storage batteries. Consider the internal resistance of a cell, and its ampere-hour rating.

BASIC ELECTRONICS

I. Basic rectification circuits

A. Vacuum diode

1. Thermionic emission
2. Photoelectric emission
3. Plate characteristic
4. Diode static resistance
5. Diode load and load line
6. Equivalent circuit
7. Application as a half-wave rectifier

B. Semiconductor diode

1. Intrinsic semiconductor
2. Doped semiconductor
3. P-N junction

BASIC ELECTRONICS

Discuss heat required for emission.

General treatment.

Show plate current vs. plate voltage curves. Discuss non-linearity and saturation.

Graphical determination.

Construction of the load line using the intercept and slope method.

The diode can be represented by a switch and a resistance.

fier Determination of the load, peak, average, and PIV voltages.

Define a semiconductor. Illustrate graphically the effect of temperature on pure silicon and germanium. Discuss the effect of temperature on the resistance of a thermistor.

Discuss the need for conduction at room temperature. Introduce the donor and acceptor to create N and P type materials. Discuss holes and electrons.

Discuss the formation of a junction diode. Explain the formation of the depletion region and the resulting potential barrier.

4. Diode characteristic curve

5. Equivalent circuit

6. Application as a half-wave rectifier

II. Basic amplification circuits

A. Triode vacuum tubes

1. Grid control

2. Characteristic curves

3. Concept of small signal amplification

a. Dynamic plate resistance

b. Amplification factor

c. Voltage amplification

d. Voltage source concept

BASIC ELECTRONICS

Discuss the effect of forward and reverse bias on conduction. Develop the volt-ampere characteristic. Discuss leakage current and voltage breakdown. Mention the zener diode.

The junction diode can be idealized as a battery in series with a switch.

Determination of DC output voltage. Application to an AC voltmeter and battery charger.

Discuss the effect of the grid on electron flow.

General discussion of the effect of grid voltage on plate current including cutoff and saturation. Discuss the need for a family of plate characteristics.

The analysis of the effect of small DC voltage changes at the grid.

The dynamic plate resistance is the reciprocal of the slope of the characteristic curve.

Graphical determination of voltage gain using plate characteristic curves.

Introduce the triode as a constant voltage source in series with the plate resistance.

e. Equivalent circuit

f. Application

4. Amplification of an AC signal

a. Dynamic transfer characteristic

b. Cathode bias

c. Signal wave forms

d. Small vs. large signal amplification

e. Application

B. Pentode vacuum tubes

Develop the gain formula from the analysis of the equivalent circuit $A = \frac{M_u R_L}{r_p + R_L}$.

Thermistor and triode amplifier as a heat sensing device.

Construction of the dynamic transfer characteristic from the plate characteristic. Selection of an operating point from the plate characteristic.

Computation for the cathode resistor. Introduce the bypass capacitor to eliminate degeneration.

Graphical determination of gain using sine wave signals.

Discuss the use of the equivalent circuit for small signal applications and the characteristic curves for large signal applications. Cite the need for linearity and discuss factors involved.

Use of the triode as an audio amplifier with simple resistor load.

Analysis and synthesis of circuits with a given supply voltage. Limit application to:

- Maximum gain with small signal
- Maximum large signal voltage output
- Maximum signal power output

Discuss and apply safe operating limits. Construct the maximum power dissipation curve.

Develop pentode out of limitations of the triode. Stress current source.

1. Screen grid

2. Suppressor

3. Plate characteristics

4. Transconductance

5. Current source

6. AC amplification

7. Small signal equivalent circuit

C. Transistors

1. Transistor construction

BASIC ELECTRONICS

Briefly discuss plate degeneration and the need for the screen grid.

Briefly discuss secondary emission and the need for the suppressor grid.

Using characteristic curves show the plate current is independent of E_b.

Use characteristic to show transconductance as the change in output current per volt of input. Develop $u = g_m r_p$.

Develop the equivalent circuit of the pentode as a constant current source in parallel with the plate resistance. Calculate r_p from plate characteristic. Show that output signal current is practically constant at $g_m E_g$.

Using load line, graphically show that output voltage is proportional to R_L $(E_p = g_m E_g R_L)$.

Develop the complete amplifier circuit as a constant current source $g_m E_g$ in parallel with r_p and R_L.

Develop the transistor as a current source, with the aid of the common base circuit. Stress common emitter-amplifier. Discuss the common collector configuration.

Describe the construction of the NPN and the PNP junction type transistors. Discuss the emitter, base, collector, doping, barrier potential, and effect of temperature changes.

2. Common base amplifier

   a. Transistor action

   b. Transistor currents

   c. Transistor alpha

   d. Collector characteristics

   e. Equivalent circuit (hybrid model)

   f. Current and voltage gain

   g. Applications

3. Common emitter amplifier

   a. Current gain

Transistor action requires current. Discuss input resistance.

The emitter current divides between the base and the collector.

Define alpha as the comparison of the output signal current to the input signal current using the common base configuration. Alpha is the ratio of the change of collector current to the change of emitter current. (Note: Alpha is approximately the ratio of the collector to the emitter current.)

Analyze as a constant current source with high collector impedance.

Develop input circuit as a voltage signal source in series with the input resistance h_ib (note the low orders of magnitude of h_ib).

Trace signal currents and voltages through the equivalent circuit. Compute output signal current and voltage, and current and voltage gains.

Used as a constant current source in transistor characteristic measurements.

Develop the common emitter amplifier out of the common base amplifier so as to realize a current gain greater than one.

Define Beta as the ratio of the output signal current to the input signal current

$$h_{ie} = \frac{\Delta v_{be}}{\Delta I_b}.$$

b. Collector characteristics

c. Input characteristic

d. Large signal amplification

1. Fixed bias

2. Signal waveforms

3. Gain

4. Gain in decibels

Discuss how the collector current varies with changes in base current and collector voltage. Define saturation. Discuss transistor action. Note that the common collector resistance and leakage current are both approximately Beta multiplied by the corresponding value in the common base configuration.

Develop input characteristic out of the forward biased PN junction characteristic. Graphically determine the dynamic input resistance.

$$\text{Beta} = \left.\frac{\Delta I_c}{\Delta I_b}\right| v_{cE} = K$$

Compare the magnitude of h_ie with the common base equivalent h_ib.

Selection of an operating point on an input characteristic. Determination of a bias resistor. Construction of a load line.

Graphical determination of the peak values of the signal input current, signal output current, and the peak output voltage for a given input signal voltage. Observe partial cancellation of distortion.

Calculation of current, voltage, and power gain.

Define decibel change as a power comparison where 1 bel is a 10 to 1 power ratio. Compute db change given the power at two points in a system, or two voltages across equal or same impedance.

5. Applications

e. Small signal equivalent circuit
(hybrid model)

4. Common collector

a. Input and output impedances

b. Gain

c. Application

d. Field effect transistor

1. Construction

2. Pinch off

3. Drain current characteristics

Design of an amplifier for maximum output voltage with a given load resistance and collector supply voltage.

Design of an amplifier for maximum power output including determination of load resistance.

Develop a complete equivalent amplifier circuit, including signal source, transistor hybrid equivalent, and simple resistor load. Trace signal voltages and currents from source to load. Compute output signal current, voltage, and power gains.

Develop as an impedance transformer and as a current amplifier.

Discuss qualitatively the reasons for the high input and low output impedances.

Compare current, voltage, and power gain with the CB and CE configuration.

Discuss use as a power amplifier to provide current gain without phase inversion, and as an impedance matching device.

Develop as a device that combines the advantages of both vacuum tube and transistor amplifiers.

Develop a simple junction FET. Define source, drain, and gate.

Discuss formation of depletion region due to reverse bias junction and its effect on drain-to-source resistance.

Develop a family of drain current characteristics showing the drain current as a function of drain-to-source voltage, and gate-to-source voltage.

4. Application

III. Electronic systems

A. Power supplies

1. Output voltage

a. Circuit with resistance load

b. DC load voltages

c. Silicon-controlled rectifiers

2. Peak reverse voltage

3. Ripple reduction

a. Capacitor discharge curve

b. Ripple voltage

c. Applications

d. Choke filter

Input circuits requiring high impedance.

Develop electronic systems utilizing the basic circuits with emphasis on system performance and industrial procedures used in their design and realization.

Analyze half-wave, full-wave, and bridge circuits to determine the voltage waveform across the load.

Determine the DC output voltage across the load as the average of the voltage waveform. Include diode forward voltage for vacuum tube rectifiers and for low voltage silicon rectifiers.

Develop the SCR as a three-junction semiconductor device. Discuss the function of the gate to provide output voltage control.

Determine the PIV for all three circuits.

Discuss the effect of the RC time constant on the voltage.

Discuss factors affecting ripple voltage. Determine ripple frequency.

Determine approximate output voltage for half- and full-wave power supplies using a simple capacitor filter.

The output voltage is the average of the rectified wave. Discuss the action of the choke in reducing the ripple.

e. Pi section filters

4. Regulation

a. Concept of regulation

b. Zener diode characteristics

c. Zener diode as a regulator

d. Transistor regulation circuits

5. Applications

B. Voltage amplifiers (common emitter)

1. Transistor amplifier stability

a. Temperature sensitive factors

Discuss generally (general treatment).

Discuss the effect of changes of line voltage, and load or source impedance on the output voltage.

Discuss the practical aspects of the reverse conduction characteristic of a zener diode including zener voltage, rated power dissipation, maximum current, minimum current, and dynamic resistance.

Compute size of limiting resistor for load variations only.

Current and voltage regulation (general treatment).

Design of half-wave, full-wave, and bridge power supplies to realize a specified output voltage. Selection of diodes to meet PIV and current requirements.

Selection of a capacitor (general treatment) to realize a specified allowable ripple.

Emphasize the common emitter amplifier. In a general manner, apply the principles developed to vacuum tube amplifiers.

Discuss the effect of temperature change on transistor collector characteristics and on bias stability.

Discuss individually the effect of temperature rise on base-emitter voltage and leakage current and the effect of these changes on the position of the quiescent point.

b. Base-emitter voltage compensation (swamping resistor)

c. Voltage divider bias

d. Leakage current and stability factor

e. Application

2. Frequency response

a. RC coupling circuit transfer function

BASIC ELECTRONICS

Discuss the introduction of an external emitter resistor to swamp internal resistance changes due to temperature variations.

Discuss (general treatment) the use of diodes and thermistors in temperature compensation circuits.

Develop voltage divider bias to stabilize operating point.

Define stability factor as the ratio of the change of collector current to the change of leakage current because of temperature variations.

Develop (general treatment) that the range of stability is from one to Beta-plus-one. For normal operation the stability factor is equal to the ratio of the base-to-ground biasing resistor to the external emitter resistor.

Design a practical voltage divider biasing circuit.

Apply the principle that the output signal voltage is to input signal voltage as the output impedance is to the input impedance. Devise and plot db change against frequency using the log scale for frequency. Define low frequency cutoff as the break frequency where the total series resistance equals the capacitive reactance. Determine the db loss at cutoff. Determine the response for several decades above and below cutoff.

Develop the negligibility of capacitive reactance at frequencies 10 times greater than cutoff.

TECHNICAL EDUCATION

b. Low frequency response of CE transistor amplifier

c. Miller effect

d. High frequency response of CE transistor amplifier

e. Emitter bypass capacitor

f. Vacuum tube

g. Decoupling

(General treatment) Note that the response is proportional to the capacitive reactance of the coupling capacitor for frequencies less than 1/10th the low frequency cutoff.

(General treatment) Plot the frequency response curve for a single circuit, or for *two* identical but isolated coupling circuits.

Determine the total resistance for an RC coupling circuit when a signal source feeds a CE amplifier, and when an amplifier feeds another identical amplifier. Determine the low frequency cutoff. Plot the overall (general treatment) low frequency response.

Calculate the Miller effect capacitance, given the transistor capacitances and the gain of the stage.

Define high frequency cutoff as the frequency where the total shunt capacitive reactance is equal to the parallel combination of all shunting resistances. Limit calculations to that between two cascade CE stages. Plot the high frequency response.

Discuss generally the fact that the capacitive reactance can be made to be negligible compared to the resistance. Indicate that the resistance includes the input circuit reflected through the transistor.

Generally apply the principles developed above to the triode and the pentode amplifiers. Determine the Miller capacitance.

Discuss qualitatively the effect of RC decoupling filters.

h. Dbm

C. Power amplifiers

1. Harmonic distortion

2. Power output amplifier

3. CE driver amplifier

4. Transformer coupling

BASIC ELECTRONICS

Define dbm as a power comparison with 1 milliwatt as a reference.

Emphasize common emitter emplifier.

Discuss nonlinearity factors responsible for odd and even harmonic distortion.

Determine load line using the maximum power dissipation hyperbola.

Discuss generally the transfer of an input voltage signal to a base current signal and then to the output signal, using the input characteristic and the output transfer characteristic. Note the distortion contributed by the input circuit and that contributed by the output circuit. Discuss the cancelling effect that the output circuit nonlinearity has on the input circuit. Note how the input source resistance may be varied to minimize overall distortion. (See advanced section for quantitative treatment.)

Determine the dynamic load presented by a power amplifier stage to its driver stage. Include the effect of this load in the analysis and design of the driver stage. Introduce direct coupling to eliminate unnecessary components.

Develop an understanding of the use of an output transformer to achieve maximum power transfer to a low impedance load. Determine the turns ratio required. Stress the need for matching impedance. Discuss generally the effect of transformer characteristics on frequency response and distortion.

TECHNICAL EDUCATION

5. Distortion reduction

6. Push-pull amplifiers

7. Phase inverters

8. Complementary symmetry

9. Inverse feedback

10. Emitter follower

Discuss commercially acceptable distortion percentages, and the need to reduce harmonic distortion.

Develop a transfer characteristic for push-pull amplifiers. Note effect on even order harmonics. Discuss need for amplifier balance.

Discuss the need for phase inversion, and the use of a standard CE amplifier to achieve phase inversion with unity gain.

Discuss how a PNP transistor can be used to complement an NPN transistor to directly achieve low-distortion, high-efficiency, and low standby current.

Discuss how noise and distortion introduced within an amplifier may be used to cancel itself out. Define percent feedback, db feedback, and feedback factor. Determine the gain with feedback and the percentage distortion with feedback.

Use collector-to-base voltage feedback for both AC and DC stabilization of CE amplifier.

Discuss current feedback. Apply the common collector as an output current amplifier.

ADVANCED ELECTRICITY OPTION

I. DC generators

A. Construction and basic theory

1. Separately excited

2. Self-excited (shunt)

B. Factors affecting build-up

C. Commutation

D. Characteristics of generators

1. Magnetization curve

2. External characteristics

3. Voltage control

E. Losses and efficiency (shunt only)

II. DC motors

A. Theory

ADVANCED ELECTRICITY

Review generator construction and the basic concepts underlying the generation of a voltage in the armature. Consider the action of the commutator. Develop the equation relating terminal voltage and generated voltage.

Discuss the factors affecting the build-up of a self-excited shunt generator.

Discuss qualitatively the problems surrounding proper commutation and the need for interpoles.

Briefly discuss the magnetization curve.

Consider the external characteristics of shunt and compound generators, and discuss the factors affecting the change of terminal voltage with load. Define voltage regulation.

Discuss method for controlling the terminal voltage of DC generators.

Define copper and rotational losses. Compute efficiency. Discuss method of measuring rotational losses.

Review the basic concepts underlying the development of torque in a DC motor. Consider the generation of a counter electromotive force and develop the equation relating terminal voltage and CEMF.

B. Characteristics

C. Starting requirements

D. Operation

E. Losses and efficiency (shunt only)

F. Automatic starters (general treatment)

III. Alternators

A. Construction

B. General principles of operation

C. Applications

D. Voltage regulation

IV. Three-phase systems

A. Voltage, current, and power in the three-phase alternator

ADVANCED ELECTRICITY

Discuss the operating characteristics of the DC series, shunt, and compound motors considering speed regulation and torque. List applications of the various types of motors.

Discuss basic starting equipment and the starting of DC motors (four-point starting box). Compute value starting resistor.

Discuss the operation of DC series, shunt, and compound motors. Consider reversing direction of rotation, controlling speed, and precautions to be observed in operation.

Compute the efficiency. Define losses. Compute horsepower output from the input and efficiency.

Include electronic controls.

Discuss the types of construction.

Discuss the generation of e.m.f. and show the effects on frequency of speed and number of poles.

Consider the use of alternators in the electrical industry.

Consider the effect on voltage regulation of leading, lagging, and unity power factor.

Review the advantages of poly-phase systems. Develop the three-phase alternator. Present the formula for calculation of power.

1. Wye

2. Delta

B. Three-phase, four-wire transmission and distribution system.

C. Measuring power in a three-phase system

D. Wye and delta loads (balanced)

V. Transformer principles

A. Transformer action

B. Current and voltage

C. Polarities and connections

1. Single-coil primary and secondary only

2. Two-coil primary and secondary (general treatment)

Discuss this type connection as applied to generators and transformers.

Describe the advantages of the two-wattmeter method in the measurement of three-phase power. Discuss the wattmeter readings under resistive/reactive loads.

Compute voltage, current, power, and reactive voltamperes for both resistive and reactive loads (balanced only).

Review manner in which the power input adjusts to changes in power output.

Define the term volt/turn. Explain that the voltages are directly proportional to turns ratio, and currents are inversely proportional to the turns ratio.

Discuss subtractive and additive polarities. Consider polarity and voltage in discussing the concepts underlying the paralleling of transformers. Diagram three-phase, standard transformer connections:

- Wye/wye
- Delta/wye
- Wye/delta
- Delta/delta
- Open delta (general treatment)

D. Special types

1. Instrument

2. Current

3. Potential

E. Efficiency and losses

VI. AC motors

A. Three-phase induction

1. Wound-rotor
2. Squirrel-cage
3. Synchronous (general treatment)
4. Starting
5. Efficiency and horsepower output
6. Application

Discuss the use of instrument transformers in measurement as part of control systems and as isolation devices. Discuss the current transformer (C.T.) as a low capacity, precision, current step down transformer. Demonstrate correct connections, and emphasize safety aspects of grounding. Emphasize danger in allowing secondary to become open-circuited. Calculate line currents from a meter reading.

Note: A possible enrichment for some classes might be the use of P.T. and C.T. with a voltmeter, and the use of obtained information in calculating power factor, and volt-ampere-reactive (vars).

Discuss the potential transformer (P.T.) as a low capacity, precision, voltage step-down transformer. Demonstrate correct connection to a high-voltage line, and the safety aspects of the grounded secondary. Calculate line voltage from secondary voltmeter reading and P.T. ratio. Phasing should involve correct use of standard markings (H and X) and dot.

Compute the efficiency from the losses. Discuss methods of determining iron and copper losses. Discuss hysteresis and eddy current losses.

Discuss the construction and important characteristics of the polyphase induction motor — essentially constant speed, little maintenance required. Develop the principles of operation, elaborating on the rotating magnetic field, transformer action, and slip. Mention the method of reversing direction of rotation. Discuss maintenance.

Discuss the use of the wound-rotor and squirrel-cage induction motors.

B. Single-phase

VII. Relays

A. Operation

B. Characteristics (general treatment)

C. Types (general treatment)

Demonstrate and discuss:

- Common types
  - Universal
  - Split-phase
  - Shaded pole
  - Capacitor-start
  - Synchronous
- Starting conditions
- Starters
  - Across-the-line
  - Wye/delta
  - Compensator
- Computation of efficiency and horsepower output, from input and output.

Consider relays with regard to:

- Basic operation
- Power
- Coil ratings

Discuss the operate and release times of relays:

- Definition
- DC relay
  - Operating times
  - Mechanical inertia
- AC relay
  - Phase displacement in magnetic flux
  - Operating times

Discuss the factors to consider in selecting a relay.

ADVANCED ELECTRONICS OPTION

I. Circuits

A. Amplifiers

1. Wideband

2. Tuned amplifiers

a. Parallel resonance and Q

b. Tuned RF amplifier

3. Differential amplifier

4. Operational amplifier

B. Oscillators

ADVANCED ELECTRONICS OPTION

Discuss factors affecting low-, mid-, and high-frequency response. Compute cutoff frequencies. Plot overall response.

Discuss the variation with frequency of the impedance of a parallel circuit of pure R, L, and C. Calculate impedance and band width at resonance. Apply the above to a capacitor and a coil with its series resistance.

Develop the TRF amplifier, using a parallel resonant circuit as the collector load.

Develop the differential amplifier to compensate for the effects of temperature changes and to eliminate common mode signals.

Develop a semiconductor operational amplifier. Note the need for high open-loop gain. Discuss the high input impedance characteristics of the amplifier with high negative feedback factor. Use it to add input signals and multiply signals by a constant.

Apply positive feedback to a CE transistor amplifier to achieve oscillation. Determine the conditions necessary for oscillation. Illustrate this principle with simple Armstrong, Hartley, Colpitts, RC, and crystal-controlled oscillators.

C. Circuit analysis

1. Techniques

   a. Signal tracing

   b. Circuit diagrams

      1. Schematic
      2. Simplified schematic
      3. Block

   c. Power supply

2. Equipment performance

3. Applications

   a. Complete audio amplifier
   b. Electronic voltmeter
   c. Audio signal generator
   d. Oscilloscopes
   e. Superheterodyne receiver
   f. Control circuits
   g. Linear integrated circuits

ADVANCED ELECTRONICS

Utilize signal tracing techniques to analyze a circuit. Compute stage gains, attenuator losses, and overall voltage gain. Compute overall db gain.

Simplify practical schematics and reduce to block diagrams. Plot input and output waveforms where appropriate. Discuss functional diagrams including control and impedance matching elements.

Analyze DC power distribution. Note methods used for ripple reduction and for signal decoupling between stages.

Develop an understanding of manufacturers' specifications including noise, distortion, frequency, response, accuracy, sensitivity, and selectivity. Discuss circuit features contributing to performance. Discuss power requirements.

Apply the preceding techniques to this equipment. Limit control circuits to simple temperature and photoelectric semiconductor transducers, feeding a single-stage transistor amplifier.

TECHNICAL EDUCATION

II. Communications systems

A. AM transmitter circuit

1. Operation
2. Sidebands
3. Bandwidth
4. Percentage modulation
5. Power distribution

B. FM transmitter

1. Frequency deviation
2. Bandwidth
3. Basic FM transmitter

C. AM receiver

Describe the block diagram of a basic transmitter: oscillator, buffer, driver, PA, and modulator.

Show simple basic transistor modulation circuit. Discuss the use of the high-frequency carrier to transport the audio.

Describe the circuit operation.

Discuss the generation of sidebands and draw a spectrum distribution chart.

Show how the bandwidth is twice the frequency modulation.

Show how 100 percent modulation is normal limit. Have students perform typical calculations.

Describe relationship between carrier power and modulator power. Have students perform typical calculations based on: Power in one sideband = $\frac{M^2 \; Pc}{4}$.

Develop the need for frequency modulation because of its S/N ratio advantage over that of AM.

Note that f_d is proportional to the amplitude of the modulating signal.

Discuss the bandwidth as being determined by frequency deviation and modulating frequency.

Show block diagram. Explain frequency multiplication approach.

Draw the block diagram of a typical AM superheterodyne receiver and show the waveforms present at each point.

1. RF amplifier

2. Convertor

3. IF amplifier

4. Detector

5. Audio amplifier

D. FM receiver

1. Detector circuit and operation

a. Foster Seeley

b. Ratio detector

2. Limiters

E. Transmission lines

ADVANCED ELECTRONICS

Explain that an RF amplifier is used in a superheterodyne receiver to improve S/N ratio and image rejection. Note coverage of broadcast band range, 550 — 1600 kilocycles.

Develop the concept of heterodyning. Show the circuit of the oscillator and how its signal acts on the mixer.

Define the IF amplifier and locate it in the block diagram. Show a typical IF amplifier circuit and explain its operation qualitatively. Show how the IF transformers determine the amplifier response curve. Emphasize that the IF amplifier determined the sensitivity and selectivity of the receiver.

Explain the operation of the detector as a rectifier and filter circuit.

Draw block diagram of FM receiver showing typical waveforms.

Show required response curve. Explain detection process. Describe the circuit operation by use of phasor diagrams.

Describe the need for the limiter circuit. Explain circuit operation.

Define a transmission line as any pair of conductors used to carry electromagnetic energy from one place to another. Discuss the meaning of wavelength.

TECHNICAL EDUCATION

1. Types of lines

2. Characteristic impedance

3. Standing Wave Ratio

4. Quarter-wave matching section

Show and describe the physical construction of the two-wire parallel and coaxial transmission lines. Compare their advantages and disadvantages. Show equivalent circuits in lumped constant form.

Define the characteristic impedance of a transmission line as that impedance which would be measured at the input terminals of an infinitely long transmission line of a particular type.

Demonstrate that when the length of a transmission line is of the same order of magnitude as the wavelength of the signal handled, standing waves may appear on the line.

Show that standing waves do not exist on a line when the line is feeding a load whose impedance is equal to the characteristic impedance of the line.

Explain that Standing Wave Ratio (SWR) is the ratio of the maximum total RMS voltage to the minimum total RMS voltage appearing on the line. (Or maximum total RMS current to minimum total RMS current.)

Demonstrate that standing waves appear on the line when the line is feeding a load which is not matched to the characteristic impedance of the line.

Indicate that the Standing Wave Ratio is the most common term used in practice for discussing line performance, and that an SWR of 1:1 is most desirable. Solve problems.

Discuss the quarter-wave matching section. Determine the required characteristic impedance of a matching section when given a source impedance and load impedance.

F. Antennas

1. Half-wave dipole (Hertz)

2. Quarter-wave (Marconi)

3. Directors

Indicate that when a high-frequency current passes through a conductor, a power loss takes place which cannot be accounted for by the simple $P = I^2R$ formula.

Explain that attempts at attributing this phenomenon to simple magnetic coupling are precluded by the distances and magnitudes involved as well as the fact that the losses continue even if no receptor (second conductor) is available to absorb the energy.

Explain that this loss is due to electromagnetic radiation.

Emphasize that this electromagnetic radiation can be maximized by separating the ends of a transmission line so that they are at right angles to the transmission line.

The antenna thus created is known as a dipole antenna, the most basic of antennas. The dipole is also known as a Hertz antenna.

Explain that the length of the dipole is one-half the wave length of the signal being transmitted or received.

Point out that the same antenna can be used for both transmission and reception.

Discuss the quarter-wave vertical antenna. This is also known as a Marconi antenna.

Show that the Marconi antenna can be explained as a special case of vertical dipole, the second half of the antenna appearing as a reflection in the ground.

Define a director as an element added to the basic dipole antenna in front of the dipole (front being the direction of desired radiation), for the purpose of increasing the directivity of the antenna.

4. Reflectors

G. TV receivers and transmitters

III. Pulse techniques

A. Pulse characteristics (ideal rectangular pulse)

B. RC circuit response

C. Integrators and sweep generator

D. Differentiation

Define a reflector as an element added to the basic dipole antenna behind the dipole (behind being the direction of undesired radiation), for the purpose of increasing the directivity of an antenna.

(General treatment *only*)

Develop as an introduction, the characteristics, shaping, amplification, and generation of transient signals, with application to modern fields of electronics.

Define leading edge, trailing edge, pulse duration, resting period, pulse repetition time, pulse repetition rate, and duty cycle.

Discuss the dependence of pulse harmonic content on duty cycle, and the amplifier characteristics required for distortionless amplification.

Apply a rectangular pulse signal to RC filters and observe the effect on rise time, tilt, and fall time in the time domain, and the corresponding attenuation of harmonics in the frequency domain.

Define and calculate rise time, tilt, and fall time.

Examine the response of a low-pass RC network to a rectangular pulse input as the RC time constant is increased. Develop the integrator as the limiting case. Apply as a sweep generator.

Examine the response of a high-pass RC network to a rectangular pulse input as the RC time constant is decreased. Develop the differentiation as the limiting case.

E. Pulse amplifiers

F. Limiters and clippers

G. Clamping circuits and voltage doubler

H. Transistor as a switch

I. Bistable multivibrator

J. Counting circuits

K. Time delay switch

L. Astable multivibrator and pulse generator

M. Applications

ADVANCED ELECTRONICS

Apply the analyses outline above to the use of square waves to measure the frequency response of an audio amplifier, and to the amplification of rectangular pulses.

Apply the semiconductor diode as an electronic switch at forward voltage. Develop limiting and clipping circuits.

Stress the property of capacitors to oppose a change in voltage. Develop both positive and negative clamping circuits. Apply to half-wave voltage doubler.

Introduce use of the transistor as a switch. Study voltage and current conditions at saturation (on) and cutoff (off). Determine condition necessary for switching action. Apply as a slicer and as a gate.

Connect two transistor switch circuits in cascade. Compare second stage output with first stage input. Form bistable multivibrator. Develop input signal circuit.

Use several bistable multivibrators to form a counting circuit.

Add RC circuit to transistor switch to provide delay.

Cascade two time-delay circuits to form an astable multivibrator. Generate pulses of varied width.

Relate the preceding techniques in a general manner, to radar (range problems), television (sync pulse, sync separation, vertical sweep, horizontal sweep, and blanking pulses), and to simple computer circuits.

COMPUTER CIRCUITRY OPTION

I. Number systems

A. Binary system

B. Octal

C. Hexadecimal

D. Codes

II. Logic functions

A. Binary variables

1. Definition

2. Functions

B. Logic blocks

1. AND
2. OR
3. INVERTOR
4. NAND
5. NOR

COMPUTER CIRCUITRY

Explain the construction of a positional significance number system, as demonstrated by the decimal system.

Demonstrate the binary number system. Develop student facility in conversion to and from the decimal system. Addition and subtraction in the binary system should be understood.

Demonstrate the octal number system.

Demonstrate the hexadecimal number system.

Explain the difference between a code and a number system. Explain the BCD code as a four-bit, column-by-column, binary representation of decimal digits. Briefly mention Gray Code.

Define a binary variable and describe conditions and situations which they may represent.

Explain the concept of a function dependent upon several binary variables. Show that the function itself must be representable as a binary variable.

Explain the logic function performed by each logic block. Present logic symbols used to represent each of these functions. Introduce the Truth Table as a technique for investigating logic functions. Stress the listing of combinations of variables in ascending numerical order to insure inclusion of all combinations. Show relationship between number of variables and number of combinations.

III. Logic design

A. Boolean algebra

1. Theorems and postulates

2. Equation reduction

B. Karnough map

C. Truth Table

IV. Diode logic circuits

A. AND gate

B. OR gate

C. Matrices

Mention areas in which logic design is used and give simple examples. Distinguish between logic design and circuit design.

Define Boolean algebra as a mathematical technique for reducing equations involving binary variables.

State and prove the theorems and postulates of Boolean algebra.

Assign problems in binary equation reduction using Boolean algebra.

Explain that the Karnough map is a device for simplifying the reduction of binary equations. Present the Karnough map for two, three, and four variables and explain how reductions are made. Plot the map for binary equations in "standard sum form" and write "standard sum form" equations from a Karnough map.

Show how to use a Truth Table to develop a binary equation from the statement of the problem. Show importance of Truth Table in proving validity of reduction.

Analyze two input and three input gates in terms of instantaneous voltage levels, bias conditions, and logic function. Stress the existance of only two discreet voltage levels corresponding to "one" and "zero." Explain that positive or negative logic may be used, determined by selection of voltage level.

Explain format of diode matrix for converting decimal to binary numbers. Show that this technique can be used for coding and decoding.

V. Transistor logic circuits

A. Invertor

B. Diode transistor logic

1. NAND

2. NOR

C. Other

1. RTL

2. DCTL

3. CML

VI. Pulses and pulse trains

A. The ideal pulse

B. The distorted pulse

VII. Pulse circuitry

A. Bistable multivibrator

Review phase inversion in the common emitter amplifier and explain its effect on logic voltage levels. Introduce clamp voltage to reduce forbidden zone.

Develop on DTL NAND and NOR gates as combinations of AND, OR, and Invertor. Explain that NAND and NOR are basic logic blocks which may be used to construct OR and AND gates. Show interconnections necessary to convert multiple NOR IC to OR and AND.

Present "Resistor-Transistor-Logic," "Direct-Coupled-Transistor-Logic," and "Current-Mode-Logic" forms of NAND, NOR, and Invertor.

Define and explain the terms used to describe an ideal pulse and pulse train. Define rise time and fall time. Demonstrate effect of distorted pulse on AND and OR gates. Explain need for delay lines.

Explain the operation of the saturated "Flip-Flop" and its function in logic circuits. Develop resistor capacitor pulse generating and diode pulse steering to evolve at J-K "Flip-Flop." Emphasize trigger techniques and waveshapes.

B. Astable multivibrator

C. Monostable multivibrator

D. Schmitt trigger

VIII. Computer circuits

A. Adders

1. Half

2. Full

B. Subtractors

1. Half

2. Full

C. Shift register

COMPUTER CIRCUITRY

Explain the astable multivibrator as a source of clock pulses. Show how to determine pulse width and pulse rate from feedback network. Show how "steered" Flip-Flops can be used for frequency division.

Discuss the need for an accurately timed pulse occurring at a specific time, and introduce the monostable multivibrator as the circuit to accomplish this. Show that it is half of astable and half of bistable. Explain how to calculate ON and OFF times. Show the output pulse train developed in response to an input pulse train.

Explain the operation of the Schmitt trigger in pulse shaping as in tape-read circuits.

Review binary addition. Develop a Truth Table for the sum and carry of a one-bit binary adder. Have students draw the logic block diagram from the Truth Table, and implement the diagram using discreet components and IC's. Repeat for full-adder.

Repeat the procedure for subtraction.

Review the "steered" Flip-Flops and show how they may be interconnected for shift left (multiplication) or shift right (division) registers. Explain the function of shift registers as buffering devices for memory. Demonstrate applications of IC's.

D. Counters

E. Sign comparator

IX. Computer systems

A. Block diagram

B. Input/output devices

C. Memory

D. Control

E. Troubleshooting techniques

Show how "steered" Flip-Flops may be interconnected to operate as counters (count-up and count-down). Explain the function of counters in initiating action after a specific time. Show how AND and OR gates can be used to reset counters.

Review arithmetic operations with signed numbers. Introduce "base-minus-one" complement to avoid subtractor circuits. Develop logic circuit for sign comparator and show interconnections with two-bit full-adder.

Develop a simplified block diagram of a computer showing input, output, control, memory, and arithmetic sections.

Discuss the characteristics and applications of contemporary input/output devices.

Review magnetics and discuss the principles of operation of drums, discs, and cores.

Discuss the importance of timing and the need for delay lines. Explain the concept of decision-making in terms of "more than," "less than," or "equal to." Introduce the concepts of a "central-processing-unit" and of peripheral equipment.

Discuss the purpose of diagnostic routines. Show how the oscilloscope can be used for pulse train analysis.

ELECTRICAL CONSTRUCTION

I. Safety

Discuss gen
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II. Basic hand skills

A. Hand tools

B. Drilling tools

C. Measuring tools

D. Soldering tools

Students wi
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III. Construction

A. Layout

B. Wiring

C. Testing

D. Reporting

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IV. Residential and power wiring (general treatment)

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Note: The desirable work skills may be taught in several ways,
taught as a separate "shop" subject, or integrated int
skills could be taught in a machine shop course; the p
or electronic laboratory.

Discuss general shop and field safety, considering precautionary measures and first aid. Eye safety and artificial respiration techniques should be included.

Students will be required to demonstrate a commercially acceptable degree of proficiency with tools and techniques currently used in the electricity and electronics industry.

The basic skills will include wire stripping, soldering, lacing, drilling, tapping, reaming, filing, grinding, crimping, and splicing. Use of the micrometer and wire gauges will be taught.

The construction of a project or projects will be required of all students, in order to develop practical, work-type experiences and to demonstrate ability to apply basic mechanical skills. The scope of this work will cover layout, wiring, testing, troubleshooting, and writing of a report. Time should be devoted to becoming familiar with catalogs and test equipment instruction manuals.

Attention will be given to the fundamental principles of residential and industrial wiring, and to development of the skills (manual and mental) important in performing basic wiring jobs involving the use of armored cable and conduit.

All students will be required to be familiar with the National Electric Code and local wiring codes.

ay be taught in several ways, depending on local conditions. They may be p" subject, or integrated into other courses. For example, the basic hand a machine shop course; the project could be accomplished in an electrical

ELECTRICAL-ELECTRONIC DRAFTING

I. Conventions, symbols, and standards

A. Layout of sheet

B. Terminology

C. Alphabet of lines

II. Lettering

A. Style

B. Technique

III. Use and care of drafting instruments and materials

A. T-square, parallel straightedge, and board

B. Triangles

C. Pencils

D. Paper

E. Instruments

F. Special devices

G. References and handbooks

IV. Measuring, and measuring instruments

A. Engineer's scale

Introduction, and familiarization with terminology.

Emphasize importance of proper lettering legibility, especially for photo-reduction. Demonstrate techniques used in lettering and their purpose, the use of guidelines, and the style of lettering recommended by the electronics industry.

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Emphasize the importance of "squareness" in maintaining dimensional stability. Discuss the selection of pencil, proper pointing techniques, and standard paper sizes and types. The use of drafting instruments, especially compass and dividers, and of templates and reference books as aids to the proper execution of electronic drafting should be emphasized.

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Measuring devices. Using the Engineer's scale. Reading a scale. Using the micrometer.

B. Combination scale

C. Calipers

D. Dividers

E. Mechanical aids

F. Radius gauge

G. Protractor bevel

H. Micrometer

V. Dimensioning

A. Units

B. Lines

C. Arrowheads

D. Methods

E. Angles and arcs

VI. Notes

A. Material

B. Number required

C. Trade terms

D. Title block

Emphasize the critical importance of measuring accurately those dimensions necessary to reproducibility.

Standard methods of dimensioning. Importance of accuracy. Techniques used in dimensioning, base line, centerline. Arrowhead practice.

The function of notes. Methods of placing notes on drawing. Modification indication. EIA and MIL specification methods of component and diagram numbering.

VII. Orthographic projection

A. Relationship of views

B. Selection of views

1. Necessary views

2. Choosing location on plate

VIII. Block diagram

A. Block layout

1. Inline layout

2. Row layout

3. Complex layout

4. Columns and rows

5. Line work

B. Flow path

C. Block size

D. Graphical symbols

IX. Electronic symbols and conventions

A. Resistors

B. Capacitors

C. Inductors and transformers

The orthographic projection as an introduction to pictorial diagrams. Transferring information from view to view. Selection of views to best display the object.

The role of the block diagram in electronic drafting. The use of the block diagram in electronic troubleshooting. Military specifications for block diagrams.

Standard and special (EIA and military) electronic symbols. Color codes. Pictorial representation. Pin numbering and base diagrams for tubes and transistors.

D. Electron tubes

E. Semiconductor devices

X. Schematic layout procedure

A. Data

B. Trial layout

C. Estimating dimensions

D. Symbol locations

E. Note selection

XI. Schematic diagrams

XII. Chassis and enclosures

A. Types

B. Layout

C. Marking

Decisions to be made before drafting. Selection of paper size. Determination of spacing. Techniques of layout for eye appeal. Determination of need for notes.

All phases of electronic schematic diagrams will be taught and practiced. Students will prepare diagrams to accompany their laboratory experiments and construction projects in addition to other assigned plates. Heavy emphasis on layout, linework, lettering, and symbols.

Emphasis to be placed on the development of all working drawings needed to manufacture a piece of electronic equipment. Students will be required to develop a set of drawings for one of their construction projects.

Human factors in panel layout.

Hole size and mounting methods for all common electronic components.

Degree of tolerance and its effect on cost of manufacture.

Chassis marking. Standard abbreviations. Warning labels. Prototype markings as opposed to production markings. Use of dry lettering kits.

XIII. Chassis assemblies

A. Pictorial drawing — Relation of subassem[...] equipment. Standa[...]

B. Assembly — Selection of chassis

C. Panel drawing — Panel drawings for m

Note: The basic drafting skills may be taught in various ways, depending and its facilities. For example, most of the skills could be taug while the application to the electrical-electronic field could be

Relation of subassemblies to the overall piece of equipment. Standards for subassembly designations.

Selection of chassis breakdown.

Panel drawings for manufacturing.

kills may be taught in various ways, depending on the organization of the school For example, most of the skills could be taught in a mechanical drawing course, n to the electrical-electronic field could be integrated in other subjects.

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