Student Manual

BASIC ELECTRICITY AND CIRCUITS

COYNE
ELECTRICAL AND
RADIO-TELEVISION
SCHOOL
CHICAGO 12, ILLINOIS

26-11-37

FOREWORD

This manual contains basic technical and practical information based on the curriculum outline for the Basic Electricity & Circuits Department of this school. The subject matter covered in this manual is necessary information that the student must learn in order to master the jobs that will be presented in following departments.

The purposes of this instructional manual are as follows:

1. To provide a guide for the student in his class and shop work.

2. To supply information in outline form to which the student may add supplemental notes in his own words as the different points are explained by instructors.

3. To serve as a reference both to the student in school and to the graduate after he enters the field.

Appreciation is extended to the Basic Electricity & Circuits personnel and to the entire faculty for developing the material for this manual.

B. W. Cooke,
President.

ACKNOWLEDGMENTS

We wish to acknowledge and express our appreciation for the assistance and cooperation given by the following Companies in supplying data and illustrations for the preparation of this manual.

AMERICAN INSTITUTE ELECTRICAL ENGINEERS
AMERICAN STANDARDS ASSOCIATION
CENTRAL SCIENTIFIC CO.
CHICAGO LIGHTING INSTITUTE
GENERAL ELECTRIC COMPANY
ILLUMINATION ENGINEERING SOCIETY
KELLOGG SWITCHBOARD AND SUPPLY COMPANY
NATIONAL BOARD OF FIRE UNDERWRITERS
NATIONAL BOARD CO.
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATIONS
SOLA ELECTRIC COMPANY
SYLVANIA ELECTRIC PRODUCTS, INC.
UNDERWRITERS LABORATORIES
WELCH SCIENTIFIC CO.
WESTERN ELECTRIC CO.
WESTINGHOUSE ELECTRIC CORPORATION
WESTON ELECTRICAL INSTRUMENT CORPORATION

T A B L E   O F   C O N T E N T S

PROCEDURE GUIDE
(Lesson Section)

The lesson section of this manual has been prepared with required lessons, also with supplementary lesson material which may be used as reference material of the subject.

The required lessons are covered in the following order:

Lesson No.	Title	Date of class
1-1.	Basic Electricity	....
2-2.	Simple Circuits	....
3-3.	Units and Symbols	....
4-4.	National Electric Code	....
5-5.	Electrical Switches	....
6-6.	Lighting Control	....
7-7.	Ohm's Law	....
8-8.	Resistance Measurements	....
9-9.	Watt's Law	....
10-10.	Practical Applications of Ohm's Laws	....
11-11.	Relays	....
12-12.	Annunciators	....
13-13.	Magnetism	....
14-14.	Electro-Magnetism	....
15-15.	Electro-Magnetic Induction	....
16-16.	Transformers	....
17-25.	Edison Three-Wire Systems	....

Your study of the Manual should be directed mainly to the required lessons. Between school nights you should study the lesson that was covered in the preceding class period and the lesson to be covered in the following class eriod.

Any extra time may be spent in the study of the supplementary lessons.

BASIC ELECTRICITY

Objective:

To acquire knowledge of the nature of electricity; to distinguish Static Electricity and Dynamic Electricity; to learn the various methods of producing an EMF; to learn some of the methods used for handling electric charges.

References:

Lesson Content

A. Nature of Electricity

1. Definition

Electricity is an invisible force of nature which can be controlled under certain laws. An electrical law is a fact or facts that have been proved by experiments. All MATTER IS ELECTRICITY. Matter is anything that has weight and occupies space, and it exists in three states, - solids, liquids, and gases. Matter cannot be created or destroyed, but it can be changed from one state to another, the state being determined by temperature and pressure. Properties of matter are, color, conductivity, brittleness, hardness, ductility, and elasticity. All matter is composed of small particles called molecules.

2. The Molecule

The molecule is the smallest division of a substance obtainable by physical means that retains all of the physical characteristics of that substance. For example; - molecules of air, oil, water, steel, glass, etc. All molecules of the same substance are alike. A molecule is made up of one or more smaller particles called atoms.

3. The Atom

An atom is the smallest subdivision of matter. All atoms of the same substance are alike. There are more than 90 different atoms such as, - copper, hydrogen, oxygen, helium, lead, iron, tin, etc. Each atom normally consists of an even balance of positive and negative, which is known as a neutral charge. The nucleus of the atom consists of positive protons and attracted by this nucleus is a number of electrons, which rotate around it in orbits.

4. The Proton

The proton is a particle of matter having a unit positive charge of electricity. All protons are alike.

5. The Electron

The electron is a particle of matter having a unit negative charge of electrons. All electrons are alike. An electron bound to a proton in the nucleus is called a nuclear electron. An electron which revolves around the nucleus is called a free, orbital, or planetary electron.

6. The Neutron

The neutron is composed of a single proton and a single electron which have combined to form a neutrally charged body.

7. The Ion

The ion is an atom that has lost or gained one or more electrons. We refer to the ionization of a gas or liquid. Ions can be either positive or negative. In other words, an ion is a charged atom.

8. Charges

a. A positive charge exists where atoms have lost electrons.
b. A negative charge is where atoms have gained electrons.

B. Static Electricity

These charges can be produced by means of friction or induction and when at rest on insulating materials are known as STATIC ELECTRICITY.

NOTE: Static charges are built up on paper moving at high speed through a printing press, cars and trucks moving along a highway, people walking across linoleum or carpeted floor, clouds and aircraft moving through the air, canvas grain elevators, electric drills, cotton gins, knitting machines, etc.

1. Naturally then, an atom that has lost an electron (positive charge) will have an attraction for an atom with an over supply of electrons (negative charge). This leads to the fact that unlike charges attract each other. Also, two atoms with the same amount of positive charge or the same amount of negative charge will tend to push apart or repel each other. From that we can say like charges repel each other. The above is referred to as the law of electrostatics.

2. Coulomb's Law states that "the force existing between the two small charged bodies is directly proportional to the product of the charges and is inversely proportional to the square of the distance between them.

3. Charges by induction.

When an uncharged body comes in contact with a charged body, it will take a charge similar to the charged body.

C. Capacitors (condensers).

1. Definition

A capacitor is a device used to store electricity or electrical energy in the nature of static charges. It consists of two conductors, called plates, separated by means of an insulating material called the dielectric. A dielectric is any insulating material which hinders or prevents the flow of electrons.

2. Function

The charge in a capacitor is stored in the nature of an electrostatic stress or strain in the dielectric.

3. Electrical Capacity depends upon:

   a. Area of the plates and dielectric
   b. Thickness of the dielectric
   c. Dielectric material - common materials are air, waxed paper, mica, glass, gases.

   NOTE: Capacitors are often made with flat plates of foil or metal stacked and separated by means of flat sheets of glass, mica, air, or rubber. Others are made of alternate layers of foil and waxed paper rolled together. A pair of telephone wires or power line wires stretched on poles across the country can constitute a capacitor of such size as to be dangerous.

4. Unit of Capacity

   Capacity is measured in farads. A capacitor with one farad capacity will absorb one coulomb of electricity when one volt is applied to its plates. The practical unit of capacity is the microfarad.

5. Potential, force.

   a. Difference of potential exists between two bodies if these two bodies have different degrees of electrical charge.
   b. Potential difference (PD) is measured in volts.
   c. A volt is an assigned unit of difference in pressure or electromotive force (EMF).

D. Dynamic Electricity (current)

   Dynamic electricity is the <u>result</u> of the flow of electrons, and is called current.

   a. Electrons, being negative, always travel toward a point which is positive (or less negative) in potential. Current in strictly electrical circuits is conventionally traced from positive to negative, while in radio and electronic circuits the current, electron flow, is traced from negative to positive.
   b. A conductor is a material which has many free electrons and allows the electrons to pass through it with relative ease. Some good conductors are: silver, copper, aluminum, zinc, brass, gold, tin, nickel, lead, and iron.
   c. An insulator is a material which has few free electrons and tends to oppose electron flow (current). Some common insulators are: glass, mica, rubber, paper, silk, bakelite.
   d. When electrons flow, resulting in current, the impulse travels with a speed approaching that of light or any other form of radiant energy, about 186,000 miles per second.

E. Generating an Electromotive Force (EMF).

   1. Electricity cannot be created or generated. But we can generate an electromotive force, a force that tends to move electrons, which produces current when the circuit is complete.

2. Sources of electromotive force.

   a. Chemical (cell or battery) - When two dissimilar substances, such as zinc and copper, are immersed in an electrolyte, and EMF is generated. An electrode series could consist of zinc, iron, copper, silver, platinum, and carbon, arranged from negative to positive.

b. Thermo-electric effect (heat) - when a junction or couple of two dissimilar conductors is heated, electrons will move from one of the conductors to the other thereby establishing a difference of potential between the two. Common thermo-junction materials (negative or positive); bismuth, nickel, platinum, copper, lead, silver, antimony. Used in pyrometers for electric furnaces, enameling ovens, etc.

c. Photo-electric effect (light) a photo-electric cell is a device which converts vibration of light in corresponding variations in voltage or current. Certain substances, such as selenium, have this property. Used in light meters.

d. Mechanical - Magnetic (generator) - when a conductor is moved through a magnetic field, an electromotive force is set up between the ends of the conductor. If a path is provided between the ends of the conductor, electrons will flow.

Piezo-electric effect (crystal) - a crystal is a material which will create an electromotive force when pressure is applied. Commonly used for this purpose are Brazilian quartz, Rochelle salts, and Tourmaline. Used in microphones, phono-ickups, etc.

Friction (static) - when certain substances are rubbed together, electrons are transferred from one of the substances to the other, leaving one substance negatively charged and the other substance positively charged. An electro-static series (positive to negative) would be: glass, fur, wool, silk, wood, sealing wax, hard rubber, sulphur.

F. Current is necessary to operate electrical equipment of any kind. It is measured in amperes.

1. Four effects produced by current.

a. Heating effect (thermal)
Electrical appliances using this effect are: lamps, irons, ranges, toasters, vacuum tubes, electric heaters, etc.

b. Chemical effect
This electrical effect is used in electro-plating, electrolysis, battery charging, etc.

c. Magnetic effect
This effect is used in electric bells, motors, meters, relays, electro-magnets used in industry to move iron or to crush iron in the case of the "skull crusher".

d. Physiological effect - the effect of current upon man and beast. Galvani noticed the twitching of the muscles of a pair of frog legs which led to some of the most important early discoveries in the field of modern electrical science. Common uses of this effect are the electric fence, the electric prod, electro-therapy, electric needle for killing hair, the electric chair, etc.

NOTE: The American Standards Association definition No. 05.10.015 follows:

"Electricity is a physical agent pervading the atomic structure of matter and characterized by being separable, by the expenditure of energy, into two components designated as positive and negative electricity, in which state the electricity possesses recoverable energy."

SIMPLE CIRCUITS

Objective

To study simple electrical circuits and the switches used to control them.

References

____

____

Lesson Content

A. The Electrical Circuit

1. General

The word "circuit" means to go around. An electrical circuit, to be complete must provide a continuous path for the passage of current (electron flow). Any practical electrical circuit consists of at least four parts:

a. A source of electromotive force (EMF).
b. A set of conductors
c. A load
d. A means of control

2. The source of EMF.

Electromotive force can be defined as "a force that can move electrons". It may be any kind of cell or battery, a d-c or a-c generator, an electronic power supply or any arrangement of apparatus capable of generating a difference of electrical pressure.

3. The conductors

Wires of various sizes may be used as conductors but the term "conductor" actually refers to any medium which offers relatively low resistance to the flow of current. Conductors may be "good" or "poor", but the latter are usually referred to as "resistances", or if the conductivity is very low, as "insulators". There are no sharp lines of distinction separating conductors, resistors, and insulators.

4. Load

The load on an electrical circuit may be anything which uses electrical energy, such as a lamp, a bell or buzzer, a toaster, a radio, or a motor. Usually the load is considered apart from the conductors which connect it to the source.

5. Means of control

The current flowing in an electrical circuit is turned on and off by means of switches, further control being provided by variable resistance such as rheostats and potentiometers. In certain cases this classification might include fuses, circuit breakers, or relays.

B. Electrical Symbols

Instead of using pictures to represent an electrical circuit (pictorial method), electrical symbols are generally employed (schematic method). These standard and universally recognized symbols make it easy for anyone to draw quickly electrical diagrams that are understood by everyone else in the business. Many of the common electrical symbols are shown in Fig. 2.

C. Circuit Connections

1. Series

Three resistors are shown connected in series with each other in Fig. 1A. Notice that there is only one path for the current, that the same current flows through all parts. Assuming the resistors represent lamps, if one lamp is turned off, the remaining lamps all go out. Such a connection is called a series connection. It may be used with lamps, bells, or other appliances.

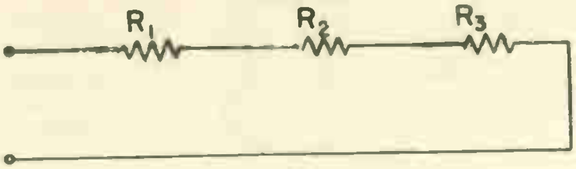
2. Parallel

Fig. 1B shows the same three resistors connected shunt or parallel, also often called multiple. In this case, note that there is more than one path for current to take; that the current in each resistor is not necessarily the same. Certainly the current in any one resistor is less than the total current, and that (if the resistors are regarded as lamps) turning off one of them will not put the others out. Parallel connections are also used for all types of electrical equipment.

Note that all parallel connections do not look the same, Fig. 1C

3. Combination

Fig. 1D shows the three resistors connected in still a different way. They are not all in series with each other, nor are they parallel, although two of the resistors are connected in series with each other, and the two taken together are parallel with the third resistor. Since the aspects of both series and parallel circuits are found here, this is called a combination circuit. Other combination circuits are found represented by Figs. 1E and 1F.

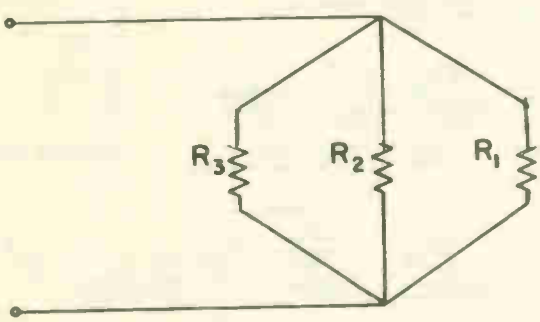


A

1. R1 is connected in series with R2 TRUE FALSE

2. R2 is connected in series with R3 TRUE FALSE

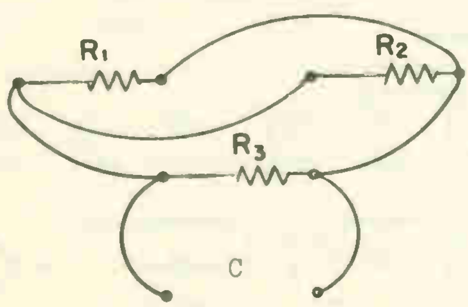
3. R1, R2 & R3 are connected in series with one another TRUE FALSE



B

1. R1 is connected in series with R2 & R3 TRUE FALSE

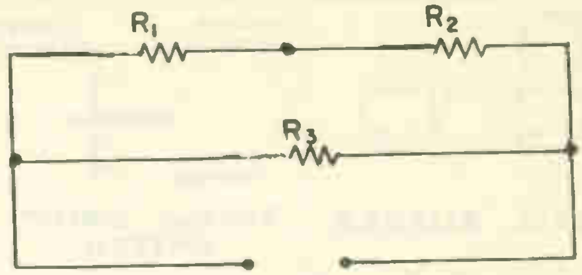
2. R2 is connected parallel with R3 & R1 TRUE - FALSE



C

1. R1 is connected in series with R2 TRUE FALSE

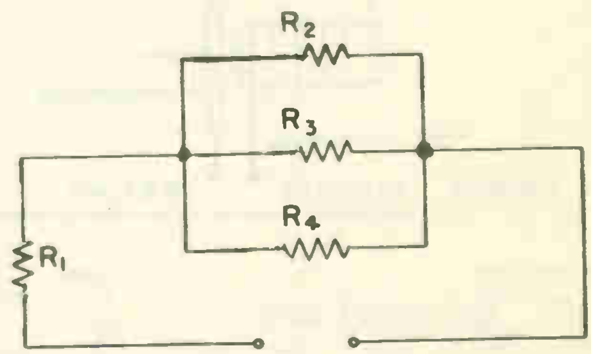
2. R2 is connected parallel with R3 TRUE - FALSE



D

1. R1 is connected in series with R2 TRUE FALSE

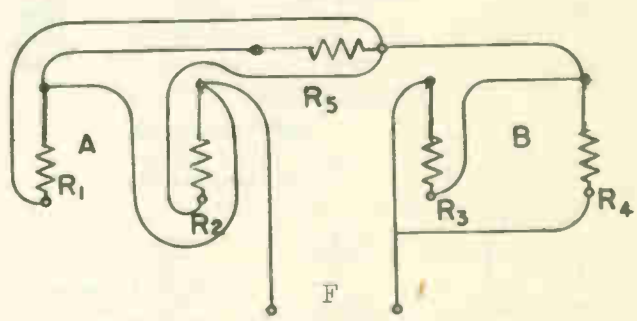
2. R3 is connected parallel with R1 & R2 TRUE - FALSE



E

1. R1 is connected in series with the network TRUE FALSE

2. R3 is connected in series with R1 TRUE FALSE



F

1. R1 is connected parallel with R2 TRUE FALSE

2. Network A is connected in series with network B TRUE FALSE

Fig. 1 Circuit Connections

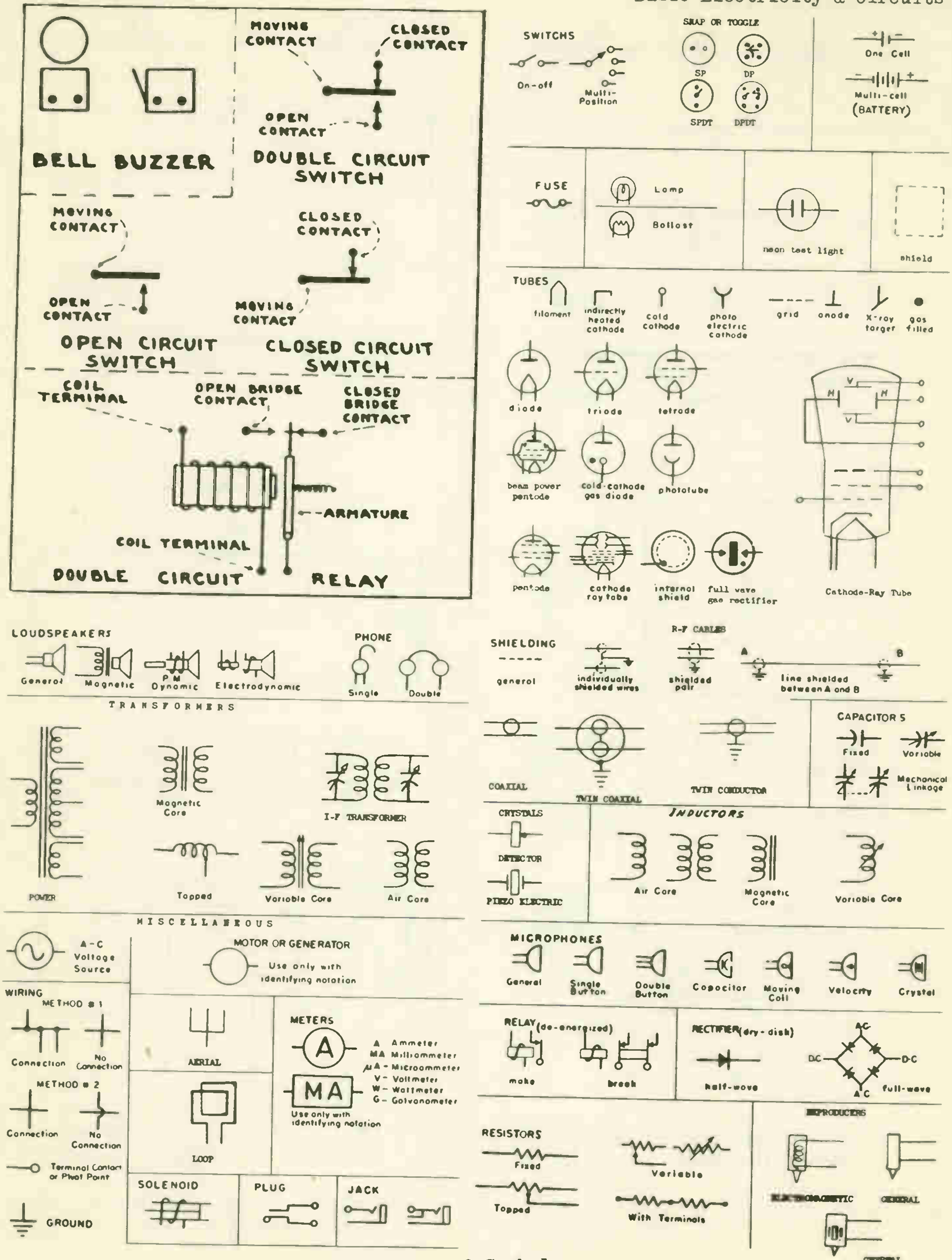
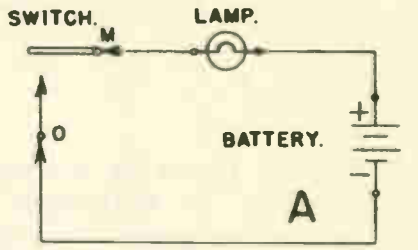


Fig. 2 Symbols

D. Identifying Switch Terminals

M = MOVING CONTACT.
C = NORMALLY CLOSED CONTACT.
O = " " OPEN "

Before wiring any circuit that involves the use of switches, it is first of all necessary to test the switches themselves to make sure that they are the type required and that they are operating properly.



The test circuit consists of a source of power, a test lamp, and a couple of leads. When the test leads are touched together, the lamp should light. If the lamp does not light, there is something the matter with the test circuit.

Diagram A shows how to test a switch. Note that the leads from the test circuit are placed on the switch terminals. As this switch is normally open the lamp will not light until the switch button is pressed. If the lamp lights when the button is pressed, two things are shown:

1. The switch is in operating condition
2. The switch is an open circuit type

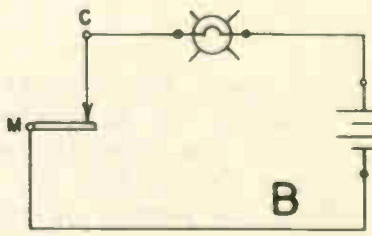
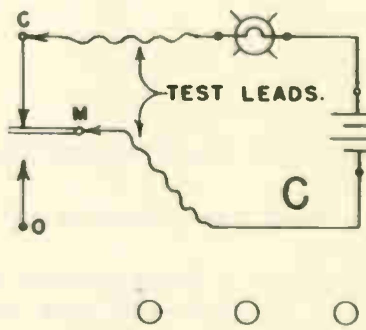


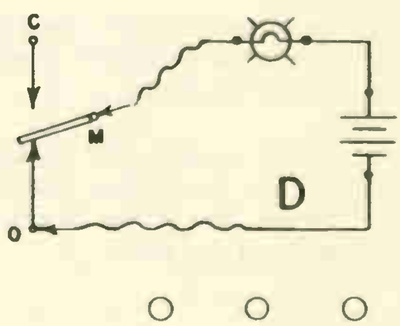
Diagram B shows the test result on a switch that is normally closed. If the test lamp lights when the leads are placed on the switch terminals but goes out when the button is pressed, two things are shown:

1. The switch is in operating condition
2. The switch is a closed circuit type

Diagram C shows a double circuit switch. This is really two switches in one, for it is a combination of an open circuit switch and a closed circuit switch. To test this switch and find which terminals connect to the various parts, first find the two terminals that will give a light without pressing the switch. These two terminals must connect to the moving contact of the switch and the closed contact of the switch. The remaining contact must be the open contact. Mark O alongside this terminal.



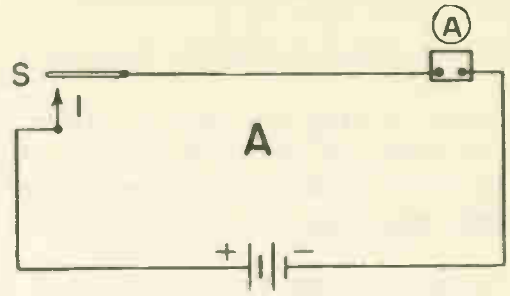
Next find the pair of contacts that produce a light only when the switch is pressed; these will be the moving and open contact. As the open contact has already been found, the other contact must be the moving contact. Mark this terminal M. The third must be the closed contact. Mark it C In this way, all of the switch terminals may be identified.



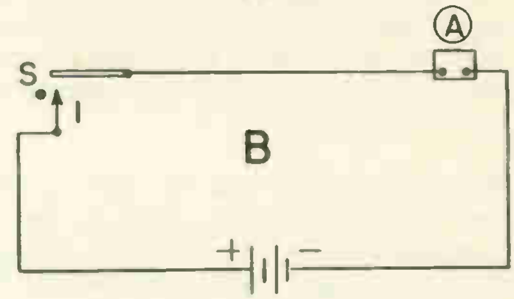
If the above indications cannot be obtained, the switch must be defective. Try another one. Always test switches before wiring them up in a circuit. In this way much time will be saved and, when the connection is properly completed, the circuit will operate.

E. Steps for Tracing an Electrical Circuit

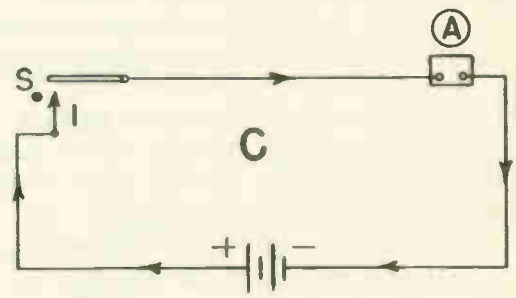
1. Mark the polarity of the source of supply, putting a (+) mark at the point of highest electrical pressure, and a (-) mark at the point of lowest electrical pressure.



2. See if there is a complete path from (+) to (-). In this case the path can be completed only by closing the switch S. To indicate that this switch is closed, place a dot beside it as shown.



3. Now trace the circuit, using the arrows to indicate the direction of current flow around the circuit from the high pressure point (+) to the low pressure point (-). Mark the number of the circuit alongside or inside the diagram and show the color of the arrow used to trace it thus:
Circuit 1 >



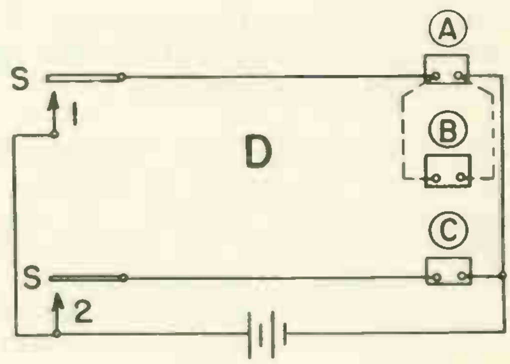
F. Practice Diagram for Circuit Tracing

1. Mark the polarity of the battery (+) (-).

2. Plaee a lead pencil dot beside switch 1 to indicate that the switch is closed. Then, using the same color, trace the circuit controlled by this switch.

3. Mark number of circuit alongside diagram and show colored arrow used to trace it thus: Circuit 1. >

4. Place a red dot beside switch 2 to indicate that the switch is closed and trace the circuit controlled by this switch in red.



CIRCUIT No. 1
CIRCUIT No. 2

UNITS & SYMBOLS

Objective

To become acquainted with some of the more common electrical units and the symbols used to represent them.

References

Lesson Content

A. Quantity

If two wires from a cell, battery, or d-c generator are immersed in a solution of copper sulphate, a quantity of copper will go out of solution and be deposited on one of the electrodes. The amount which is deposited will depend on the quantity of electricity involved. In order to deposit exactly .0000116 ounce of copper in this way, requires a very definite quantity of electricity (electrons). This quantity is referred to as a "coulomb".

B. Current

If the source of electro-motive force is increased, the time required to deposit the copper is decreased. If the time required is exactly one second, then we say that the electrons are flowing at the rate of one coulomb per second. We call this rate of flow "1 ampere". Thus an ampere measures current or electron flow and is equal to one coulomb per second.

If we were able to count these electrons as they passed a given point in one second we would find the number was tremendous, about 6,280 quadrillion. We call this number of electrons a "coulomb" (whether they are moving or at rest). If for a "counter" we place an instrument called an ammeter in the circuit, its needle will be deflected to a certain point whenever a coulomb passes through the meter at the rate of one coulomb per second. We can mark the point indicated by the ammeter's needle and call it "one ampere". The ammeter then can be further calibrated so it will always tell us at what rate electrons are flowing. That is, it will measure coulombs per second, or amperes.

C. Resistance

Electrons must overcome opposition or resistance in moving along a conductor. This resistance depends upon the nature of the conductor itself, its size, material and temperature. If we take a long glass tube, 106.3 centimeters long (about 41 inches) and one square millimeter in cross-sectional area and fill it with mercury, a metallic conductor in a liquid state; and if we maintain the temperature constant at zero degrees Centigrade (32 degrees Fahrenheit), it will offer a definite amount of resistance to the flow of current. This amount of resistance is called an "ohm". Anything that offers the same amount of opposition is said to have a resistance of one ohm.

D. Pressure Difference

If we connect the one-ohm resistance described above in an electrical circuit with an ammeter and source of electro-motive force and adjust the electro-motive force until the ammeter reads exactly one ampere, then we are using a definite amount of pressure difference to force current at the rate of one ampere through a resistance of one ohm. We call this difference of pressure "one volt".

E. Conductance

If resistance measures the opposition offered to the flow of current, then conductance can be said to measure the ease with which the current will be permitted to flow. Since a material like copper which has low resistance will have high conductance, and a material like nichrome which has high resistance will have low conductance, we say that conductance is the "reciprocal" of resistance and we measure it in reciprocal ohms, called "mhos", the word "ohm" spelled backwards.

F. Power

1. Mechanical

Power is the rate at which work is done. A horse works at a particular rate, called a "horse-power". For example, the average draft horse is supposed to be able to raise 165 pounds, 200 feet in one minute (the same as 33,000 lbs., one foot in one minute or 550 pounds, one foot in one second). If a motor does the same work in the same time, it is called a one-horse-power motor. Assum-

ELECTRICAL UNITS AND SYMBOLS

UNITS	SYMBOLS	
Coulomb	q	Unit of electrical quantity. The quantity which will deposit .0000116 oz. of copper from one plate to the other in a copper sulphate solution. The quantity of electricity which must pass a given point in a circuit in one second to produce a current of one ampere.
Ampere	A or amp.	Unit of current. (Rate of Flow) One coulomb per second.
Milliampere	ma	.001 amp. (The prefix "milli" means one-thousandsth)
Microampere	mu a	.000001 amp. (The prefix "micro" means one-millionth)
OHM	ohm or Ω	Unit of resistance (R); measure of the opposition offered to the flow of current. The resistance offered by a column of mercury 106.3 centimeters long and 1 square millimeter in cross sectional area, at a temperature of 32 degrees fahrenheit, or 0 degrees centigrade.
Megohm	Meg Ω	1,000,000 One-million ohms.
Microhm	μ Ω	.000001 One-millionth ohm.
Mho	g	Unit of conductance (g) measure of the ease with which a conductor will permit current to exist. It is the reciprocal of resistance.
Volt	v	Unit of pressure difference. (EMF - Electromotive Force) The pressure required to force current at the rate of one ampere through the resistance of one ohm.
Millivolt	mv	.001 v One-thousandth volt.
Microvolt	uv	.000001 v One-millionth volt.
Kilovolt	kv	1000 v (The prefix "kilo" means one-thousand)
Watt	w	Unit of power. One watt is equal to current at the rate of one ampere under the pressure of one volt. P=IxE.
Milliwatt	mw	.001 w One-thousandth watt.
Kilowatt	kw	1000 w Unit of power.
Watthour	wh	Unit of work. (Power x Time) w x h = wh
Kilowatt hour	kwh	1000 wh Unit of work.
Horsepower	hp	746 w The power required to raise 33,000 pounds, one foot in one minute.
Farad	f	Unit of capacitance. Capacity of capacitors (condensers).
Microfarad	mf or μf	.000001 f One-millionth farad.
Micro-micro farad	mmf or μμf	.000001 mf One-millionth microfarad.
Henry	h	Unit of inductance
Millihenry	mh	.001 h One-thousandth henry
Microhenry	μh	.000001 henry

ing 100% efficiency, this mechanical work is performed by the motor when the electrical input is equal to 746 watts so we say that one horse-power is equal to 746 watts.

2. Electrical

If 746 watts is equal to one horse-power, to what is one watt equal? Going back to our original experiment when we forced current at the rate of one ampere through a resistance of one ohm, it required a pressure of one volt. This is an example of power and it is taken as the fundamental unit of electrical power, one watt.

G. Work or Energy

If a one-horse-power (746 watts) motor continued to work at the rate of 746 watts for a definite length of time, a certain amount of work would be performed. The work would be equal to the power employed, multiplied by the time the work was continued. In other words, work equals power multiplied by time. So a practical unit of work is the Watt-hour.

A larger unit, frequently used in electricity, is the kilowatt-hour, KWH.

H. Conversion of Units

It is frequently convenient to use larger or smaller units than the fundamental ones described so far. In such cases, one unit may be readily converted to another by means of the following rules:

1. Kilo - to change standard units to kilo-units, divide by 1,000.
   to change kilo-units to standard units, multiply by 1,000.

2. Meg. - to change standard units to meg-units, divide by 1,000,000.
   to change meg-units to standard units, multiply by 1,000,000.

3. Centi. - to change standard units to centi-units, multiply by 100.
   to change centi-units to standard units, divide by 100.

4. Milli. - to change standard units to milli-units, multiply by 1,000.
   to change milli-units to standard units, divide by 1,000.

5. Micro. - to change standard units to micro-units, multiply by 1,000,000.
   to change micro-units to standard units, divide by 1,000,000.

NATIONAL ELECTRICAL CODE

Objective

To enable the student to grasp readily the general plan, scope, and intent of the National Electrical Code requirements and to make the practical application of the rules clear and understandable.

References

____

____

Lesson Content

A. Important Points in Wiring

The important things to be considered in any electrical wiring job are; first, the selection of wires of the proper size to carry the amount of current required by the equipment, and with the proper insulation according to the voltage of these wires; second, proper mechanical support and protection for the runs of wire; third; secure and permanent splices and connections; fourth, protection and precautions to eliminate all danger of fire and shock.

____

____

____

B. National Electrical Code

"The purpose of the National Electrical Code is the practical safeguarding of persons and of buildings and their contents, from electrical hazards which may result from the use of electricity for light, heat, power, radio, signalling, and for other purposes."

To standardize and simplify the rules of good wiring and provide some reliable guide for electrical construction men, the National Electrical Code has been provided. This code was originally prepared in 1897 and is kept frequently revised to meet changing conditions, and improved equipment and materials. It is a result of the best efforts of electrical engineers, manufacturers of electrical equipment, insurance experts, and architects.

____

____

____

C. State and Local Codes

There are at least four "Codes" or sets of rules governing electrical work.

1. National Electrical Code

2. State Code

3. Local (city) code

4. Central station rules

D. Wiring Methods Allowed by National Code and Local Codes

The National Electrical Code recognizes the following seventeen types of wiring for general use, for light and power systems.

1. Rigid metal conduit - article 346

2. Flexible metal conduit (Greenfield) - article 350

3. Armored cable (BX and BXL) - article 334

4. Electrical metallic tubing (steel tube, thinwall conduit or "Thinwall)" article 348

5. Surface metal raceway (Wiremold) - article 352

6. Cellular metal floor raceways - article 356

7. Underfloor raceway - article 354

8. Wireways - article 362

9. Busways - article 364

10. Non-metallic sheathed cable (Romex or Loomflex) - article 336

11. Non-metallic waterproof wiring (rubber-sheathed cable wiring) - article 340

12. Non-metallic surface extensions - article 342

13. Service entrance cable - article 338

14. Concealed knob and tube work - article 324

15. Open wiring on insulator (cleats) - article 320

16. Bare conductors (feeders) - article 328

17. Underplaster extensions - article 344

After eliminating those methods which apply to only special installations, we can divide methods into seven general groups:

1. Conduit

2. Armored cable

3. Electrical metallic tubing

4. Metal raceway

5. Non-metallic sheathed cable

6. Knob and tube

7. Cleats

The first four methods are known as "metallic systems" while the remaining three are referred to as "non-metallic systems".

In comparing the National Electrical Code with the average city code (such as that in Chicago) we find that the local code, except under special circumstances, permits the metallic methods only.

E. Branch Circuit Requirements of the National Code and Local Codes

1. A branch-circuit is defined by the National Electrical Code (article 100) as "that portion of a wiring system extending beyond the final over-current device protecting the circuit".

2. The code (section 2103 and section 2127, table) recognizes four branch-circuits with ratings of 15, 20, 30 and 50 amperes, respectively, but the 50 ampere branch circuit is confined generally to ranges and water heaters, the 30 ampere branch circuit is used generally only for appliances or for lighting units in other than dwelling occupancies, and the 20 ampere branch circuit (as well as the 30 and 50 ampere branches) may use only heavy-duty lampholders of the mogul or porcelain keyless type when used for lighting purposes (section 2126) and fixture wire must be no smaller than #14. Hence, the only branch circuit suitable for general lighting is the 15 ampere branch circuit. Any type lampholder may be used on the 15 ampere branch circuit, and it may be used for appliances as well as lighting. (section 2126).

3. For the 15 ampere branch circuit, the National Electrical Code requirements are (section 2127).

   a. No wire smaller than #14.
   b. No fuse larger than 15 amperes

      If conductors of a larger size are used (#12) in order to reduce the voltage drop, the change in the size of the conductors does not change the classification of the circuit, so the 15 ampere fuse would still be the largest permitted.

F. Number of Branches Required - National Electrical Code.

1. So far, the National Electrical Code requirements as to branch circuits are substantially the same as those required by most local codes. But as to the minimum number of branch circuits required there is usually a difference. First let's consider the National Electrical Code requirements.

2. The table on page 34 of the National Electrical Code (page 346 of Abbott) gives, in column "A", the "standard load" or minimum load to be allowed for general illumination in various types of occupancies, ranging anywhere from 0.25 watt per square foot for warehouses and storage spaces up to three watts per square foot for barber shops, beauty parlors, schools and stores. A dwelling occupancy, it will be noted, is assigned a standard load of two watts per square foot.

   "The floor area shall be computed from the outside dimensions of the building, apartment, or area involved, and the number of floors, not including open porches, garages in connection with dwelling occupancies, nor unfinished spaces in basements or attics of dwellings." National Electrical Code, section 2116 a, 1.

   In the fine print at the bottom of section 2125a however, it is "recommended" (for general illumination in dwelling occupancies) that one 15 ampere branch circuit be installed for each 500 square feet of floor area. This is approximately three watts per square foot. This will vary in different districts.

   In addition to this lighting load, section 2115b reads: "For the small appliance load in kitchen, laundry, pantry, dining room and breakfast room of dwelling occupancies, one (or more) branch circuits shall be provided for all receptacle outlets (other than outlets for clocks) in these rooms and such circuits shall have no other outlets. The conductors of such circuits shall be not smaller than #12."

   This small appliance branch may have either 15 or 20 ampere over-current protection (Abbot, page 339) but because of the restrictions as to lampholders and fixture wire, the 15 ampere fuse is generally used.

G. Receptacle Outlets Required

"In dwelling occupancies, in every kitchen, dining room, breakfast room, living room, parlor, library, den, sun-room, recreation room, and bedroom, one receptacle outlet shall be provided for every 20 linear feet or major fraction thereof or the total (gross) distance around the room as measured horizontally along the wall at the floor line. The receptacle outlets shall in so far as practicable, be spaced equal distances apart. At least one receptacle shall be installed for the connection of laundry appliances. This receptacle shall be 3-pole, of a type designed for grounding. Receptacles in floor outlets shall not be counted as part of the required number of receptacle outlets unless located close to the wall." N.E.C. section 2124 (2).

These outlets should as nearly as possible, be equally divided among the branch circuits to avoid overloading circuits (N.E.C. section 2125 a.c). For example, in a large space where outlets for general illumination are evenly spaced the total branch circuit load is computed from the floor area and the specified watts per square foot, assume that the average number of outlets per circuit is four. In such a case not more than four outlets may be wired on one circuit, it would not be satisfactory to wire three outlets on some circuits and five outlets on some other circuits. (Abbott 339-340).

H. Examples

Dwelling occupancy, Exclusive of circuits for a range, water heater, or other large appliances, what branch circuits are required for a two-story house having outside dimensions of 30 x 36 feet with a finished recreation room 16 x 20 feet in the basement and no other finished rooms in the basement or attic?

Floor area; First and second floors, 30 x 36 x 2	2,160	square feet
Recreation Room 16' x 20'	320	
TOTAL	2,480	square feet
Lighting load: 2,480 square feet at 2 watts per square foot.	4,960	watts
Appliance load	1,500	
	6,460	watts

One circuit is required for the appliance load. At 115 volts the capacity of a 15 ampere circuit is 1,725 watts.

Number of 15 ampere branch circuits for lighting load = $\frac{4960}{1725}$ = 2.88 (or at least 3)

Therefore three 15 ampere circuits will be required for the lighting load.

Total circuits is four (three 15 ampere branches for lights, using #14 wire, and one 15 ampere branch for appliances using #12 wire.)

To provide fully adequate circuit capacity it is desirable to install at least one #12 circuit for small appliances as required by section 2115b and for the other circuits to follow the recommendation in the fine-print note in section 2115a. Application of this method to the house described in the foregoing example would require one circuit of #12 and five 15 ampere circuits or a total of six circuits altogether.

I. Local Code Requirements (Chicago)

Section 2005 Chicago Electrical Code (page 247, 1938 code) limits each 125-volt 15 ampere branch circuit to 1000 watts and the number of receptacles or medium base sockets to 16, (except by special permission).

Hence, under this "local" code, number of branches= $\frac{6460\text{watts}}{1000\text{watts}}$=6.4 or 7

That would be six 15 ampere lighting circuits and one #12 branch for appliances.

J Definitions and General Provisions

1. Article 110 - General, Section 1103, headed "Mandatory and Advisory Rules" reads; "Mandatory rules of this code are characterized by the use of the word "shall" Advisory rules are characterized by the use of the word "should" or are stated as recommendations of that which is advised but not required".

2. Types of insulation used

   a. Rubber, used for inside work.
   b. Weather-proof, used for outside work. Beware of this as strictly speaking, it is not insulation at all. It is a weather proof covering of asphalt and creosote and contains no rubber. Never touch a live weather proofed wire, with any part of your body and never put one inside a length of conduit.
   c. Slow-burning, used when heat is above normal.
   d. Asbestos, used when heat is above normal, for extremely high heat.

3. Lugs - all wire larger than #8 must have a lug placed on end (N.E.C. Art. 1116).

4. Stranded wire - small stranded wire shall be twisted and soldered before fastening under binding screw.

5. Short circuit - a short circuit occurs when two wires of opposite polarity come together without sufficient resistance between them to limit the current to a safe value.

6. An "accidental ground" occurs when the ungrounded wire comes in contact with some part of the metallic system that is not permanently grounded to earth, causing the metal system to become charged.

7. An "outlet box" is a location on a branch circuit of any wiring system at which access to the conductors is intentionally provided for the purpose of connecting energy-consuming devices, control devices, or switches.

8. A "pull-box" is a conduit box, cabinet or fitting which is installed only for convenience of pulling in the conductors.

9. A "junction box" is a conduit box, or fitting for housing the connections of conductors.

10. Whenever the size of the conductors forming a junction are the same, one set of conductors may be soldered to or otherwise connected to the other set.

K. Maximum Current Carrying Capacity of Wire Sizes (N.E.C.).

RUBBER COVERED WIRE

WIRE SIZE	IN CABLE OR CONDUIT	KNOB AND TUBE WORK	BARE & WEATHERPROOFED WIRE
14	15 amps	20 amps	20 amps
12	20 amps	26 amps	30 amps
10	25 amps	35 amps	35 amps
8	35 amps	48 amps	50 amps
6	45 amps	65 amps	70 amps
4	60 amps	87 amps	90 amps
2	80 amps	118 amps	125 amps
0	105 amps	160 amps	200 amps

Note that wire exposed to air has a greater current carrying capacity than wire run in conduit due to better heat dissipation from wire to air.

L. Handy Index For the 1947 National Electric Code

SUBJECT	PARAGRAPH	PAGE
Splicing	1118	19
Receptacle circuit	2115-b	26
Range Load	2121-1	29
Receptacle outlets required	2124-b	31
Feeders article 220	2201	33
Electric ranges - dwelling occupancies	2201-1	35
Service-	2302	37
Service entrance conductors	2304-a	38
Point of attachment to building	2324	40
Service head	2337	42
Fuses	2451	57
Spacing from lightning rod	2534	63
Grounding electrodes	2581	69
Free length of conductors at outlet	3006	81
Article 310 - conductors	3101	85
Non-metallic sheathed cable	3262	97
Number of conductors in deep boxes	3709	117
Article 380 switches	3801	124
Article 410 rosettes	4101	132
Rosettes 4163 4165	4166	137
Grounding non-metallic	4212	141
Fixtures near grounded surface	4215	142
Method of grounding	4216	321
Rosettes	-94100	321
Rosettes	-94104	324

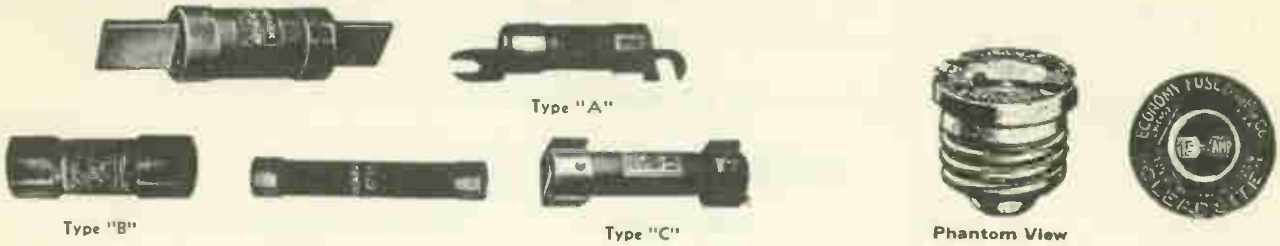


Fig. 1 Non renewable fuses

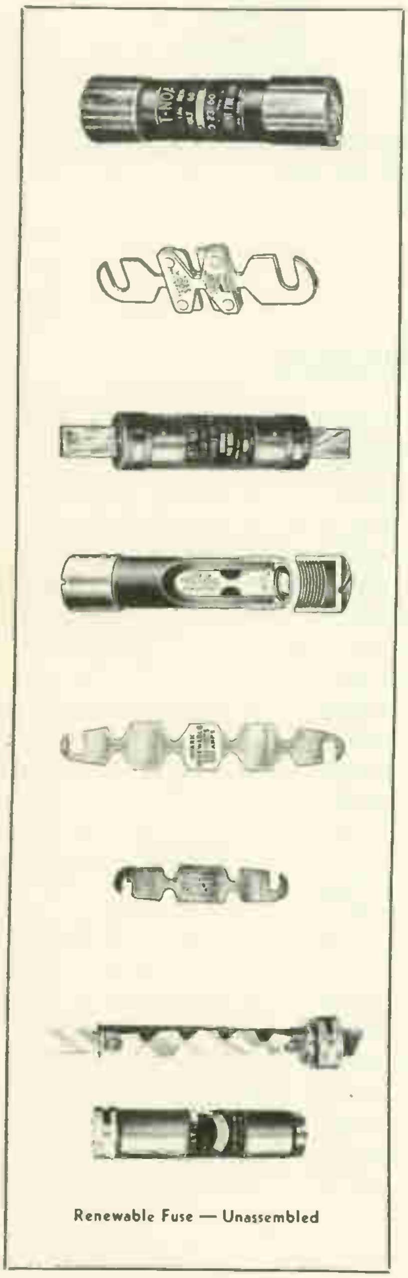


Fig. 2 Renewable fuses

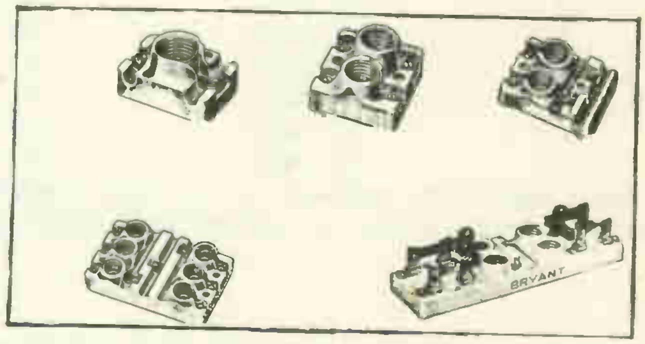


Fig. 3

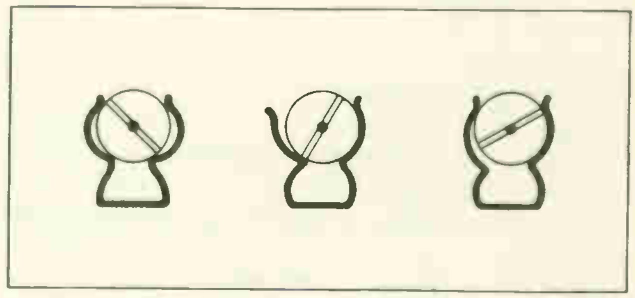


Fig. 4

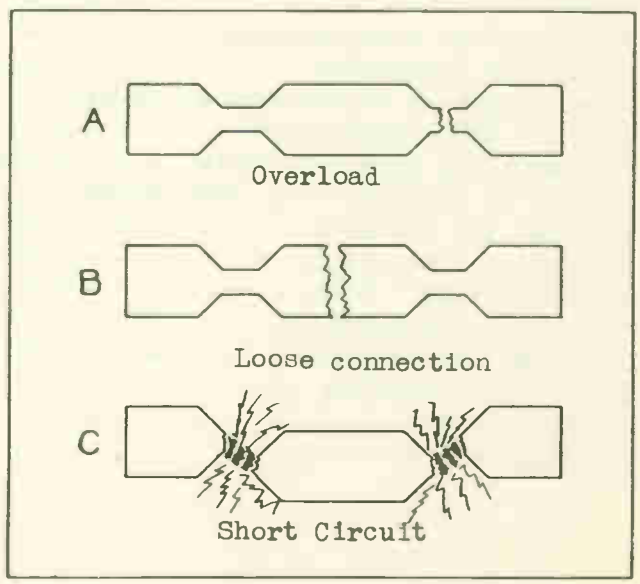


Fig. 5

Hot wires - Brass Screw
White - Nickel Screw

ELECTRICAL SWITCHES

Objective

To learn the purposes, uses and distinguishing features of the common types of switches employed in lighting control circuits.

References

Lesson Content

A. General Information

1. Definition - a switch is a device for making, breaking or changing the connections in an electric circuit.

2. Classification - switches may be classified as follows:

   a. Mounting - surface, flush.
   b. Construction - knife, push-button, toggle, tumbler, key, selector, pull-chain, levolier, snap.
   c. Indicating or non-indicating.
   d. Operation - silent (mercury), momentary contact, lock, manual, automatic.
   e. Use - single-pole, double-pole, 3-way, 4-way, electrolier.
   f. High or low voltage - above or below 750 volts.
   g. Miscellaneous - air or oil, instrument, isolating, auxiliary, alarm, transfer, grounding, vertical break, side break, quick make, quick break, etc.

3. Parts and symbols Fig. 1.

   a. A stationary contact member of a switch is a conducting part which bears a contact surface and remains substantially stationary.
   b. A pole of a switch consists of the parts necessary to contact one conductor of a circuit. A switch may be single pole or multipole, depending upon the number of single poles that are operated simultaneously.
   c. A blade of a switch is the moving contact member which enters or embraces the contact clips.

B. Single-pole Switches

1. Construction - single-pole switches have only two terminals for the wires and only one blade (pole).

2. Use - single-pole switches are normally used to control a light or group of lights from one place by breaking only one wire of a circuit, Fig. 2.

3. Connections - single-pole switches must always be connected in the ungrounded wire.

C. Double-pole Switches

1. Construction - a double-pole surface-type switch always has four terminals and two straight poles. These poles are mounted one above the other on the shaft and are insulated from each other.

2. Use - double-pole switches are normally used to open both wires to a light or device and thus break all connections from it to the line, Fig. 2.

3. Connections - always connect the line wires to terminals on the same side of the switch; never to opposite terminals.

D. Three-way Switches

1. Construction - three-way surface-type switches have four terminals and usually one pole. Flush-type have three terminals. Two of the terminals are permanently connected together in the switch with a shunt wire. Usually these terminals can be located by a strip of sealing wax in a groove between them on the base of the switch. This wax covers the shunt wire. Sometimes the shunt is indicated by the word "connected" stamped on the procelain base. On flush-type switches, the three-way is the only one which has just three terminals. The shunt of a flush type switch is known as the "marked" or "common" and it is usually marked by being of a different color, usually a dark or oxidized finish.

2. Use - three-way switches are normally used to control a light or group of lights from two different places, so they can be turned on or off at either switch. Figs. 3 & 4. They may also be used as reversing switches.

3. Connections - connect the shunts of the switches to the line and to the lamp, respectively; then connect the remaining terminals of one switch to the remaining terminals of the other.

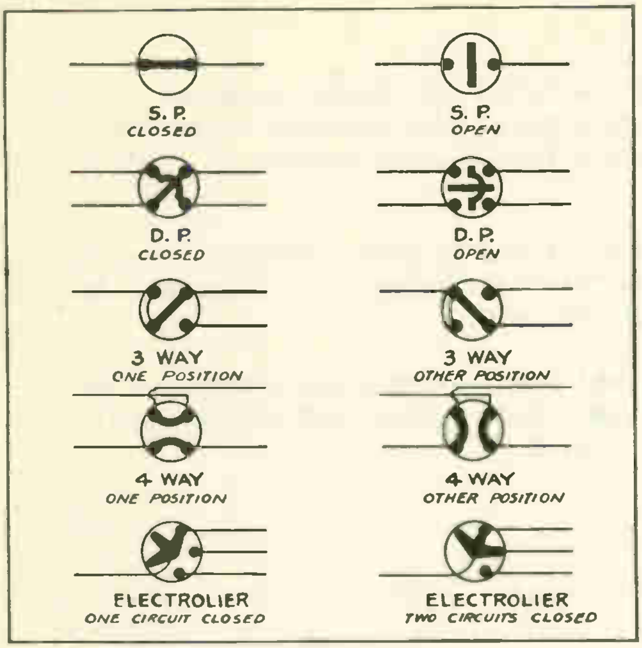


Fig. 1

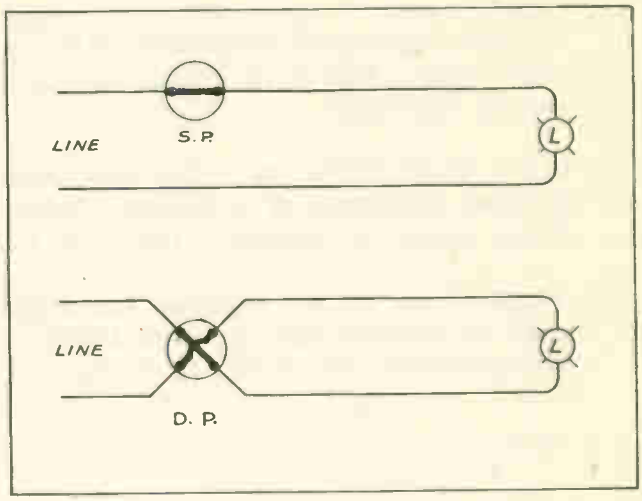


Fig. 2

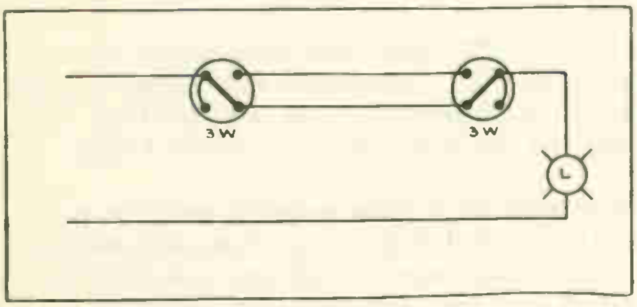


Fig. 3

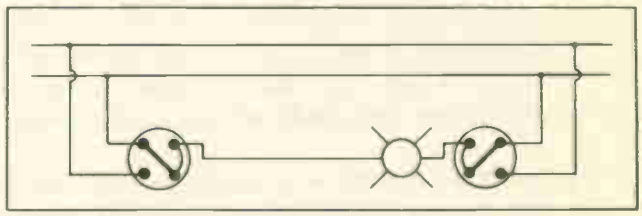


Fig. 4

E. Four-way Switches

1. Construction - the four-way surface-type switch has four terminals and two poles and can be quite easily distinguished from the other switches because its poles always connect to adjacent terminals.

2. Use - four-way switches are normally used where it is desired to control a light or group of lights from more than two places. By their use in combination with three-way switches, a light can be controlled from as many places as desired, Fig. 5.

3. Connections - four-way switches must always be connected in the ungrounded wire of the line and never to a grounded wire.

   When two or more four-way switches are used together or in conjunction with a three-way switch, the dummies or travellers, (the two wires leaving the switch), are always connected to opposite terminals, never to adjacent terminals. Fig. 5. The foregoing statement applies to surface-type switches; with some flush-type switches it is unnecessary to cross the wires, because the cross over is made inside the switch, Figs 8, E and F.

F. Electrolier Switches

1. Construction - electrolier switches have one "line" or "main" terminal and two or more "circuit" terminals with two or more poles electrically connected to each other, but usually mounted on different levels so a variety of control can be obtained.

2. Use - electrolier switches are used to control one or more circuits, such as several sections of a heater element in an electric range, two filaments in a 3-way lamp, or several lights on a chandelier, etc.

3. Connections - Fig. 6 shows the manner in which an electrolier switch can be used to turn on one or more lights at a time. Push-button and toggle-type electroliers are shown in G, H, and I of Fig. 8.

G. Substituting Various Switches

1. Indicating switches - switches with a definite "off" position are known as indicating switches. Switches with no definite "off" position are known as non-indicating. In their normal use, single-pole, double-pole, and electrolier switches are indicating; three-way and four-way switches are non-indicating.

2. Substitutions - a double-pole switch can be used as a single-pole switch; a three-way switch can be used as a single-pole switch,Fig. 7; a four-way switch can be used as a single-pole switch, Fig. 7, a four-way switch can be used as a three-way switch, Fig. 7; a four-way switch can be used as a two-circuit electrolier switch; a three-way switch can be used as a two-circuit electrolier switch.

H. Knife Switches Fig. 9.

1. Definition - a knife switch is a form of air switch in which the moving element, usually a hinged blade, enters or embraces the contact clips. In some cases, however, the blade is not hinged and is removable.

2. National Electric Code requirements

   a. Connection: "Knife switches, unless of the double-throw type, shall be so connected that the blades will be dead when the switch is open". (N.E.C. 1948, Art. 380, Sec. 3807). All single throw knife switches shall close against gravity. Double throw shall be mounted horizontal.

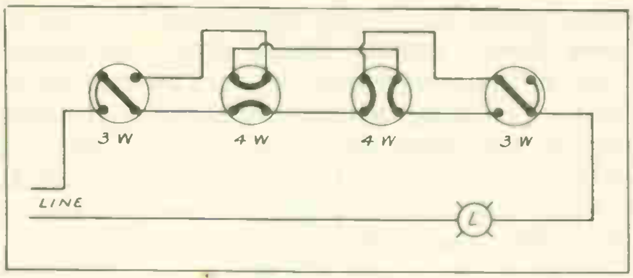


Fig. 5

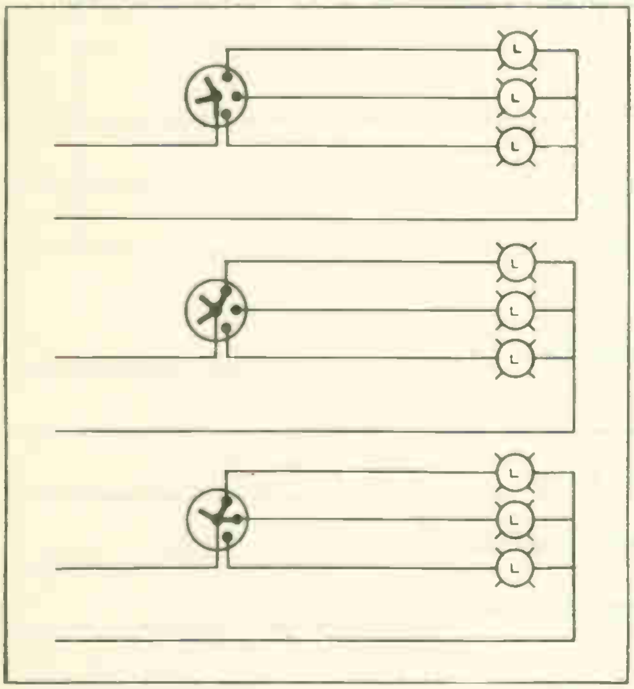


Fig. 6

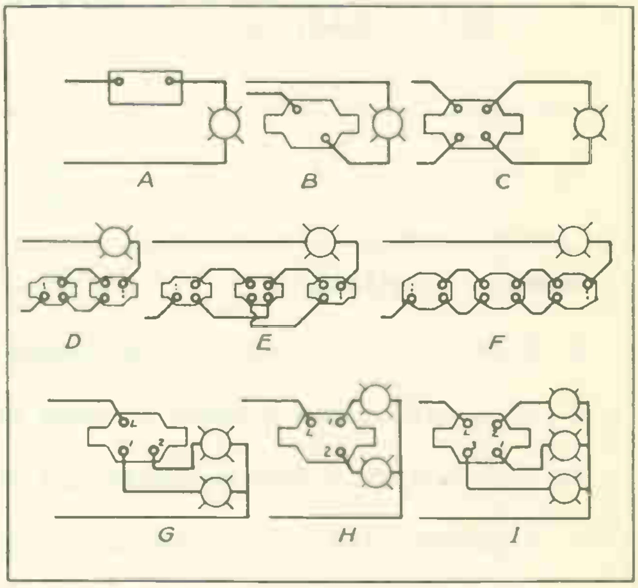


Fig. 8

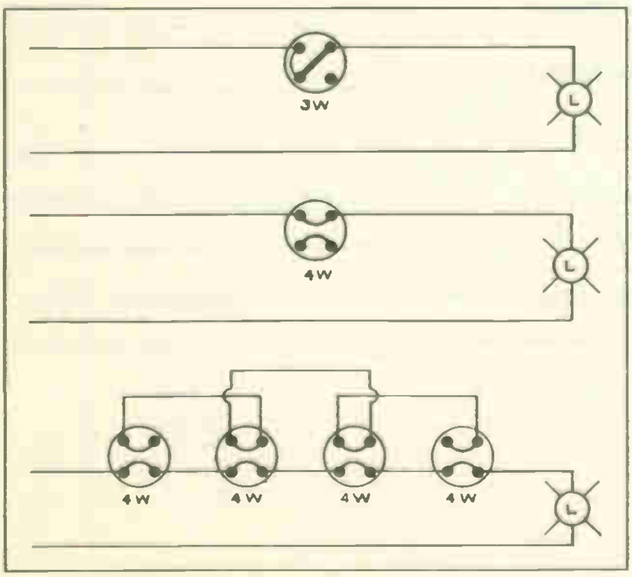


Fig. 7

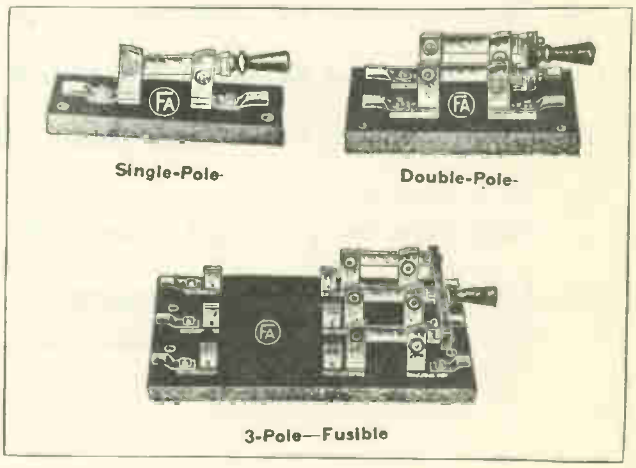


Fig. 9

b. Position: "Single-throw knife switches shall be so placed that gravity will not tend to close them. Double-throw knife switches may be mounted so that the throw will be either vertical or horizontal as preferred, but if the throw be vertical a locking device shall be provided which will insure the blades remaining in the open position when so set. "N.E.C. 1948, Sec. 3806.

c. As a general rule, all knife switches should be enclosed in metal boxes.

d. On circuits of over 150 volts to ground, enclosures for switches shall be grounded. N.E.C. 1948, Sec. 3812.

e. If a switch is located in a wet place or outside of a building, it shall be enclosed in a weatherproof box or cabinet. N.E.C. 1948, Sec. 3804.

f. "No switch shall disconnect the grounded conductor of a circuit unless the switch simultaneously disconnects the ungrounded conductor or conductors." N.E.C. 1948, Sec. 3801.

____

____

____

I. Summary Questions

1. A switch with only two stationary contacts is a ____________________

2. If a switch has a shunt it must be a ____________________

3. A switch with four contacts and one pole is a ____________________

4. A switch with four contacts and two poles is either a ________ or a ________

5. If the above switch has no "off" position it is a ____________________

6. If it has an "off" position it must be ____________________

7. The only switch that breaks the neutral as well as the hot line is ________

8. The following switches are always indicating ____________________

9. The following switches are always non-indicating ____________________

10. A switch used to control three different circuits is the ____________

11. If a four-way switch is used in place of a D.P. switch by mistake, one position will turn on the light, the other position will ____________________

12. A device for making, breaking or changing the connections in an electric circuit is called a ________________________________

LIGHTING CONTROL

Objective

To study the various types of switches in use for controlling lights.

References

____

____

Lesson Content

A. Introduction

1. Basic circuits

   Twenty lighting control circuits are shown in Figs. 1 to 20 inclusive. Each circuit has its particular use, and combinations of the various basic circuits are possible in order to secure different results.

2. Tracing the circuits

   While these circuits are designed mostly for operation on 115 volts AC it is best to trace the circuits with single arrows in order to study their operation.

3. Hot and Neutral

   The words "hot" and "neutral" should not be confused with "positive" and "negative". In a-c operation, either wire may be positive, since the polarity of a 60 cycle, a-c supply reverses 120 times each second. The hot wire, however, is always the ungrounded wire, whether it is positive or negative, while the neutral wire is always grounded and identified in polarized systems and it, too, may be either positive or negative at any instant. In the diagrams, the hot wire is shown as a heavy line and the neutral as a lighter line.

B. Identifcation of Circuits

In determining the number of circuits, trace the first circuit in black. Then, if any of the lamps can be operated with the switches in a different position, trace this circuit in red. Use blue to trace a third circuit, if one is possible, etc. Be sure and dot with the same color that is used to trace the circuit any switch that must be closed to complete the circuit being traced.

____

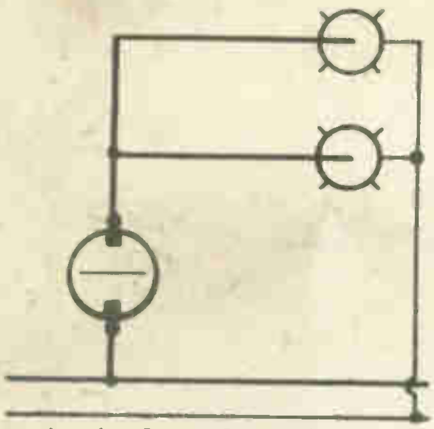
____

____

____

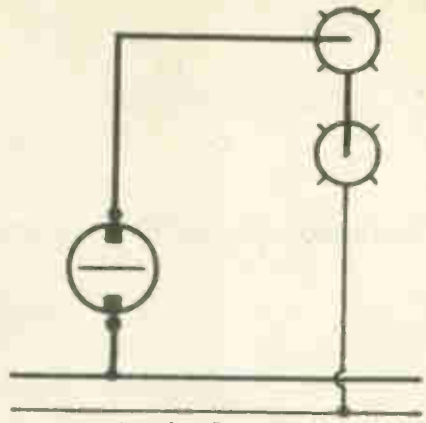
____

1



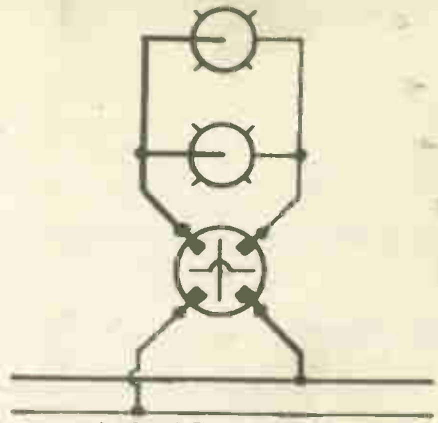
A single-pole switch used to control two lights in parallel.

2



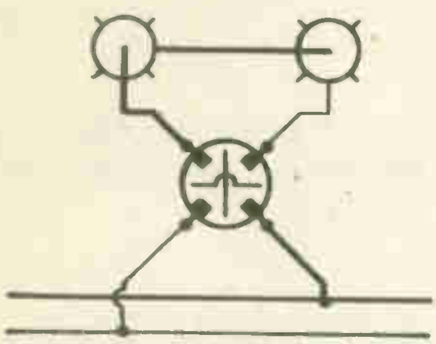
A single-pole switch used to control two lights in series.

3



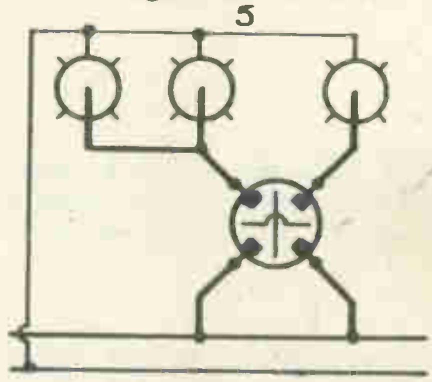
A double-pole switch used to control two lights in parallel.

4



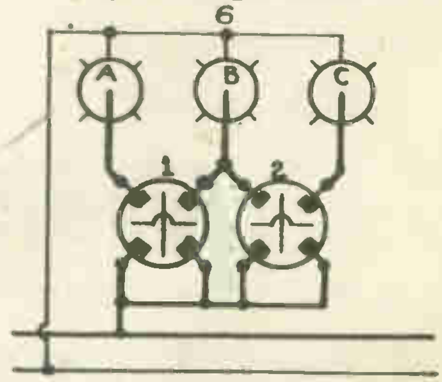
A double-pole switch used to control two lights in series.

5



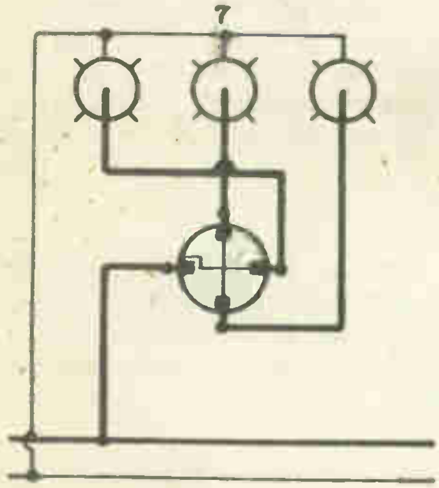
A double-pole switch used to take the place of two single-pole switches.

6



A selective control provided by 2 double-pole switches. Lights A and B are controlled by switch #1; lights B and C are controlled by switch #2.

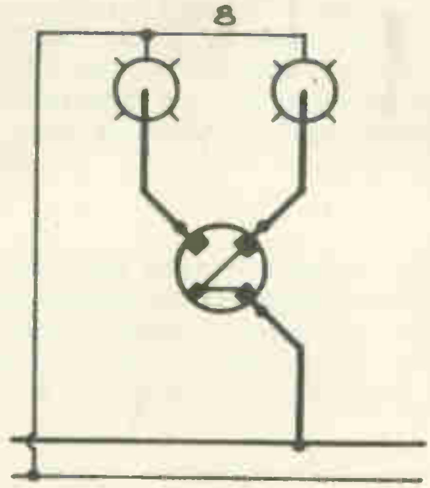
7



Electrolier switch used to control three separate lights from one place.

1st position lamp #1 on
2nd " " #2 "
3rd " " #3 "
4th " all off.

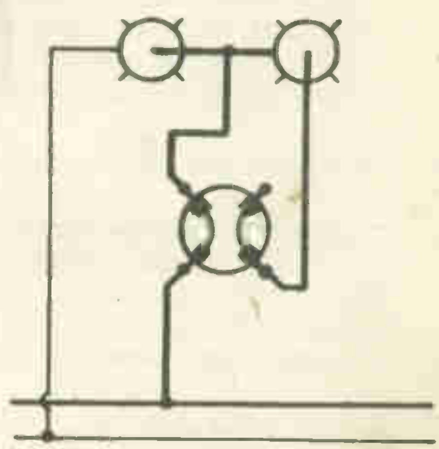
8



A 3-way switch used to control 2 lights alternately. One or the other will be lighted.

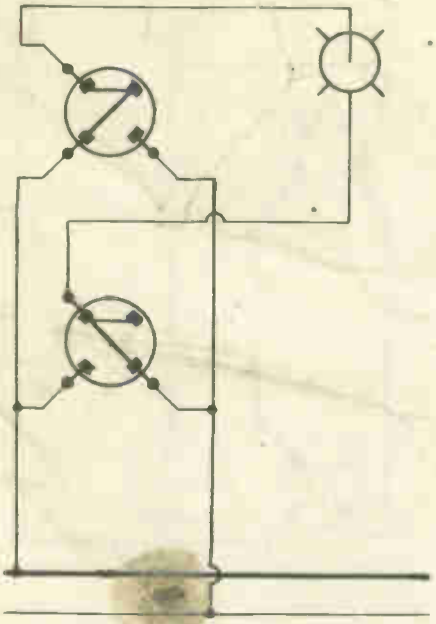
1st position lamp #1 on.
2nd " " #1 and #2 on.
3rd " " #1 #2 and #3 on.
4th " " all off.

9



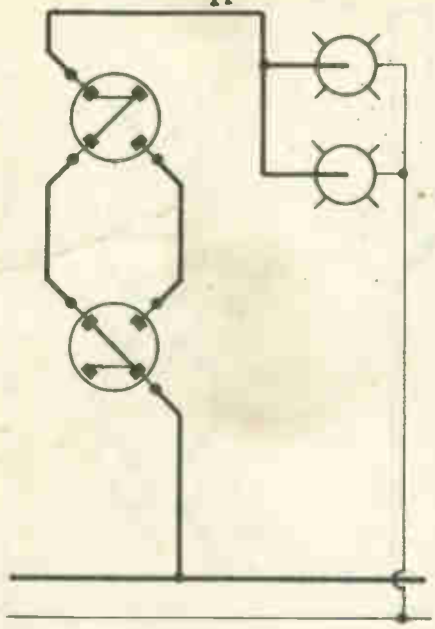
A 4-way switch used to control one light only, or 2 lights in series.

10



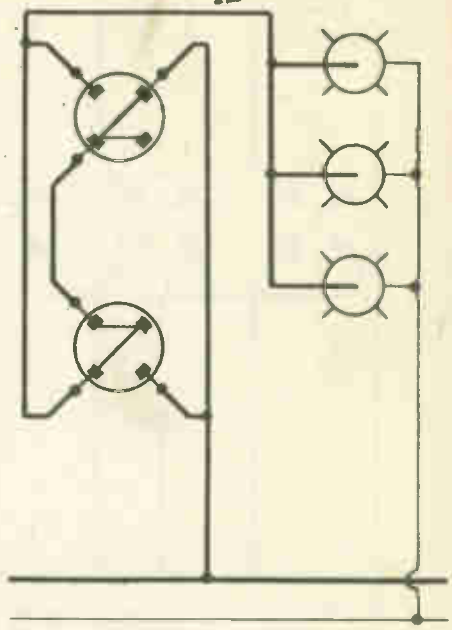
This is the "Carthweise" method used to control lights from 2 places, using two 3-way switches. This system is not approved by the Code for 110E systems, but may be used on 32E systems.

11



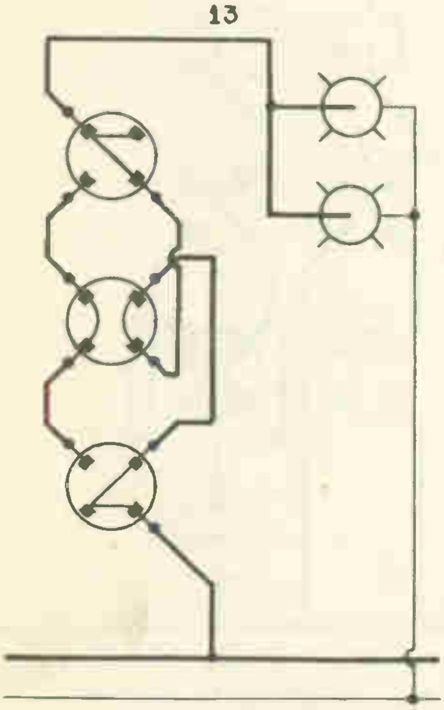
This circuit is the "Standard" method for two-place control using two 3-way switches and is approved by the Code for 110E.

12



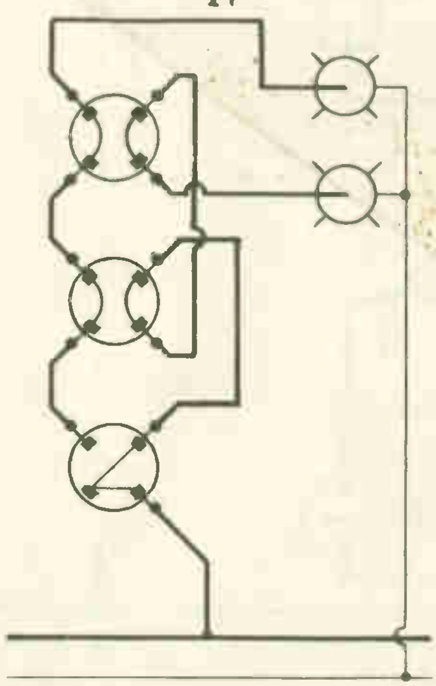
This shows another method of controlling lights from 2 places.

13



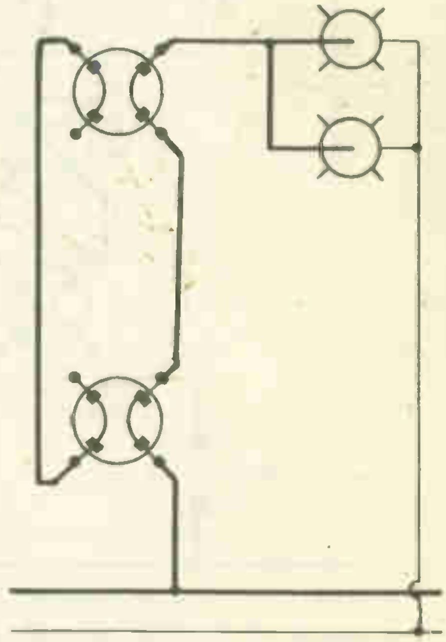
Method used to control one or more lights from three places.

14



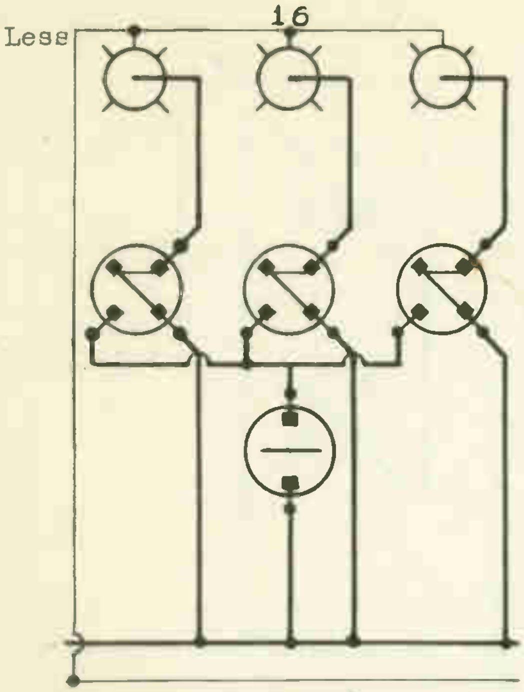
This diagram shows how to control each light alternately from three different places.

15



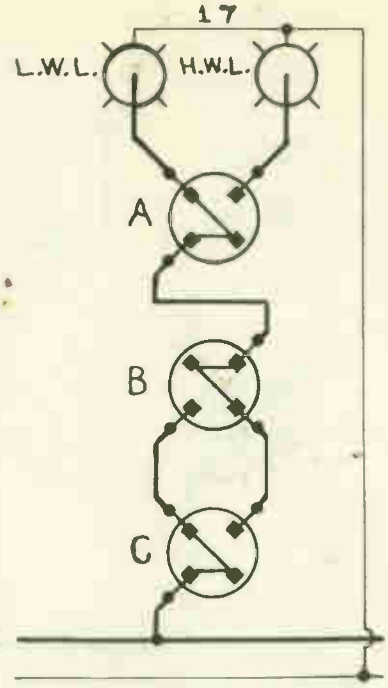
Possible circuit used to control two lights in parallel from two places using two 4-way switches.

16



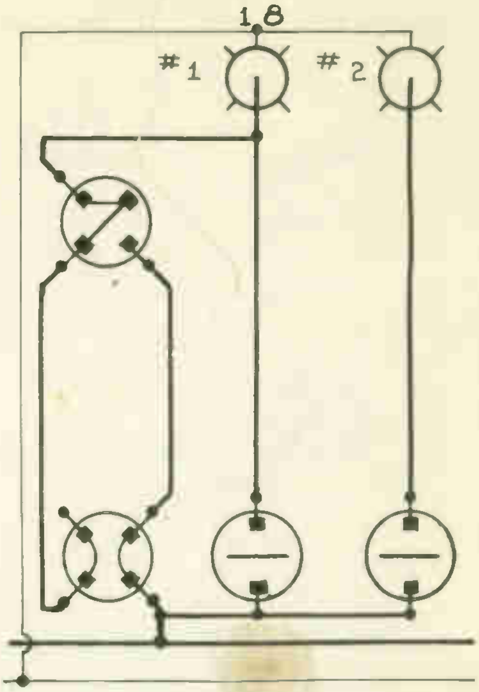
This shows 3 lights, each one individually controlled from one place, using a three-way switch as a single-pole switch. The one single-pole switch is used as a master switch when the master switch is on; the other lights cannot be turned off.

17



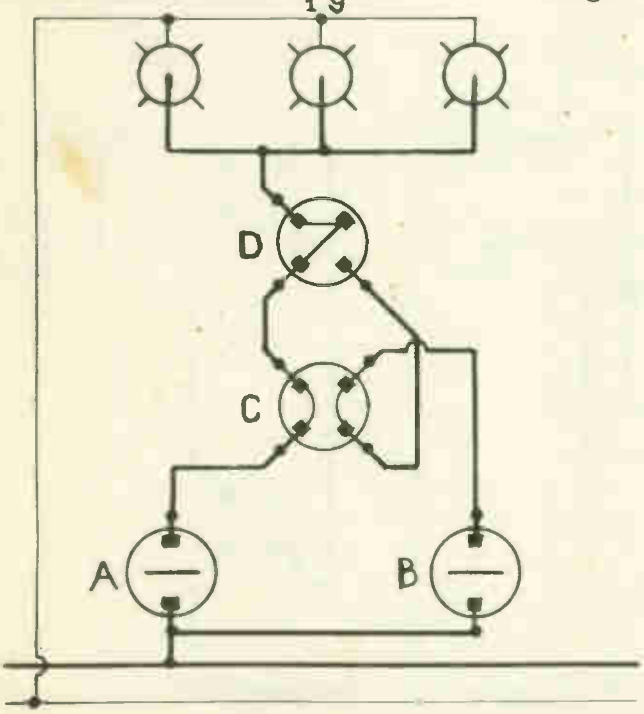
An additional 3-way switch used when it is desired to use a low wattage lamp part of the time. Switches B and C will control the circuit and switch A will select either the high or low wattage lamp.

18



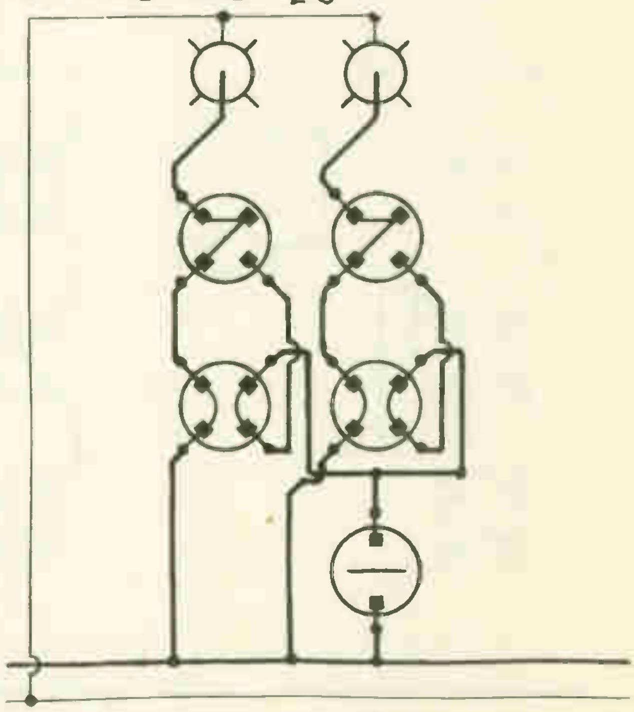
A 3-way switch and a 4-way switch used to control lamp #1 with a single-pole switch as a master switch. Lamp #2 has separate control.

19



By means of 2 single-pole switches at A and B, it is possible to prevent turning the lights on or off at switches C and D. When switches A and B are closed, the lamps cannot be turned off. When switch A is on and B is off, the lamps may be controlled from switches C and D.

20



When the single-pole switch is open, each of the 2 lights may be controlled from 2 places. When the single-pole switch is closed, all the lamps will remain lighted.regardless of the position of the other switches.

OHM'S LAW

Objective

To learn Ohm's Law and how to apply it to the solution of simple electrical circuits.

References

Lesson Content

A. General

1. Ohm's Law concerns the relationship among the voltage E, current, I, and resistance, R, in an electrical circuit.

2. Ohm's Law, the most important law in the field of electricity, was published in 1827 in Berlin by Dr. George Simon Ohm (1781-1854) a German physicist. Before Ohm, only intensity and quantity were used in electricity and there were no accurate definitions of these. Ohm introduced and defined accurate notions of electromotive force, current strength, and resistance.

B. Development of Ohm's Law

1. In a d-c circuit with constant resistance, R.

   a. An increase in voltage, E, causes an increase in current, I.
   b. A decrease in voltage causes a decrease in current.
   c. The current varies directly proportional to the voltage. (This is known as the DIRECT or "swing" relation).

2. In a d-c circuit having constant voltage, E.

   a. An increase in resistance causes a decrease in current.
   b. A decrease in resistance causes an increase in current.
   c. The current varies inversely proportional to the resistance. (This is known as the INVERSE or "see-saw" relation).

3. The current, I, in a d-c circuit varies directly proportional with the voltage, E, and inversely proportional with the resistance, R. This is "Ohm's Law."

C. Ohm's Law Formulas

1. Current in amperes is equal to the pressure in volts divided by the resistance in ohms.

$$I = \frac{E}{R}$$

2. The resistance in ohms is equal to the pressure in volts divided by the current in amperes.

$$R = \frac{E}{I}$$

3. The pressure in volts is equal to the current in amperes multiplied by the resistance in ohms.

$$E = I x R$$

D. Memory Device

All three of the Ohm's Law formulas can be easily memorized by means of a circle shown below. Merely cover up the unknown symbol and perform the indicated operation with the other two symbols.

$$\frac{E}{I \times R}$$

E. Rules for Solving Problems

1. Draw a clear-cut diagram.

2. Label all parts.

3. Trace the current (electron flow).

4. Assign all known values.

5. Use Ohm's Law to solve for the unknown.

$$I = \frac{E}{R} = \frac{12V}{3\Omega} = 4A$$

$$I = \frac{E}{R} = \frac{6V}{3\Omega} = 2A$$

I = AMPS
E = VOLTS
R = RESISTANCE

F. Examples

1. What is the current flowing through an electric lamp, if the lamp has a resistance of 240 ohms and is operated on 120 volts?

   Using Ohm's Law: $I = \frac{E}{R}$; therefore $I = \frac{120}{240} = 0.5$ amperes, current flowing through the circuit.

X 2. If a wire-wound resistor allows 4 amperes of current to flow through it when connected to a 12-volt battery, what is its resistance?

   a. Draw the diagram, affixing all labels and values.
   b. Select the form of Ohm's Law for finding resistance. ($R= \frac{E}{I}$)
   c. Substitute known values and solve: $R = \frac{12}{4} = 3$ ohms, resistance of wire-wound resistor.

NOTE: Resistance depends upon the nature of the material, its size and, to some extent, its temperature. If we remove the 12-volt battery in the above example, there will be no current through the resistor, but its resistance will remain three ohms.

X 3. If a door bell has a resistance of 36 ohms and requires an average current of 0.5 amperes, what is the voltage required to operate it?

   a. Set up the Ohm's Law formula for finding voltage. (E= IxR)
   b. Substitute the known values and solve.

   $E= .5 \times 36 = 18$ volts required.

4. Solve the following:

   a. R = 4, E = 16, I=?
   b. I = 0.5 E = 120, R =?
   c. R = 3, I = 4, E=?

G. Summary Questions (Application of Ohm's Law)

1. A tungsten lamp has a resistance of 420 ohms, when heated to incandescence. When operating on 115 volts, what will be the value of current through the lamp?

2. An electrical soldering iron takes 1.05 ampere when used on a 110 volt circuit. What is the iron's resistance?

3. What voltage will produce a current of 6 amperes through a resistance of 18 ohms?

4. What resistance must a 115 volt incandescent lamp have in order to draw. .25 amperes?

5. The resistance of a heater is 2 ohms. The current required is 3 amperes. What voltage must be impressed across the heater?

6. What resistance must a cigar lighter have to be used on 6 volts and take 5 amperes?

7. What is the resistance of an electric oven if it draws 35 amperes from a 110 volt line?

8. How much current can 45 volts force through 6 ohms?

9. A relay having a resistance of 3,200 ohms requires .02 amperes to operate. What voltage is required to energize it?

10. What current is produced by 30 volts acting across .735 ohms?

RESISTANCE MEASUREMENTS

Objective

To learn that there is always a line voltage drop when current is flowing through the line resistance, but that there is no line drop when no current is flowing; to learn how to apply Ohm's Law in order to determine line resistance by means of a voltmeter and an ammeter.

References:

Lesson Content

A. Line Voltage Drop

1. When no current is flowing in the line, there is no line voltage drop, Ed, because Ed = I x R, and regardless of the value of R, if I = 0, then Ed = 0. This can be shown by the first part of experiment A.

2. When current flows through the line, a line voltage drop results and this voltage drop is directly proportional to the length of the line, because Ed = IxR, and while the current will remain the same at any point along the line, any increase in the resistance will result in an increase in voltage drop. This can be shown by the second part of experiment A.

B. Measuring Line Resistance

With current flowing through the wire, there will be a difference of potential between any two parts of the wire, as shown on a voltmeter, and the greater the distance between the points, the greater the voltmeter reading will be, since a long line has more resistance than a short one.

Hence, the formula E = IxR, can be transposed to read R = E/I and the latter can be used to find the resistance of any length of wire, so long as a current is flowing in it. This is demonstrated in experiment B.

C. Limitations To Be Considered

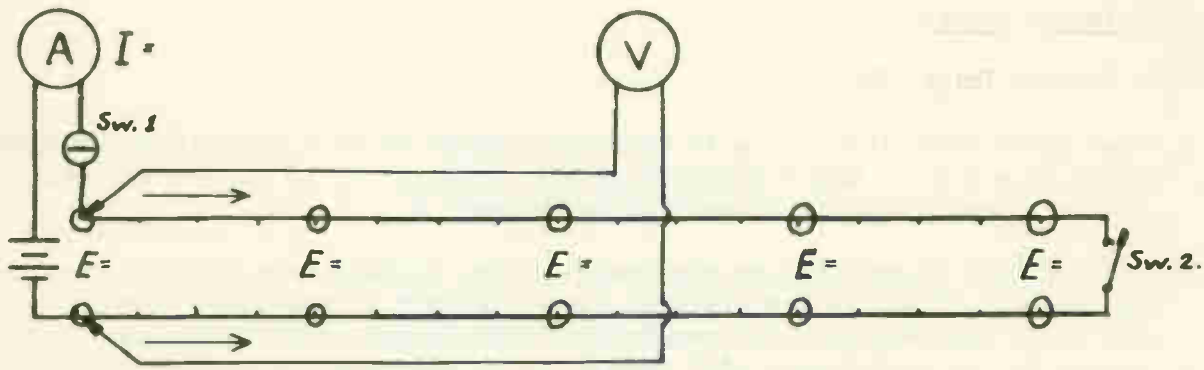
This "voltmeter-ammeter" method of measuring resistance becomes more accurate as the resistance of the voltmeter increases and theoretically accurate when the resistance of the voltmeter is infinite.

While it is assumed that the voltmeter itself draws no current, a small amount of current does flow, the amount depending upon the resistance of the meter (ohms per volt).

D. Experiment A.

Place the voltmeter leads as shown. With switch-1 closed and switch-2 open, draw the voltmeter leads slowly toward opposite end of the line and notice that the voltmeter does not vary because there is no current flowing.

Repeat the experiment with both switches closed and mark the voltmeter readings on the drawing at the dots. The dots indicate the points where the wire is stapled to the table. This will prove that when current is flowing in the wire, the voltage drops as the length of line or the distance from current source is increased.

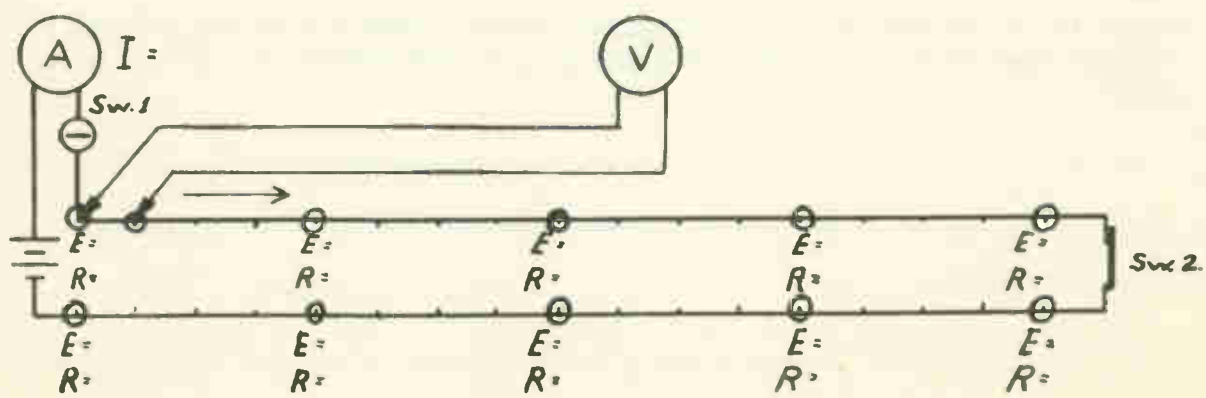


E. Experiment B

With both switches closed place the voltmeter leads together on one of the wires, then slowly draw them apart. Note the voltage at different intervals marked. THE VOLTAGE DROP increases with the length of the wire between the voltmeter leads.

Using this test determine the resistance of different lengths of the wire. Place the voltmeter leads at two points on the same wire and observe the voltmeter reading. Divide the voltmeter reading "E" by the current flowing "I" and the answer obtained is the resistance "R" of the wire between the two points.

Mark the voltmeter readings and the resistance between the points indicated by dots on the diagram.



WATT'S LAW

Objective

To learn the various forms of the formula known as "Watt's Law".

Lesson Content

A. General

Watt's Law is a statement pertaining to electrical power in a circuit, the rate at which work is being done.

B. Horsepower

After inventing the reciprocating steam engine, James Watt (1736-1819) found it was difficult to sell the engine unless the power could be compared with that of a horse. Consequently a series of experiments were performed to determine the power of the average English draft horse.

In the experiments, a coal bucket weighing 165 pounds was drawn up through a mine shaft by a number of horses, one at a time, one minute being allowed for each trial. It was found that the average horse covered a distance of 200 feet in that time. Then, using the formula "Work is equal to Force exerted through a Distance," average horsepower was determined as follows:

$$
\begin{aligned}
W &= F \times D \\
&= 165 \text{ pounds} \times 200 \text{ feet} \\
&= 33{,}000 \text{ foot-pounds}
\end{aligned}
$$

And since power is equal to work divided by time (P=W/T).

$$P = \frac{33{,}000 \text{ ft-lbs}}{\text{MINUTE}} \quad \text{or} \frac{550 \text{ ft-lbs.}}{\text{SECOND}}$$

So it was concluded that, 1 hp = 33,000 foot-pounds per minute or
1 hp = 550 foot-pounds per second.

C. Electrical Power

An electric motor was later used instead of the horse and if it did the same work in the same time, it was rated as a "one horsepower motor" Under these circumstances, it was found that the electrical energy input, represented by the pressure difference in volts multiplied by the current in amperes, was always equal to 746. Although this figure actually represents "volt-amperes," a term which is still applied to it, the unit "watt" was coined for the occasion, in honor of the man who had first defined a horsepower, and this gave us the statement "The power (watts) in a d-c circuit is equal to the product of the current (I) multiplied by the voltage (E)".

The above statement is referred to as "Watt's Law", although the formula for the law is also frequently referred to in the same way.

D. Formulas

1. There are three general forms of the Watt's Law formula:

   a. Power (W) = current (I) x voltage (E), $W = I \times E$

   b. Current (I) = power (W) divided by voltage (E); $I = \frac{W}{E}$

   c. Voltage (E) = power (W) divided by current (I); $E = \frac{W}{I}$

2. Simplified Formula

   Fig. 1 shows a simplified formula or memory device similar to the one used for Ohm's Law, Fig. 2. This formula can be used for remembering all three watt's law formulas.

3. Examples:

   a. An electric flat-iron operating on 120 volts draws 6 amperes. How much power is being used to heat the iron?

   $$W = I \times E$$
   $$W = 6 \times 120$$
   $$W = 720 \text{ watts}$$

   b. What voltage is required to light a 150 watt lamp if the lamp normally draws 1.5 amperes?

   $$E = \frac{W}{I} \qquad E = 100 \text{ volts}$$
   $$E = \frac{150}{1.5}$$

   c. Another 150 watt lamp is made to be operated on 120 volts. How much current will the lamp draw?

   $$I = \frac{W}{E} \qquad I = \frac{150}{120} \text{ therefore } I = 1.25 \text{ amperes}$$

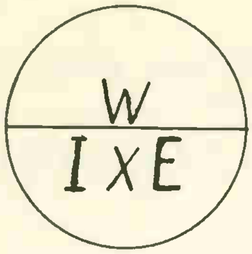


Fig. 1 Watt's Law, simplified.

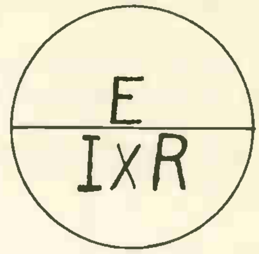


Fig. 2. Ohm's Law, simplified.

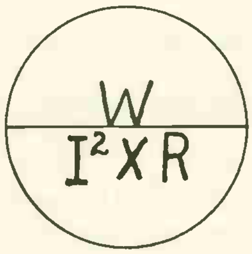


Fig. 3. Simplified formula for use when voltage is unknown.

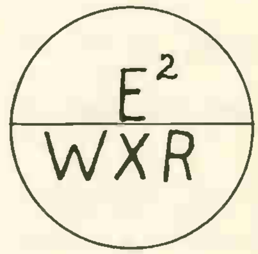


Fig. 4. Simplified formula for use when current is unknown.

Note: To find any value represented in any of the above four circles, cover up the missing or unknown value and perform the indicated operation.

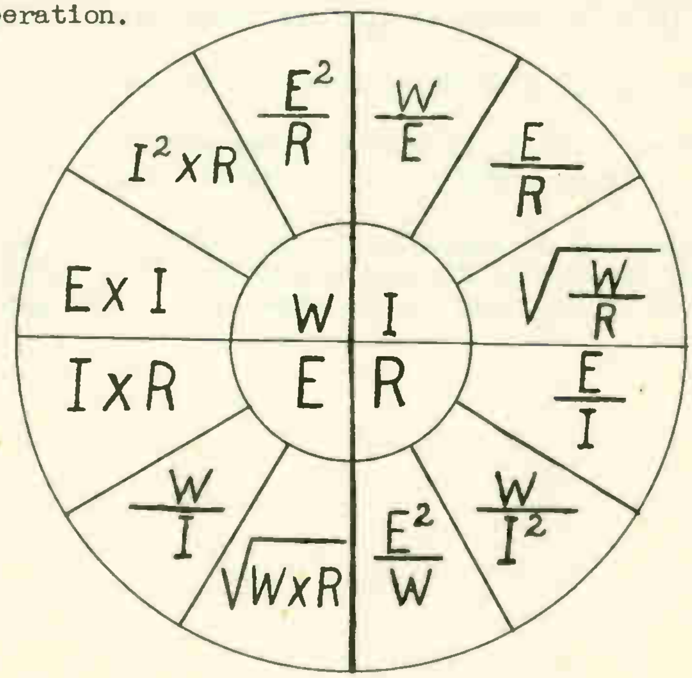


Fig. 5. "WIRE" Wheel. Any of the four values shown in the center-- W, I, R, or E, can be found in three different methods, according to which values are known.

E. Time-saving Power Formulas

1. Where only current and resistance are known; how much power is used in a resistance of ten ohms when the current is five amperes?

   In order to use the Watt's Law formula, we must first find the voltage by Ohm's Law.

   E=IxR; E= 5x10; E=50 volts.

   Now to find the power: W= IxE; W= 5x50; W=250 watts.

   Instead of using two formulas, one after the other, we can combine the two, by substituting (IxR) in place of the E, like this:

   W=Ix(IxR), or W= I^2R, which will give us the same answer, 250 watts.

   This new combined formula can be arranged in a memory circle, as shown in Fig. 3.

2. Where only voltage and resistance are known; if an appliance with a resistance of 20 ohms is connected to a 200 volt line, how much power is dissipated?

   In order to use the Watt's Law formula here, we must first find the current by Ohm's Law:

   $$I = \frac{E}{R}\ ; \qquad I = \frac{200}{20}; \qquad I=10 \text{ amperes}$$

   Now we find the power; W= IxE; W=10x200; W=2000 watts (2KW)

   But here again we found it necessary to use two formulas. They can be combined by substituting (E/R) in place of the (I), like this:

   W=(E/R) x E or $W = \frac{E^2}{R}$ is also shown inside a memory disc in Fig. 4.

   Since each of these circles represents three formulas, we now have a total of twelve formulas concerning Ohm's Law and Watt's Law.

   All twelve formulas may be conveniently arranged in the so-called "WIRE" wheel, which shows three methods of finding any of the four values, watts, amperes, ohms, or volts, if we know any of the other two. This memory device is shown in Fig. 5.

F. Problems For Practice

1. E = 100, I = 3, W = __________.
2. W = 60, E = 120, I = __________.
3. I = 2, W = 64, E = __________.
4. I = 1/2, R = 240, W = __________.
5. W = 100, R = 4, I = __________.
6. W = 648, I = 3, R = __________.
7. E = 3, R = 3, W = __________.
8. W = 60, R = 240, E = __________.
9. E = 120, W = 100, R = __________.
10. Identify each of the following formulas as right or wrong.

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

PRACTICAL APPLICATIONS OF OHM'S & WATT'S LAWS

Objective

To obtain practice in the application of Ohm's Law and Watt's Law to the solution of series, parallel, and combination circuits.

References

Lesson Content

A. Parallel Circuits, Fig. 1

1. Finding voltage drop

   The only value given is the total or source voltage, 120 volts. In a parallel circuit, however, Et=E1=E2=E3, etc. We therefore know the voltage drop, Ed across each lamp.

2. Finding resistance

   a. Since all lamps are 60 watts, 120 volts, the current through such a lamp at rated voltage is found by Watt's Law, I=W÷E = 60÷120 = .5 ampere.

   b. We next find the resistance, by Ohm's Law, R=E÷I = 120 ÷ .5 = 240 ohms.

   NOTE: This resistance can be used for every lamp rated 60 watts, 120 volts, regardless of how it is connected.

3. Total current

   This can now be found by Ohm's Law, It=Et÷Rt or by multiplying .5 by 5 (the number of lamps).

4. Total Watts, use any of these methods:

   a. Wt= It x Et

   b. Wt = W1 + W2 + W3 + W4 + W5

   c. Wt = I^2 Rt

   d. Wt = $\frac{(Et)^2}{Rt}$

5. Individual values

   Since the resistance and the voltage of each lamp is known, the remaining values can now be found by the use of the two formulas, I=E÷R and W = IxE.

6. Cost per kilowatt hour

   a. WH = Wt x Hours

b. Kwh=wh÷1000

c. Cost = kwh x rate (8¢ per kwh).

B. Series Circuits, Fig. 2.

1. Resistance

The resistance of each lamp is known to be 240 ohms. Since they are connected in series, we find the total resistance by the formula: $Rt=R1 + R2 + R3 + R4 + R5$.

2. With the total resistance and total voltage known, the total current and total watts can be found by means of the Ohm's Law formula, $I = E \div R$, together with any of the Watt's Law formulas.

3. Current in each lamp

In a series circuit, the current is everywhere the same, or $I_t = I_1 = I_2 = I_3 = I_4 = I_5$.

4. Voltage drop across each lamp

a. Voltage drop across one lamp is equal to the total voltage divided by the number of lamps, since all lamps have equal resistance, or $E_1 = E_t \div L_t$.

b. It can also be found direct, $Ed = IxR$.

5. Remaining values

These are found in the same manner as described under "Parallel Circuits".

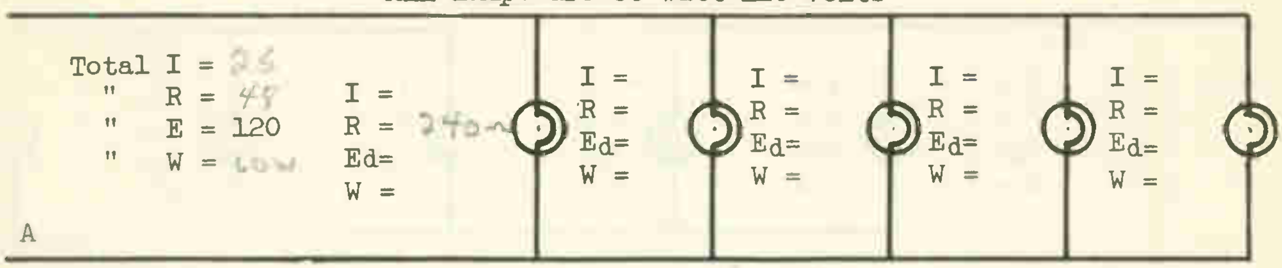
C. Combination Circuits, Fig. 3.

1. Total resistance

a. First find the equivalent resistance of the two lamps in parallel, $R_x=R_1 \div 2$.

b. Now add this to the resistance of the remaining two lamps in series to find the total resistance, $R_t = R_1 + R_2 + R_x$.

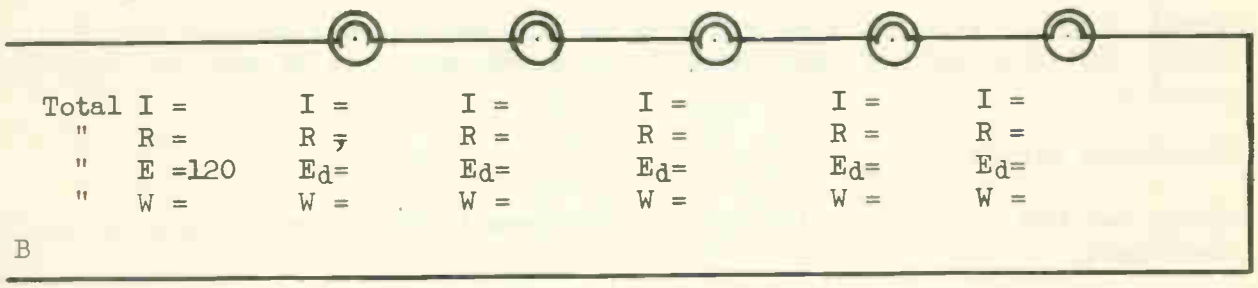
All lamps are 60 watt~120 volts



Cost for 50 hrs. at 8¢ per kwh =

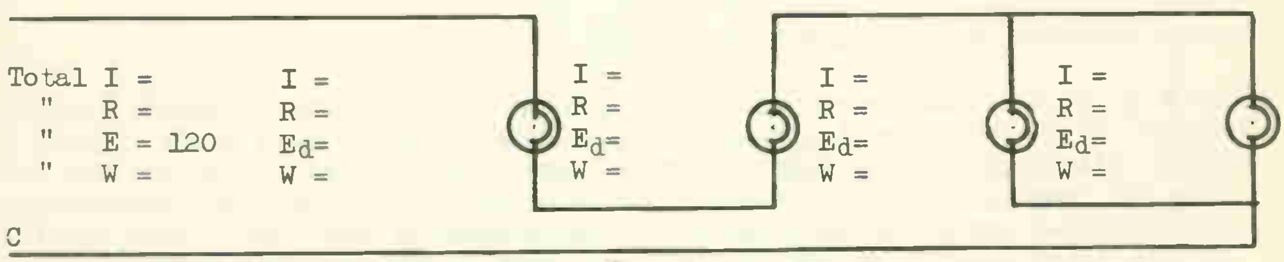
$R = \frac{E^2}{W} = \frac{120 \times 120}{60} = \frac{14,400}{60} = 240\Omega$

Fig. 1



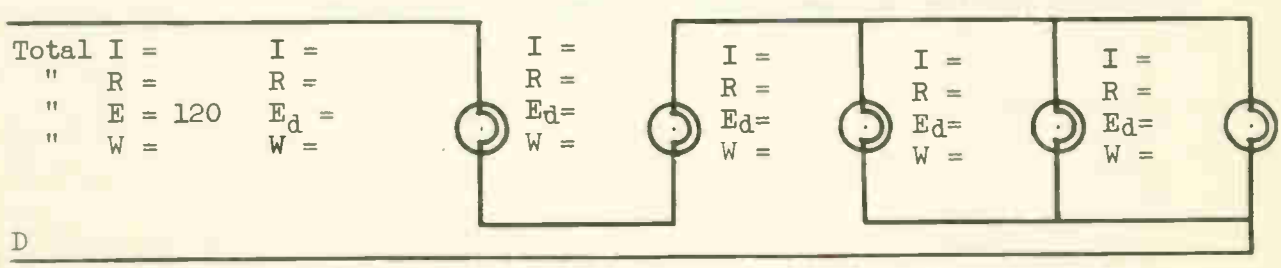
Cost for 50 hrs. at 8¢ per kwh =

Fig. 2



Cost for 50 hrs. at 8¢ per kwh =

Fig. 3



Cost for 50 hrs. at 8¢ per kwh =

Fig. 4

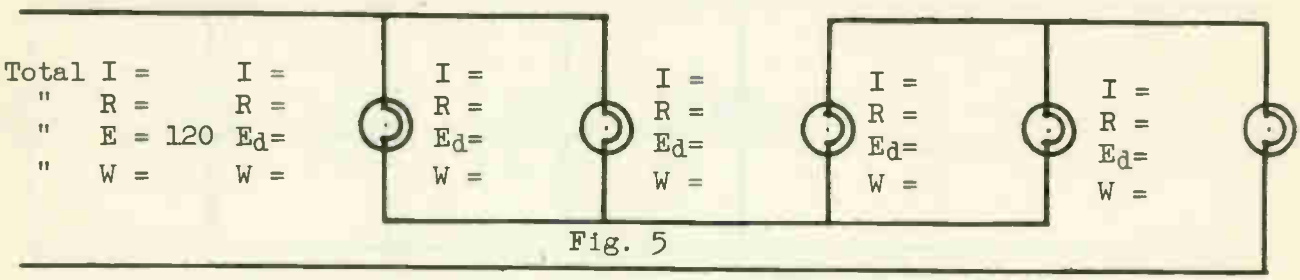


Fig. 5

Cost for 50 hrs. at 8¢ per kwh =

2. Current through the lamps.

   Total current, $I_t = E_t \div R_t$ and this is also the current through the first two lamps, but only half of this current passes through each of the two lamps in parallel.

3. Remaining values

   These can now be found easily, since the current and the resistance is known in each case.

D. Further examples, Figs. 4 and 5.

1. In Fig. 4, the same procedure is followed as in the previous example, but the values will be different because in this case there are five lamps instead of four, with three of the lamps connected parallel with each other and the remaining two lamps connected in series with this parallel Group. The resistance of the parallel group is one-third of the resistance of one lamp. Only one-third of the total current passes through each lamp in the parallel group.

2. The remaining example, Fig. 5, shows a parallel group of two lamps connected in series with another parallel group of two lamps and a single lamp is connected in series with these. First find the equivalent resistance of each parallel group, then the total resistance, after which the total current is calculated. The total current passes through the single lamp, but it divides in half when passing through either of the parallel groups.

RELAYS

Objective

To study the construction and operation of different kinds of relays used to control electrical circuits.

References

Lesson Content

A. Definitions

1. A relay is a magnetically operated switch.

2. A relay according to the American Standards Association, "is a device that is operative by a variation in the conditions of one electric circuit to affect the operation of other devices in the same or another electric circuit". (20.25.005).

B. Uses

1. To control circuits distant from the operating point.

2. To control a relatively high voltage or high wattage circuit by means of a low power, low voltage circuit.

3. To obtain a variety of control operations not possible with ordinary switches.

NOTE: Whether the circuits controlled will be closed or opened when the relay coil is energized will depend upon the arrangement and condition of the relay contacts.

C. Relay classes, (American Standards).

1. Auxiliary relay.

A relay which operates in response to the opening or closing of its operating circuit to assist another relay or device in the performance of a function.

2. Control relay

   A relay which functions to initiate or to permit the next desired operation in a control circuit or scheme.

3. Protective relay

   A relay, the principle function of which is to protect service from interruption or to prevent or limit damage to apparatus.

4. Regulating relay

   A relay which operates because of a departure from predetermined limits of a quantity and which functions through supplementary equipment to restore the quantity within these limits.

D. Auxiliary Relays

1. General

   Fig. 1 shows a common type of auxiliary relay. The arrangement of the electrical circuits and terminals is shown in Fig. 2. Relay bridges may be insulated and arranged either for open circuit, closed circuit, or double circuit operation, as shown in Fig. 3.

2. Simple applications

   a. Using the open contacts only, for remote control, Fig. 4.
   b. The same relay used to control a high energy circuit by means of a low energy circuit, Fig. 5.
   c. Using the closed contact only, as a simple alarm, Fig. 6.
   d. Using both open and closed contacts, for dual control, Fig. 7.

3. Action

   When current flows through the relay coil, it magnetizes the iron core with a polarity that depends upon the connection of the coil to the source. See Fig. 8. This pole induces in the iron section of the movable assembly, a pole of opposite sign, and the attraction between these operates the relay switch. If the current through the coil is reversed, both poles are reversed; therefore attraction always occurs and this type of relay will operate on AC as well as DC.

4. Mechanical construction.

   The relay Figs. 1 to 8 are known as a Pony Relay because of their construction. Three other types are shown in Figs. 9 to 16. These are the Western Union, Fig. 9; The Dixie, Fig. 10; and the Clapper, Fig. 11. A specific type of relay known as a drop relay is shown in Fig. 12 and the operation of this type of relay is shown in Fig. 13.

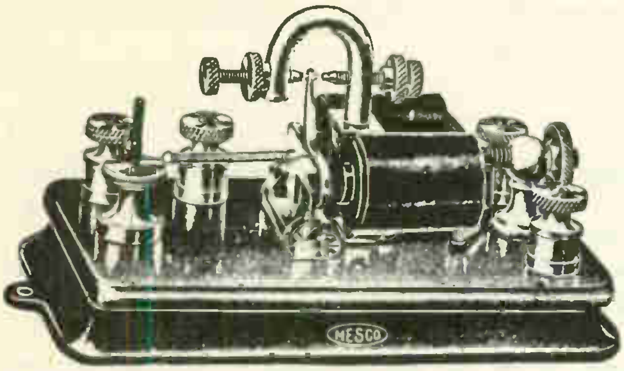


Fig. 1

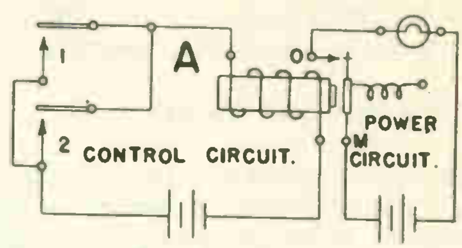


Fig. 5

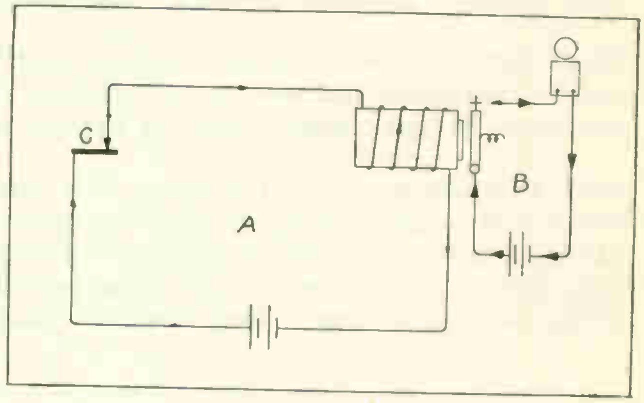


Fig. 6

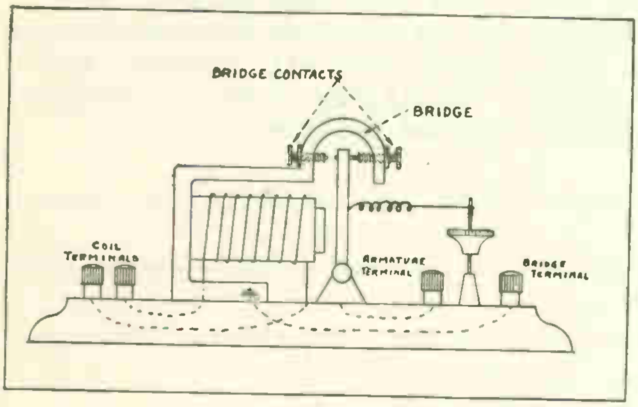


Fig. 2

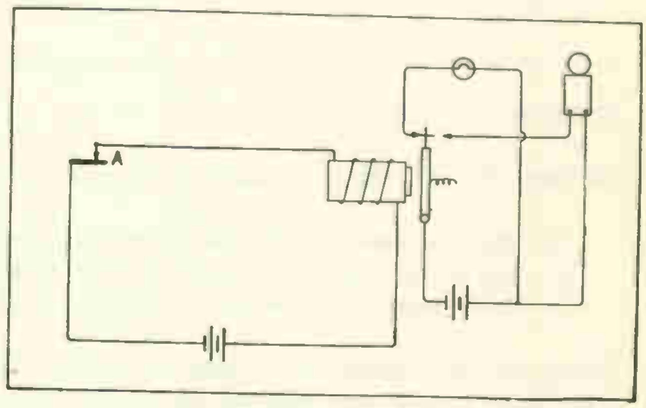


Fig. 7

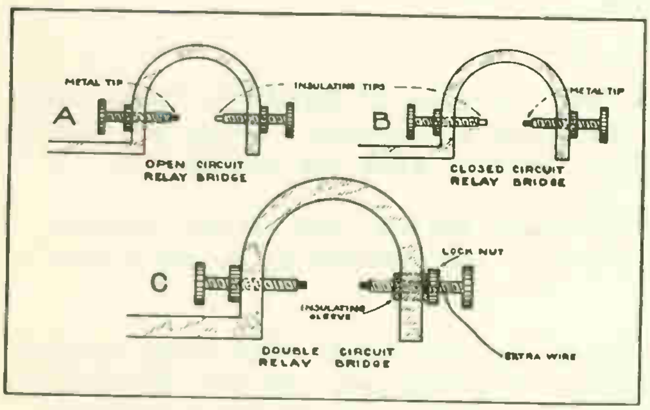
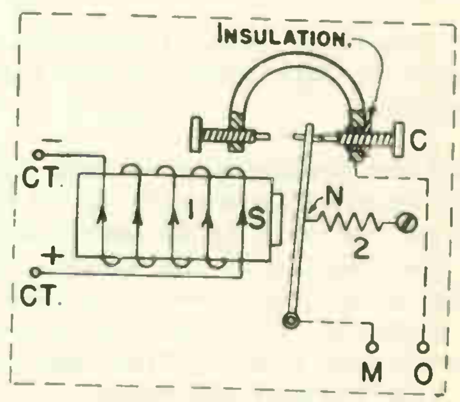


Fig. 3



C = NORMALLY CLOSED CONTACT.
O = " OPEN "
M = MOVING CONTACT.
1 = MAGNET COIL WITH TERMINALS CT.
2 = SPRING.

Fig. 8

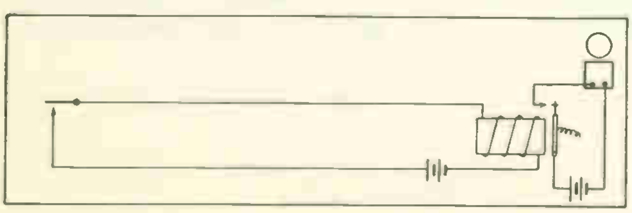


Fig. 4.

It is important to note that while relays may vary widely in mechanical construction, they all operate on the same principle.

E Specific Types of Relays.

Relays exist almost without number. The drop relay previously described is just one of these types, known as a "hand reset." Others include self-reset, electrical reset, balanced relays, ground relays, overcurrent and undercurrent relays, overload and underload relays, surge, temperature and timing relays, reverse-current relays, pressure relays, time-delay relays, etc.

There are relays which are highly specialized, such as percentage differential relays, impedance and reactance relays, frequency relays, locking relays, zero phase-sequence relays, synchronizing relays and even rate change relays.

Many interesting circuits depend on stepping relays and step-back relays. All these and a great many others are clearly defined by the American Standards Association under "Switch Equipment," Group 20, Section 25. They all, however, fall into one or the other of the four general classes -- auxiliary, control, protective, or regulating - they are all "magnetically operated switches."

F. Testing

Before any attempt is made to connect a relay in a circuit.

1. Make a sketch of the terminal locations.
2. Test and identify all switch terminals
3. Make sure the relay is operating!

Using an ordinary test lamp circuit, first find the pair of terminals that, when the test leads are placed on them, causes the relay to operate. These are the coil terminals. Identify them, on the terminal sketch, with the symbols CT.

Next locate by test, inspection, or both, the open, moving, and closed contact terminals. Mark them, on the terminal sketch, with the symbols O, M, and C respectively.

After the terminals have been identified, check the operation. The relay should pull the movable section up as soon as the coil is energized, and drop it out as soon as the coil is de-energized. The moving section should not touch the core, and the tension on the spring should not be too low or too high. The relay switch contacts must be clean. Carbona (carbon tetrachloride) may be used for cleaning the contacts. It is used with a piece of chamois on a stick. Connecting a relay in a circuit without first making these tests is, in the general, an inefficient and time-wasting procedure.

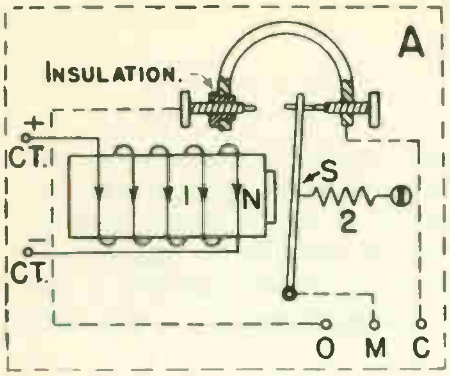


Fig. 9

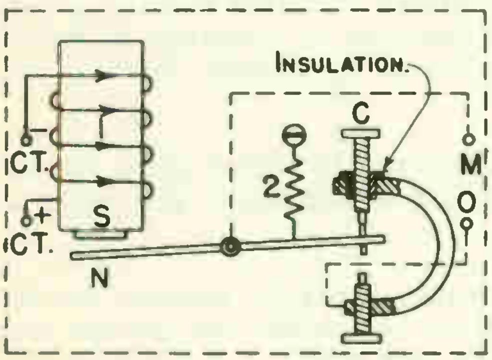


Fig. 10

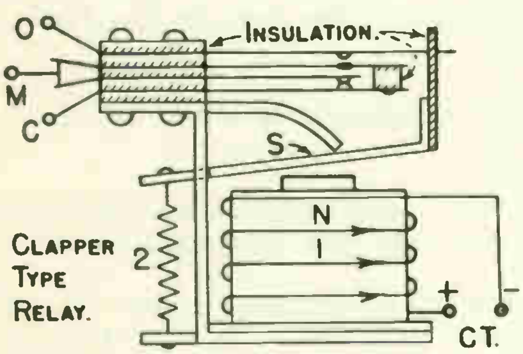


Fig. 11

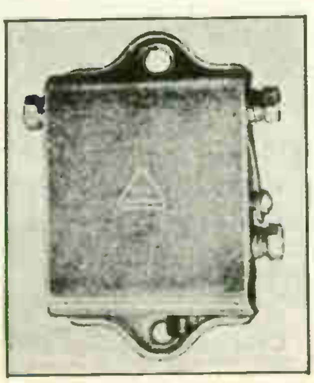


Fig. 12

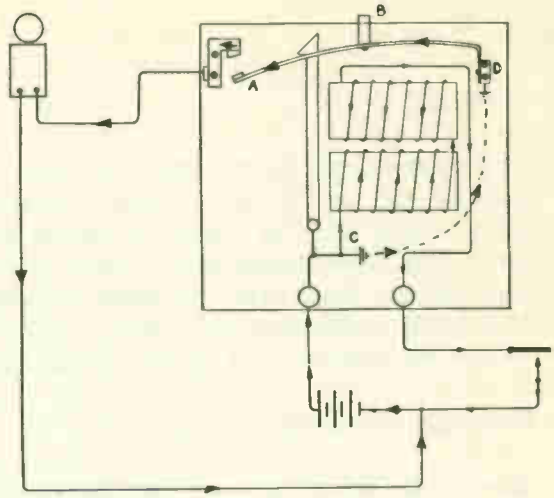


Fig. 13

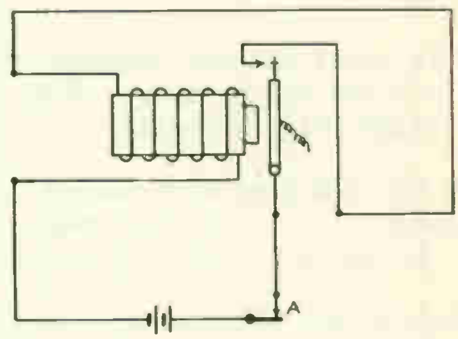


Fig. 14

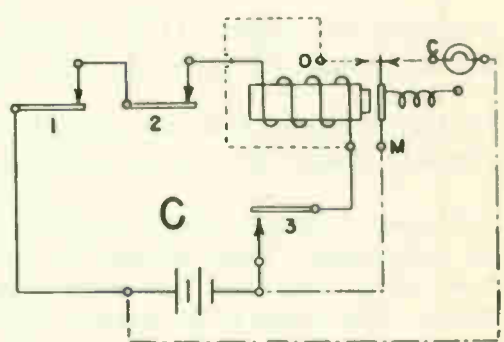


Fig. 15

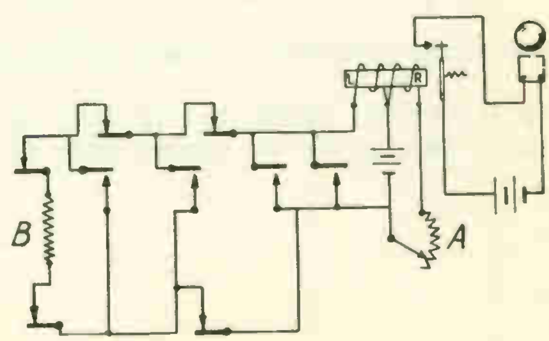


Fig. 16

G. Relay Circuits

1. General

The operations performed by open circuit, closed circuit, and double circuit relays may be accomplished, in most cases, by simple push-button switches. A drop relay may be used to cause constant operation of the signal once the circuit has been molested. This effect can also be secured by a simple switch. But relays may also be used to obtain a variety of control operation not possible with ordinary switches. This is generally accomplished by connecting the relay to operate as a "holding relay."

2. Holding circuits

The term "holding" or "stick" comes from the manner in which the relay armature closes a circuit to the coil, and causes the armature to continue to feed the coil until it is forced away, or its circuit broken by another switch. See Fig. 14.

This relay has its armature M and bridge O connected in series with its coil CT-CT and the battery. This is the basic circuit around which are built all holding relay circuits.

If the armature were pushed to the left, manually, until it touched the bridge contact, it would stay there, because as soon as it touches the bridge contact, it closes a circuit for current to flow through the coil.

Then to get the armature to go back to its original position it would be necessary to force it away, in spite of the pull of the magnets, or to open the closed circuit switch at A. This would stop the current flow through the coils, and allow the armature to release.

A practical application of this holding circuit principle is shown in the alarm system pictured in Fig. 15.

Switch 3 must first be closed momentarily. This "sets" the alarm. The holding circuit keeps the relay energized. In this condition, the lamp will be out.

Switches 1 and 2 might represent pieces of thin wire stretched across windows or doorways. When either is opened, the circuit is broken. This de-energizes the relay coil, at the same time closing the relay switch, which lights the lamp. The lamp will remain on until Switch 3 is pressed again. Another lamp or bell could be placed in parallel with the relay coil. It would then operate whenever the alarm lamp was out. Many other modifications of this circuit are found in the field.

3. Balanced resistance alarm circuit.

This circuit shown in Fig. 16, is a very dependable alarm system, as it is almost impossible to tamper with it without causing the alarm to sound.

H. Summary Questions

1. What is a relay?

2. What are the requirements for a stick or holding circuit?

3. Using five double-circuit relays, one open circuit push-button switch, one closed circuit push-button switch and one battery, show how they may be conne ted so that when the "start" switch is pressed, relay #1 will close, thereby energizing relay #2, which will energize relay #3, and so forth down to relay #5. When relay #5 is energized it will open relay #1, which will open relay #2, which opens relay #3, etc., the cycle being repeated continuously until t "stop" switch is pressed.

4. Show how lamps may be connected in parallel with all the relay coils so that they will flash on and off in succession when the relays are operating.

5. Using one double-circuit push-button switch, one lamp, one battery and seven double-circuit relays, show how they may be connected so that when the push-button is first pressed, the lamp will go on, and when the push-button is pressed the second time, the lamp will go out.

ANNUNCIATORS

Objectives

1. To learn how to test and use electrically operated annunciators.
2. To learn how annunciators are used in signal systems.

References

Lesson Content

A. Definition

An annunciator is a device for use in a signal system that gives a visual signal.

American Standards Association definition for an annunciator, No. 95.50.015 -

"An annunciator is a signaling apparatus operated electromagnetically, and serving to indicate whether a current is flowing or has flowed in one or more circuits. It is usually employed in connection with electric bells or buzzers."

B. Construction and Operation

The annunciator consists of five main parts. These parts are as follows:

1. Frame
2. Electro-magnet
3. Armature
4. Shutter
5. Armature Spring

The operation is very much like a drop type relay. When current passes through the coil of the electro-magnet the magnet coil becomes magnetized and attracts the armature which is pulled toward the electro-magnet against the spring tension. This movement of the armature releases the shutter which drops and allows the signal to be visable. These steps are listed in order on Fig. 1.

C. Practical Application

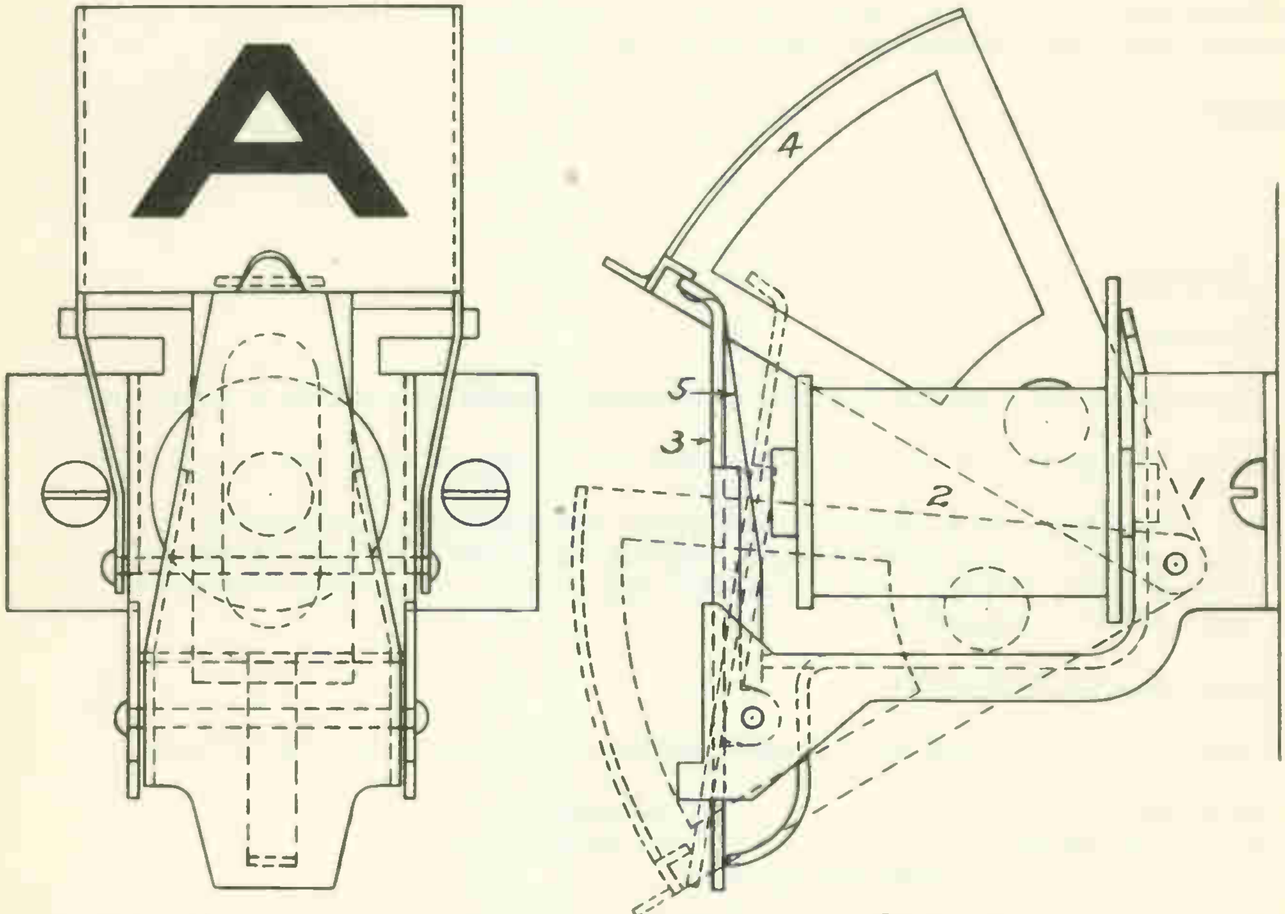
Annunciators are used in hospitals to indicate which patient is making the call. Used in connection with inter-office call systems; on elevators to indicate which floor is calling; in fire alarm and burglar alarm systems to indicate which part of the system has been disturbed; etc.

D. Drop Relay (Job Nos. 21 and 22)

The drop relay is so constructed that when current energzies the coil the armature trips the relay switch and it remains closed until reset by hand. Usually used in annunciator circuits to keep an alarm sounding until answered.

1 Frame of annunciator.
2 Electro magnet
3 Armature.
4 Shutter.
5 Armature spring.

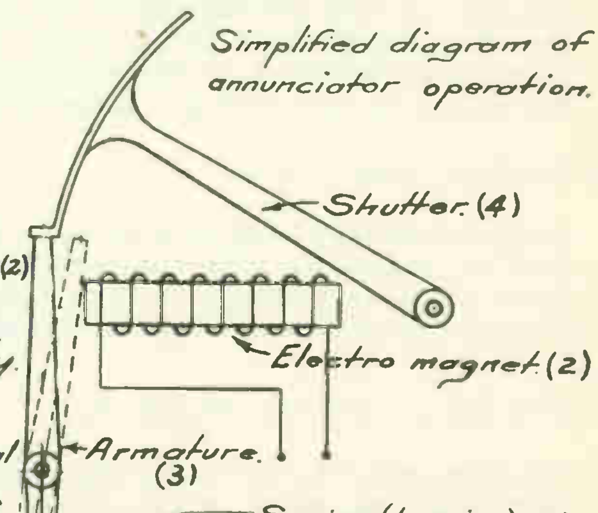
Diagram shows the annunciator at twice the actual size.



Front Elevation.

Side Elevation.

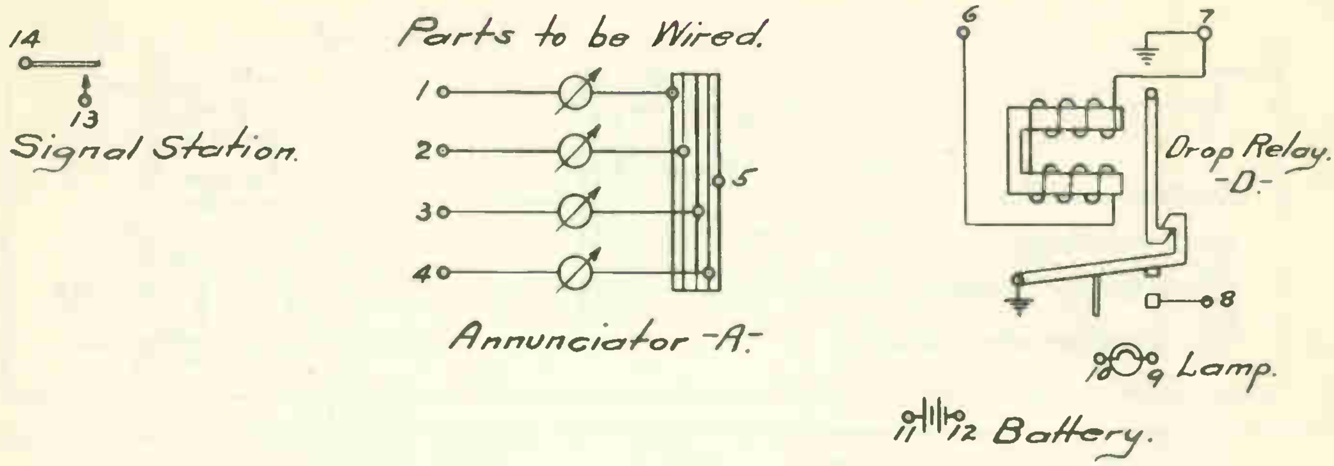
Simplified diagram of annunciator operation.



Operation.

The armature (3) is held in position supporting the shutter (4) by the spring (5) until the electro magnet (2) is energized and draws it away when the shutter falls by gravity. The shutter must then be reset manually for which purpose a vertical plunger rod projecting through the bottom of the annunciator case is usually provided.

Fig. 1 Gravity drop type annunciator



Terminal Connections.

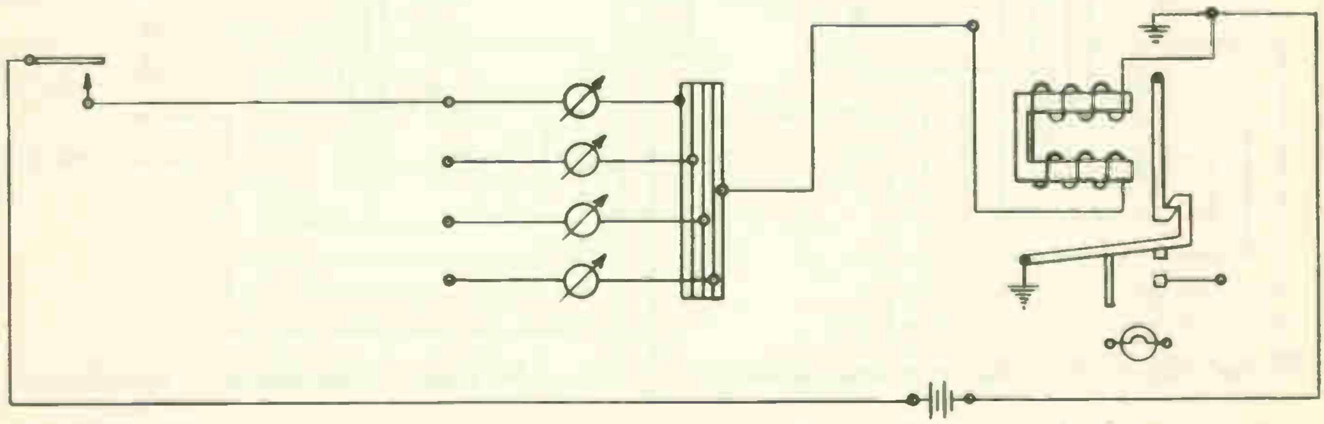
Annunciator -A-
- 1-Shutter. }
- 2- " } Marked to indicate
- 3- " } station location.
- 4- " }
- 5-Common Return.

Relay -D-
- 6-Insulated terminal of coil.
- 7-Grounded " " "
- 8-Drop contact.

Lamp or bell.
- 9-and 10-Terminals.

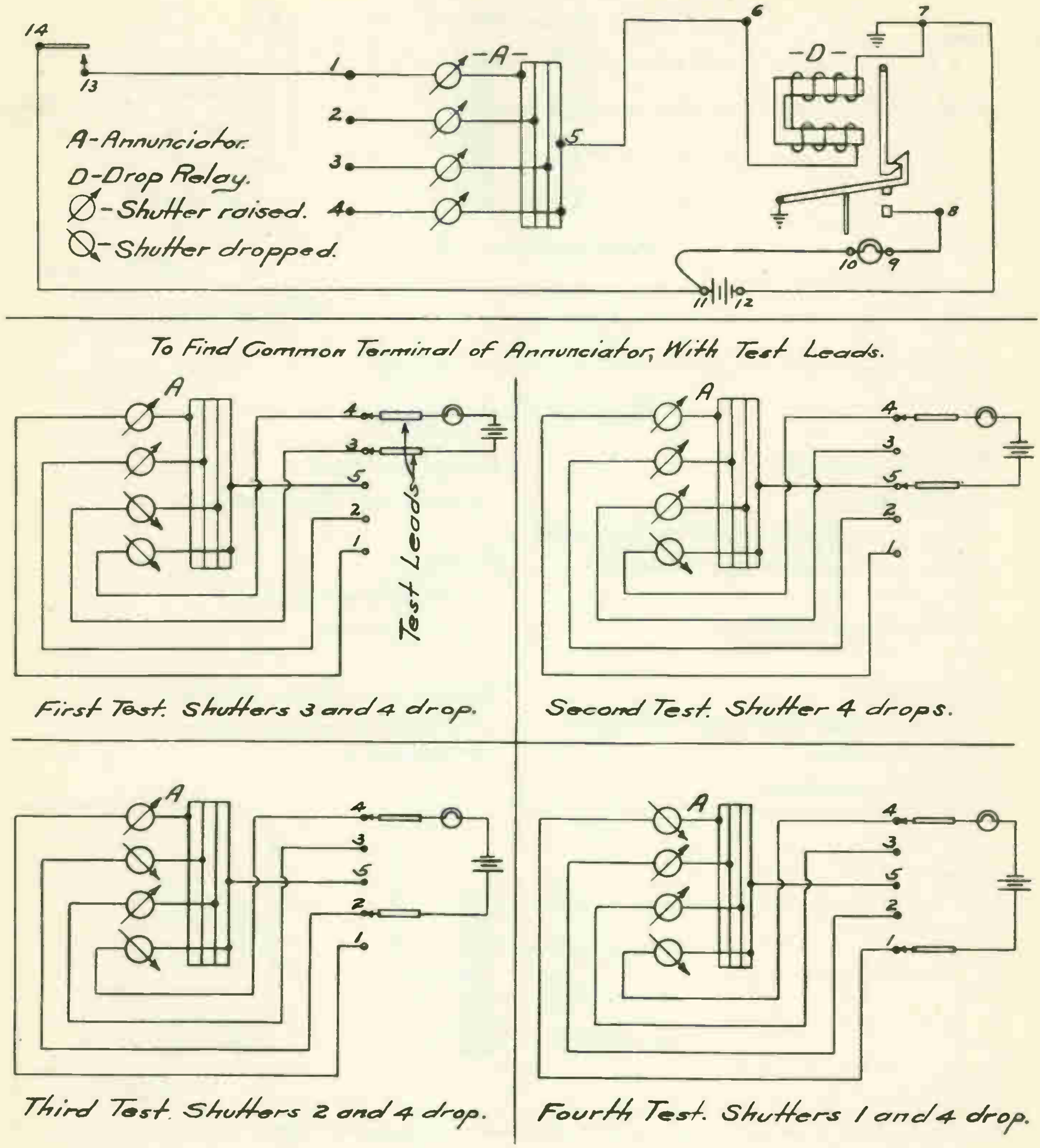
Battery.
- 11-Positive terminal
- 12-Negative "

Signal or alarm station.
- 13-Fixed contact (open)
- 14-Movable "



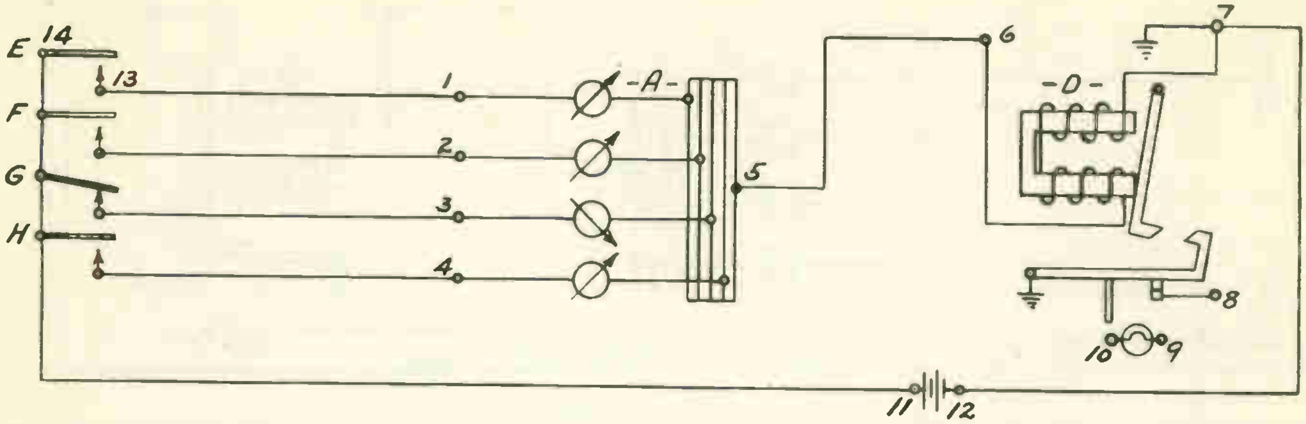
Required wiring connections to battery, annunciator and relay so that station signaling is recorded and relay tripped. For wiring of warning lamp or bell signal eqipment see following sheet.

Fig. 2 Steps for wiring an annunciator

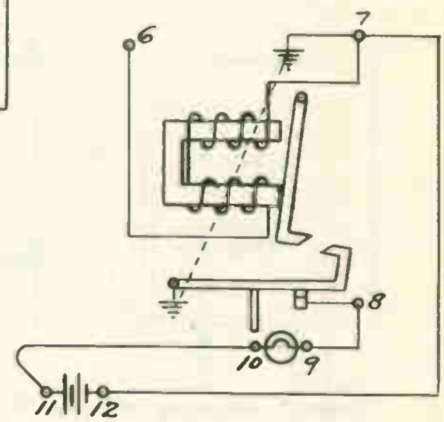


In the second test but one shutter dropped indicating that one test lead was on the common terminal 5 but the relative position of this terminal varies and can only be determined by trial.

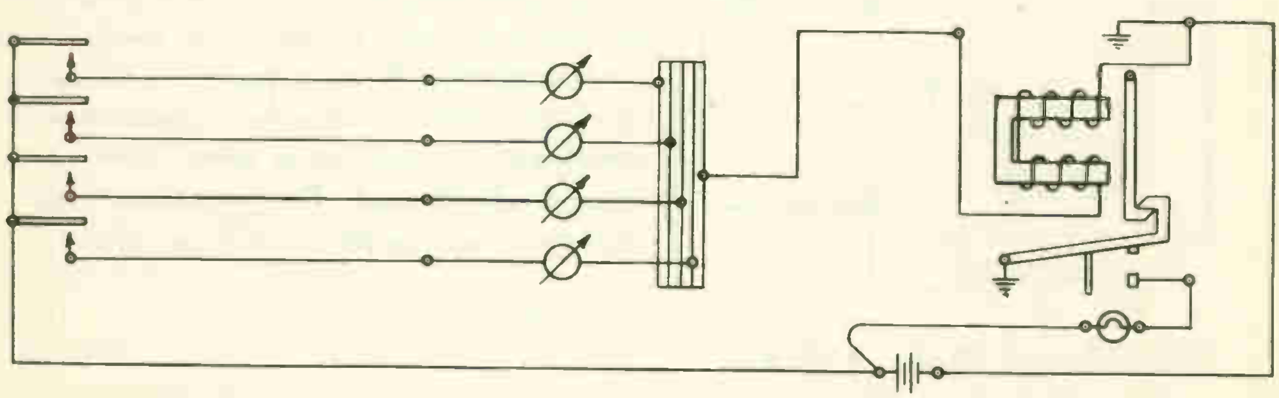
Fig. 3 Annunciator circuits



The circuit through battery, relay and annunciator has been completed through the movable contact at signal station G when the annunciator shutter #3 indicating the station falls and relay trips.

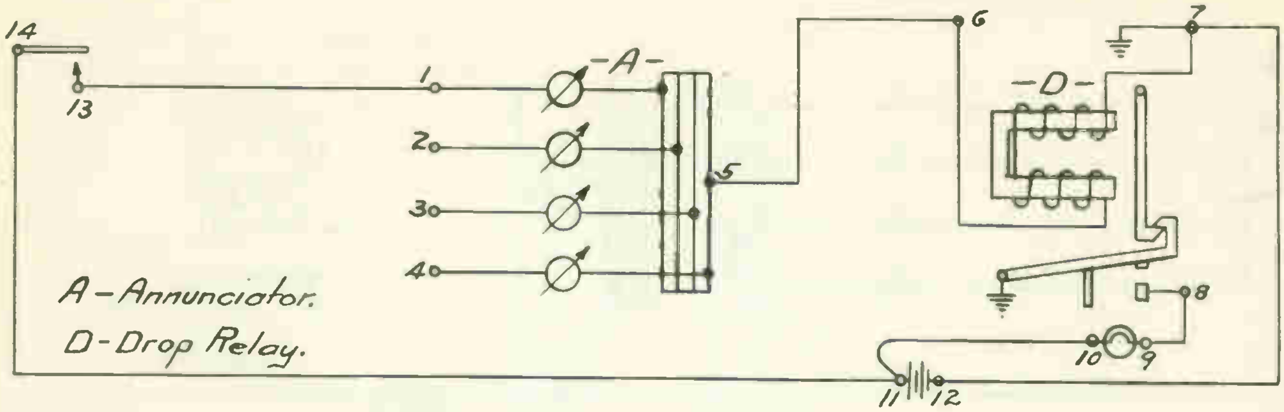


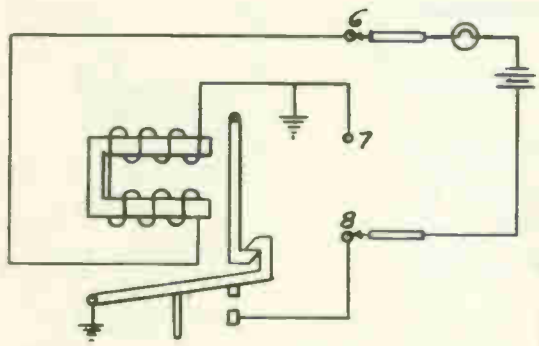
When relay trips the light or bell circuit is completed through the drop terminal #8 and ground, as indicated by the dotted line, and alarm will continue to operate until relay is reset manually.



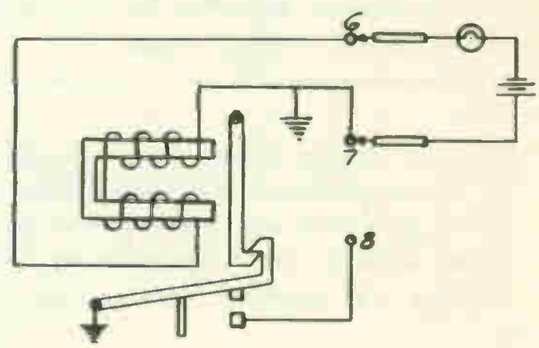
The two open circuits are here shown ready for operation.

Fig. 4 Open circuit annunciator system

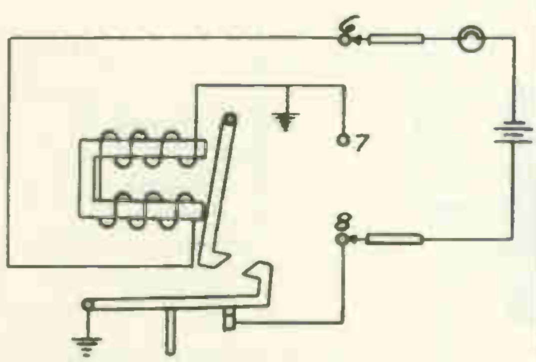




Test leads from 6 to 8.
Lamp does not light. Relay does not trip.



Test leads from 6 to 7.
Lamp lights and Relay trips.



Test leads from 6 to 8.
Lamp lights dimly. Relay must be reset manually.

Application.
When connected in an open circuit as indicated at top of sheet and the circuit becomes closed the relay and annunciator form a complete signal or alarm system which will continue to operate until both are manually reset. The system will operate on either A.C. or D.C.

Fig. 5 An annunciator system with a drop relay.

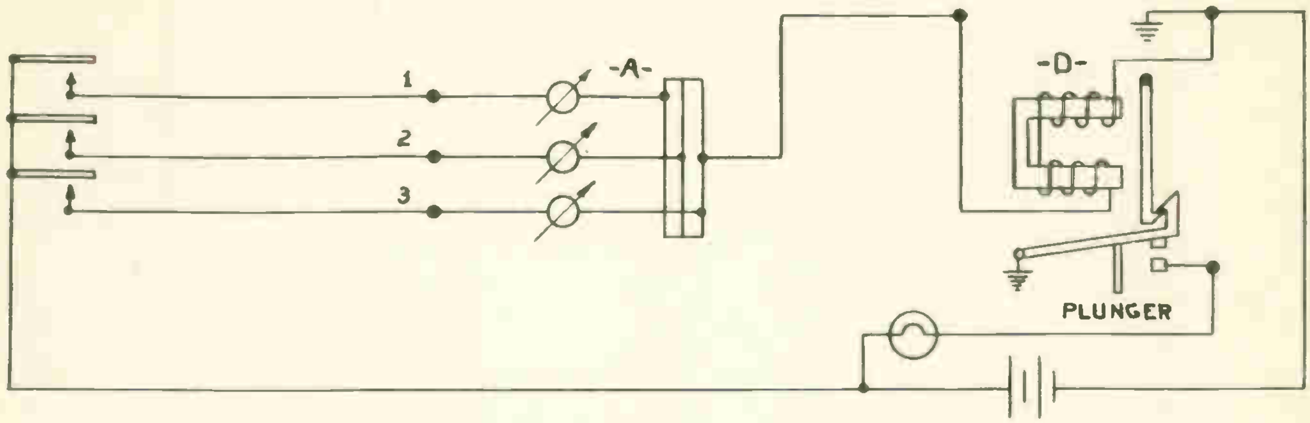


Fig. 6 This is an alarm or signal system using an annunciator A and a drop relay D (drop switch) to provide a continuous alarm until the relay is reset by hand.

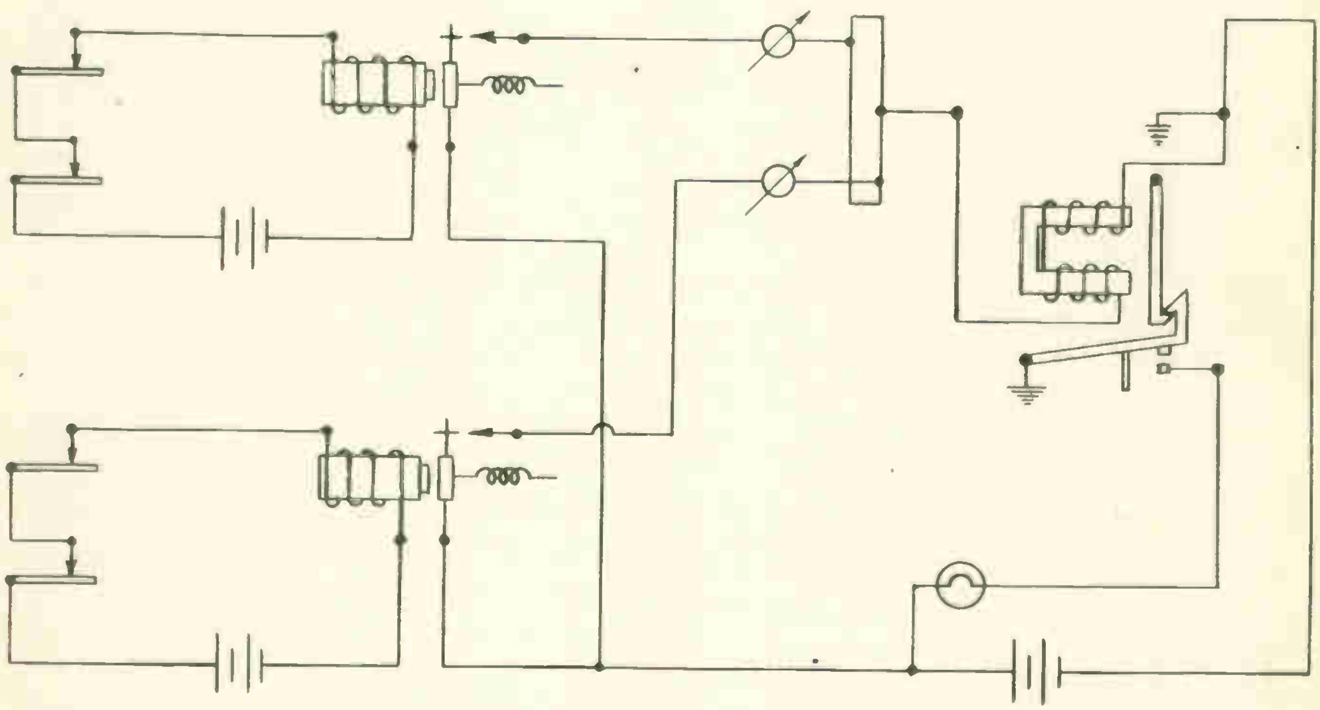


Fig. 7 This is a two-section alarm or signal system. Two or more floors, buildings, or departments can be protected in this manner. The annunciator indicates which floor or building the call comes from and the drop relay gives a continuous indication after the system has been disturbed. A bell can be used in place of the lamp if an audible signal is desired.

MAGNETISM

Two classes of magnets
1 Natural (Lodestone)
2 Artificial {Permanent
Temporary
Electro

Objective

To obtain information on magnets, magnetism, and magnetic laws.

References

Lesson Content

A. General

1. Importance of magnetism

The construction of all equipment used in electricity, radio, and electronics is founded directly or indirectly on magnetism. It has been said that without magnetism, the entire electrical world would collapse. There is hardly a piece of electrical machinery in use today which doesn't make use of magnetism.

2. Legend and history

Many ancient peoples claim to have discovered the phenomenon of magnetism. The Chinese claim to have invented the magnetic compass about 2637 BC. These early magnets used in the compass were called lodestones or 'leading stones. Today it is known that they were crudely shaped pieces of iron ore known as magnetite, the symbol for which is Fe_3O_4. See Fig. 1.

Since they are found magnetized in their natural state, lodestones are classified as natural magnets. The only other natural magnet is the earth itself; all other magnets are known as artificial magnets.

3. The earth is a magnet

It was the action of the earth on a magnet (or compass) that led to the conclusion that the earth itself is a huge magnet, although a weak one, considering its size. The magnetic poles of the earth do not coincide with the geographic poles. Hence, a compass points to true north only when it is at a particular longitude, called the agonic line. At other points there is a variation or declination in its direction (to be distinguished from "deviation", which is the result of nearby masses or metal). At the magnetic equator or "aclinic line", the compass needle is horizontal. North of this line it dips, or inclines, the inclination being 90 degrees directly over the north magnetic pole.

The polarity of the north magnetic pole is assumed to be south, since it attracts the north (seeking) pole of the compass. See Fig. 2.

4. Definitions

Magnets "A magnet", says the American Standards Association (05.25.155), "is a body which produces a magnetic field external to itself".

Magnetism - while there is no official A.S.A. definition for magnetism, it may be defined as the mysterious power which a magnet has of attracting or picking up small pieces of iron or steel, such as nails, tacks, needles, or iron filings.

Magnetic material - generally, magnetic material consists of iron and various alloys of iron, such as steel, alnico, permalloy etc., although nickel, cobalt and gadolinium are also magnetic. All other materials can be regarded as non-magnetic.

A simple test to determine whether a material is magnetic or non magnetic is to place it under a magnet. If attracted it is magnetic and if not attracted it is a non magnetic material.

B. Theory of Magnetism

1. The field about a moving electron.

Because of its negative charge, each electron is surrounded by an electrostatic field. As the electron revolves about its nucleus, its dielectric field revolves with it. With every moving dielectric field there is a magnetic field set up at right angles to the direction of the motion of the dielectric field.

2. Ferromagnetic materials

If the electrons in a substance are lined up in approximately the same plane, the substance is easily magnetized and is said to be ferromagnetic.

3. Diamagnetic materials

If the units of magnetism cancel one another, the substance cannot be magnetized and is said to be diamagnetic.

4. Another classification

The permeability of a perfect vacuum is said to be one, or unity. Air, paper and other non-magnetic materials are usually regarded as having unit permeability as well. Substances like nickel and cobalt, with a permeability slightly higher than "one" are called paramagnetic and substances like iron and its alloys with much higher permeability are called ferromagnetic, while substances like antimony and bismuth, with a permeability of less than one are called diamagnetic.

5. Breaking a magnet

When a magnet is broken each piece becomes a new magnet with north and south poles. See Fig. 3.

C Artificial Magnets

Definition - all man-made magnets are known as artificial magnets.

How prepared - by stroking a piece of iron or steel several times in the same direction. This is known as the contact method.

By pointing a piece of iron or steel in a north-south direction and tapping it with a hammer. This method is known as the induction method.

By heating a piece of iron or steel in a north-south direction and tapping it with a hammer. This method is known as the induction method.

By heating a piece of iron or steel and allowing it to cool while the steel is under the influence of a strong magnetic field. This method is known as the induction method.

NOTE: In all practical cases, the field is produced by means of the electric current.

D. Permanent Magnets

1. Definition - any magnet which will retain its magnetism once the molecules are lined up in the proper manner.

2. Materials used - hard iron or hard steel make excellent permanent magnets. Still better permanent magnets are made from various alloys, the best permanent magnets today are made of alnico, a combination of iron, aluminum, nickel, and cobalt. Other modern magnetic materials are permendur, remalloy, perminvar and vicalloy.

3. Retentivity - is the ability of a material to retain magnetism for a long period of time. It should be distinguished from "residual magnetism", which is the magnetism remaining in a magnetic material after the magnetizing force has been removed.

4. Shape of permanent magnets

   a. Bar, with a pole at each end. Useful in experiments but of little commercial use, See Fig. 4.

   b. Horseshoe, used in motors, meters, phones, generators, magnetos, speakers etc. Usually in one piece, with a pole at each end, but it may consist of two bar magnets joined together by a "yoke". In a strict sense, even if it is in one piece, the horseshoe magnet may be considered as two bar magnets joined together by the curved portion, which is still called the yoke, a yoke being defined as the portion connecting two magnets. See Fig. 5 and 6.

   NOTE: The term "yoke" must not be confused with "keeper". A keeper is a piece of soft iron placed across the ends of horseshoe magnets when they are not in use, to provide a complete closed circuit of magnetic material and eliminate air-gap reluctance, thus greatly lengthening the life of the magnet. See Fig. 7.

c. Special permanent magnets

If two or more permanent magnets are joined with like poles clamped together the combination is called a magnetic battery or compound magnet. Fig. 8.

Occasionally in a permanent magnet evidence will be found of more than two poles or points of attraction. If adjoining sections of a magnetic material are magnetized with opposite polarity, there will be additional poles formed in the magnet. These are called consequent poles. Consequent poles can also be induced in temporary magnets by the action of two like poles of a strong magnetic force operating on opposite ends of the temporary magnet. See Fig. 9.

d. Flat, magnetized through the thickness of the material rather than lengthwise. These are used primarily as pole pieces in motors and generators having permanent field magnets.

e. Ring, commonly used in certain types of instruments and having no poles at all. A closed core in a transformer is a good example of a temporary ring magnet.

5. Poles of a permanent magnet.

Poles are usually located at the ends or points of the material and represent the greatest concentration of magnetic force. Every magnet (except a ring magnet) has a north and south pole. See Fig. 10.

A compass always tends to line up parallel with, and pointing in the same direction as the lines of force.

E. The Magnetic Field

1. Magnetic lines of force.

One line of magnetic force is known as a maxwell. A magnetic line of force may be defined as the path along which a unit north pole would travel if such a pole could exist, and were free to move, such as the Maxwell (line of force).

The total of the magnetic lines of force is called magnetic flux or flux. The symbol for flux is the Greek letter phi (ϕ).

The area in which flux is found is called the magnetic field. A magnetic field of force exists around each magnet. See Fig. 11. The strength of the field depends upon its density, for example, the number of lines or maxwell per unit area.

2. Rules for magnetic lines of force about a magnet.

Lines of force always travel from north pole to south pole externally, from south to north internally.
They enter and leave at right angles to the surface of the magnet.

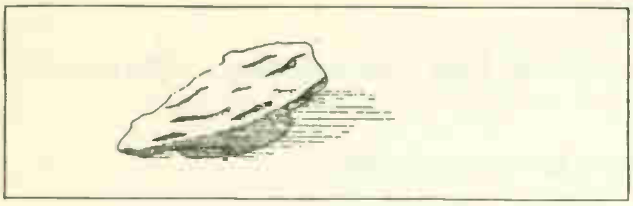


Fig. 1

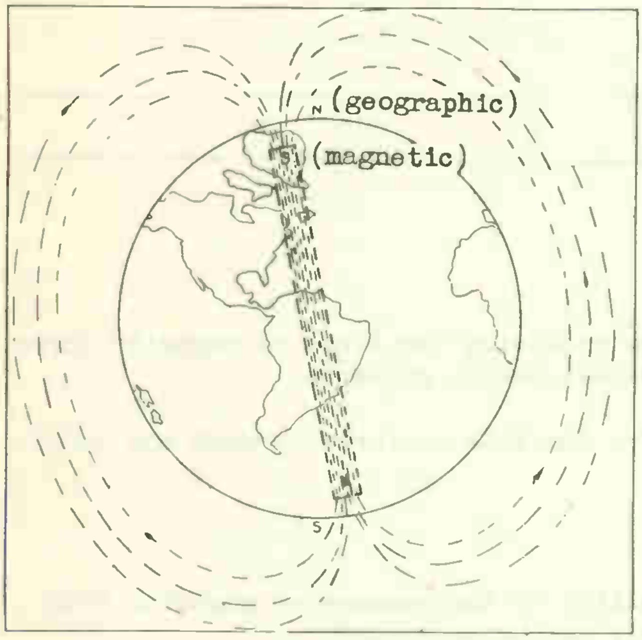


Fig. 2

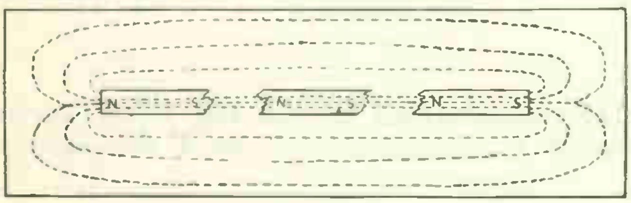


Fig. 3

Fig. 4

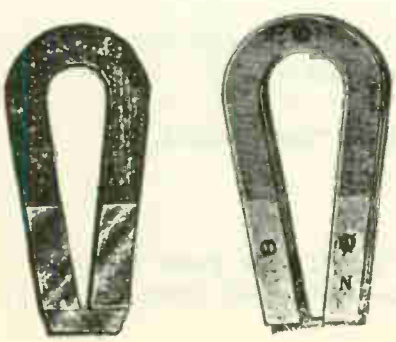


Fig.5

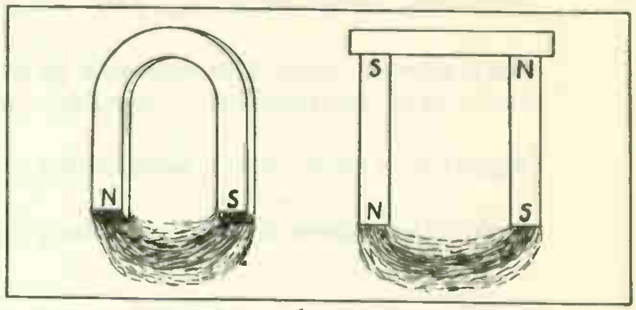


Fig. 6

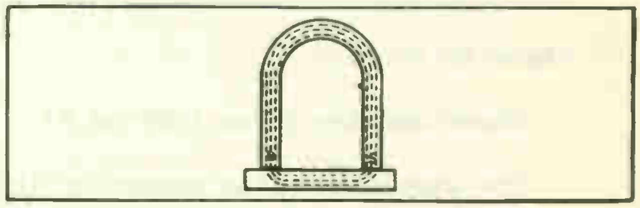


Fig. 7

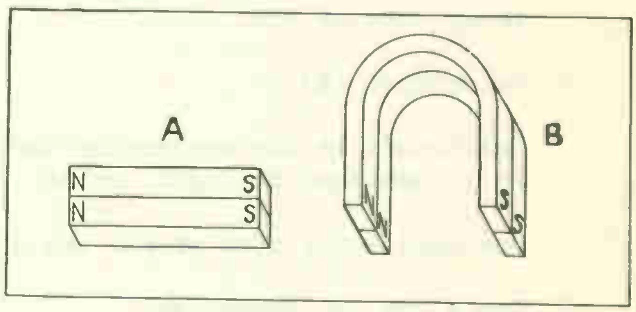


Fig. 8

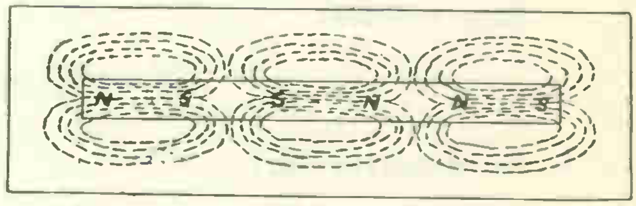


Fig. 9

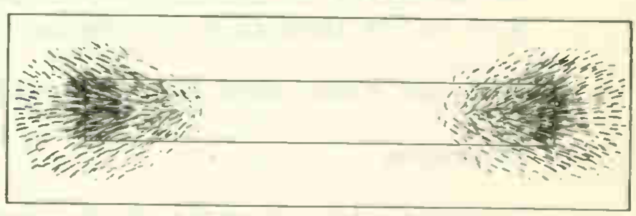


Fig. 10

They are under tension, like rubber bands.

They always take the easiest path (the path of least reluctance). This accounts for field distortion. See Fig. 12.

Magnetic lines repel each other; hence, they never cross.

Each line makes a complete loop or circuit.

F. Magnetic Units

1. Magnetomotive force (MMF or F)

The strength of the magnet or the force producing the lines of magnetic force is known as magnetomotive force. It is measured in gilberts.

One Gilbert is the MMF required to drive one line of force through one centimeter cube of air.

2. Reluctance (R)

Reluctance is the measure of the opposition to the passage of magnetic flux. It is measured in C.G.S. units (formerly called oersteds).

One centimeter cube of air has a reluctance of one C.G S. unit, or one oersted.

3. Ohm's law for magnetism.

The amount of flux in maxwells is directly proportional to the MMF in gilberts, and inversely proportional to the reluctance in C G.S. units. As a formula, this becomes:

$$\phi = \frac{MMF}{R} \text{ or } \phi = \frac{E}{R}$$

4. Permeability (Mu)

The ease with which magnetic lines of force pass through a medium is dependent on the permeability of the material.

Permeability is measured in terms of the number of maxwells which one gilbert will drive through a centimeter cube of the material.

Iron and steel have high permeability, iron higher than steel.

5. Permeance

Permeance is a measure of the ease with which flux lines pass through a magnetic circuit by virtue of the size, shape and the material from which it is made.

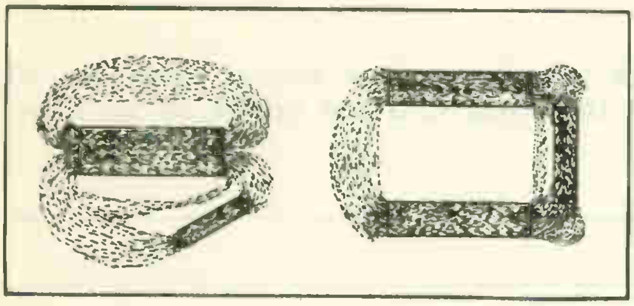


Fig. 11

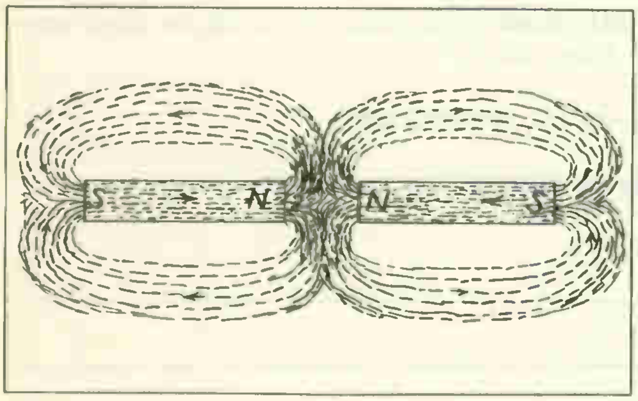


Fig. 12

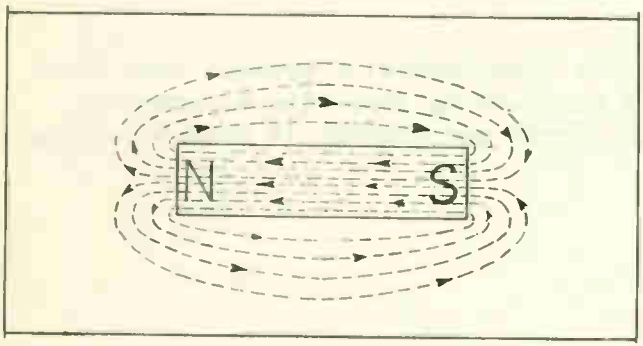


Fig. 13

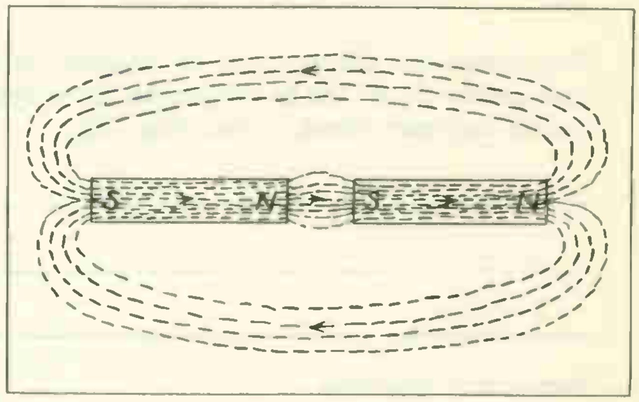


Fig. 14

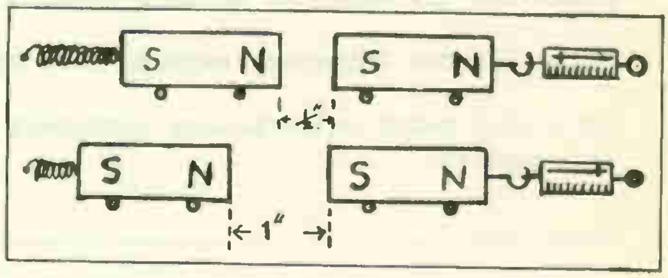


Fig. 15

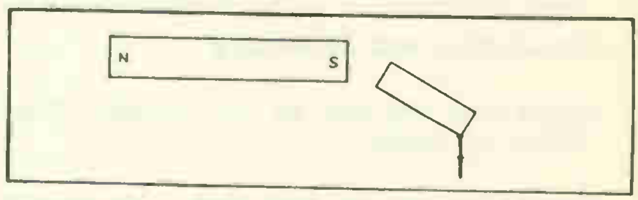


Fig. 16

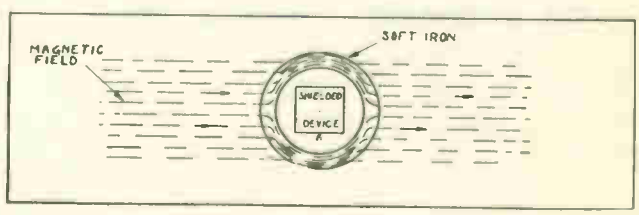


Fig. 17

G. Laws of Magnetism

Like magnetic poles repel and unlike poles attract each other. See Fig. 13 and 14.

The force of attraction or repulsion between two magnet poles varies directly with the product of their separate strengths and inversely with the square of the distance between them. See Fig. 15.

H. Temporary Magnets

Temporary magnets are those which retain their magnetism only so long as they are under the influence of another magnet. See Fig. 16.

Materials for temporary magnets have little or no retentivity.

Soft iron makes satisfactory temporary magnets. Permalloy makes excellent temporary magnets.

I. Insulation and Shielding

Magnetism can not be insulated. There is no known insulator against magnetic lines of force.

Magnetism can be shielded. We shield sensitive instruments to protect them from the influence of magnetism. This is done by surrounding them with a permeable material which will by-pass the flux through itself and prevent it from affecting the instrument. See Fig. 17.

J. Summary Discussion

Below is a discussion of magnetism, interspersed with missing words. The student is to consult the list of words to the right of each paragraph, and insert the correct word in the proper blank space.

1. Magnetism is a peculiar property of the following three elements: iron, nickel, and cobalt. It is highly pronounced in certain alloys such as steel, alnico, permendur, remalloy, and permalloy. Magnets may be classed as natural magnets and artificial magnets. Hard steel when magnetized retains its magnetism for long periods and is said to have high retentivity. Soft iron tends to become easily magnetized when subjected to a magnetizing influence, but when the magnetizing influence is removed a large part of the external magnetic effect of the soft iron is lost. Soft iron is said to have low retentivity. Thus in the case of a permanent magnet loud speaker, a material with high retentivity is desirable such as alnico, permendur and remalloy. In the case of a dynamic speaker which employs an electro-magnet, a core of per-meability is desirable such as permalloy and soft iron, Materials which have high retentivity require a high initial magnetizing force than those of low retentivity.

retentivity
permanent
permalloy
high
soft iron
low
nickel
steel
cobalt
remalloy
perminvar
temporary
permendur
permeability
alnico
larger
smaller

2. A steel bar magnet attracts bits of iron brought near either end, and will exert a force of either attraction or repulsion upon other magnets in its vincinity. This force exerted in the space surrounding the magnet is found to vary inversely as the square of the distance from the magnet. The space in which this force acts is known as the magnetic field which is thought of as existing in the form of lines. These lines are collectively known as the flux. Outside the magnet these lines of force are thought of as passing from the North pole to the South pole. Inside the magnet they are thought of as passing from the South pole to the North pole. They are always closed loops, and act somewhat like stretched rubber bands in that they tend to become as short as possible.

Cube
north
flux
inversely
attraction
closed
round
directly
open
south
square
repulsion
field
lines of force
short
long

3. The regions where the lines of force are most concentrated are called the poles. The action of one magnet on another is that like poles repel and unlike poles attract. When a piece of soft iron is placed within the magnetic field, the lines of force will be increased as well as concentrated. This is analogous to decreasing the resistance of an electrical circuit by substituting a conductor of lower resistance for one of greater resistance.

Higher
poles
lower
increasing
attract
concentrated
increased
decreasing
repel

ELECTRO-MAGNETISM

Objective

To become acquainted with the rules and principles of electro-magnetism; to learn the units used in connection with electro-magnetism; to be able to solve practical problems involving electro-magnetism.

References

Lesson Content

A. Historical

While magnetism is almost as old as recorded civilization itself, the phenomenon of electro-magnetism has been in use only since 1830. The first "strong" electro-magnet was made in 1830. It could lift nine pounds. Later the same year Joseph Henry, an American physicist, made an electro-magnet that would lift more than 700 pounds and a year later he made one that would lift nearly a ton.

Modern electrical industry and science got its real start when it was found possible to produce a magnet with an electric current and then to produce an electric current from magnetism. Electro-magnets are used in door bells, buzzers, chimes, and other signals, telegraph sounders, relays, annunciators, motors, motor controllers, generators, telephone receivers, radio receivers, broadcast transmitters, meters, transformers, induction coils, amusement devices, hoists, elevators, electric railways, arc lamps, circuit breakers, and many other appliances.

B. Basic Concepts

1. Magnetic lines of force appear around a conductor when electrical current flows in that conductor, Fig. 1.
   a. The strength of the magnetic field around a wire depends on the amount of current.
   b. The direction of the lines rotation depends on the direction of current. Fig. 2.
2. Rules "A" and "B", Fig. 3.
   a. When current in a conductor is away from the observer, the magnetic lines of force revolve clockwise.
   b. When current in a conductor is toward the observer the magnetic lines of force revolve counter-clockwise.

3. Magnetic forces between parallel wires.

   a. When current in two parallel wires is in opposite directions the wires tend to repel each other, Fig. 4.

   b. When current in two parallel wires is in the same direction the wires tend to attract each other, Fig. 5.

   c. The lines of force around the turns of a coil join together in a single field of very great strength. This field will have a north and south pole, Fig. 6.

4. Rules "C" and "D", Fig. 7.

   a. When current in a coil travels clockwise the end of the coil nearest the observer is the south pole.

   b. When current in a coil travels counter-clockwise the end of the coil nearest the observer is the north pole.

C. Coils

1. The Helix, Fig. 6.

   A self-supporting coil of a single layer is called a "Helix".

2. The solenoid, Fig. 8.

   a. The coil wound with many layers of insulated wire on a spool of brass or fibre or some other non-magnetic material, is called a "Solenoid".

   b. If we place an iron core inside a solenoid the field will at once become much stronger, because the iron offers a much better path than air for the lines of force. A solenoid will give a strong and fairly uniform pull for about half its own length. This is the most effective distance, since the flux is more dense inside the coil.

3. The electro-magnet, Fig. 9, 10, and 11.

   An electro-magnet is a core of soft iron with several turns of insulated wire wound around it.

4. Miscellaneous "coils"

   The helix, solenoid, and electro-magnet appear in many forms and are known by various names according to the uses to which they are put, but in all cases they operate on the same principles. Such coils are known as ballasts, reactors, reactances, spark coils, ignition coils, induction coils, inductances, inductance coils, choke coils, transformers (power, modulation, audio frequency, radio frequency, intermediate frequency, air core, and iron core, etc).

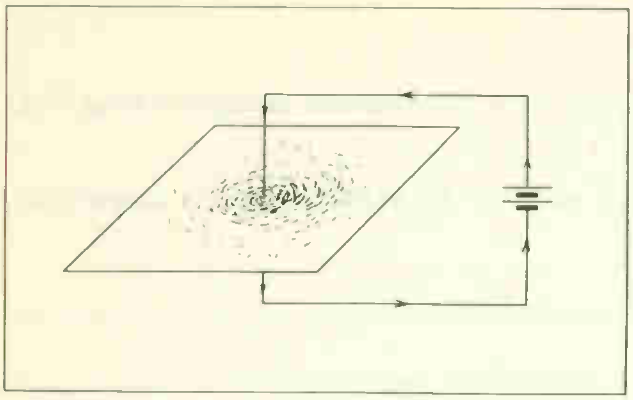


Fig. 1

Electro-magnetic lines shown by iron filings around a conductor.

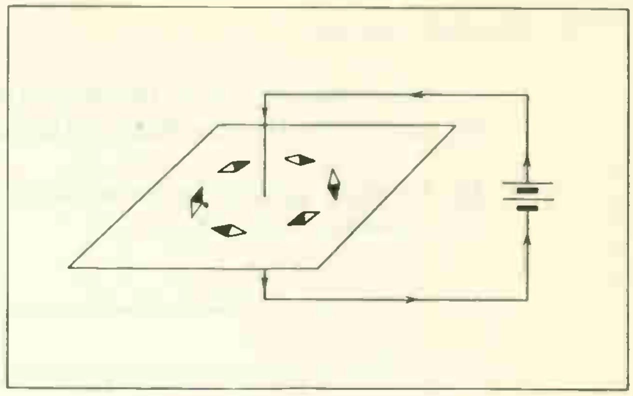


Fig. 2

Small compass needles showing shape and direction of lines around a conductor

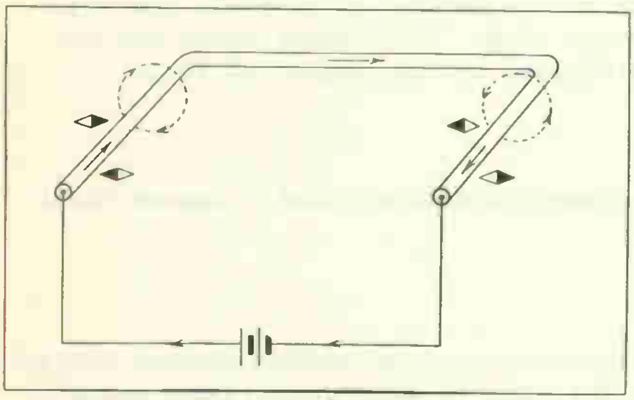


Fig. 3

Convenient compass test for direction of flux around conductors. Note carefully the direction of current and flux of each end of the wire.

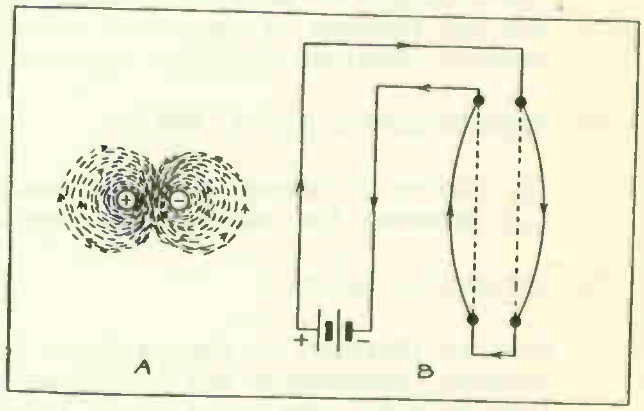


Fig. 4

This sketch shows the repulsion of parallel wires, carrying current in opposite directions.

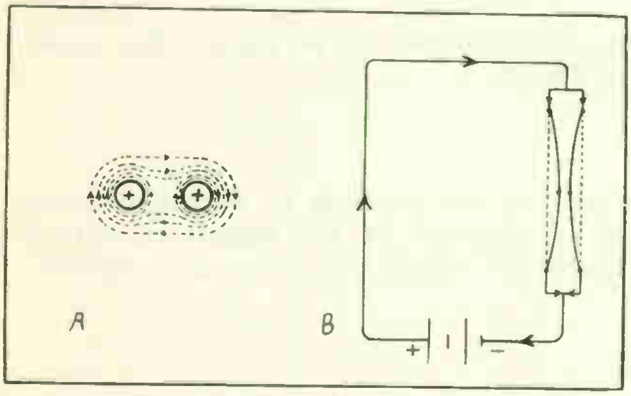


Fig. 5

When parallel wires carry current in the same direction, their flux tends to draw them together.

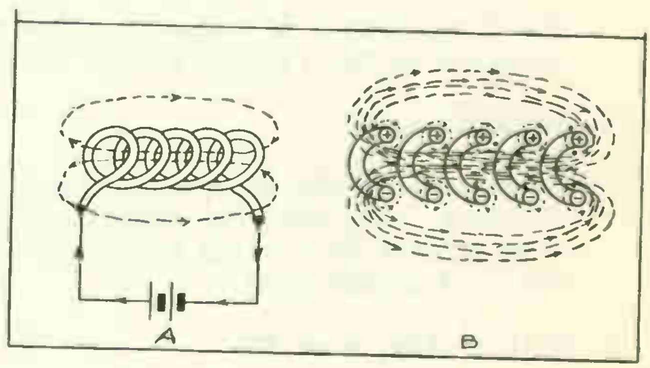


Fig. 6

The lines of force around the turns of a coil join together in one very strong field. Sectional view, note how the lines join around all turns, and the dense flux set up in the center of the coil.

5. Special coils

   a. Certain special electro-magnets are wound with a separate demagnetizing coil, in addition to the main coil, Fig. 12.

   b. It is also possible to wind a coil on a core so it will create no magnetism in a core, Fig. 13.

D. Magnetic Units, Saturation, and Strength

1. Ampere turns, IN

   The strength of an electro-magnet depends on the number of turns in the coil and the amperes or amount of current through them. The ampere turns are the product obtained when the amperes are multiplied by the number of turns.

2. Magneto-motive force, MMF.

   The number of ampere turns determines the magneto-motive force. Ampere turns also measure the magnetizing force.

3. Saturation point

   When an increase in ampere turns fails to cause a proportional increase in flux density, saturation has been reached and the core is saturated. Good magnetic iron or steel can carry about 100,000 lines per square inch before reaching the saturation point. Fifteen ampere-turns per inch of core length, on a closed core of one square inch area, will produce approximately 100,000 lines of force. Other values can be determined from the chart shown in Fig. 14.

4. Flux, Ø or PHI

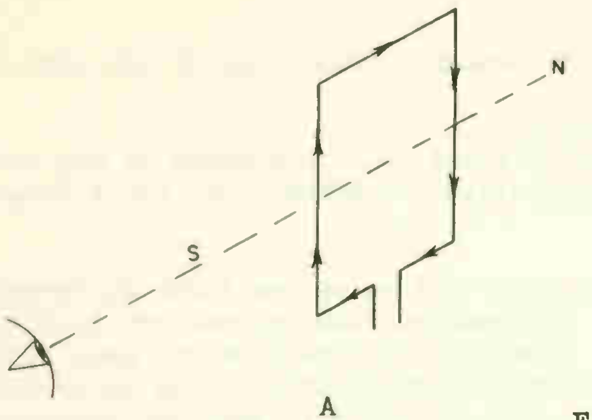
   The total number of magnetic lines of force are referred to as flux. The area occupied by the flux is called the magnetic field.

5. Reluctance, R

   Reluctance is the opposition a material offers to the passage of magnetic lines of force. The unit for reluctance is the rel. One rel is the amount of reluctance offered by a prism of air or any non-magnetic substances, one inch square and 3.19 inches long.

6. Reluctivity, v or NU.

   The reluctivity of a material is its specific reluctance, i.e., its reluctance in rels per inch cube. For example, the reluctance of all non-magnetic material is about .313 rel (per inch cube), while mild steel or wrought iron usually has a reluctivity of about .00018 rel, and cast iron, .00164 rel.



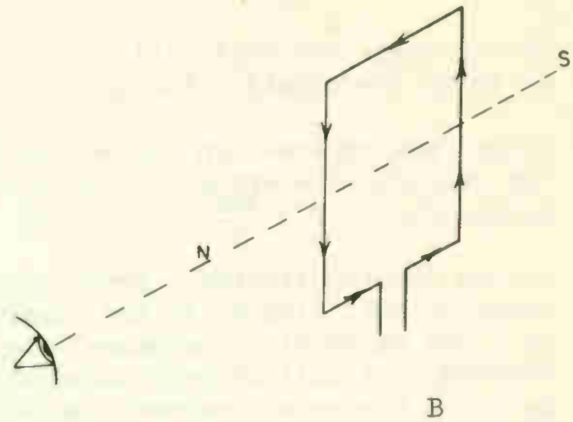


Fig. 7

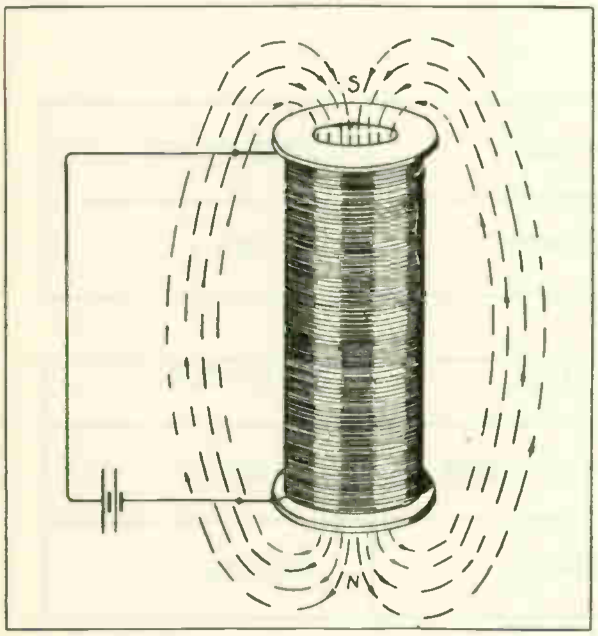


Fig. 8

Solenoid, or coil wound on a non-magnetic tube. Note the direction of the lines, and polarity of this solenoid.

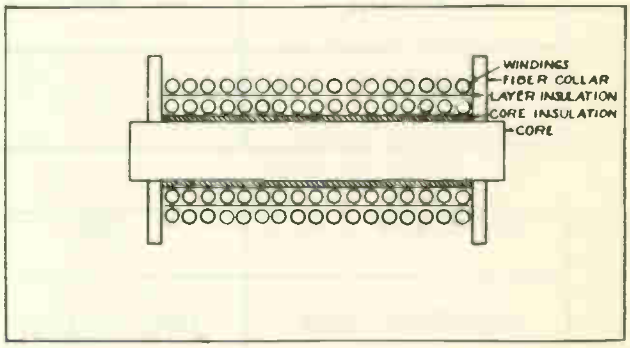


Fig. 9

Sectional view of electro-magnet, showing core, insulation and winding.

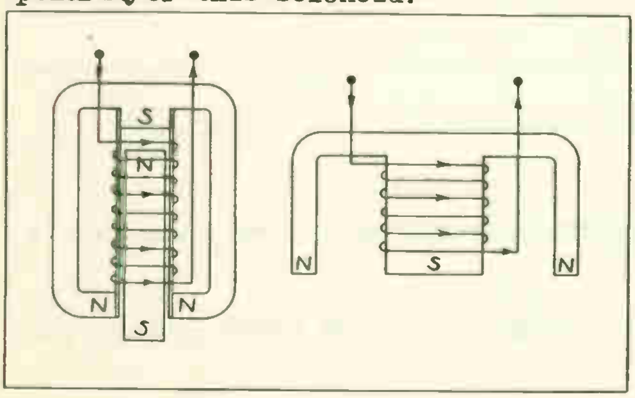


Fig. 10. Plunger type magnet at left.
Shell type magnet at right.

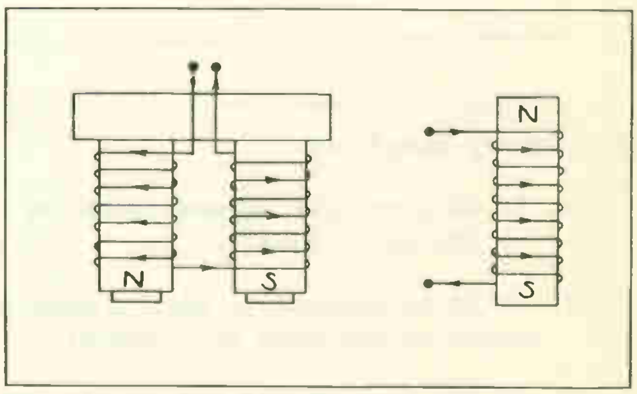


Fig. 11 Double and single electro-magnets.

E. Ohm's Law for Magnetic Circuits

We say that "one volt will force one ampere through a resistance of one ohm" and we write the equation E=IxR.

Since "one ampere-turn can set up one line of force in a reluctance of one rel, "we can likewise write an "ohm's Law for Magnetism" as MMF=ϕ R or, as it is generally found, $\phi = \frac{MMF}{R}$.

In the CGS (centimeter, gram, second) system of units, we use three different units of MMF, similar to the ampere turn, but smaller (one ampere-turn is equal to 1.257 Gilbert). The Maxwell is a unit flux equal to one line of force. The Oersted is a unit of reluctance and represents the reluctance of one cubic centimeter of air on non-magnetic material. The various units in both the practical and the CGS. systems can be compared with the standard electrical units as follows:

ELECTRICITY	EMF	CURRENT	RESISTANCE
UNIT	VOLT	AMPERE	OHM

MAGNETISM	MMF	FLUX	RELUCTANCE
PRACTICAL UNIT	AMPERE-TURN	LINES OF FORCE	REL
CGS UNIT	GILBERT	MAXWELL	OERSTED

NOTE: Direct current is best for operation of electro-magnets, as its steady flow gives a much stronger pull per ampere-turn, than alternating current. Many a-c magnets, however, are used on electrical equipment.

F. Summary Questions

1. If we have 1200 ampere-turns MMF on a magnetic circuit of .03 rel, what would be the total flux?

2. If it is desired to make a magnet using a wrought iron core 2x2x8 inches, what would be the core reluctance?

3. If the same magnet has an air gap of about 2x2x1 inches, what would be the total reluctance of the circuit, including the core and air

4. If 1,000 turns of wire are wound on the core, and five amperes of current passed through the coil, how much flux will be set up?

5. If a magnet has a pole area of four square inches and a flux density of 100,000 lines per square inch, what would be its lifting power?

NOTE: The constant, "72,134,000", determined by test of the ratio of lines to pounds, is used to determine lifting power in the following formula:

$$\text{Pounds pull} = \frac{\text{Area x (flux density)}^2}{72{,}134{,}000}$$

Check your answer by the thumb rules that a good magnet (100,000 lines) should lift over 138 pounds per square inch of pole surface and that we can usually depend on a lift of over 100 pounds per square inch even though the magnet is only working at a density of 90,000 lines per square inch.

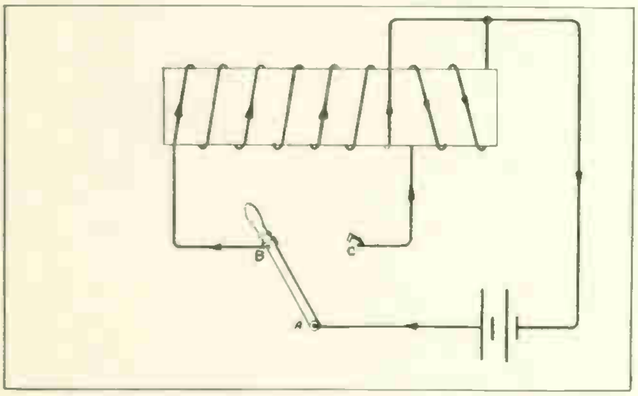


Fig. 12 Electrc magnet with demagnetizing coil for destroying residual magnetism.

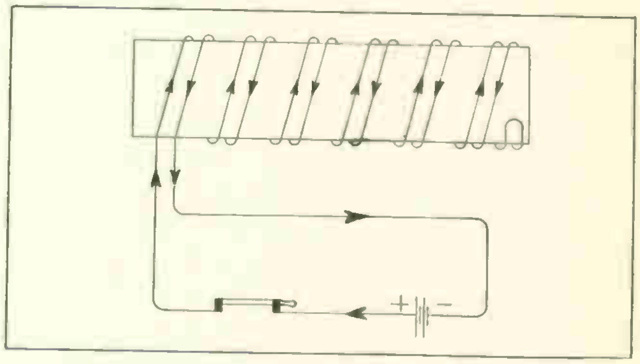


Fig. 13 Non-magnetic winding. One half of the turns oppose the other half, so the core does not become magnetized.

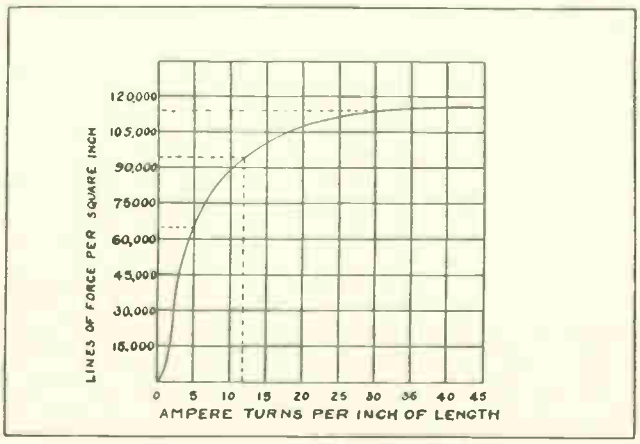


Fig. 14 Curve showing number of lines of force that can be set up in soft sheet iron, with various numbers of ampere turns.

ELECTROMAGNETIC INDUCTION

Objective

To learn how a voltage can be induced in a conductor by means of magnetism and the factors which determine the value, amplitude, and direction of the resulting current.

References

____

____

Lesson Content

A. General

Definition - electromagnetic induction refers to the action of producing or inducing an electromotive force by movement between a conductor and a magnetic field.

Importance - the action of all electric motors, generators, and transformers depends directly on the principle of electromagnetic induction.

____

____

____

B. General Theory

Conductor cutting through a field - electromagnetic induction was discovered in 1831 by Michael Faraday. He found that if he moved a wire through magnetic lines of force as shown in Fig. 1, so that the wire cuts across the path of the flux, a voltage would be induced in the wire and if the circuit were complete, current would flow.

Field cutting across a conductor - if the magnet is moved instead of the wire, the result is the same. See Fig. 2.

Field produced by electric energy - any relative motion between conductors and a magnetic field will cause the same result. This is shown in Fig. 3, where it will be noted that instead of a permanent magnet, a wire carrying a current is employed. Such a wire, we have learned, is always surrounded by a magnetic field.

Changing field even if the wires remain motionless, an induced voltage will result provided the magnetic lines of force can be made to move. This can be done by varying the electric current applied to one of the conductors (the primary) which causes the surrounding magnetic field to alternately expand and collapse, thus cutting the other conductor. See Fig. 4.

Basic rule - pressure is generated whenever lines of force are cut by a wire, no matter which one is in motion.

C. Value of Voltage Induced

1. Angular velocity

Angle of cutting: if we move the wire parallel to the lines of force, no lines will be cut and no pressure is generated. The wire must cut across the flux path to generate voltage, i.e., it must cut the lines of force. The number of lines cut per second will depend, then upon the angle at which the conductor moves. When moving parallel with the flux, the angle is zero degrees and the EMF is zero. The EMF is greatest when the conductor moves at right angles or 90 degrees.

Speed of cutting - the faster the wire is moved through the magnetic field, or the stronger the field and greater the number of lines of force, the farther the meter needle will move.

Value of induced voltage - one conductor cutting 100,000,000 lines of force per second will produce one volt difference in pressure.

Definition: "The angular velocity of a periodic quantity is the frequency (f) in cycles per second, multiplied by 2 pi (where pi equals 3.1416)" - A.S A., 05.05.185.

2. Conductors connected in series

The voltage of several wires can be added together by connecting them in series to form coils, as shown in Fig. 5.

D. Inductance

This property of an electric circuit, or of two neighboring circuits, which determines the electromotive force induced in one of the circuits by a change of current in either of them is called "inductance". A.S.A. 05.20.165.

Self-inductance is the property of an electric circuit which determines, for a given rate of change of current in the circuit, the electromotive force induced in the same circuit. - A.S.A. 05.20.170.

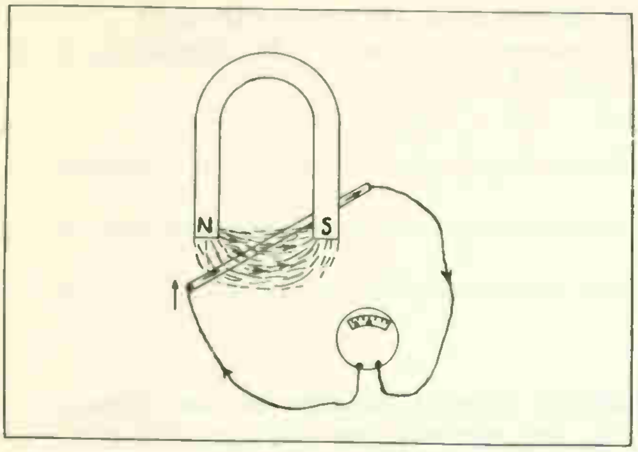


Fig. 1

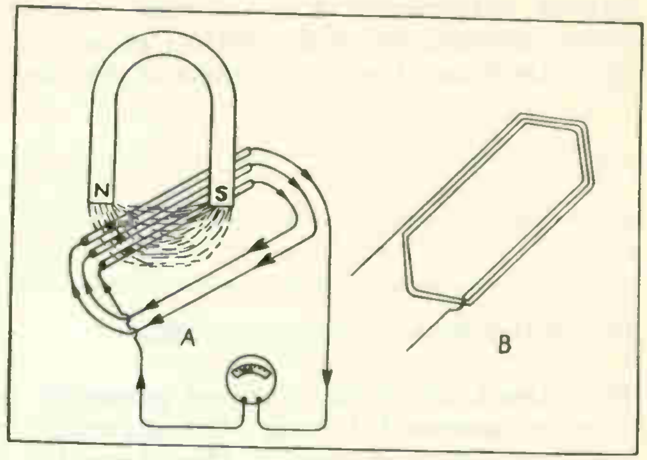


Fig. 5

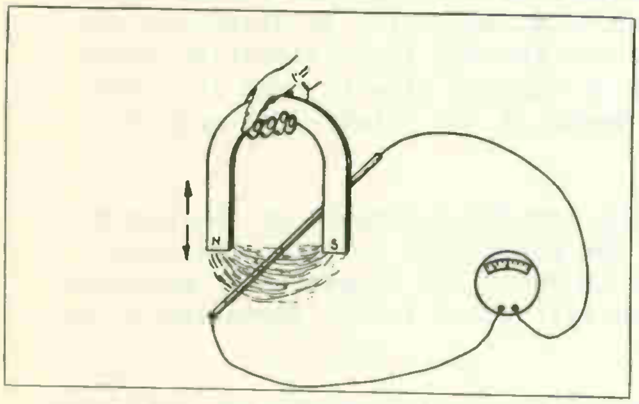


Fig. 2

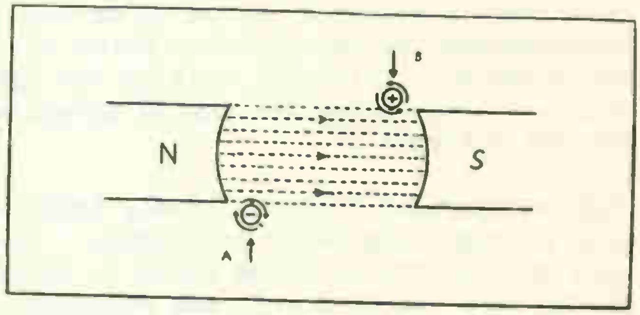


Fig. 6

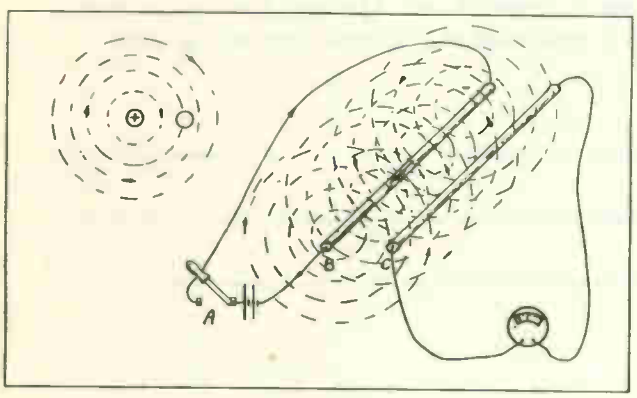


Fig. 3

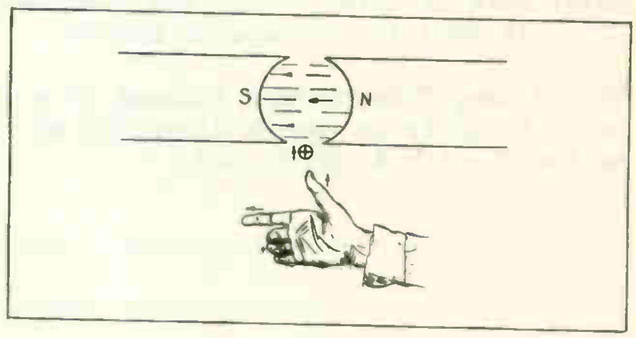


Fig. 7

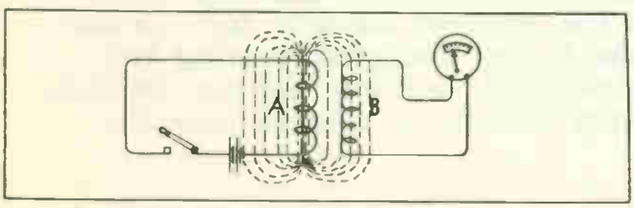


Fig. 4

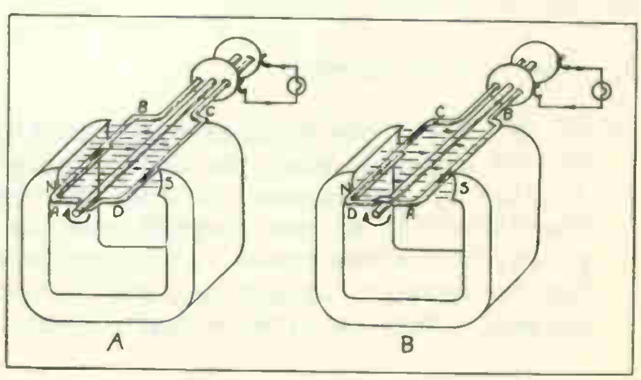


Fig. 8

Mutual inductance is the common property of two associated electric circuits which determines, for a given rate of change of current in one of the circuits, the electromotive force induced in the other. - A.S.A. 05.20.175.

E. Direction of an Induced Current

The direction of the induced pressure and resulting current depends on the direction of movement through the magnetic field. We can reverse the voltage and current merely by reversing the direction of movement of the wire.

If we think of the flux lines from north to south pole as stretched rubber bands, then, when a conductor moves up or down through them, they will be distorted and concentrated, either above or below the conductor. Knowing their direction about the conductor, this will tell us the direction of current flow through it. See Fig. 6. Or the direction may be determined by means of the "right-hand rule for induced voltages".

Right-hand rule; hold the thumb, forefinger, and remaining fingers of the right hand at right angles to each other. Then let the forefinger point in the direction of flux travel (from north to south), the thumb in the direction of movement of the wire (up or down), and remaining fingers will point in the direction of induced pressure (positive or negative), Fig. 7.

NOTE: This is often called the right-hand rule for generation, since the left hand is used in the case of motors.

Lenz's Law; "The current induced in a circuit as a result of its motion in a magnetic field is in such a direction as to exert a mechanical force opposing the motion." - A.S.A. 05.40.020.

F. Nature of Current Induced

1. Alternating current

If we expand the diagram shown in Fig.6 to show a complete coil, as in Fig. 8A, we see that when the coil rotates clockwise, the current will flow as indicated by the arrows. In Fig. 8B, the coil has revolved one-half turn farther. The direction of the current remains the same in the conductors passing the poles, but since these conductors have reversed their position and are now moving in opposite directions the current flowing through the lamp has also reversed. This is alternating current.

2. Direct current

If we wish to obtain direct current, DC actually PDC, we must use a commutator, a sort of rotary switch, to reverse the coil leads to the brushes as the coil moves around. All common generators produce AC in their windings so we must convert it or rectify it if we wish to have direct current.

G. Summary Questions

1. Electromagnetic induction is the action of producing an EMF by movement between a conductor and a magnetic field. TRUE FALSE

2. It is impossible to generate voltage in a wire without producing any current.

   TRUE FALSE

3. If we reverse the direction of flux travel and the direction of movement of the wire, this will reverse the direction of the induced pressure thereby resulting current.

   TRUE FALSE

4. One conductor cutting 100,000,000 lines of force per second will produce one volt difference in pressure.

   TRUE FALSE

5. All common generators produce AC in their windings.

   TRUE FALSE

6. If we wish to obtain DC from a generator we must use a commutator.

   TRUE FALSE

7. No induction takes place in a transformer unless the current is changing, thus causing the flux to expand or contract and cut across the wire.

   TRUE FALSE

TRANSFORMERS

Objective

To learn about the construction, operation, and characteristics of transformers and the factors which determine the efficiency of these devices.

References:

Lesson Content

A. Definition

"A transformer is an electric device, without continuously moving parts, which by electromagnetic induction transforms electric energy from one or more circuits to one or more other circuits at the same frequency, usually with changed values of voltage and current." - American Standards Association 15.20.010. See Fig. 1.

B. Transformer Types

Iron Core - used as power and audio transformers.

Air core - used on higher frequencies such as antenna, oscillator, r-f and i-f transformers in radio circuits.

C. Coupling

Coupling between primary and secondary windings of iron core transformers is close or tight, compared with that in air core transformers. In the latter it depends upon distance between primary and secondary, and also the angle between them. Coils at right angles to one another will have minimum coupling between them.

D. Construction

1. General

The ordinary transformer is a device to either step-up or step-down a-c voltage or a periodically varying d-c voltage. The transformer usually consists of two separate windings of insulated wire wound on a laminated iron core. One winding is known as the high tension winding and the other the low tension winding.

2. The high tension winding

The high tension (high voltage) winding has the greatest number of turns and smaller wire; therefore it also has the higher ohmic resistance.

3. The low tension winding

The low tension (low voltage) winding has fewer turns and larger wire; hence it has lower ohmic resistance.

4. The core

When an iron core is used, it serves as an efficient means of magnetically coupling together the primary and secondary windings.

5 Laminations

Laminated iron core means a stack or bundle of thin sheets or strips (laminations) of iron, which are insulated from each other by an oxide film. This arrangement of thin sheets or strips tends to limit or confine the eddy currents induced in the iron and thus reduce heating of the iron.

6. Current requirements

Since a transformer operates on the principle of induction, it will not operate if pure DC is applied to the primary; in fact, pure DC may burn out the winding. If direct current of a fluctuating nature is applied, however, the a-c component will cause a transfer of energy from primary to secondary.

7. Core saturation

If the d-c component is great enough to completely saturate the core, however, at a particular value of current, the transformer's inductance is materially reduced, and the waveform output is distorted. The transfer of energy will also be reduced. This cannot occur if the core is large enough. It can also be avoided by inserting an "air gap" in the core.

F Connections

1. Either winding may be the "primary".

When connecting a transformer, either the low tension or high tension winding can be used as the primary, provided the proper voltage and frequency is applied to it. When used as a step-up transformer the low tension winding is connected to the source as the primary and the high tension winding to the load as the secondary. See Figs. 2 and 3.

2 Primary defined

The primary is always the side connected to the source or input, Fig. 2.

3. Secondary defined

The secondary is always the side to which the load or output is connected, Fig. 3.

F. Transformer Action

1. Depends upon induction

   A periodically varying voltage applied to the primary winding produces a varying primary current which in turn develops a varying flux in the iron core. This varying flux cuts all windings thereby inducing in each of them a voltage proportional to the number of turns. See Figs. 4 and 6.

2. Secondary voltage

   The voltage induced in the secondary will depend upon the ratio of turns and the voltage applied to the primary.

3. Turns ratio

   The ratio of the primary voltage to any secondary voltage is practically equal to the ratio of the primary turns to the secondary turns as indicated by the formula shown in Fig. 7.

4. Current ratio

   The ratio of secondary to primary currents, however, is inverse to the turns or voltage ratios.

5. Induced or counter voltage

   The voltage induced in the primary winding by the growing and dying core flux is practically equal to the applied voltage; morever, this induced voltage (or counter voltage) directly opposes the applied voltage. The current drawn from the supply is therefore small under no load.

6. The efficiency of an iron core transformer under no-load is nearly 100%. This is due not only to the permeability of the iron core, but also to the close degree of coupling between the windings. This "coefficient of coupling: is almost unity under such conditions.

G. Action Under Load

Since the voltage induced in the secondary is 180 degrees out-of-phase with the primary voltage, when a secondary circuit is completed, current circulates around the iron core in the opposite direction to the primary current, thereby reducing the core flux and the counter voltage of the primary. This action causes the current in the primary to vary in accordance with the secondary load. It is through this action that the transformer automatically adjusts itself to change in secondary load. See. Fig. 8.

H. Transformer Efficiency

1. General

A transformer is the most efficient of all electrical devices. Certain large sub-station transformers achieve better than 99%.

2. Losses

There are certain losses, which do reduce the efficiency of a transformer somewhat.

a. Copper losses, also called I^2R losses, depend upon the size of the wire used in the windings.
b. Eddy current losses, a function of frequency, result in heating the iron core.
c. Hysteresis losses, also a function of frequency, refer to the energy lost in reversing the molecules of the core with each alternation. These losses are reduced by employing a core of low reluctance.
d. Leakage flux, which are magnetic lines which do not cut all the windings. This loss is reduced by proper core design, most of the lines being confined and concentrated in a large, iron core.

NOTE: All losses are manifested in the form of heat.

I. Summary Discussion

The following is a discussion of transformers. Fill in the blank spaces with suitable words or phrases. A choice of some of these will be found in parentheses following the blanks.

1. Iron core (audio and power) transformers.

a. Good design in an iron core transformer principally involves construction of the primary winding and the core. With proper design of these parts, the primary current will be almost ________ when no secondary current flows.

This condition will be due to the ________ developed in the primary by ________ (mutual) (self) induction, such ________ being almost ________ to the applied EMF. Efficiency of the transformer will then be nearly ________. Coefficient of coupling between windings will be close to ________. This high degree of efficiency and close coupling is possible only in ________ (iron core) (air core) transformers, because the flux produced in this type of core is not only very great, but also more concentrated or confined, thus mimimizing the amount of ________ flux. To produce the necessary high level of flux density, it is desireable to have a large core of high ________ (permeability) (conductance) (reluctance), and ________ (many) (few) turns of primary winding. It is also necessary that the core material be of low ________ to minimize hysteresis losses. The core is ________ to reduce eddy current losses. Power losses in the

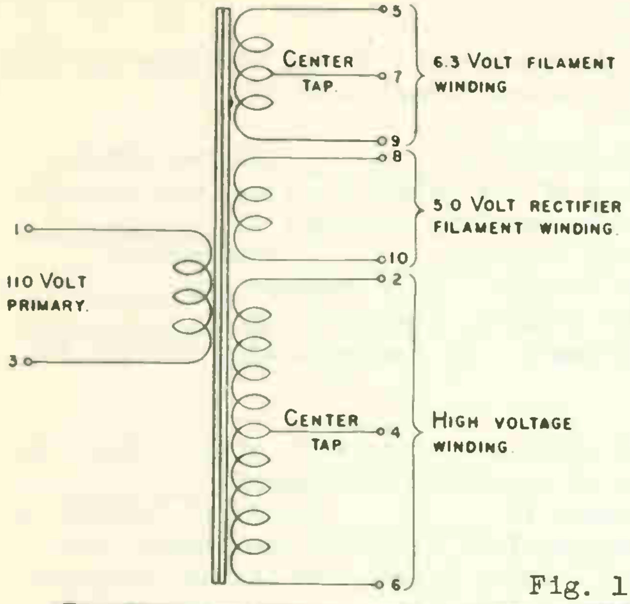


Fig. 1

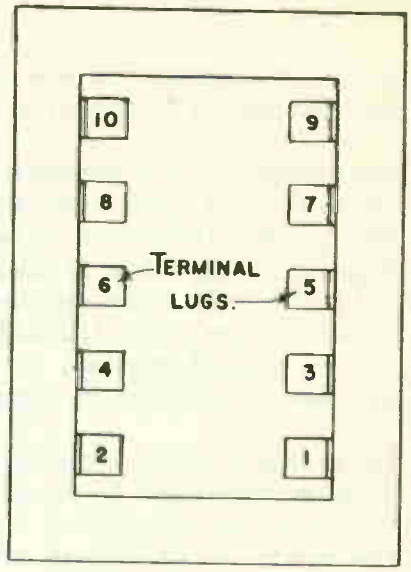
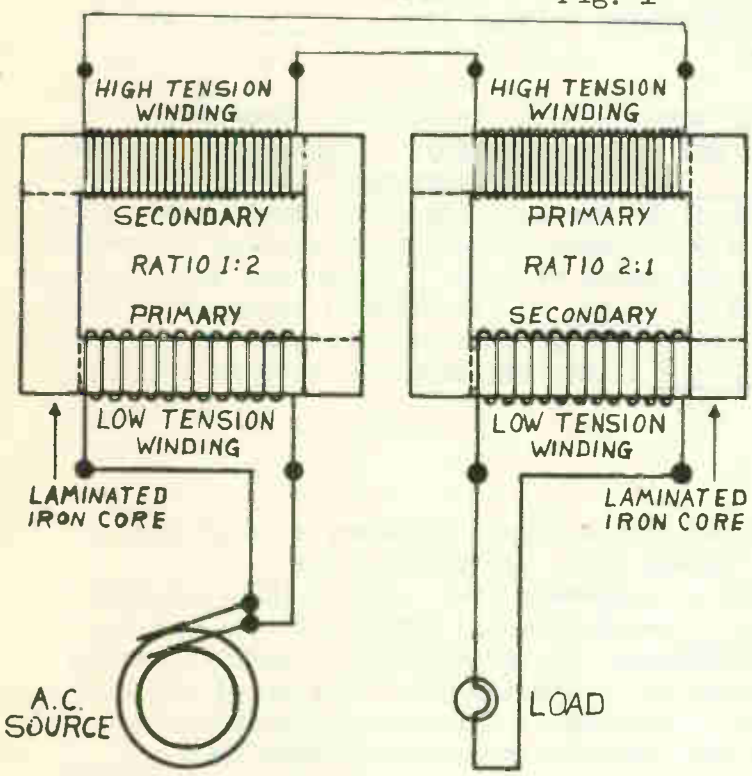


Fig. 5



STEP UP TRANSFORMER

Fig. 2

STEP DOWN TRANSFORMER

Fig. 3

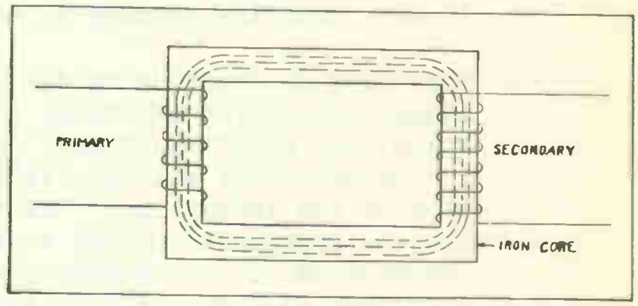


Fig. 6

$$\boxed{\frac{E_P}{E_S} = \frac{N_P}{N_S}}$$

Fig. 7

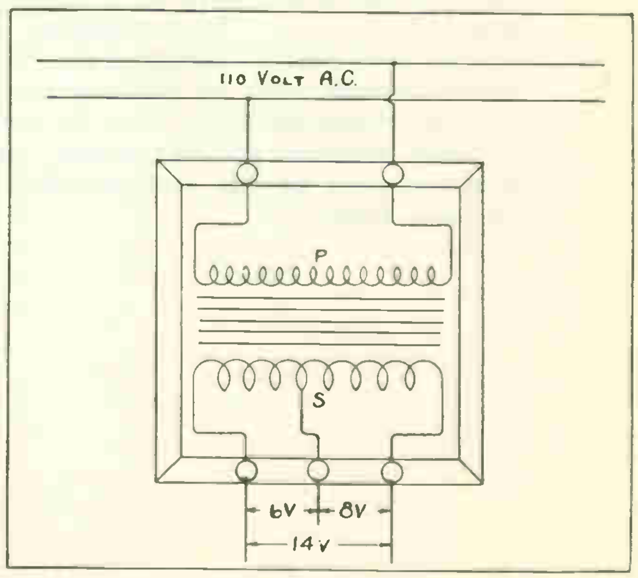


Fig. 8

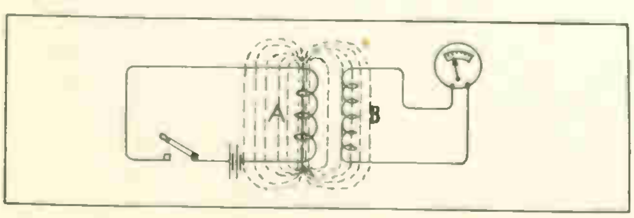


Fig. 4

windings themselves are a function of the resistance of the windings and may be reduced by using wire of _________ cross-sectional area.

b. Frequency of the secondary voltage and current is _________ (higher than) (lower than) (the same as) the frequency of the primary voltage and current. The phase difference between primary and secondary voltages is _________ degrees. The flux produced by secondary current _________ (increases) (opposes) the flux produced by primary current. This reduces the _________ (conductance) flux)(counter EMF) in the primary, thus causing _________ (more) (less) current to flow in the primary. As the secondary current increases, the primary current _________.

c. In a transformer considered to be 100% efficient, the ratio of secondary to primary voltages is equal to the ratio of secondary to primary _________; the ratio of secondary to primary currents is _________ (inverse) (equal) to the ratio of secondary to primary voltages. In a step-up transformer, the secondary voltage is _________ (higher) (lower) than the primary voltage; in a step-down transformer, the secondary voltage is _________ (higher) (lower) than the primary voltage.

d. When used on fluctuating d-c only the _________ (A-C) (D-C) component causes a transfer of energy from primary to secondary. During proper operation, the waveform of the _________ (A-C) (D-C) component is reproduced in the secondary without distortion. If the d-c component causes magnetiziation of the transformer core to a point near, or beyond practical saturation. the a-c component induced in the secondary will be _____ and the total energy transferred to the secondary will be _________ (increased) (reduced). This condition of saturation is remedied by using a larger iron core, and by introducing a small _________ _________ into the magnetic circuit of the core.

2. Air core transformers, RF.

Ordinary iron cores are not used in r-f transformers because, at high frequencies _________ and _________ losses would be so high that _________ (power) (current) (efficiency) would be extremely low. Air is more suitable as core material because its _________ (conductivity) (resistivity) is low, and its _________ (retentivity) (reluctance) (permeability) is zero. Antenna coils, r-f coils, oscillator coils and i-f coils are all examples of air core transformers used in radio circuits. Coupling in air core transformers is "loose" compared with that in iron core transformers, and depends upon _________ betwean primary and secondary, and also the _________ between them. Coils at right angles to one another will have _________ (minimum) (maximum) coupling between them.

ALTERNATING CURRENT

Objective

To learn the fundamental principles concerning alternating current.

References

Lesson Content

A. Definitions

"An alternating current," says the American Standards Association, (05.20.070) "is a periodic current the average value of which over a period is zero."

Alternating current is current that constantly changes in value and periodically reverses in direction.

B. Importance

One of the greatest advantages of AC is that it can be more economically transmitted over longer distances than DC. It is a vital part of all radio and television equipment and many types of motors can be operated only on AC. Although AC differs from DC in many ways, practically all the principles of electricity studied so far, with a few modifications, can be easily applied to AC.

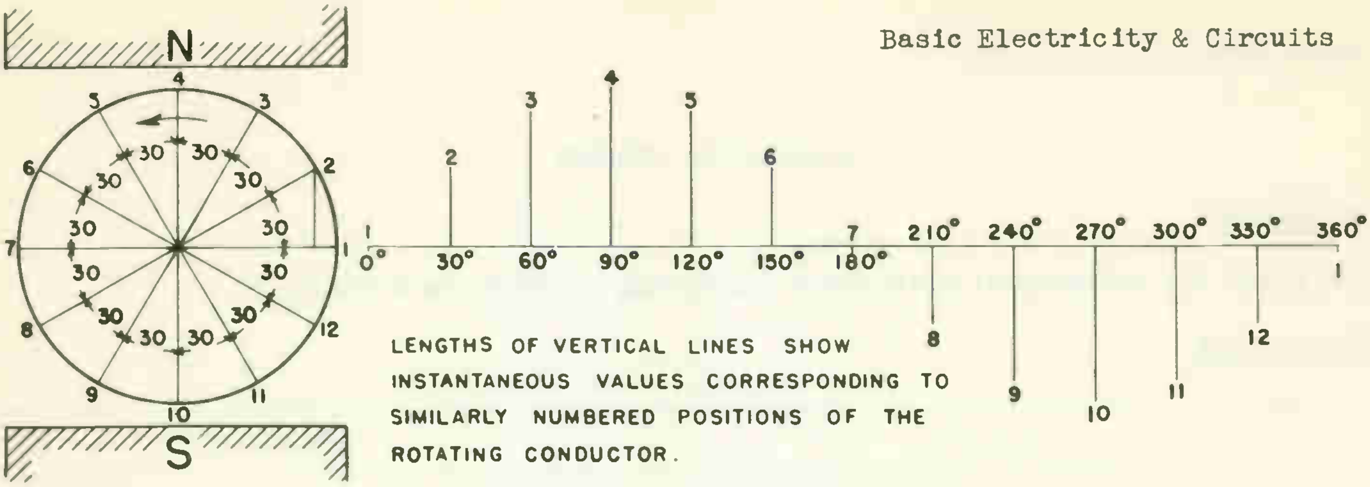
C. General Theory

When a conductor moves in a magnetic field the voltage induced in it depends on:

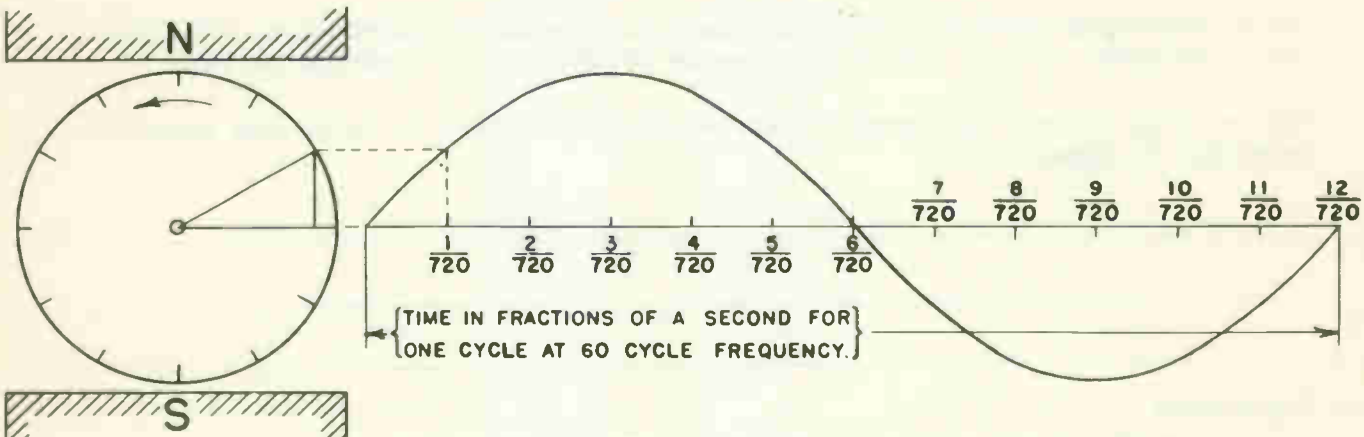
1. The strength of the field.

2. The speed of the conductor.

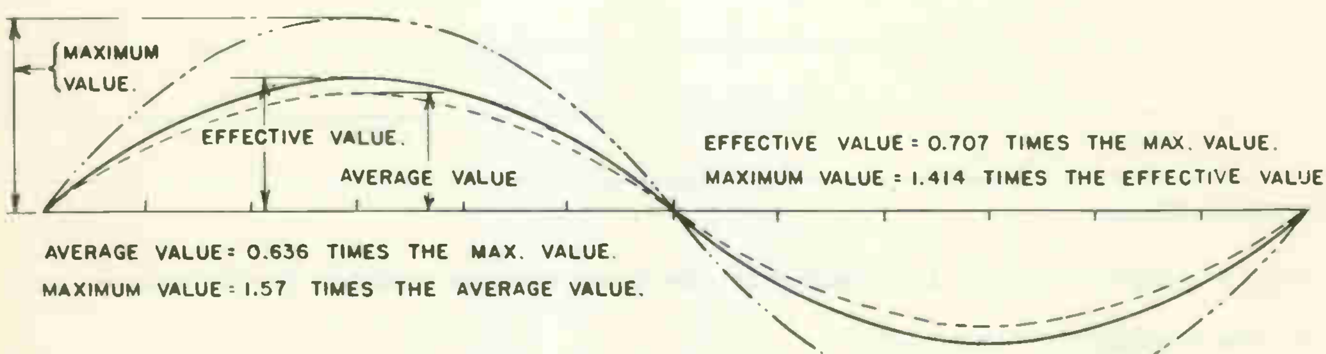
3. The direction of motion of the conductor with respect to the field.



These values are based on the assumption that the conductor moves at constant angular velocity thru a magnetic field of uniform strength.



The smooth curve above shows the manner in which the generated voltage varies from instant to instant. The distance of the curve from the base line at any point is a measure of the voltage generated at that instant.



The meter values of the A. C. volt and the A. C. ampere are values that represent equivalent D. C. values. An A. C. current that will produce the same heating effect as a D. C. current of one ampere is said to have an effective value of one A. C. ampere. Note that the curve of effective values is somewhat lower than the curve of maximum values, and slightly higher than the curve of average values.

Fig. 1 Development of the Sine Curve

D. Voltage Generated by Revolving Conductor

If we assume a conductor to rotate counter-clockwise at a constant angular velocity through a magnetic field of uniform strength, we find that the number of lines cut per second will depend upon the angle the conductor is making with the line being cut. And since this also determines the value of the induced voltage, the latter will be constantly changing in value.

fter the conductor has made one-half revolution, the voltage induced will reverse polarity.

E. Development of the Sine Curve

The manner in which the voltage varies from point to point as the conductor rotates is shown in Fig. 1.

F. Summary Questions

1. What are the factors which determine the value of the voltage induced in a conductor moving in a magnetic field?

2. Define alternating current.

3. Define an alternation, a cycle.

4. Are ordinary a-c voltmeters and ammeters calibrated to read effective or maximum values in an a-c circuit?

5. What would be the maximum voltage value in an a-c circuit when the effective value is 110 volts?

ILLUMINATION FUNDAMENTALS

Objectives

1. To learn what constitutes adequate illumination and the factors upon which good lighting depends.

2. To learn the terms used in practical illumination.

References

____

____

Lesson Content

A. Why Study Illumination?

1. Good light means good sight.

All our daily impressions are acquired by means of our five senses. Sight is the most important of all the senses. Without light we would be worse off than a blind man.

2. Illumination is a desirable occupation.

It is clean, interesting and not particularly difficult. Has very little sales resistance and is a profitable sideline.

3. Terminology and principles of illumination also apply to radio and television.

____

____

____

B. History of Incandescent Lighting.

1. From caveman to Edison

Artificial illumination probably began when a caveman accidentally picked up a burning faggot at the cold end and found he held a crude sort of torch. Since then, illumination has taken many forms, lamps, gas, candles, the arc and finally Edison's incandescent lamp. All these forms are still in use today, together with the more modern fluorescent lamp and cold cathode lighting.

2. Development of the incandescent lamp.

A steady increase in lumens per watt efficiency as shown below has resulted in a proportionate decrease in the cost of good lighting.

1879 - Edison's first commercial lamp. Carbon filament. 1.4 lumens per watt.
1893 - Carbonized cellulose filament, 3.3 lumens per watt.
1897 - H. W. Nernst's porcelain filament lamp
1904 - Von Bolton tantalum filament
1905 - Metallized carbon, 4 lumens per watt
1906 - Osmium and tantalum, 4.8 lumens per watt
1907 - Pressed or squirted tungsten, 7.9 lumens per watt
1911 - Mazda-drawn tungsten wire, type B, 10 lumens per watt
1913 - Gas filled (nitrogen) type C, 1000 and 750 watts
1915 - 500, 300, 200, 100 watt sizes. Efficiency 12.6 lumens per watt
1916 - 75 watt size
1920 - Tips removed and argon added to nitrogen

To-day the larger mazda lamps have reached an efficiency of 26 lumens per watt.

3. Glare

Development of more efficient lamps also increased the glare. At first the light was diffused by frosting on the outside of the bulb, but this greatly decreased the efficiency. This type of lamp has since been replaced by the more efficient type "bulb", which is inside frosted.

4. Lamp sizes and types, Fig. 1.

Incandescent lamp sizes range from the .2 watt "grain of wheat" lamp used by surgeons, to the 50,000 watt Mazda made by General Electric for movie production in Hollywood.

The types previously mentioned, A, B and C refer to the lamps themselves. The bulbs (glass envelopes) also come in a variety of types such as Ps, F, G, S, P, A, C, and T, according to shape, these letters usually being followed by a number to indicate the bulb's diameter in eighths of an inch (e.g., T-12 is tubular, 1½ inches in diameter.)

Among these are the reflector flood and spot, the projector flood and spot, the two-filament of "3 light," the sealed beam (developed by General Motors in 1940), and the lumiline.

5. Lamp bases

Edison (screw-shell) lamps are made in six sizes, minature, candelabra, intermediate, medium, admedium, and mogul.

Special types of bases are the bayonet, disc, skirted, prefocus, and prong or bi-pin.

6. Lamp Life

The life of the average Mazada lamp is about 1000 hours. Incandescent lamps should always be operated at their rated voltage. Undervoltage operation increases the life of the lamp but greatly reduces the light and efficiency; overvoltage operation increases the light output but the efficiency and lamp life are greatly reduced.

C. Light Distribution

1. Fixtures or luminaires

Lamps and candles have always been portable or semiportable. Fixtures came into being with the use of gas for illumination. They are generally divided into five classes, according to the percentage of light which is directed downward and the percentage directed upward.

2. Classification of fixtures

Direct - 90% to 100% down, 0 to 10% up.
Semidirect - 60 to 90% down, 10 to 40% up.
Direct indirect or general diffused - 40 to 60% up, 60 to 40% down.
Semi-indirect - 60 to 90% up, 10 to 40% down.
Indirect - 90 to 100% up, 0 to 10% down.

3. Importance of reflectance

Reflectance, or reflection factor, is the percentage of light reflected from a surface, the remainder being absorbed by the surface. Reflectance may vary from 7% for dark greens to 87% for matte white.

The reflection factor is very important in the case of small rooms with indirect light, but almost negligible in the case of a large room where the fixtures are direct or semidirect.

D. Illumination Units and Terms

The nature of light and illumination - light is radiant energy evaluated according to its capacity to produce visual sensation. Radiant energy travels in the form of electromagnetic waves. Illumination is the density of luminous flux incident upon a surface. The result of a light source striking surfaces we wish to see is called illumination.

The candle and candlepower - Fig. 2 - the candle is the unit of luminous intensity and the candle power is luminous intensity expressed in candles. The International candle adopted in 1909, is composed of spermaceti, it was made to burn at the rate of 120 grains per hour.

The footcandle, Fig. 3. The foot candle is the unit of illumination when the foot is the unit of length. A footcandle represents the intensity of illumination that will be produced on a surface that is one foot distant from a source of one candlepower, and is at right angles to the light rays from the candle. When one lumen of light is evenly distributed over a surface of one square foot, that area is illuminated to an intensity of one footcandle. A footcandle meter, Fig. 7 is a direct reading light meter consisting of a light sensitive cell connected to a meter which is calibrated in footcandles.

The lumen is the unit of luminous flux. It is used to measure light quantity, or the total amount of light actually given off by a source. A lumen may be defined as the quantity of light which will strike a surface of one squarefoot, all points of which are one foot distant from a source of one candlepower. Since the area of a sphere with a one foot radius is 12.57 square feet, a one candlepower source emits 12.57 lumens. In other words, lumens equals candlepower times 12.57 and candlepower equals lumens divided by 12.57. Mazda filament lamps are rated in lumens output. For example a 100 watt lamp is rated at 1620 lumens, a 1000 watt lamp at 21,000 lumens, etc. The standard 40 watt white fluorescent lamp is rated at 2320 lumens.

The illumination on a surface varies directly with the candlepower of the source of light, and inversely with the square of the distance from the source. This is called the Inverse Square Law for Light, Fig. 5.

E. Under-voltage Burning, Fig. 6.

For every one percent drop in voltage, the wattage is reduced one and one-half percent, but the amount of light is reduced over three percent. For example, if a lamp is operated five percent below its rated voltage, its life will be doubled and the watts consumed will be eight percent below normal, but the lumen output will be seventeen percent below normal, thereby resulting in a ten percent decrease in efficiency.

The use of improper lamps - New York City uses 120 volt lamps and most New Jersey communities use 115 volt lamps.

The full load voltage drop should never exceed two percent from the meter to the most distant lamp socket.

F. Lamp Operation

The efficiency of new lamps drops from five to fifteen percent when the bulb has burned seventy percent of its life. For most efficient operation, a replacement schedule should be followed, rather than allowing lamps to burn out. This is particularly advisable in the case of fluorescent lamps.

The probable number of lamps needed for renewals in a large plant can be estimated by means of the following formula:

$$\text{Expected number of burnouts} = \frac{\text{No of lamps in the installation} \times \text{average actual hours burned per year}}{\text{Rated life of lamps, in hours}}$$

BULB DESIGNATIONS consist of a letter to indicate its shape and a figure to indicate the approximate diameter in eighths of an inch.

BASE DESIGNATIONS

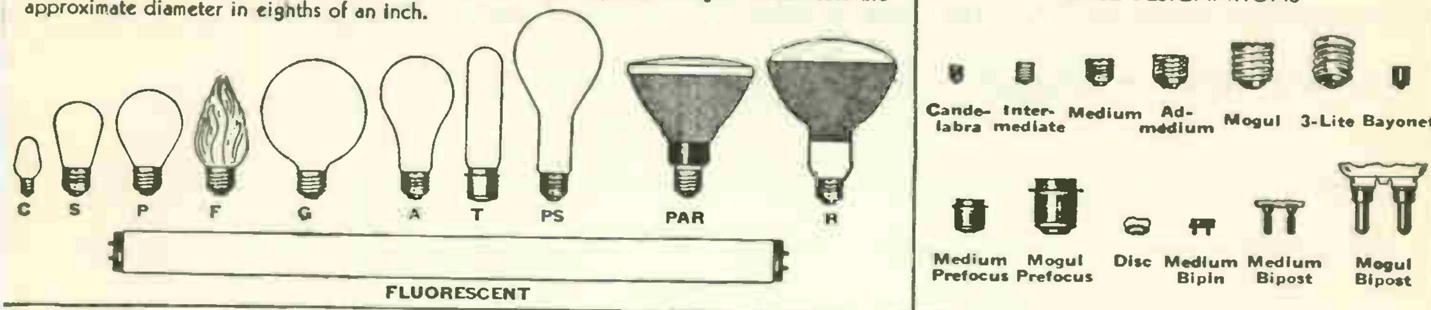


Fig. 1

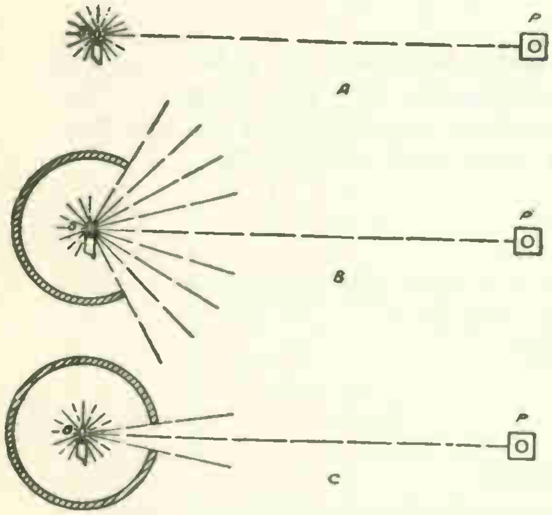


Fig. 2

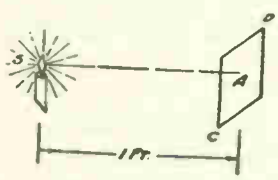


Fig. 3

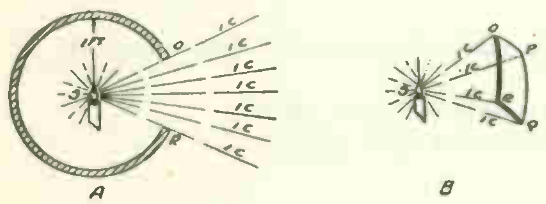


Fig. 4

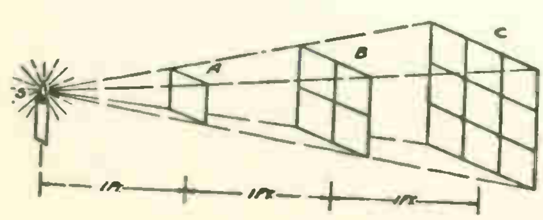


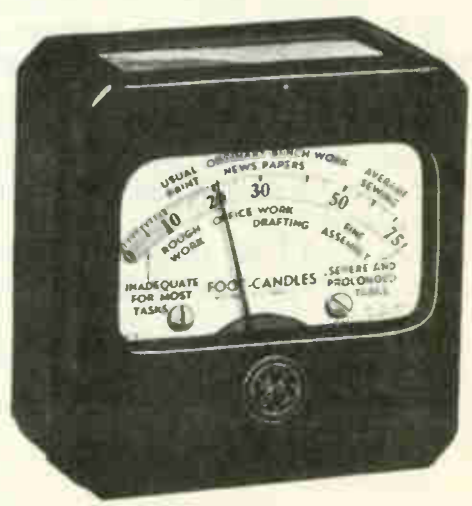
Fig. 5

Typical Performance of Large Incandescent Lamps Burned Below Rated Voltage

Note, for example, that 120-volt lamps burned on 115-volt circuits will deliver only 86.4% of their normal light output.

120-Volt Lamps Operated at (Volts)	% of Normal Voltage	% of Normal Light Output	% of Normal Watts	% of Normal Efficiency
120	100.0	100.0	100.0	100.0
119	99.2	97.3	98.8	98.2
118	98.3	94.4	97.4	96.9
117	97.5	91.8	96.1	95.4
116	96.7	89.2	95.0	93.8
115	95.8	86.4	93.6	92.3
114	95.0	84.0	92.4	90.8
113	94.2	81.5	91.2	89.4
112	93.3	78.0	89.8	87.7
111	92.5	76.6	88.7	86.2
110	91.7	74.1	87.5	84.8
108	90.0	69.5	85.0	81.7
106	88.3	65.0	82.5	79.4
104	86.7	60.8	80.3	75.8
102	85.0	56.6	77.9	72.8
100	83.3	52.0	75.5	69.7

Fig. 6



This G-E Light Meter closely resembles a small thin desk clock. It is 2¼ inches square and 1⅛ inches thick and can be carried in the vest pocket. The normal scale range of the meter is from 0 to 75 footcandles but each meter is provided with a multiplying shield so that illumination values up to 750 footcandles can be read.

Fig. 7

For example: a room has 14 lamps, their rated life being 1000 hours. They are burned two hours daily, five days a week, 52 weeks. (hours = 2x5x52=520).

$$\text{No. of burnouts} = \frac{14 \times 520}{1000} = 7 \text{ to } 8 \text{ lamps per year}$$

G. Summary Problems and Questions

1. A certain 15 ampere, 120 volt lighting branch circuit consists of a 50 foot run from the meter to the load, consisting of thirty 60 watt, 120 volt lamps. The wire used is #14 in accordance with the minimum safety requirements of the National Electrical Code. It is desired to keep the volt drop within 2%.

   a. How many feet of wire is involved?
   b. What is the resistance of the wire?
      NOTE: Resistance of #14 wire is apporximately 2.5 ohms per 1000 feet.
   c. How much current does a 60 watt, 120 volt lamp require?
   d. What is the total current consumed by the load?
   e. What is the line voltage drop?
   f. What is the percentage of volt drop?
   g. What is the voltage at the lamps?
   h. Is this greater than the 2% allowed? (question f)
   i. What size wire should have been used for this particular branch circuit?
   j. Would this have reduced the voltage drop?

2. A lecture room is equipped with forty-eight 40 watt white fluorescent lamps. The rated life of these lamps depends greatly on how often they are turned on and off, as shown below:

   With 3 burning hours per start, the life of each lamp is 2500 hours.
   With 6 burning hours per start, the life of each lamp is 4000 hours.
   With 12 burning hours per start, the life of each lamp is 6000 hours.

   a. At the 6 hour rate, 5 days a week, 52 weeks, how many of these lamps should burn out in one year?
   b. If all 48 lamps were replaced at 70% life, how often would they have to be replaced?
   c. What would be the average number of lamps replaced per year?
   d. At $0.85 per lamp, how much more would this cost per year?

FLUORESCENT LAMPS

Objective

To gain knowledge concerning the advantages, operation, and characteristics of the fluorescent lamp, and the functions of the various auxilliaries used with this type of lamp.

References

Lesson Content

A. History and Development

1602 - Phosphorescence discovered accidently in Italy
1652 - Fluorescence discovered.
1896 - Edison's "Fluorescent Lamp"
1933 - First appearance, Chicago Century of Progress Exposition.
1938 - Modern fluorescent lamp introduced to public (April)

B. Efficiency and Advantages

Even when we consider the additional power required for control equipment with the fluorescent and not with the incandescent, the fluorescent lamp still produces about 90% more light than the small incandescent lamp for the same power consumed.

C. Nature and Construction, Fig. 1.

Fluorescent lamps are made with long glass tubes having metal caps with two contact pins at each end, sometimes called bi-pin bases. The construction of a lamp as it would appear broken open is shown in Fig. 1. At each end is a small coiled wire filament connected through the gas-tight glass to the two contact pins carried in phenolic insulation by the end cap. The filament is coated with materials such as used on filaments of radio tubes, to provide a large emission of electrons at fairly low temperatures. The inside of the lamp tube is filled with argon gas, and there is a small drop of mercury which is vaporized by heat from the filaments and then provides a path of fairly low resistance through which electrons may pass from one filament to the other after the lamp is in operation. The inside of the lamp tubing is coated with a thin layer of materials called "phosphors". A phosphor is a substance which becomes luminous or glows with visible light when struck by streams of electrons which are caused to pass through space between filaments inside the lamp. When the phosphors are thus made luminous the action is called "fluorescence", which gives this kind of lamp its name, fluorescent. If there were no phosphors there would be practically no visible light.

D. Fluorescent Lamp Operation, Fig. 2.

The basic principles of fluorescent lamp operation are shown in Fig. 2, where we have two filaments connected together on one side through a switch and on the other side to the alternating current supply line.

1. See diagram A Fig. 2 in which the switch is closed. Line current flows through the filaments and switch in series, preheating the filaments so they will emit electrons and vaporize the mercury.

2. In diagram B the switch is opened, we have the effect shown in diagram C.
3. Diagram C shows one connection to a filament pin at each end of the AC line. Electrons are emitted and they collide with mercury molecules and the resulting radiation (invisible) collides with phosphors which produces visible light. The resulting color of the light depends upon the phosphors used.

E. Starters

1. Manual Starter Switch - All manual or hand-operated switches do three things in order. First, they close the line circuit, preheating the filaments and vaporizing the mercury; second, they open the connection between the two filaments (which are now called "electrodes"), thereby, lighting the lamp; third, they open the line circuit to extinguish the light. The manual starter switch, therefore, acts also as the line current on-off switch.

2. Automatic Starters (time-delay switches) - a. Magnetic Starter - This was the earliest type used and operated on the principle of the magnetic relay. This type is now rarely found in use.

   b. Thermal Starter, Figs. 7, 8, & 9. - This type includes a resistance element which carries the filament current and is heated by this current. The heater element heats a bi-metallic thermostat blade and causes this blade to bend and open the filament connection after the filaments have been heated enough to glow.

   c. Glow type starter, Figs. 4, 5, & 9. - This type used on alternating current supply, also employs a bi-metallic thermostat blade, but instead of using a heater element the blade is heated by a glow discharge that takes place through neon, argon, or helium gas that fills the glass bulb containing the switch.

   d. No-blink Type, Fig. 6. - The no-blink type of automatic starter (also known as cut-out, reset, or push-button types) prevents the switch from opening and closing when the lamp fails to light. It is similar to the glow type except that there is an added heater operated bi-metallic switch which cuts the lamp out of the circuit when it begins to blink.

   NOTE: Any automatic starter acts only as a switch to close and open the connection between filaments. Some type of on-off switch must be connected in the line the same as for any other kind of lamp.

F. Lamp-holders, Fig. 3.

Two styles of lamp-holders are illustrated in Fig. 3, the push-pin type and the rotary type. Since a separate starter is required for each lamp, one of the holders will have a starter socket and the other will not.

G. Ballast Coils, Fig. 9.

1. Voltage requirements of Lamp-- Fluorescent lamps require an operating voltage of only 40% to 90% of the average line voltage, but for starting they require a momentary voltage higher than line voltage in order to establish this electronic discharge through the gas inside tubing. Both of these things are accomplished by inserting in series with one side of the line an inductance coil or choke coil which is called the fluorescent lamp ballast.

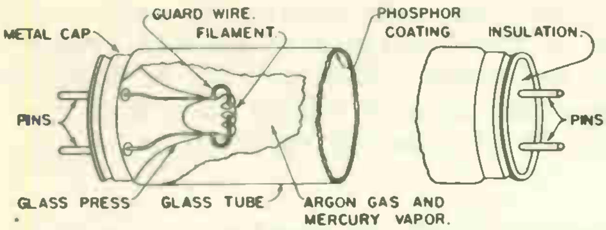


Fig. 1 . Construction of a Fluorescent Lamp.

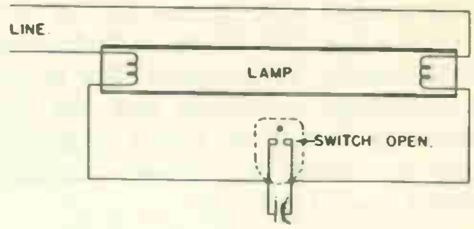


Fig.5 How the Glow Starter Is Connected To the Lamp.

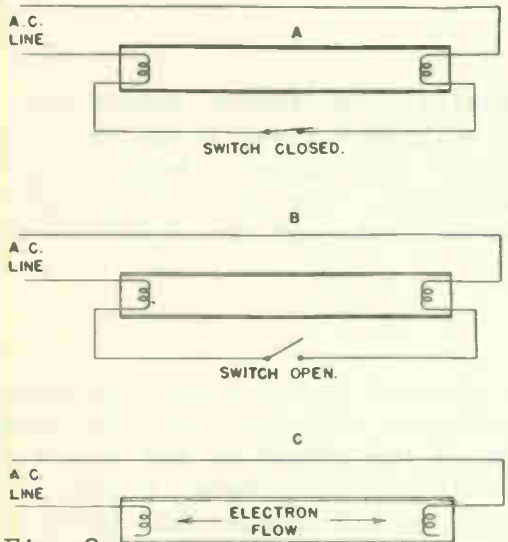


Fig. 2

Fundamental Operating Principle of Fluorescent Lamps.

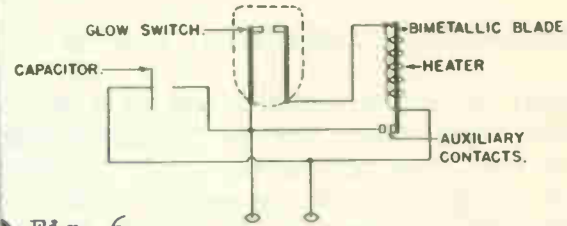
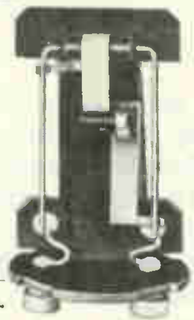


Fig. 6

The No-blink Type of Glow Starter.



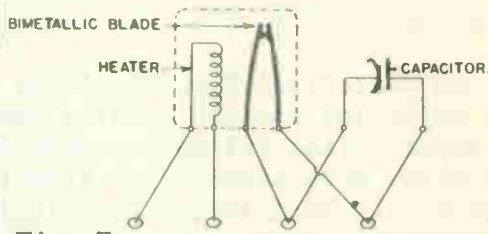


Fig. 7

The Parts and Connections In a Thermal Starter.

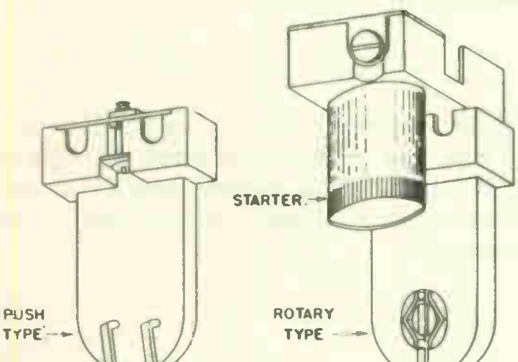


Fig. 3

Lampholders for Supporting the Lamp and Making Contact With the End Pins.

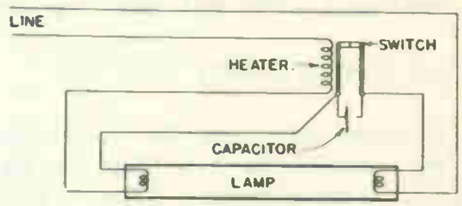


Fig. 8 How the Thermal Starter Is Connected To the Lamp.

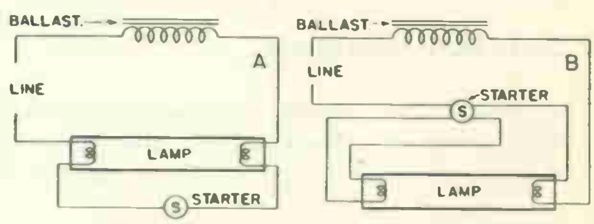


Fig. 9 How the Ballast Is Connected In Circuit With the Lamp and Starter.

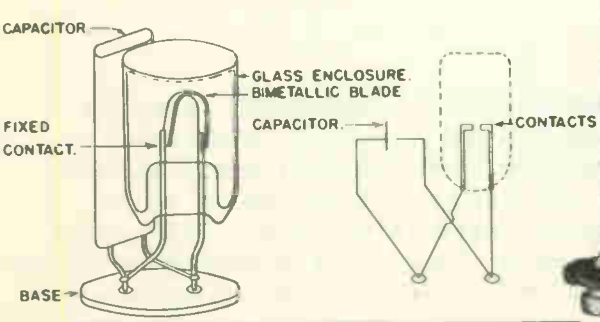


Fig.4 Construction and Connections of a Glow Switch Starter.

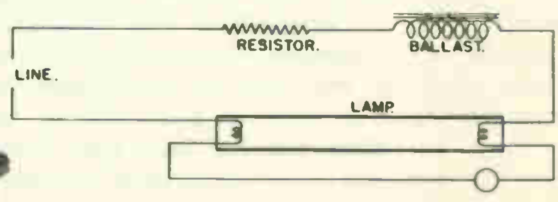


Fig. 10 The Connection for a Voltage Dropping Register Used With Direct-current Supply.

2. Construction and Operation of Ballast - a. A coil having many turns wound on an iron core has high inductance. When current has been flowing in such a coil and suddenly is stopped the magnetic lines of force which have existed around the windings collapse and cut back through the turns. This cutting of the conductor by lines of force induces a voltage which is much higher than that which was sending current through the coil. It is commonly referred to as "inductive kick".

   b. Once the ballast has furnished the starting "kick", it continues to operate as an inductive reactance to limit the current to the lamp electrodes.

H. Power-Factor Correction, Fig. 11.

Fig. 11 shows connections in a two-lamp circuit having power-factor correction. The lower lamp, marked "lagging lamp", has only a ballast between it and one side of the line. In series with the ballast for the other lamp marked "leading-lamp" is a capacitor by-passed by a small high-resistance unit. The power factor of the entire circuit, including the two lamps, their ballasts and the capacitor will be better than 90%.

I. Compensator, Fig. 12.

In the circuit of Fig. 11, there may be so little current in the path containing the capacitor and the leading lamp that this lamp lights with difficulty because of insufficient filament preheating. To over-balance the effect of the capacitor and allow more current for starting, we connect additional inductance in the branch. As soon as the lamp is lighted, the starter switch is open and since the compensator is in series with the starter, the compensator carries no current after the lamp lights. Compensators are not required with 85 and 100 watt lamps but are used with all smaller lamps in high power factor circuits.

J. Step-up Transformer, Fig. 13.

The voltage required to start the electron discharge through the 30, 40, 85, & 100 Watt lamps is too high to be furnished even from the inductive kick of the ballast when operated from a 110 - 125 volt supply line. With these lamps it is necessary to provide a transformer which will increase the starting voltage. Fig. 13 shows a two-lamp circuit with a step-up transformer.

K. Auxiliary Equipment.

Starters, ballasts, compensators and auto-transformers are called "Auxiliaries". Whichever of these parts are used and in whatever combination they are used, the whole collection of control devices for a lamp fixture is called an auxiliary.

L. Lamp characteristics, Fig. 15.

This table shows the normal operating characteristics of fluorescent lamps in general use. The degree (°) symbols are for KELVIN units, which is to say the raising of a theoretically black body from absolute zero (-273°C) until it becomes visibly red and as more heat is applied the color will gradually pass through the various hues of color, until a bluish-white is reached. This point is what is known as the daylight (6500°) fluorescent lamp. The accuracy is checked with a sensitive phototube arrangement. The 3500°K white lamp is the most efficient of the white light group, and is the most commonly used when only white

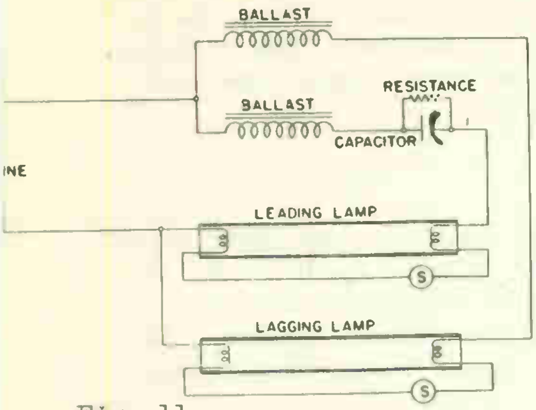


Fig. 11

A Two-lamp Circuit With Power Factor Correction.

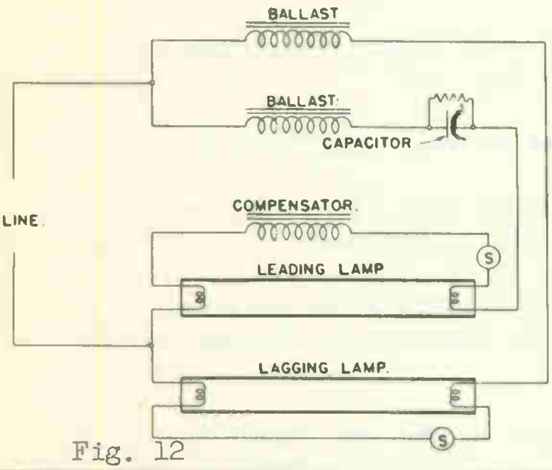


Fig. 12

How the Compensator Is Connected

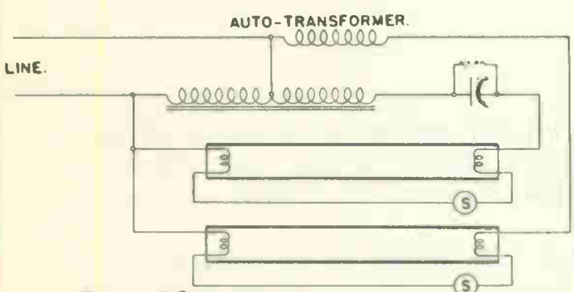


Fig. 13

A Transformer Used To Increase the Voltage

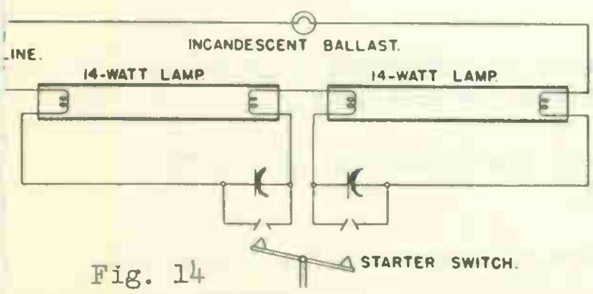


Fig. 14

Circuit for Two 14-watt Lamps In Series and Sequence Switch.

LAMP WATTS - SLIM LAMPS — HOT CATHODE →											16	25	33	24	39	51	22	38	51	29	51	69
LAMP WATTS — HOT CATHODE		6	8	14	15 (T8)	15 (T12)	20	30	40	85 + 100												
NOMINAL LENGTH, INCHES		9	12	15	18	18	24	36	48	60	42	42	42	64	64	64	72	72	72	96	96	96
DIAMETER, INCHES		5/8	5/8	1-1/2	1	1-1/2	1-1/2	1	1-1/2	2-1/8	3/4	3/4	3/4	3/4	3/4	3/4	1	1	1	1	1	1
APPROXIMATE LAMP AMPERES		.145	.160	.395	.310	.330	.360	.355	.420	1.50	.100	.200	.300	.100	.200	.300	.100	.200	.300	.100	.200	.300
APPROXIMATE LAMP VOLTS		48	57	38	55	46	59	98	106	71	180	150	130	285	230	200	250	220	200	335	295	265
RATED AVERAGE LIFE IN HOURS	BURNING HRS. PER START 3 6 12	2500	2500	2500	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	3000 4500 6500	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000	2500 4000 6000
MINIMUM STARTING VOLTAGE		100	118	80	118	100	118	220	220	165	450	450	450	600	600	600	600	600	600	750	750	750
LUMEN OUTPUT	WHITE - 3500^0	210	330	490	615	600	920	1470	2320	4200	930	1400	1710	1440	2250	2700	1410	2350	3000	1890	3200	4150
	DAYLIGHT	186	295	435	585	540	800	1350	1920	3900												
	WHITE - 4500^0	198	310	460	600	570	860	1380	2100	4000	880	1320	1620	1370	2150	2600	1340	2250	2850	1800	3050	3950
	SOFT WHITE			380	480	465	700	1170	1720	3300												

Fig. 15

light is desired. The soft white and warm white lamps are best suited for food counters and meat markets because of the presence of a great deal of red color. Daylight lamps are used chiefly where natural daylight is desired. The various colored lamps are used for decorative work, although the green lamps (the most efficient) are sometimes used in photographic processes.

M. Stroboscopic Effect

If it were not for the hold-over effect of the phosphor coating, the light would go out twice during each cycle, or 120 times per second on a 60 cycle line. If a rapidly moving object is viewed by light that increases and decreases at a rapid rate, you see it as a succession of images along the path of motion. This is called "stroboscopic effect". When operated on DC, there is no stroboscopic effect because of constant voltage and current values.

N. Direct-Current Operation, Fig. 10.

1. When fluorescent lamps are operated on a direct current supply line, the ballast is used in series with a resistor as shown in Fig. 10.

2. Direct current operation of fluorescent lamps is relatively inefficient.

3. Lamps of the 25 watt and smaller sizes may be operated from 110 to 115 volt DC lines, but larger sizes must be run from 220 - 230 volt lines.

4. For DC operation it is usual practice to use thermal starters for lamps up to and including the 40 watt size, and to use manual starters for larger sizes. The glow starter seldom works satisfactorily on DC.

5. Direct current causes an electronic discharge always in the one direction through the tube or lamp resulting in lamp end blackening. This fault may be overcome by using a reversing type of on-off switch or periodically changing the lamps end for end.

O. Lamps in Series, Fig. 14.

1. Two of the 14 watt fluorescent lamps may be operated in series with each other and with a special incandescent lamp with the circuit shown in Fig. 14. This circuit is used on either 110-125 volt AC or on 110-115 volt DC lines.

2. Single 6-watt or 8-watt fluorescent lamps sometimes are operated in series with a voltage dropping resistor and without any ballast on 110-125 volt AC lines or on 110-115 volt DC lines.

P. Fluorescent lamp Operation

1. Fluorescent lamps start most easily and operate most satisfactorily in delivering steady light when the room temperature is between 50° and 90°F.

2. The life of the fluorescent lamp depends largely on the condition of its filament. Low line voltage does decided harm to them.

3. The fewer the starts during a given number of hours of operation the longer the lamps will last.

4. Lamp requirements for a desired distribution and level of illumination with fluorescent lamps are calculated just as they are when using incandescents.

5. The lumen output from a new fluorescent lamp drops rapidly during the first 100 hours of operation, then levels off to the average values given in the table of characteristics.

COEFFICIENT OF UTILIZATION

A factor in per cent which denotes the actual utilization of light from the light source or sources when used in the specific luminaire and used in an area having walls and ceilings of known reflection factors. Coefficients of Utilization are not necessarily the same for two fixtures having the same outward appearance. Their distribution and efficiency will effect the C. U.

AMBIENT TEMPERATURE

The temperature of the surrounding air. When applied to transformers the surrounding air is that air within a few inches of the transformer i.e., the air within a box housing a transformer.

MAINTENANCE FACTOR

A factor expressed in per cent denoting the depreciation of light output due to dirt and dust accumulation and to depreciation of the light source. In selecting the M. F., consideration must be given to the cleanliness of the location as well as to the possibility of regular or irregular maintenance. Maintenance should mean washing of lamps and luminaires as well as changing lamps. Cleaning or repainting of walls and ceilings should also be considered a necessary part of the maintenance program.

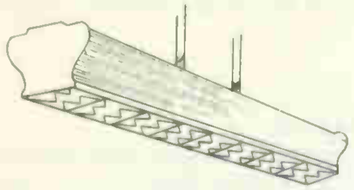
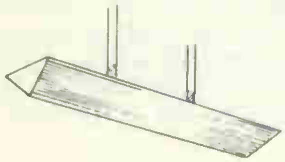
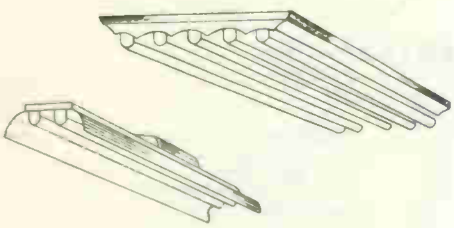
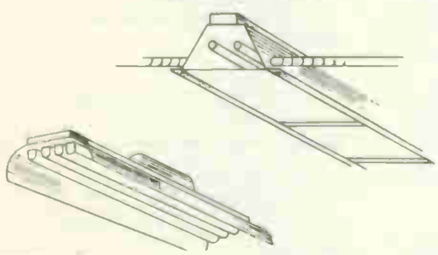
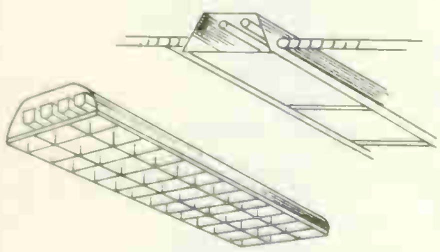
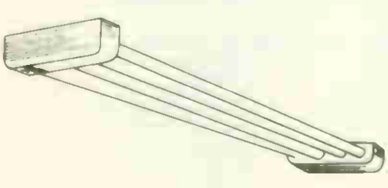
RECOMMENDED LEVELS OF ILLUMINATION

	FOOTCANDLES MODERN PRACTICE
AIRPLANE MANUFACTURING	
Stock Parts	
Production	50
Inspection	100
PARTS MANUFACTURING	
Welding, Drilling, Riveting	30
Spray Booths	30
Sheet metal layout-template work	50
SUB ASSEMBLY	
Landing gear, fuselage, etc. large parts	30
FINAL ASSEMBLY	
Planing motors, gun mounting etc.	30
Inspection of plane and equipment	50
Machine tool repairs	100
ARTILLERY MANUFACTURING	
Forging and casting of gun barrels and mounts	10
Machining and grinding of gun barrels, breeches, mounts and carriages	30
Measuring and testing of parts and assembly of range adjusters and firing mechanisms	50
General assembly	50
ASSEMBLY	
Medium	20
Medium fine	50
Fine	100
Extra fine	200
BREWERIES	
Brew house	5
Boiling, keg washing and filling	10
Bottling	20
FOUNDRIES	
Changing floor, tumbling, cleaning, pouring and shaking out	5
Rough moulding, core making	10
Fine moulding, core making	20
GARAGES—AUTOMOBILES	
Storage	10
Repair Dept. & washing	50
HANGARS-AIRPLANE	50
MACHINE SHOPS	
Rough bench and machine work	20
Medium bench and machine work	
Rough grinding, medium buffing & polishing	30
Fine bench and machine work	
Fine automatic machines grinding and polishing	100
Extra fine bench and machine work	200

	FOOTCANDLES MODERN PRACTICE
OFFICES	
Bookkeeping, typing accounting	50
Business machines—local illumination	100
Conference rooms—general meetings	30
Corridors and stairways	5
Desk work	
Intermittent reading and writing	30
Prolonged close work, designing, studying, reading blueprints, plans	50
DRAFTING	
Prolonged close work—detail designing	50
Filing and index references	30
Mail sorting	30
Stenographic work—prolonged reading of shorthand notes	50
PRECISION WAR EQUIPMENT	
Assembly and adjustment of range finders, binoculars, periscopes, gun sights, etc.	100
SHEET METAL WORKS	
Miscellaneous machines, medium bench work, punch presses, shears, etc.	20
SHELL LOADING PLANTS	
Fuse and booster manufacturing	50
Inspecting, cleaning and spraying of shell forgings	
Loading of shells, bombs, mines, etc.	
Hand	50
Automatic	30
Cleaning and inspection	30
STEEL & IRON MANUFACTURING	
Billet, Blooming, Sheet bar, skelp and slabbing mills	10
Boiler Room Power house, etc.	10
Hot sheet and hot strip mills	10
Cold strip, pipe, rail, rod, wire drawing	10
Merchant & Sheared plate mills	20
Tin Plate Mills	20
Inspection	30
Machine shops (see machine shops)	20-200
PUBLIC BUILDINGS	
Auditoriums	10
Banks	
Lobby	20
Cages	50

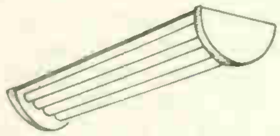
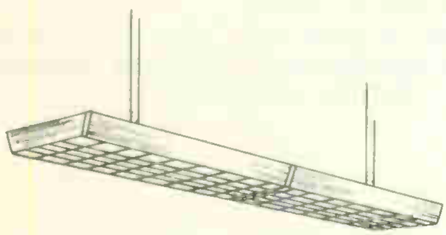
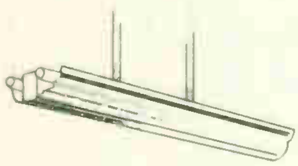
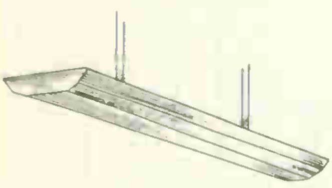
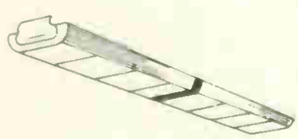
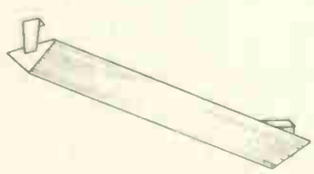
	FOOTCANDLES MODERN PRACTICE
HOSPITALS	
Corridors	5
Laboratories	30
Lobby and Reception room	20
OPERATING ROOM	
General	50
Major operations	1000
Minor operations	200
Private rooms and wards (local)	30
HOTELS	
Lobby	20
Dining Room	5
Kitchen	20
Guest rooms (local lighting)	30
Corridors	5
PROFESSIONAL OFFICES	
Waiting rooms	20
Consultation rooms	30
Examination rooms (local lighting)	100
Dental Chairs (local lighting)	200
SCHOOLS	
Auditoriums	10
Class & Study rooms	30
Corridor & Stairways	5
Drawing rooms	50
Gymnasium	20
LABORATORIES	
General	20
Close work	50
MANUAL TRAINING	
General	30
Close work (local lighting)	100
Sewing room (local lighting)	100
Sight Saving Classes	50
STORE INTERIORS	
Circulating areas	20
General merchandising areas	50
Show cases, wall cases and open counter displays	100
Feature Display	200
Stock rooms	10
SHOW WINDOWS	
Small cities & Towns	
General	50
Feature displays	100
Large cities-secondary	
Business areas	
General	100
Feature displays	200
Large cities—main business areas	
General	200
Feature displays	500

COEFFICIENTS OF UTILIZATION

LUMINAIRE	M.F.		INDEX ROOM	CEILING 75% WALLS 50%	CEILING 75% WALLS 30%	CEILING 50% WALLS 50%	CEILING 50% WALLS 30%
	G .75*	30/45	J	.23	.19	.21	.17
	A .65*		I	.28	.24	.26	.22
	B .65*		H	.31	.27	.29	.25
			G	.35	.31	.31	.28
			F	.38	.34	.34	.30
			E	.42	.38	.37	.34
			D	.45	.41	.40	.37
			C	.48	.43	.42	.39
			B	.51	.47	.45	.41
			A	.53	.49	.47	.43
	G .70	45/30	J	.26	.21	.22	.19
	A .60		I	.31	.26	.27	.24
	B .50		H	.34	.30	.30	.27
			G	.38	.34	.34	.30
			F	.41	.37	.36	.33
			E	.45	.41	.40	.36
			D	.49	.45	.42	.41
			C	.51	.48	.44	.44
			B	.55	.51	.47	.45
			A	.57	.53	.49	.46
	G .70	0/80	J	.36	.29	.35	.29
	A .60		I	.45	.39	.44	.38
	B .55		H	.49	.44	.48	.44
			G	.53	.48	.52	.48
			F	.56	.51	.54	.50
			E	.61	.57	.60	.56
			D	.66	.62	.64	.62
			C	.68	.65	.66	.63
			B	.72	.69	.70	.67
			A	.74	.70	.72	.69
	G .70	0/70	J	.32	.28	.32	.28
	A .60		I	.40	.36	.39	.35
	B .55		H	.43	.39	.42	.39
			G	.46	.43	.45	.43
			F	.48	.45	.47	.45
			E	.52	.50	.51	.49
			D	.56	.54	.55	.53
			C	.57	.55	.56	.54
			B	.60	.58	.59	.57
			A	.61	.59	.60	.58
	G .70	0/60	J	.30	.26	.29	.26
	B .60		I	.37	.34	.36	.33
	A .50		H	.40	.38	.39	.37
			G	.43	.40	.42	.40
			F	.45	.43	.44	.42
			E	.48	.46	.47	.46
			D	.52	.49	.50	.49
			C	.53	.51	.52	.50
			B	.55	.53	.53	.52
			A	.56	.54	.55	.53
	G .75	10/70	J	.32	.27	.32	.26
	A .65		I	.40	.35	.39	.34
	B .55		H	.44	.39	.43	.39
			G	.48	.43	.46	.42
			F	.52	.47	.50	.46
			E	.57	.52	.55	.51
			D	.62	.56	.59	.55
			C	.65	.59	.62	.57
			B	.69	.63	.65	.61
			A	.71	.66	.67	.63

* G = GOOD, A = AVERAGE, B = BAD MAINTENANCE FACTOR

COEFFICIENTS OF UTILIZATION

LUMINAIRE	M.F.		ROOM INDEX	CEILING 75% WALLS 50%	CEILING 75% WALLS 30%	CEILING 50% WALLS 50%	CEILING 50% WALLS 30%
	G .75*		J	.27	.25	.26	.22
	A .65*		I	.35	.29	.33	.28
	B .55*		H	.38	.34	.36	.32
		25	G	.43	.38	.40	.36
		—	F	.46	.41	.43	.39
		60	E	.50	.46	.47	.43
			D	.55	.50	.51	.47
			C	.58	.53	.53	.49
			B	.62	.57	.57	.53
			A	.64	.60	.59	.55
	G .70		J	.26	.23	.23	.21
	A .65		I	.31	.28	.28	.26
	B .60		H	.35	.32	.31	.28
		50	G	.38	.35	.34	.31
		—	F	.41	.38	.36	.34
		30	E	.44	.42	.39	.37
			D	.48	.45	.42	.39
			C	.50	.49	.43	.41
			B	.53	.50	.46	.43
			A	.54	.52	.47	.45
	G .60		J	.18	.14	.14	.11
	A .50		I	.22	.19	.17	.15
	B .40		H	.26	.22	.20	.17
		70	G	.29	.25	.22	.19
		—	F	.32	.28	.24	.21
		10	E	.35	.32	.27	.24
			D	.39	.35	.29	.26
			C	.42	.38	.31	.28
			B	.46	.42	.34	.31
			A	.48	.44	.36	.33
	G .60		J	.16	.12	.10	.09
	A .50		I	.20	.16	.13	.11
	B .40		H	.23	.20	.15	.13
		80	G	.27	.23	.18	.15
		—	F	.29	.25	.20	.17
		0	E	.33	.29	.22	.19
			D	.36	.32	.24	.22
			C	.39	.35	.26	.23
			B	.43	.40	.28	.26
			A	.45	.42	.30	.28
	G .65		J	.25	.23	.24	.22
	A .55		I	.32	.28	.29	.27
	B .50		H	.34	.32	.32	.31
		15	G	.37	.35	.35	.33
		—	F	.39	.37	.36	.35
		45	E	.42	.40	.39	.38
			D	.45	.42	.42	.40
			C	.46	.44	.43	.41
			B	.48	.46	.45	.43
			A	.49	.47	.46	.44
	G .70		J	.24	.20	.23	.19
	A .60		I	.30	.26	.28	.24
	B .50		H	.33	.29	.31	.28
		20	G	.36	.32	.34	.31
		—	F	.39	.35	.36	.33
		50	E	.42	.39	.40	.37
			D	.46	.43	.43	.40
			C	.48	.45	.44	.42
			B	.51	.48	.47	.45
			A	.52	.50	.49	.46

* G = GOOD, A = AVERAGE, B = BAD MAINTENANCE FACTOR

THE LUMEN METHOD FOR LIGHTING CALCULATIONS

The lumen method for calculating general lighting intensities is comparatively simple. It is in general use today as the majority of our lighting installations are made on the basis of average maintained footcandle values over a given area.

While the use of the lumen method is simple, inaccuracies can easily result if the factors used are not carefully evaluated. Careful evaluation of the Coefficient of Utilization of the fixture type to be used and the Maintenance Factor will generally produce results that are sufficiently accurate to satisfy the purchaser of the installation. In general the following steps are recommended in preparing the lighting estimate and layout.

1. Choose the required footcandle level for the particular task from the chart showing recommended footcandle levels or other more comprehensive data.
2. Select the type of luminaire which best fits the particular installation.
3. Determine the dimensions of the space to be lighted and refer to the Room Index Chart.
4. Using the Room Index and the luminaire selected to determine the Coefficient of Utilization (CU) from C.U. tables.
5. The Maintenance Factor (MF) of luminaire is included in the CU tables. Care must be taken to evaluate this factor depending upon the actual conditions rather than ideal conditions as dirt and dust absorb a great deal of light.
6. Apply the data to the following formula.

$$\text{Lamp Lumens required} = \frac{\text{Footcandles} \times \text{area in square ft.}}{\text{Coefficient of Utilization} \times \text{Maintenance factor.}}$$

7. The required lamp lumens can now be used to obtain the number of lamps and the number of fixtures needed to produce the selected footcandle level. Use the following formula.

$$\text{No. of Fixtures} = \frac{\text{Lamp Lumens Required}}{\text{Lamp Lumens} \times \text{No. of Lamps/Fixture}}$$

8. With the number of fixtures determined, it is only necessary to space them in the area in a uniform fashion that will produce a pleasing appearance and good distribution of light. Coefficients of Utilization vary considerably for different fixture types. Those shown in the CU tables are typical, and similar data may be obtained from the fixture manufacturers for luminaires having different distribution or efficiency characteristics.

While spacing and layout of fixtures is important in providing uniform distribution of light over the working area, considerable thought should be given to lighting comfort. In general, fixture manufacturers design side and bottom panels of commercial fixtures to have a low surface brightness. However, the layout man can often eliminate the possibility of annoying brightness in the field of vision by remembering two simple rules:

(a) Hanging or surface mounted commercial fixtures should generally be hung parallel to the line of vision.

(b) Troffer or flush type and industrial fixtures should generally be hung perpendicular to the line of vision.

ROOM INDEX

(Classification according to proportions)

CEILING HEIGHT—FEET: For Semi-Indirect and Indirect Lighting		9 and 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50		
MOUNTING HEIGHT ABOVE FLOOR—FEET: For Direct and Semi-Direct Lighting		7 and 7½	8 and 8½	9 and 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50
Room Width (Feet)	Room Length (Feet)	ROOM INDEX										
9 (8½–9)	8–10	H	I	J	J							
	10–14	H	I	I	J							
	14–20	G	H	I	J	J						
	20–30	G	G	H	I	J	J					
	30–42	F	G	H	I	J	J	J				
	42-up	E	F	G	H	I	J	J				
10 (9½–10½)	10–14	G	H	I	J	J						
	14–20	G	H	I	J	J	J					
	20–30	F	G	H	I	J	J					
	30–42	F	G	G	H	I	J	J				
	42–60	E	F	G	H	I	J	J				
	60–up	E	F	F	H	H	I	J				
12 (11–12½)	10–14	G	H	I	I	J	J					
	14–20	F	G	H	I	J	J					
	20–30	F	G	G	H	I	J	J				
	30–42	E	F	G	H	I	J	J				
	42–60	E	F	F	G	H	I	J				
	60–up	E	E	F	G	H	I	J				
14 (13–15½)	14–20	F	G	H	H	I	J	J				
	20–30	E	F	G	H	I	J	J				
	30–42	E	F	F	G	H	I	J	J			
	42–60	E	E	F	F	H	I	J	J	J		
	60–90	D	E	E	F	G	H	J	J	J		
	90–up.	D	E	E	F	F	G	I	J	J		
17 (16–18½)	14–20	E	F	G	H	I	J	J				
	20 30	E	F	F	G	H	I	J				
	30–42	D	E	F	G	H	H	J	J	J		
	42–60	D	E	E	F	G	G	I	J	J	J	
	60–110	D	E	E	F	G	G	I	J	J	J	
	110–up	C	D	E	E	F	G	H	I	J	J	
20 (19–21½)	20–30	D	E	F	G	H	I	J	J			
	30–42	D	E	E	F	G	H	I	J	J		
	42–60	D	D	E	E	F	G	I	J	J	J	
	60–90	C	D	E	E	F	G	H	J	J	J	
	90–140	C	D	D	E	F	F	H	I	I	J	J
	140–up	C	D	D	E	F	F	H	H	I	J	J
24 (22-26)	20–30	D	E	E	F	G	H	I	J	J		
	30 42	C	D	E	F	G	G	I	J	J		
	42–60	C	D	D	E	F	G	H	I	J	J	
	60–90	C	D	D	E	F	F	H	I	J	J	J
	90–140	C	C	D	E	E	F	G	H	I	J	J
	140–up	C	C	D	E	E	F	G	H	I	I	J
30 (27–33)	30–42	C	D	D	E	F	G	H	I	J	J	
	42–60	C	C	D	D	F	F	H	H	I	J	
	60–90	B	C	C	D	E	F	G	H	I	J	J
	90–140	B	C	C	D	E	E	F	G	H	I	J
	140–180	B	C	C	D	E	E	F	G	H	I	J
	180–up	B	C	C	D	E	E	F	G	H	I	J
36 (34–39)	30–42	B	C	D	E	F	F	H	I	I	J	
	42–60	B	C	C	D	E	F	G	H	I	J	J
	60–90	A	C	C	C	E	E	F	H	H	J	J
	90–140	A	B	C	C	D	E	F	G	H	I	J
	140–200	A	B	C	C	D	E	F	F	G	H	I
	200–up	A	B	C	C	D	E	F	F	G	H	I
42 (40–45)	42–60	A	B	C	C	E	F	G	H	I	I	J
	60–90	A	B	B	C	D	E	F	G	H	I	J
	90–140	A	B	B	C	D	D	E	F	G	H	J
	140–200	A	A	B	C	D	D	E	F	G	H	I
	200–up	A	A	B	C	D	D	E	F	F	G	I
50 (46–55)	42–60	A	A	B	C	D	E	F	G	H	I	J
	60–90	A	A	B	C	C	D	F	F	G	H	J
	90–140	A	A	A	C	C	D	E	F	F	G	I
	140–200	A	A	A	C	C	D	E	E	F	G	I
	200–up	A	A	A	C	C	D	E	E	F	G	H
60 (56–67)	60–90	A	A	A	B	C	D	E	F	G	H	I
	90–140	A	A	A	B	C	C	D	E	F	G	H
	140–200	A	A	A	B	C	C	D	E	E	F	H
	200–up	A	A	A	B	C	C	D	E	E	F	H
75 (68–90)	60–90	A	A	A	A	B	C	D	E	F	G	I
	90–140	A	A	A	A	B	C	D	E	F	F	H
	140–200	A	A	A	A	B	B	C	D	E	F	G
	200–up	A	A	A	A	B	B	C	D	E	F	G

ELECTRIC SIGNS

Objective

To learn how electric signs and sign flashers are installed and operated.

References:

Lesson Content

A. General

While the design of electric signs is an art in itself, their installation and maintenance can be both interesting and profitable. Although advertising signs were used thousands of years ago, the first electric sign of any consequence did not appear until 1893. Located at Broadway and 23rd Streets, New York City, it advertised "Heinz's 57 Varieties". Today, with lower power costs, improvements in sign flashers and greater lamp efficiencies, not to mention the advent of neon, the whole sign industry occupies a field of its own and there is hardly a community of any size in the world without at least one "spectacular" as they are called.

B. Types of Electric Signs

Since the National Electrical Code devotes a whole chapter (sections 6001 to 6037, 1947 Code) to "signs and Outline Lighting", both incandescent and electric discharge tubing, it is necessary to first determine what constitutes an electric sign. The following definition has been adopted both by the National Electrical Code and by the American Standards Association: "A fixed or portable, self-contained electrically illuminated appliance with words or symbols designed to convey information or to attract attention."

Electric signs may be grouped according to construction and illumination into four classes:

1. Exposed or exterior illuminated.
2. Concealed, or interior illuminated.
3. Silhouette, or reflector illuminated.
4. Gaseous conductor (neon) signs.

They may also be divided into four groups according to operation: steady, on and off flashing, script and talking signs.

A further classification regards the use of color. Various combinations of these methods may be employed for special effects.

C. Exposed Lamp Type

1. Uses and adaptability

This type of sign is best suited for electrical advertising which must be effective at the greater distances. When the reading distance is less than 250 feet, this type of sign should not be used.

Lamps are carefully spaced to avoid blurring. They are usually mounted in troughs in order to reduce light spillage. Every effort must be made to minimize the effect of glare. This type of sign may be made most brilliant and excels in its adaptability to the use of color and motion.

2. Color effect

Colored lamps - colored lamps of low wattage may be used but they cost more than clear lamps, they hold more heat and the replacement expense is greater than with clear lamps.

Colored hoods - colored hoods or caps as shown in Fig. 5 make it cost more than clear lamps only. Replacement costs are lower, efficiency is high, the sign has great flexibility and the hoods themselves last indefinitely.

3. Moving signs

It has been estimated that a moving sign consumes only about 75% as much power as a steady sign. In addition, it is more effective in attracting attention.

Sign flashers - one of the sign flashers is shown in Fig. 3 and another in Fig. 6. Flashers use of shoes or brushes as shown in Fig. 4. The mercury tube is nothing but a mercury switch. The mercury type switch is used so as to cut down the effect of arcing at the switch contacts.

Script effect - in the script effect, the individual lamps are turned on one at a time, making it appear as if the letters were being written in the sky. The mechanism used for this effect consists of a rotating drum so shaped that it makes contact successively with a row of metal "fingers" each of which is connected to a single lamp. An alternative method is to connect each brush to the group of lamps constituting a single letter or group of letters or even to a group of words, the groups coming on in rotation. This is shown in Fig. 2.

Chaser effect - the chaser effect is shown in Fig. 1. It is used chiefly for borders. Starting at any point, lamps are numbered 1, 2, 3, 4, 1, 2, 3, 4, etc. All the number 1 lamps are connected together and the same with all number 2 lamps and so on. Then the number 1 lamps are connected to one brush, the number 2 lamps to another brush, etc. In operation, only one set of lamps is out at any one instant and this shadow can be made to progress either clockwise or counterclockwise, or a combination may be used to achieve a fountain effect.

The talking sign is illustrated in Fig. 8. Each contact on the Kraft paper belt is wired to a lamp in corresponding position on the sign so that the reading matter appears to travel from one end to the other.

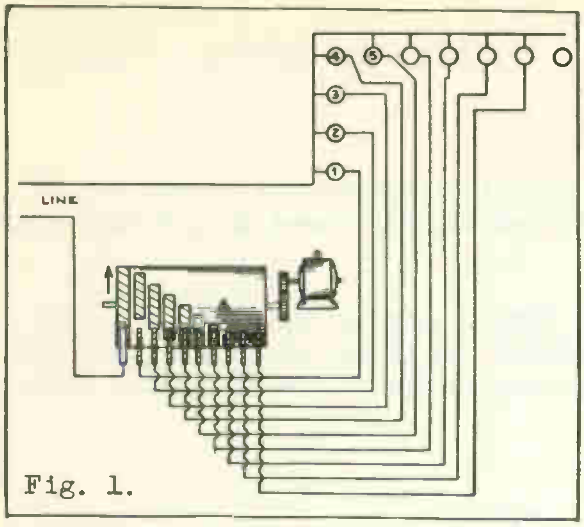


Fig. 1.

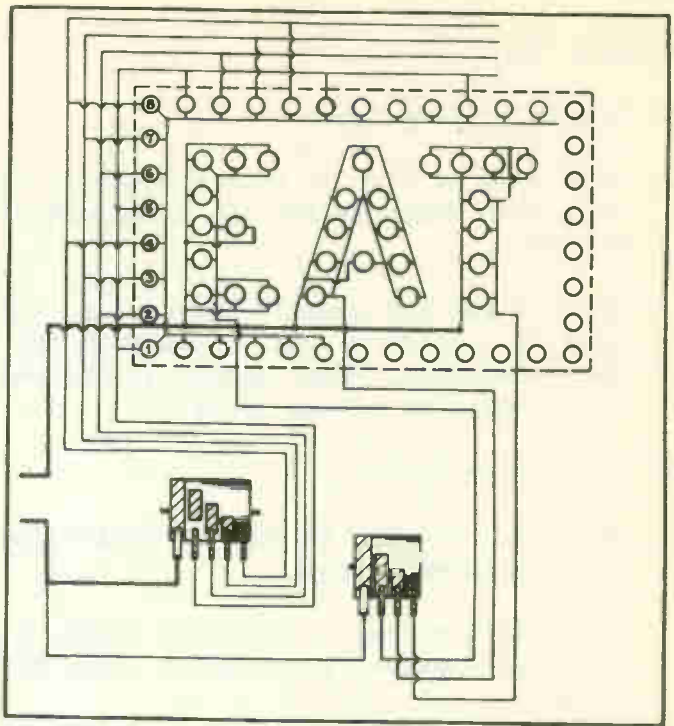


Fig. 2

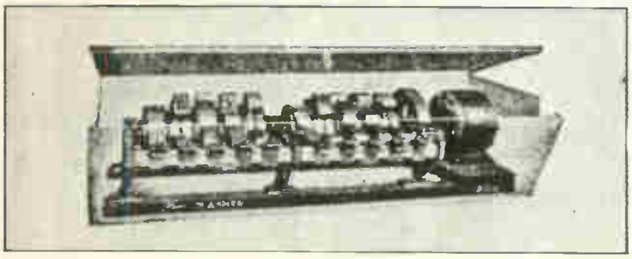


Fig. 3

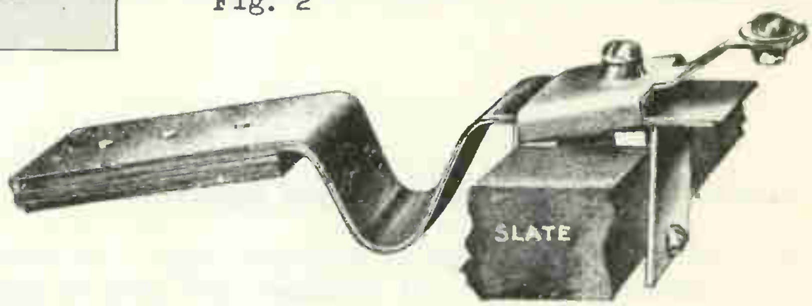


Fig. 4


Fig. 5

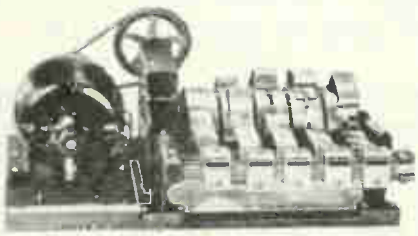


Fig. 6

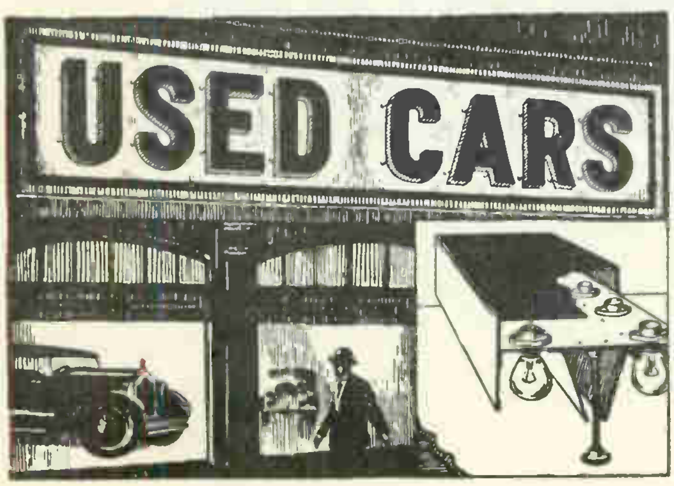


Fig. 7

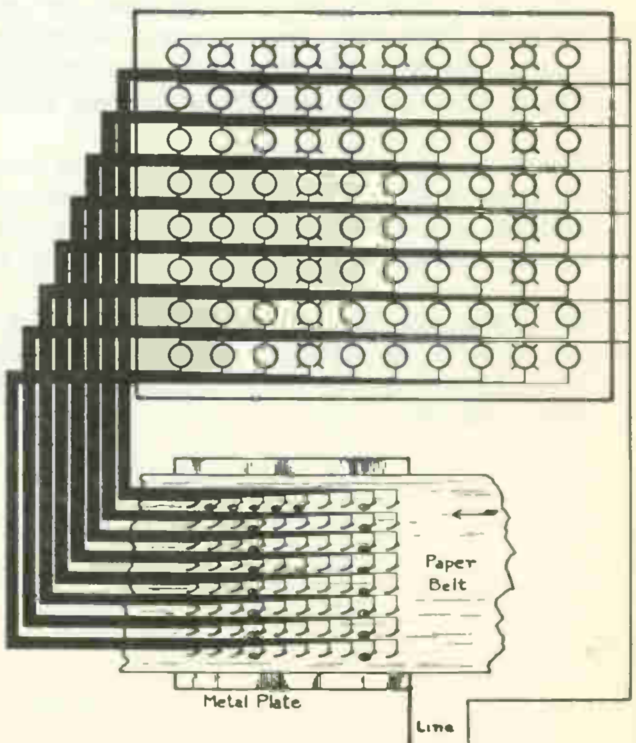


Fig. 8

D. Concealed Lamp Type

This type of sign is most frequently used for location markers and is not effective with color or motion. It should be used in reading distances of not more than 250 feet.

These signs are usually motionless, such as an "exit" sign or the like, and they usually consist of opal glass with the lamps behind the glass, although there are many varieties. When motion is desired, it is usually the on and off type, obtained by means of a time clock.

E. Silhouette Type

This type of sign is most effective for reading distances up to 1500 feet. It is made in three styles:

1. Letters placed in front of light, Fig. 7.
2. Letters placed in front of lamp, so that they cast large shadows on a blank wall.
3. Lights overhead, facing the sign, as in illuminated billboards.

F. Gaseous Conductor Lighting (Neon Signs)

This is the newest type of electric sign. It uses neon and other rare gases for color effect, and special flashers are used to provide motion.

The principle parts of a neon sign are shown in Fig. 9. The exposed parts consist of glass tubing containing neon or other gases which become luminous when high voltage from the transformer secondary forces current through the gas. The tubing is continuous from one transformer connection to the other, with portions which are to be invisible formed with black glass or coated with black paint.

The high voltage secondary of the transformer furnishes a potential difference of 2000 to 15000 volts for its section of tubing, the voltage depending upon the length and diameter of the tubing and the type of gas used. Current through the tubing usually is between 15 and 20 milliamperes (0.015 to 0.02 ampere).

An electrode is attached to each end of the tubing section as shown in Fig. 10. The electrode with its wire lead comes assembled in a short piece of glass tubing. A style of electrode housing having a spring contact for the electrode cap is shown in Fig. 8-B.

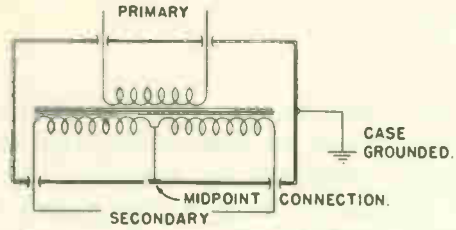


Fig.8A **How the Secondary Midpoint is Grounded.**

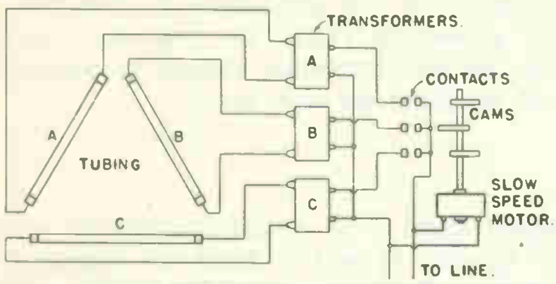


Fig.8C **Sign Flasher on Primary Side of Transformers.**

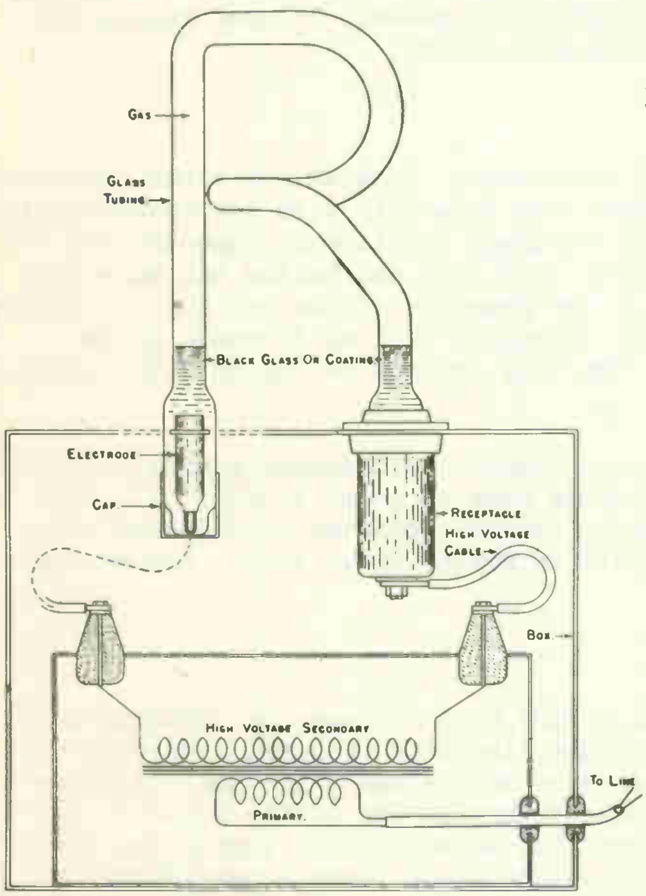
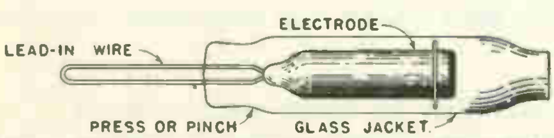


Fig. 9 **The Principal Parts of a Neon Sign.**



An Electrode in its Glass Jacket for Attachment to Tubing.

Fig.19

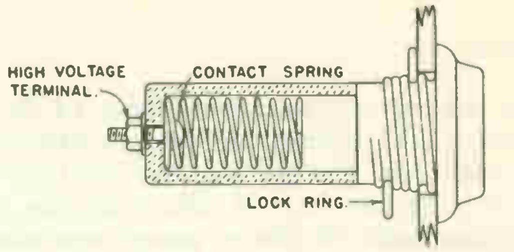


Fig. 8B **A Receptacle for Luminous Tubing.**

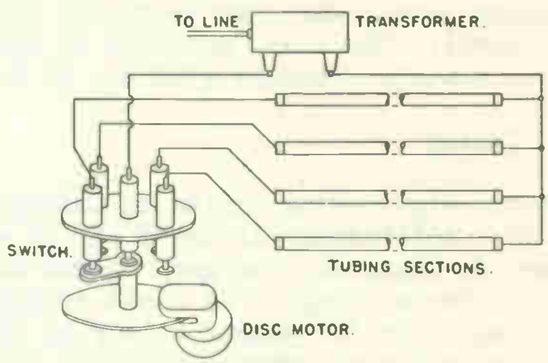


Fig.8D **Sign Flasher Operating in the High Voltage Secondary Circuit of a Single Transformer.**

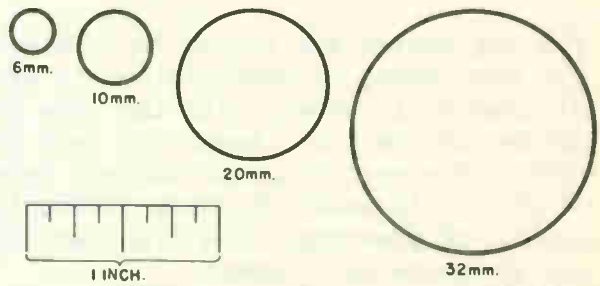


Fig.11 **Relative Sizes of Some Luminous Sign Tubing.**

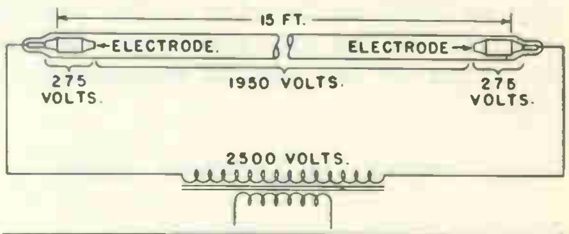


Fig. 12 **Voltage Distribution in Sign Tubing.**

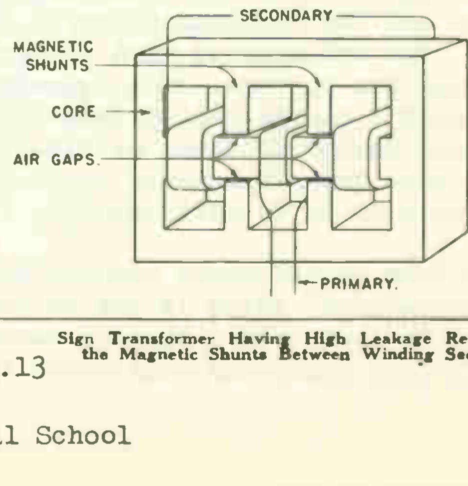


Fig.13 **Sign Transformer Having High Leakage Reactance, Showing the Magnetic Shunts Between Winding Sections.**

G. Gases

The tubing of luminous signs is filled with neon, helium, or argon, with a mixture of all three, or with a mixture of neon and argon or one of helium and argon. In addition the tubing may contain mercury vapor, produced by evaporating a drop of liquid mercury by means of the heat of the discharge within the glass tube. Combinations of these gases are used to obtain a variety of colors.

The quantity of gas in the tubing is proportional to the pressure of the gas. Gas pressures are always far below the normal air pressure (14.7 lb. per sq. in. at sea level). The usual pressure is from 10 to 20 millimeters, which is about 2% of atmospheric pressure (760 mm, 30 inches of mercury at sea level).

H. Sign Tubing

Luminous sign tubing varies in outside diameter from 5 to 45 millimeters. There are 25.4 millimeters in one inch, so we have tubing from 1/5 inch to nearly 2 inches in diameter, the more common sizes ranging from 6 to 20 millimeters (in one millimeter steps) as shown in Fig. 11. The tubing may be clear in which case the color is secured solely by the selection of gases. Colored tubing may also be used with various gases to form different colors.

I. Voltage and Current

The gas inside the tubing is an electrical conductor. As with any other conductor, the resistance increases directly with length and inversely with the cross-sectional area or inversely with the tube diameter squared. Resistance depends upon the nature of the gas. Argon has less resistance than neon and helium has more than neon. The resistance of the gas depends on the pressure of the gas and its temperature. It is least at three millimeters and increases with an increase or decrease of pressure. The light emitted by the tube depends on the relation between gas pressure and current.

In a typical sign with 15 feet of tubing the potential difference across the ends may be 2500 volts with a 275 volt per electrode drop as shown in Fig. 12. With shorter tubing the electrode drop will remain the same but the tubing drop will decrease as the length decreases. Since this is waste, tubes should not be too short.

J. Transformers for Luminous Tubes

The luminous tube transformer must furnish a very high voltage for breaking down the resistance of the cold gas and starting the discharge of current through the tubing. But, if this high starting voltage were maintained after the discharge commences and the resistance drops, the current through the tubing would be excessive. Consequently we need a transformer that automatically limits the current, by lowering its voltage, once current commences to flow. Such a transformer is secured with a design that permits high leakage reactance. The general principle of one such design is shown by Fig. 13. Even when the secondary terminals of a luminous tube transformer are short-circuited on each other the secondary current will be only 20 to 60 milliamperes.

Luminous tube transformers usually are rated according to their open circuit secondary voltage, which is the voltage available for starting the discharge, and according to their short-circuit secondary current, which is the maximum current that will flow under any conditions in the tubing circuit.

Transformers rated at 7500 volts (secondary) or more have the center of their secondary windings grounded to the frame and the frame is then connected to some good electrical ground, in order to reduce the hazards in using high voltages, Fig. 8A.

Standard secondary voltages are 2,000, 3,000, 4,000, 5,000, 6,000, 7,500, 9,000, 12,000, and 15,000 volts, at various current ratings.

After allowing for the electrode voltage drop, which is constant, the voltage required will vary directly with the length and inversely with the cross-sectional area. It also depends on the kind of gas used. With other conditions the same, a transformer which can handle thirty feet of neon tubing will handle about 36 feet with mercury and argon but only about thirteen feet with helium. Generally speaking, 65 feet of tubing is the maximum operated with one transformer.

Because of its high reactance, luminous tube transformers have a very low power factor, usually between 45 and 60 percent. This power factor can be raised to 90% or better by connecting a capacitor on the primary side.

K. Sign Flashers

The great majority of luminous tubes except the very small ones operate with sign flashers, which not only attract attention but also save power. Flashers are of two general types, one of which operates on the primary side of the transformer for each section of tubing, as shown in Fig. 8C, and the other operating on the secondary side of a single transformer which lights several sections of tubing Fig. 8D. Luminous tubing is always operated in series. If two sections were in parallel and an attempt were made to light both at once, the one having even slightly lower resistance than the other would light first and then the voltage would drop so low, due to flow of current, that the other section never would light.

L. Summary Questions:

1. How can you determine the effect noticed when a sign is in operation?
2. How can color be added to exposed lamp type signs?
3. What is the advantage of using mercury switches in a sign flasher?
4. What is the purpose of a border effect on the "DO IT ELECTRICALLY" sign?
5. What happens to the effective reading distance of a sign when the letters are placed in troughs?
6. What is the voltage range of luminous tube transformers?
7. Name the principle parts of a neon sign?
8. What gases are used in gaseous conductor signs?
9. What, generally, is the gas pressure inside a neon tube?
10. Is there a high or low rate of current inside the tube?

CELLS AND BATTERIES

Objective: To study the dry cell and other types of voltaic cells; to learn how to connect cells and batteries.

References:

Lesson Content

A. Electrical and Chemical Action

The production of current electricity by chemical action was accidentally discovered in 1785 by Luigi Galvani while observing the peculiar twitching of a frog's legs.

Alessandro Volta followed this discovery by devising a voltaic pile, alternate layers of dissimilar metals separated by acid-soaked paper. Later the first electric cells, consisting of zinc and silver electrodes in a saline solution, was constructed.

The simplest voltaic cell consists of a strip of copper and a strip of zinc immersed in a sulphuric acid solution, Fig. 1. The copper becomes the positive electrode and the zinc is the negative electrode, this difference of potential arising as a result of chemical action taking place in the acid electrolyte.

B. Definitions

Electrolytic cell - an electrolytic cell is a unit apparatus designed for carrying out an electrochemical reaction. It includes a vessel, two or more electrodes, and one or more electrolytes.

Galvanic (or Voltaic) cell - a galvanic cell is an electrolytic cell that is capable of producing electric energy by electrochemical action, Fig. 1

Electric battery - a battery is a combination of two or more cells electrically connected to work together to produce electrical energy. Common usage permits this designation to be applied also to a single cell used independently.

C. Classification

1. Reversibility

A primary cell is a cell designed to produce electric current through an electrochemical reaction which is not efficiently reversible and hence the cell, when discharged, cannot be efficiently recharged by an electric current.

A primary battery is a battery consisting of primary cells.

A secondary or storage cell is an electrolytic cell for the generation of electric energy in which the cell, after being discharged, may be restored to a charged condition by an electric current flowing in a direction opposite to the flow of current when the cell discharges.

A storage battery or accumulator is a connected group of two or more storage cells. Common usage permits this term to be applied to a single cell used independently.

NOTE: While primary cells cannot be recharged, they can be "rejuvenated" by periodically passing through them a low value of current of proper voltage for about 24 hours. This greatly extends their life.

2. Use

An "A" battery is a battery designed or employed to furnish current to heat the filaments of the tube in a vacuum tube circuit.

A "B" battery is a battery designed or employed to furnish the plate current in a vacuum tube circuit.

A "C" battery is a battery designed or employed to furnish voltage used as a grid bias in a vacuum tube circuit.

A flashlight battery is a battery designed or employed to furnish power to light a lamp in an electric lantern or flashlight.

3. Condition of electrolyte

A wet cell is a cell whose electrolyte is in liquid form and free to move. Wet cells fall into two general classes, single fluid cells and two fluid cells. A one fluid cell is a cell having the same electrolyte in contact with both electrodes. A two fluid cell is a cell having different electrolytes at the electrodes.

A dry cell is a cell in which the electrolyte exists in the form of a jelly or is absorbed in a porous medium, or is otherwise restrained from flowing from its intended position, such a cell is completely portable and the electrolyte non-spillable.

4. Kind of electrolyte

A sal ammoniac cell is a cell in which the electrolyte consists primarily of a solution of ammonium chloride, and water (3.4 fluid ounces in a No. 6 dry cell).

A caustic soda cell is a cell in which the electrolyte consists primarily of a solution of sodium hydroxide.

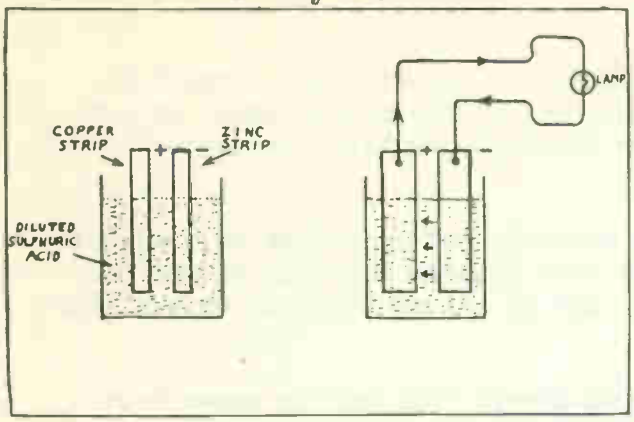


Fig. 1

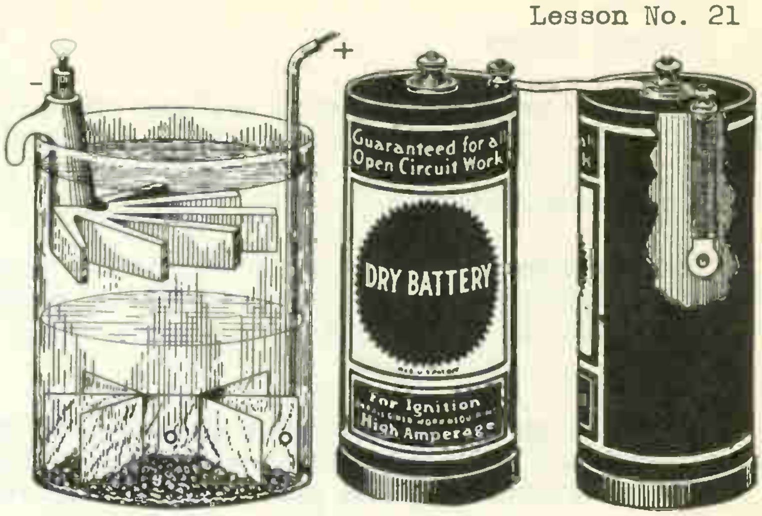


Fig. 2

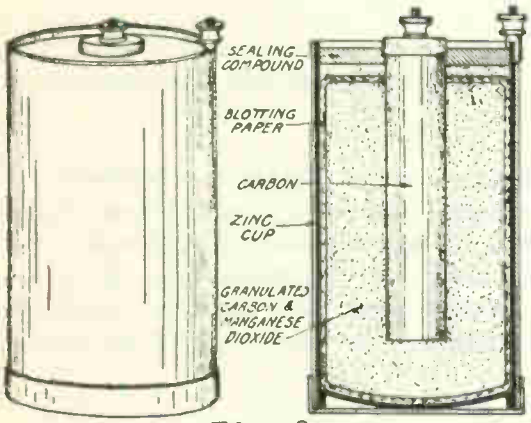


Fig. 3.

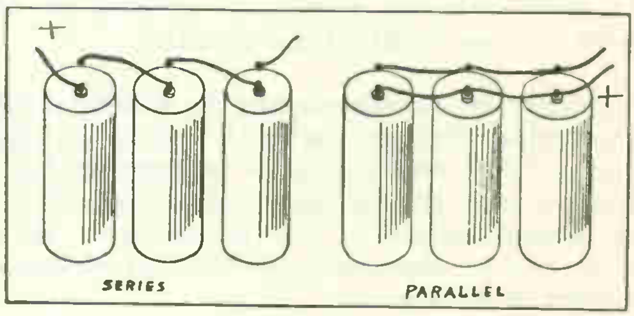


Fig. 4

A bichromate cell is a cell having an electrolyte consisting of a solution of sulphuric acid and a bichromate.

5. Chemical action

A gas cell is a cell in which the action of the cell depends on the absorption of gases by the electrodes. An air cell is a gas cell in which depolarization is accomplished through the reduction of oxygen of the air.

A carbon consuming cell is a cell intended for the production of electric energy by voltaic oxidation of carbon.

6. Miscellaneous types

The various classes of primary cells are further divided into a great many types such as the Daniell Two-Fluid Cell, the Daniell Gravity (or crowfoot) Cell, the Edison Primary Cell, the Smee Cell, the Grove Cell, the Bunsen Cell, the Fuller Cell, the Grenet (plunger) Cell, the silver-chloride cell, the Columbia, the Leclanche cell, and the many varieties of dry cells which have almost entirely superceded cells of other types for all open circuit work.

NOTE: All practical cells which produce current by destruction of a metal have zinc or some compound of zinc for one of their elements and the zinc element always is negative. In all these cells the zinc is gradually disolved or eaten away, but nothing happens to the other element, which is positive.

The poles or terminals of a cell are the parts to which the external circuit is attached. The opposite ends of the terminals are called the electrodes. By common usage the discharge current is said to flow from the positive electrode through the external circuit.

The electromotive force of a cell is the total electric potential due to its parts. The electromotive force produced by any voltaic cell depends entirely on the materials in the plates and in the electrolyte and not at all on its size or construction.

The total quantity of current (measured in ampere-hours) that may be taken from any voltaic cell before the cell becomes discharged depends on the quantities of active materials in the plates and the electrolyte. The bigger the cell, the more electricity (ampere-hour) it will deliver.

The watt hours of a cell or battery is the product of its voltage and its ampere hours. Since W=EI, then WH=EIH.

Polarization is the change in electromotive force which occurs while the current is passing through the cell and is in opposition to such current flow. It has also been defined as "a counter electromotive force caused by exhaustion of the substances used in the electrolyte reaction faster than they can be replaced, or by the accummulation of the products of this reaction faster than they can be removed". It is due to chemical or physical changes in the electrodes or electrolyte at their contact surfaces.

In most cases the chief causes of polarization are the formation of hydrogen at the positive plate and the transfer of metal from the negative plate to the positive plate, or depletion of the electrolyte. In a primary cell, polarization reduces the discharge voltage. In a secondary cell, polarization decreases the discharge voltage but increases the charging voltage.

When a polarized cell is allowed to stand on open circuit, the polarization effects disappear and the terminal voltage returns to its initial value except as it may be reduced by the partial or complete exhaustion of the cell.

Mechanical depolarization may be accomplished by producing a relative motion between the electrolyte and the plates. This method is not used in any practical cell. Physical depolarization may be accomplished in certain cases by roughening the electrode surfaces or by the electrode position of a loose mass of metal on the electrode, such as platinum black on a smooth positive platinum electrode. Hydrogen escapes more readily from such a surface.

The chemical method is used in all practical cells. It consists in reducing the hydrogen or metal liberated at the positive pole to a form which is readily soluable in the electrolyte. In the case of gravity cells, such as the Daniell, the copper positive plate is surrounded by copper sulphate. When the cell discharges, additional copper is deposited on the copper plate instead of hydrogen. In most cases the depolarizer is an oxidizing agent surrounding or incorporated in the positive plate. This reduces the amount of hydrogen formed.

With certain electrodes and electrolytes the action of a cell may cause the deposition of relatively insoluable or insulating substances on the electrode surface. The effect of this is to increase the internal resistance of the cell.

Creepage is the travel of electrolyte up the surface of electrodes or other parts of the cell above the level of the main body of the electrolyte.

E. The Dry Cell

The only "dry battery" in extensive commerical use is a modification of the Leclanche cell, in which the sal ammoniac solution is held by capillary action in a porous medium separating the zinc from the opposite electrode and in the pores of the carbon depolarizing electrode.

The entire cell is contained in a jacket or cylindrical Fig. 4 covering of insulating material, topped with sand and sealing compound, and closed at the bottom. Next comes the tube, also a cylindrical covering of insulating material but without closure at the bottom. Inside the tube is the cup or can, a metal container, usually zinc, in which the cell is assembled and which constitutes also its negative element. Some cells omit the jacket, others omit both jacket and tube. Next to the negative electrode is the electrolyte, either as a liner or as a paste. This consists of sal ammoniac and zinc chloride, the latter being added to diminish open circuit deterioration. Adjacent to the electrolyte is the depolarizing mix, a mixture containing a depolarizer and an electrically conducting material which together constitute the positive electrode. The depolarizier of a dry cell (crushed coke, graphite and manganese dioxide) is always a cathodic depolarizier which is adjacent to or part of the positive electrode. When the depolarizing mix is molded around a central rod of carbon or other conducting material, constituting the positive electrode, the whole assembly is referred to as a bobbin.

There are several types of construction:

1. Paper lined construction, a type in which a paper liner, wet with electrolyte, forms the principle medium between the negative electrode, usually zinc, and the depolarizing mix. A liner is the paper or cloth sheet placed between the depolarizing mix and the negative electrode to separate them physically or to protect the surface of the mix.

2. Bag type construction - a type in which a layer of paste forms the principle medium between the negative electrode and the depolarizing mix, the mix being contained in a muslin wrapper or bag. Paste consists of pulpboard, starch, or flour medium, sometimes in the form of a jelly, containing electrolyte, which lies adjacent to the negative electrode.

3. Non-lined construction - a type in which a layer of paste forms the only medium between the negative electrode and the depolarizing mix.

   The two most commonly used sizes of standard cylindrical dry cells are the #6 which is $2\frac{1}{2}$ inches in diameter, and six inches high, with a capacity of about 20 ampere hours, and the flashlight battery which is $1\frac{1}{4}$ inches in diameter and $2\frac{1}{4}$ inches high, with a capacity of about three ampere hours. The heavy-duty type for telephone and industrial service has a capacity of 50 to 60 ampere hours, respectively. The smallest dry cell is the type "N", 7/16 inches in diameter and 11/16 inches high.

Open circuit voltage of a new cell is about 1.6 volts, the minimum acceptable being 1.5 volts for cells one inch in diameter and over, although voltages of 1.47 to 1.49 are acceptable for smaller cells. When a dry cell has been discharged to the limit of its useful life, its voltage will have dropped to between 0.75 and 1.1 while delivering a normal current. End-voltages under load conditions, as measured with a high resistance voltmeter are as follows: industrial, #6, 0.85; general purpose #6, 0.93; telephone type #6, 1.08; flashlight cells, 0.75 to 0.90 hearing aid cells, 1.0 volt; radio cells, 1.0 to 1.1 volt per cell.

The average capacity of the standard #6 dry cell is twenty ampere hours (IH) or thirty watt hours (WH).

F. Storage Battery Types

Storage batteries are made of secondary cells which usually fall in one of the following classifications:

a. Lead plate cell - the lead plate cell such as commonly used in automobile batteries developes a working voltage of 2 volts and uses a sulphuric acid electrolyte.

b. Nickel-iron cell (Edison) - the nickel iron cell used in the Edison Battery developes a working voltage of 1.2 volts and uses an alkaline solution as the electrolyte.

c. Nickel-cadmium - the nickel cadmium cell also developes 1.2 volts and like the Edison cell it uses an alkaline electrolyte. This cell has been in use for many years outside the U.S.A. but it was not introduced in U.S.A. until after world war No. 2.

G. Battery Connections

1. Series connection Figs. 6, and 8)

"Series connection is the arrangement of cells in a battery by connecting the positive terminal of each cell to the negative terminal of the next adjacent cell, all cells being electrically in line so that their voltages are additive." (A.S.A. 60.11.110).

While the voltage adds in a series connection, the capacity or ampere hours remains the same as for one cell. The watt hours is the product of the watt hours of one cell multiplied by the number of cells in series.

2. Multiple (parallel) connection Figs. 7, and 9)

"Multiple connection is the arrangement of cells in a battery by connecting all positive terminals together and all negative terminals together, the voltage of the group being only that of one cell and the current drain through the battery being divided among the several cells." (A.S.A. 60.11.115).

While the voltage of a parallel or multiple connection remains the same as for one cell, the ampere hours are additive. The watt hours represent the product of the watt hours of one cell multiplied by the number of cells in multiple.

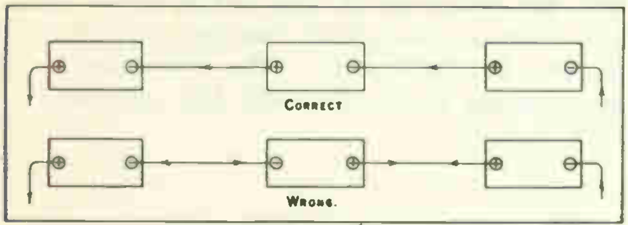


Fig. 6

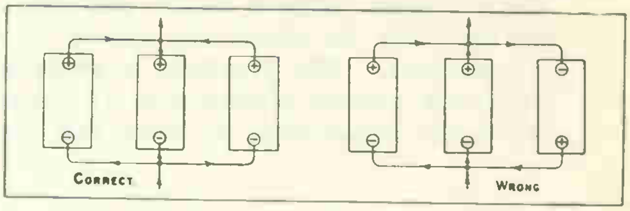


Fig. 7

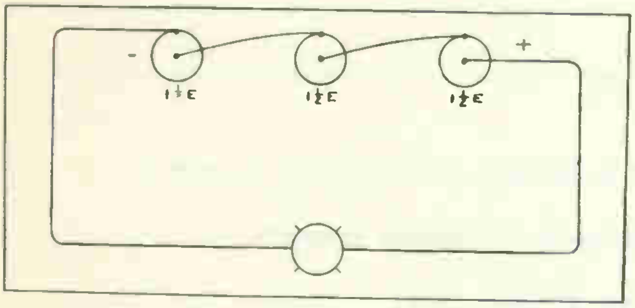


Fig. 8

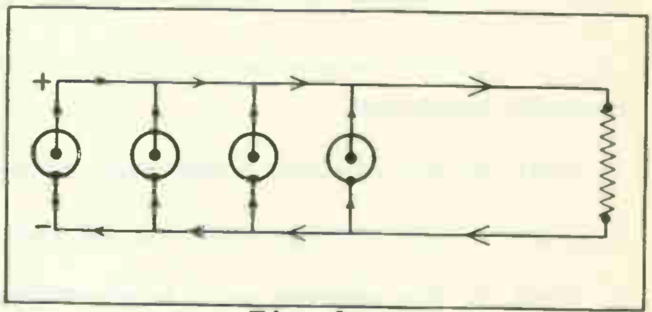


Fig. 9

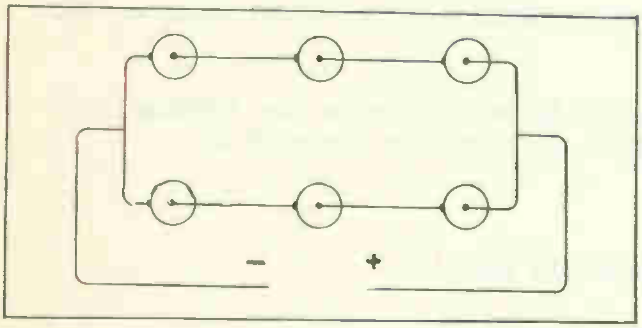


Fig. 10

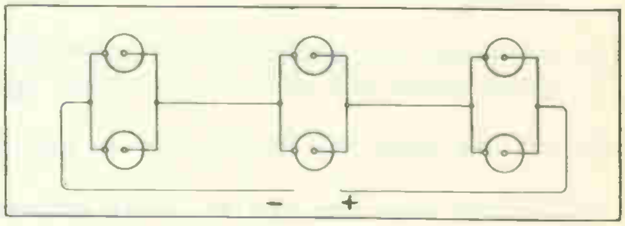


Fig. 11

3. Multiple series connection

"Multiple series connection is the arrangement of cells in a battery by connecting two or more series connected groups, each having the same number of cells, so that the positive terminals of all groups are connected together and the negative terminals are connected together in a corresponding manner." (A.S.A. 60.11.120) See Fig. 10.

The overall voltage is that of one of the series groups and the overall current is the sum of the current from the groups. The watt hours are found the same as in the other connection, by multiplying the watt hours of one cell by the number of cells in the entire battery.

4. Series multiple connection

This type of circuit is not defined by the American Standards Association except by inference, in which case it would be as represented in Fig. 11. According to present established practice, such a circuit is defined as "a series connection of a number of multiple circuits", i.e., a number of minor circuits in series.

The voltage and capacity of a series multiple connection is the same as for the recognized multiple series connection. For example, if twelve cells are connected three in series, four in parallel, to form a multiple series connection, the voltage, ampere hours and watt hours are the same as if the cells were connected four in parallel, three in series, to form a so-called "series multiple" connection. The physical arrangement, however, is different. The standard multiple series connection is preferred for storage batteries and the series multiple connection is best for dry cells.

H. Summary Questions.

1. What is the minimum acceptable voltage of a #6 dry cell on open circuit?

2. What is the average capacity of the #6 dry cell in ampere hours?

3. What is the average watt hour rating of the #6 dry cell?

4. What is the American Standards Association's definition for a multiple series connection?

5. Show how you would connect five #6 dry cells in series; show the voltage, ampere hours and watt hours which would result from such a connection.

6. Do the same for five cells in multiple.

7. Do the same for twelve cells connected multiple series.

8. Do the same for twelve cells connected series multiple.

99. Do the same for six cells connected series multiple.

10. Do the same for six cells connected multiple series.

TELEPHONE PRINCIPLES

Objective: To study the basic principles of sound as related to telephony; to learn parts used in the telephone, their function, and connections.

References:

Lesson Content

A. Definition

A telephone is an instrument used for the transmission of articulate sound or speech by means of an electric current.

B. Development

In its broadest sense, "telephony" or "sound at a distance" began with primitive drum beats and the like, while the broader term, "telecommunication", probably began even earlier with smoke signals or crude relay arrangements. A limitation on the term was introduced by Alexander Graham Bell, when he defined the instrument which he patented as one which makes use of an electric current. In this sense, the history of the telephone might be outlined as follows:

1876 - First sentence was transmitted
1878 - First telephone excnange established
1880 - 50,000 telephones in use
1938 - 20,000,000 telephones in use
1948 - 100,000,000 telephones in use

C. Basic Principles of Sound

1. Importance

A thorough knowledge of sound and its characteristics is important in order to fully understand the principles upon which the telephone is built and operated.

2. What is sound?

a. Sound is a form of energy consisting of alternate rarefactions and compressions (condensations) of air.

b. Sound is produced by a vibrating body.

c. Sonic waves are caused by a vibrating medium (matter). There are three classes of sound waves:

Vibrating air column (whistles), vibrating surfaces (drum-heads) and vibrating strings (violin strings). Refer to Fig. 2.

3. Transmission of sound

Sound energy is transmitted through an elastic medium by a Longitudinal wave. The medium may be solid, a liquid, or a gas, but sound will not pass through a vacuum.

4. Speed of sound

   a. In air at zero degrees Centigrade, the velocity of sound energy is 1087 feet per second.

   b. In water the velocity is about four times as great, about 4770 feet per second for fresh water at zero degrees Centigrade.

   c. In steel the speed of sound is about sixteen times as much as in air.

   d. In air a change of one degree Centigrade causes a two-foot-per-second change in velocity, so the speed of sound in air at twenty degrees Centigrade is 1087 plus 40 or 1127 feet per second.

   e. In water, a change of one degree Centigrade causes a nine foot per second change in velocity.

   NOTE: Compare the speed of sound with that of electricity, which is about 186,000 miles per second.

5. Frequency

   The frequency of a sound wave is determined by the vibration rate at which the rarefactions and compressions of the wave occur. If these appear more often per unit of time, the frequency of the wave is increased.

   The longitudinal wave produces an audible effect on the human ear drum known as "sound" for frequencies from 16 cycles per second to 15,000 cycles per second. Frequencies above the audible limit are considered supersonic waves.

6. Noise and music,

   Bodies that vibrate at a regular rate (at a definite frequency) produce musical tones. Bodies that do not vibrate at a regular rate produce noises. Musical tones have these characteristics, loudness, pitch and quality.

7. Amplitude (volume or loudness)

   Any change in the amount of energy causing the wave motion changes the amplitude or volume but does not affect any other characteristics of the wave form. The intensity of a sound depends upon the amplitude of the waves. The intesity of a sound wave diminishes inversely as the square of the distance.

8. Pitch

   By pitch we mean the lowness or highness of a musical tone. When the frequency is increased, the pitch of the audible wave is higher, and when the frequency is decreased, the pitch is lower. Since the velocity will remain constant provided the characteristics of the transmitting medium are unchanged, any increase in frequency results in a corresponding decrease in wave-length.

9. Quality (harmonic content)

   Sounds differ in quality or timber, depending upon their complexity of vibration. Tones produced in addition to the main or fundamental tone are called harmonic or overtones and the ear hears a combination of these as well as the fundamental. Quality is determined by the number and intensity of the overtones present. See Fig. 4.

D. Kinds of Current Found in the Telephone, Fig. 3.

1. Direct current, constant in direction and value (amplitude).

2. Pulsating direct current (PDC), constant in direction, but constantly changing in value.

3. Alternating current, constantly changing in value and changing in direction at certain regularly stated intervals of time.

E. Principle Parts of the Telephone

1. Transmitter (carbon microphone)

   Purpose - to change sound energy into electrical energy, thereby producing PDC in the transmitter circuit.

   Operation - Fig. 1 shows how the equipment and connections for one telephone connection can be made to another telephone through the points indicated as "line 1" and "line 2". The transmitter button is everything enclosed in the brass cup. Sound or voice waves, passing through the mouthpiece, strike the aluminum diaphragm, and cause it to vibrate. These vibrations move the front of the transmitter button in and out, thereby, tightening and loosening the carbon granules. This decreases and increases the resistance of the transmitter circuit, thus affecting the value of the current through the primary side of the induction coil.

   Notice that there is nothing magnetic about the operation of the transmitter. It operates on the principle of variable resistance.

2. Induction coil (transformer).

   The purpose of the induction coil is to change PDC into AC and step up the voltage for transmission at higher efficiency.

   The operation, Fig. 1, is the effect of the change in rate of current in the primary which induces an alternating voltage in the secondary, and causes current to flow first in one direction then in the other, through the receiver circuit.

The induction coil operates on the principle of induction.

3. The receiver

The purpose of the receiver is to change electrical energy into sound energy.

Operation of a receiver, Fig. 1, - the alternating current in the electromagnet varies the strength of the permanent magnets and causes the iron diaphragm to vibrate. These vibrations of the receiver diaphragm are a reproduction of those impressed on the transmitter diaphragm.

The receiver operates on the magnetic effect of current. It demonstrates the application of three artificial magnets, the permanent magnet, the temporary magnet, and the electro-magnet.

4. The hook switch

Purpose - the purpose of the hook switch is to make and break the transmitter and receiver circuits, thereby effectively preventing drain on the battery when the telephone is not in use.

The operation - Fig. 1 shows the conditions as they exist when the receiver is off the hook. Ordinarily the receiver hook switch, when on the hook, keeps the receiver and transmitter circuits open.

5. The bell (ringer)

The purpose of the bell is to deliver an audible alarm or signal.

Operation - the polarized bell, Fig. 5, is the device commonly used in connection with the telephone to sound an audible alarm when calling. It requires a source of energy separate from the transmitter circuit and receiver circuit. The north pole of the permanent magnet induces the consequent poles "S" and "S" in the soft iron bar, thereby making the main poles both north poles. The iron bar is pivoted in the center. This permits its ends to move up and down when attracted and repelled, which occurs when a-c of a low frequency changes the polarities of the electro-magnets. By tracing the circuits for each alternation separately, it will be seen that the right-hand rule for electro-magnets applies here, as well as the first law of magnetism. Fig. 6 shows another type of polarized bell. These bells have high resistance so that they operate on low current at high voltage. Such a source of energy is found in the hand-operated magneto.

6. The magneto

Purpose - the magneto is used on long-line local battery telephones to energize a bell which calls another party or the operator.

Operation - Fig. 7 shows a sketch of a magneto. The armature is rotated between the poles of a compound magnet which supplies the field flux. The armature is revolved quite rapidly by means of a large gear on the hand crank shaft and small pinion on the armature shaft, produces alternating current usually from about 80 to 100 volts and at a frequency of about 20 cycles.

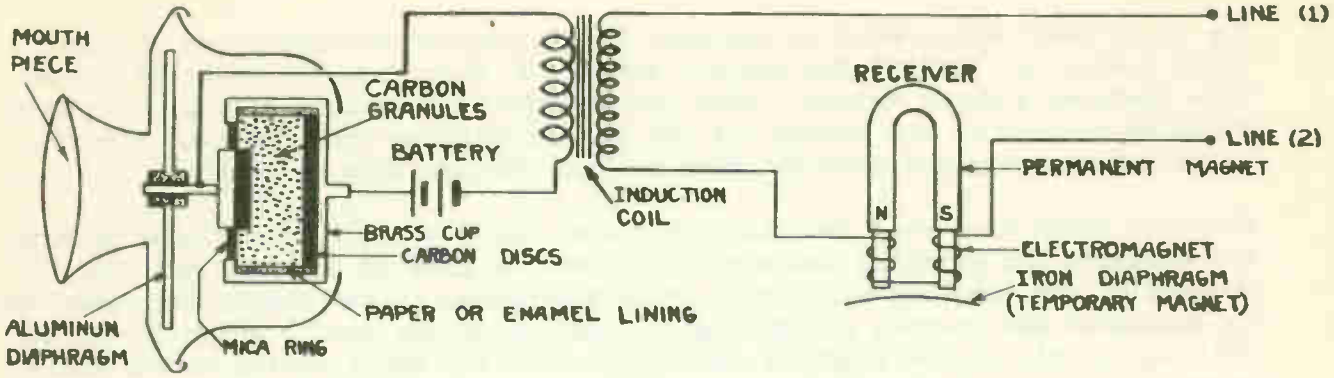


Fig. 1

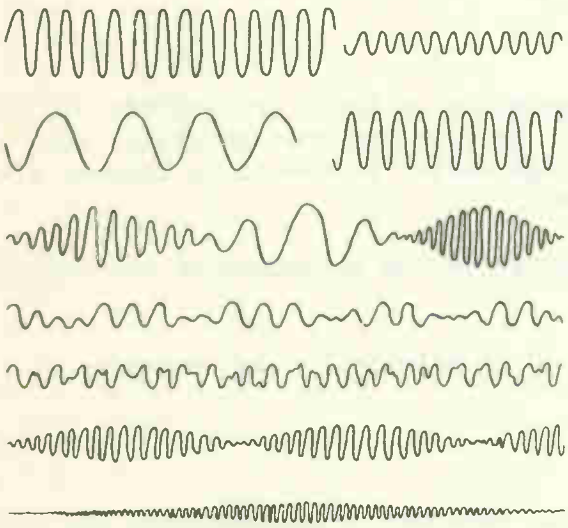


Fig. 2

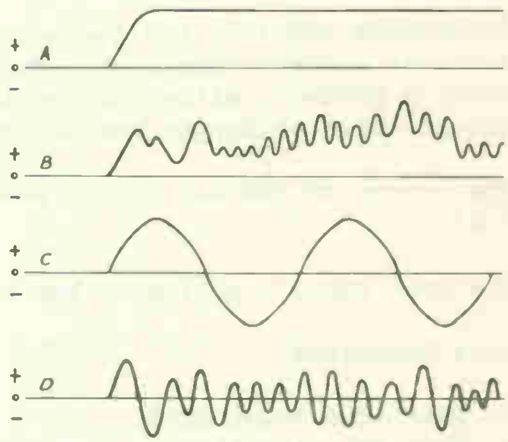


Fig. 3.

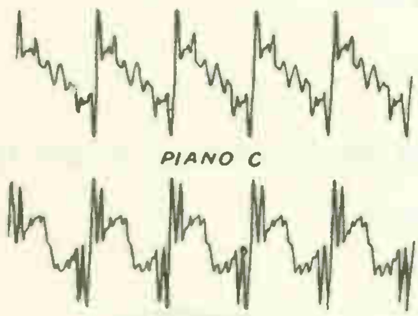


Fig. 4

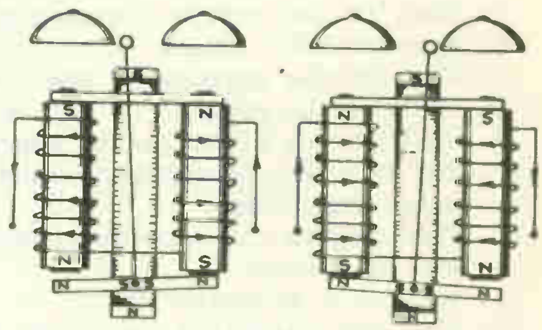


Fig. 5

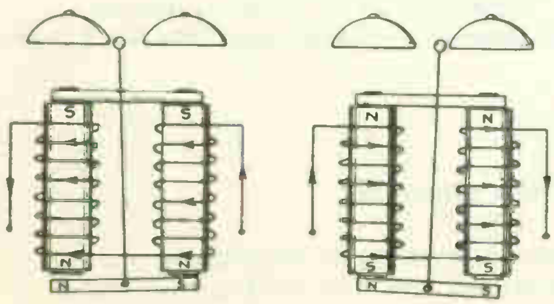


Fig. 6

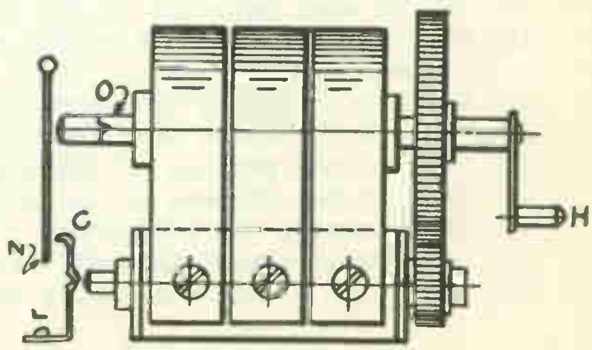


Fig. 7

The crank shaft shown at O is equipped with a slotted extension and spring which pushes out against the contact spring, N, each time the crank is turned. This operates a shunt switch. When the magneto is idle this spring falls back, touching contact C, and shunts out the magneto winding from the line circuit, so the ringing current does not have to pass through this resistance.

When the crank is turned the shaft is forced out a small distance thus opening the contacts and allowing the magneto current to flow to the line and bells. One end of the armature winding is usually grounded to the shaft; the other end is insulated and carried out through the center of the shaft, which is hollow. This end or tip of the shaft is in contact with the small spring as the shaft rotates.

7. Current supply, DC, PDC, and AC.

Telephones require, for the successful operation of their transmitter cicuits, a direct current supply of a very smooth or constant voltage value. This is usually a battery, either dry cells or storage cells, lead-acid or Edison, although large exchanges use d-c generators.

The source of the a-c in the receiver circuit is the secondary of the induction coil.

The bell circuit employs a low frequency AC of relatively high voltage.

F. Summary Questions

1. What is a telephone?
2. What two circuits are completed when the receiver is removed from the hook?
3. What kinds of current do we find in a telephone system?
4. What is an induction coil? Explain its action and purpose.
5. What is the carbon button and where is it found?
6. What is PDC? Where is it found? When?
7. What is the purpose of the transmitter?
8. What is the purpose of the receiver?
9. What is the first law of magnetism?
10. The receiver demonstrates the application of three types of artificial magnets; name them.
11. What causes the receiver diaphragm to vibrate?
12. What is sound?
13. What is a polarized bell?
14. Does the polarized bell have high resistance or low resistance?
15. Is the polarized bell dependent in any way on the direction of current?
16. What are the two windings of an induction coil called?
17. Out of what material is the core of the induction coil usually made?
18. Why is the mouthpiece of the transmitter made cup-shaped and why is it usually made of bakelite?
19. What is the speed of sound waves?
20. What is the speed of electricity?
21. What is the purpose of the magneto?
22. What is the purpose of the diaphragm in the receiver?
23. Who invented the telephone?
24. Does sound travel through a vacuum? Does light travel through a vacuum?
25. What kind of current supply is always required for the talking circuit?

TELEPHONE LINES AND CIRCUITS

Objective

To study telephone lines, both metallic and grounded, the local battery and central energy types of telephone circuit, and transpositions.

References

Lesson Content

A. Types of Telephone Systems

Local battery, energy source for the transmitter, located within or near the telephone. Used mostly in rural districts and in emergency systems. See Fig. 1.

Central energy or common battery, all the telephones in a district are connected to one common battery as the energy source for the transmitter circuit. Used for city telephone service. See Fig. 2.

B. Telephone Line Systems

Metallic line, uses two lines for connections to telephones or from telephones to switchboards.

Grounded line, uses one metallic line and uses the earth itself as a common return. Sometimes called non-metallic system.

C. Transpositions

Transpositions are made in metallic systems by crossing the line wires.

The purpose of transpositions is to balance or trap the induced voltages caused by lines running parallel to other telephone or power lines.

Transpositions are used to prevent noises and cross-talk from interrupting and interferring with telephone conversation.

Transpositions are usually spaced not more than 1300 feet apart.

D. Explanation of Local Battery Type Telephone - Silent Ringing

Observe that when the receiver is off the hook, as shown in Fig. 1, all of the contacts on the hook switch (at A) are closed, thus completing both the receiver circuits to the line and the transmitter circuit.

Hang the receiver back on the hook. Notice that all of the contacts open, thereby breaking receiver and transmitter circuits. This type of telephone is called silent ringing because, by turning the crank on the magneto to call out, the bell is shunted and does not ring.

The reason for this can be clearly seen when turning the crank. The mechanical arrangement of the shaft moves the moving contact of the double-circuit switch, on the end of the magneto, away from the closed contact over against the open contact.

This type of telephone can be used on a grounded line by connecting line 2 to the earth and line 1 to a wire extending to the other telephone. It can also be used on metallic line by connecting one wire of the line to line 1 and the other to line 2.

It should be noted that the pulsations in the battery circuit produced by operation of the transmitter, result in alternating voltages being induced in the secondary winding of the transformer and that these a-c voltages force AC through the line thereby, which operates the receiver at the other end.

The magneto shown is also an alternating current device. This explains the need for using a polarized bell on this unit, since positive ringing cannot be satisfactorily obtained on a bell of the ordinary type when it is operated from an alternating current source.

E. Central Energy Type Telephone

The purpose of the condenser in the central energy telephone is to prevent the DC of the transmitter circuit from flowing through the receiver circuit, but still permitting the a-c for ringing.

When ringing is done from a central source the magneto will not be necessary. Instead of connecting the polarized bell to the moving contact, connect it direct to line 1 and eliminate the connection from the receiver to the open contact on the magneto.

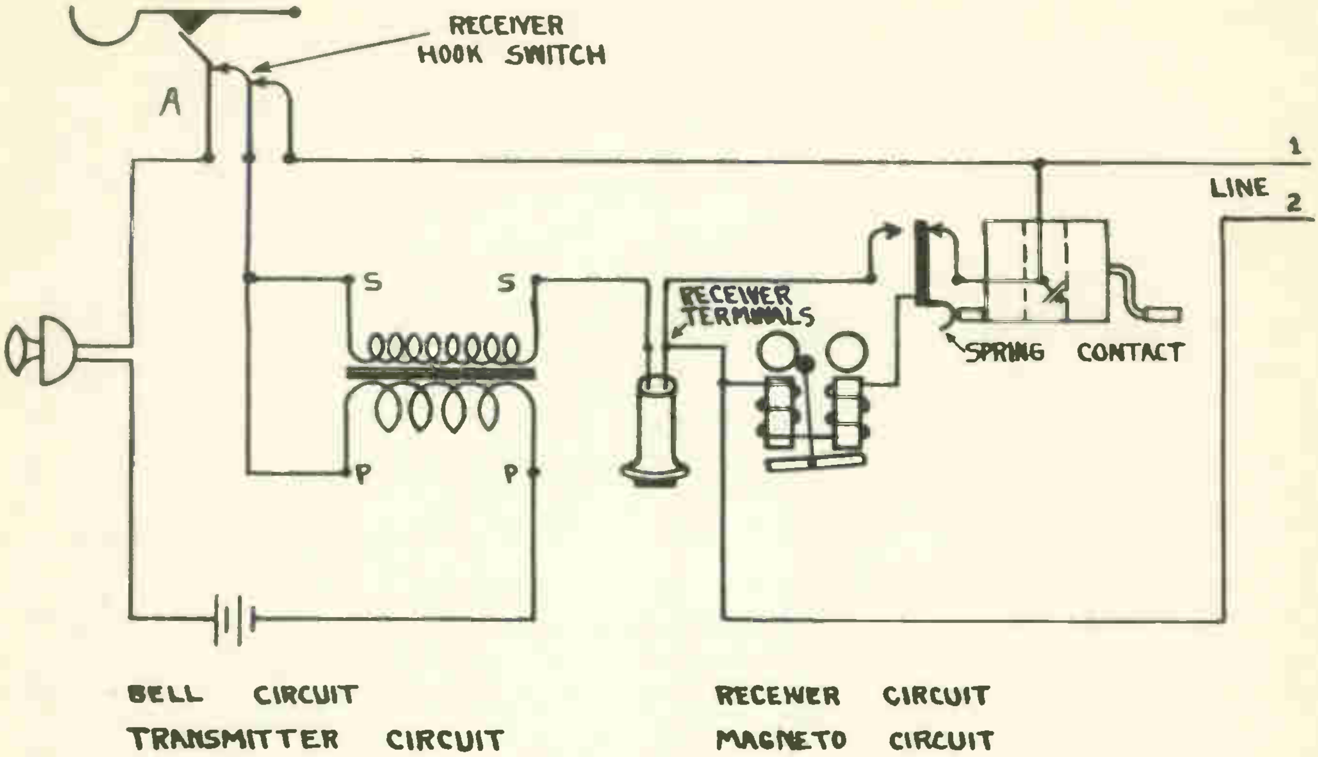


Fig. 1 Local battery type telephone - silent ringing.

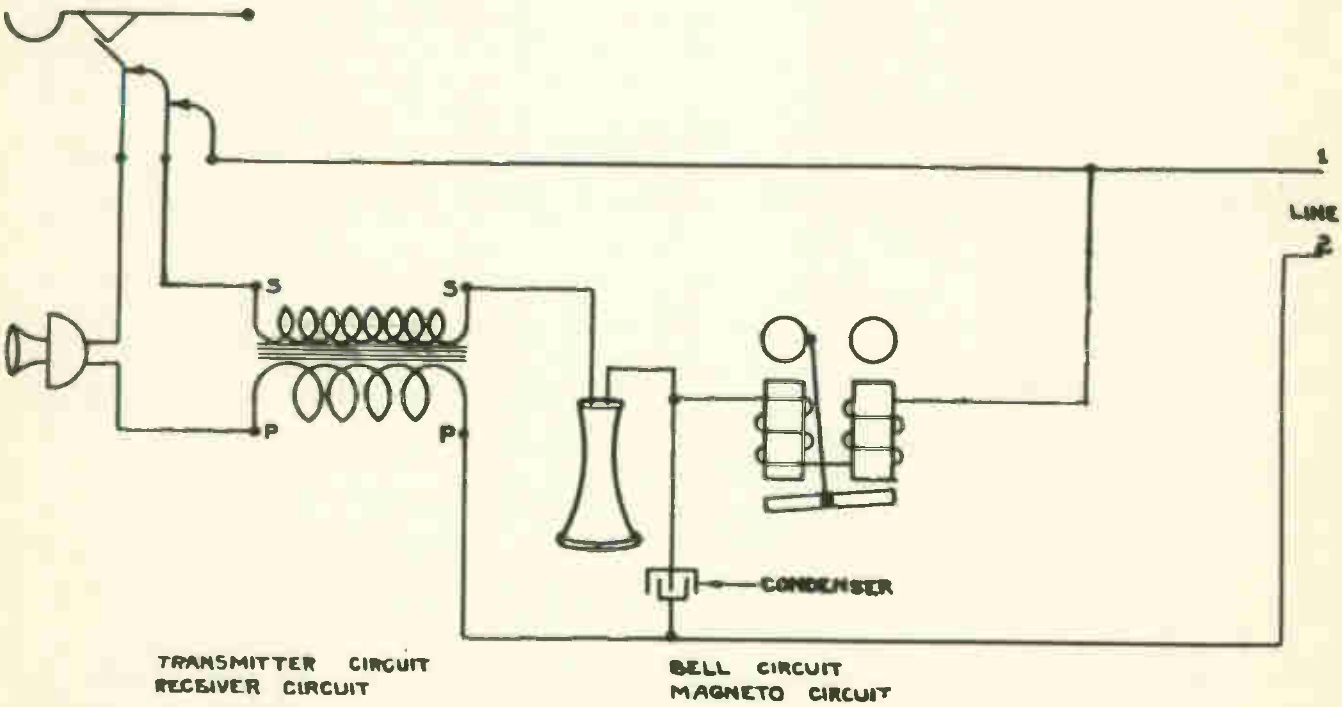


Fig. 2 Central energy type telephone

M E T E R S

Objective

To study the construction, operation, and use of meters.

References

____

____

Lesson Content

A. General

1. Definition and purpose

The term "meter" is used in a general sense to designate any type of measuring device including all types of electric measuring instruments. An instrument is a device for measuring the present value of the quantity under observations - - American Standards Association, 30.20.005.

By using the proper meter it is possible to measure the amount of current the voltage, the resistance, or the power being used in any circuit.

2. Classification by operation, function, result, or use.

Operation - Electrodynamic, electrostatic, induction, rectifier, electronic (Thermionic), permanent-magnet moving iron, permanent-magnet moving coil (d'Asonval), moving-iron, electrothermic.

NOTE: Electrothermic may be either expansion (such as the "hot-wire" or "Hot strip") or the thermocouple (either direct or indirect).

Moving-iron is further subdivided into plunger, vane, repulsion, attraction, and repulsion-attraction.

Function - Watt-hour, ampere-hour, coulometer (voltmeter), demand meter, etc.

Result - Indicating or recording

Use - Galvanometer, ohmmeter, voltmeter, wattmeter, electrometer, faradmeter, frequency meter, magnetometer, permeameter, oscillograph, phase meter, power factor meter, flux meter, telemeter, etc.

B. Direct-current Meters

1. Galvanometer, Fig. 1.

The permanent-magnet moving-coil galvanometer (formerly called the d'Arsonval galvanometer) is the basis of most d-c meters. It has a movable coil of wire wrapped on an aluminum form and placed between the poles of a permanent magnet.

This unit is similar to a motor, but instead of rotating 360 degrees, it is held in position by two coil springs, which are free to rotate a limited distance on jewel bearings, around a soft iron cylinder.

When current exists in the coil the coil acquires a magnetic polarity and turns against the spring, trying to line up its poles with the opposite poles of the permanent magnet. The greater the current, the greater will be the deflection, and if the current is reversed, the coil will turn in the opposite direction. A pointer attached to the coil will indicate on a zero-center scale, the amount and direction of current.

Eddy currents, induced in the aluminum form, will act as a brake to "dampen" the movement without affecting its accuracy.

2. Voltmeter, Fig. 2.

Voltmeters are used for measuring volts and should always be connected in parallel with the device being tested.

The permanent-magnet moving-coil d-c voltmeter (d'Arsonval) is a galvanometer having its terminals marked positive and negative so the current is applied in one direction only, the pointer also being made to swing in only one direction the springs acting against the rotation and returning the moving coil and pointer to stop at zero. The dial is marked in volts, the range being secured by means of a multiplier resistor connected in series with the moving coil.

For example, the moving coil of a typical d-c voltmeter has a resistance of 5 ohms and requires a current of 0.01 ampere (10 millamperes) for full-scale deflection. What must be the value of the resistor if the meter is to measure 150 volts?

This is found by Ohm's Law:

$$E = I \times R = 0.01 \times 5 = 0.05 \text{ volt or } 50 \text{ millivolts};$$

To measure 150 volts, we use Ohm's Law again,

$$R = \frac{E}{I} = \frac{150}{.01} = 15{,}000 \text{ ohms (total)}$$

From this we must subtract the resistance of the meter.

$$R \text{ multiplier} = R \text{ total} - R \text{ meter}$$
$$= 15{,}000 - 5 = 14{,}995 \text{ ohms}$$

3. Ammeter, Fig. 3.

An ammeter is used to measure current and should always be connected in series in the circuit. The d-c ammeter is really a voltmeter with its dial marked in amperes. It shows the drop in voltage across a low resistance when current is passing through the resistance. This resistance is called a shunt and the range of an ammeter can be changed by changing the value of the shunt.

For example, to extend the range of the galvanometer-voltmeter previously described, the voltmeter showing a drop of .05 volt on full-scale deflection (0.01 amp) the value of the shunt needed to extend the range to read 1000 amperes is found as follows:

$$Rs = \frac{Es}{Is} = \frac{.05}{1000} = 0.00005 \text{ ohm}$$

This is close enough for practical purposes, Ohm's Law being applied only to the shunt, since it carries almost all the current. An exact answer can be had however, by subtracting the current in the meter (.01 amp) from 1,000 amperes. This results in a value of 0.000050005 ohm for the shunt!

4. Voltammeter

Some meters have a switch which will either connect a shunt in parallel with the moving coil to measure amperes or to connect a resistor in series with the moving coil to measure volts. These are known as voltammeters and can measure volts or amperes in a great number of steps or ranges.

5. Ohmmeter, Fig. 4.

A direct-reading ohmmeter is used for measuring resistance and it should always be connected directly across the resistance being measured with all power disconnected.

The ohmmeter consists of a milliammeter and a low voltage d-c power supply, usually a battery of known voltage, connected in series, the resistance being connected across the terminals. The battery is usually contained in the meter case (shown by dotted lines). The dial is marked in ohms.

The higher the resistance, under test the lower the current that will flow through it and the lower the meter reading will be. A low resistance, on the other hand, will allow a high current to pass and result in a high meter reading. "Zero ohms" is consequently found on the extreme RIGHT of the meter scale.

6. Watt-hour meter

A watt-hour meter is used to measure electrical energy. It operates like a small motor. The armature is connected across the line in series with a high resistance, like a voltmeter, to measure voltage, and the field coils are connected in series with the line, like an ammeter, to measure the current.

The voltage across the armature and the current in the field coils, together give the same effect as multiplying volts times amperes, which gives watts. The higher the voltage or current, the faster the armature rotates and the higher the wattage that is used.

To dampen the armature speed, an aluminum disc is attached to it, and made to revolve between two permanent magnets. The eddy currents induced in the disc by the permanent magnet increase with increasing speed and results in a dragging effect. The rotating shaft is connected by gears to the registering mechanism, which shows the energy used, usually in kilowatt-hours.

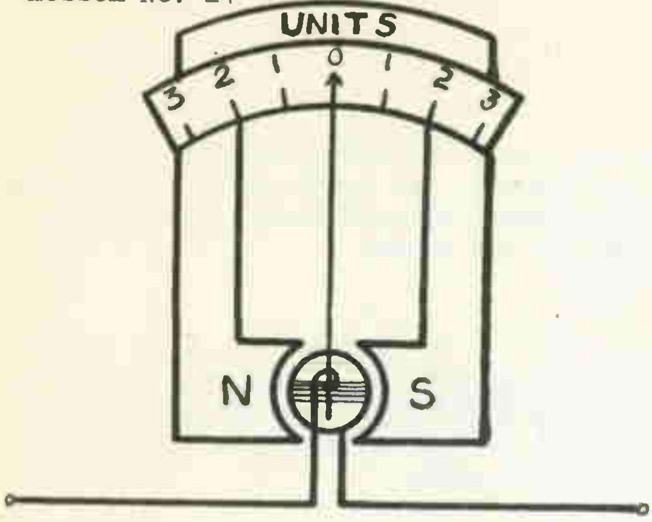


Fig. 1 Moving Coil d'Arsonval Galvanometer

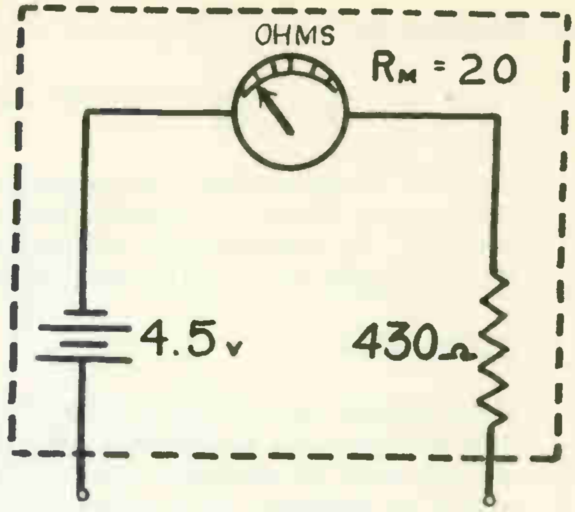


Fig. 4 Basic Ohmmeter Circuits

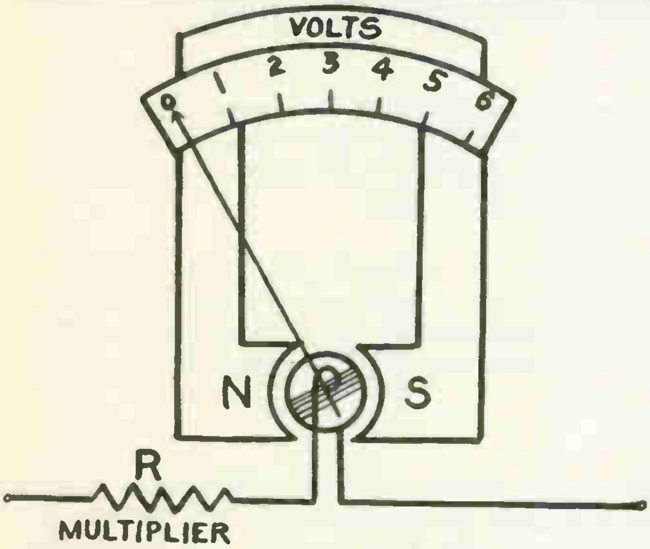


Fig. 2 D-c Voltmeter

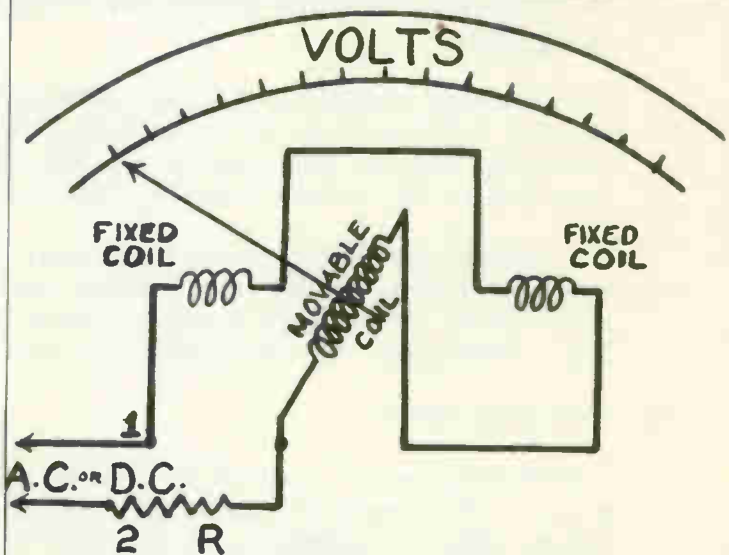


Fig. 5 - Dynamometer type voltmeter

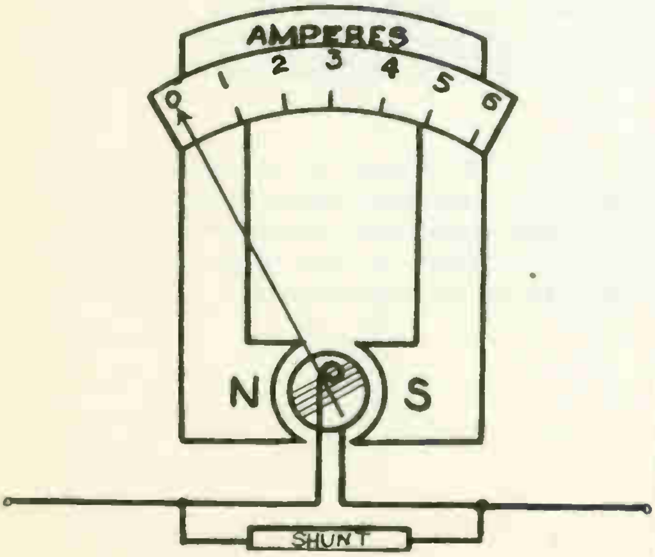


Fig. 3 D-c ammeter

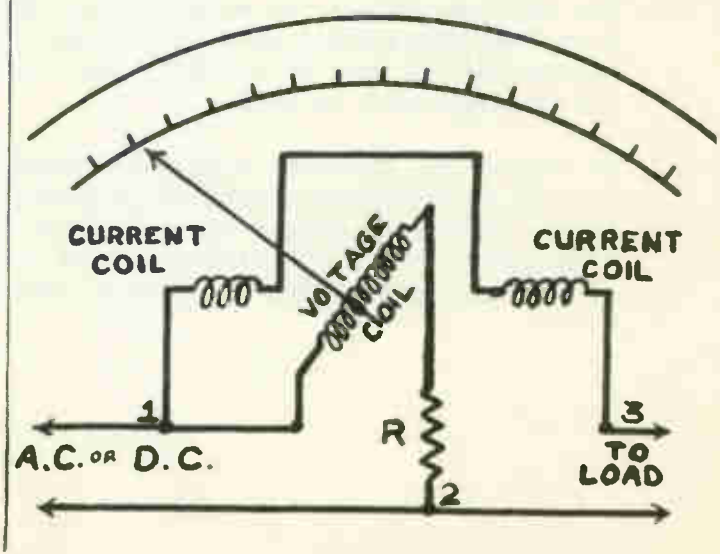


Fig. 6 Dynamometer type wattmeter.

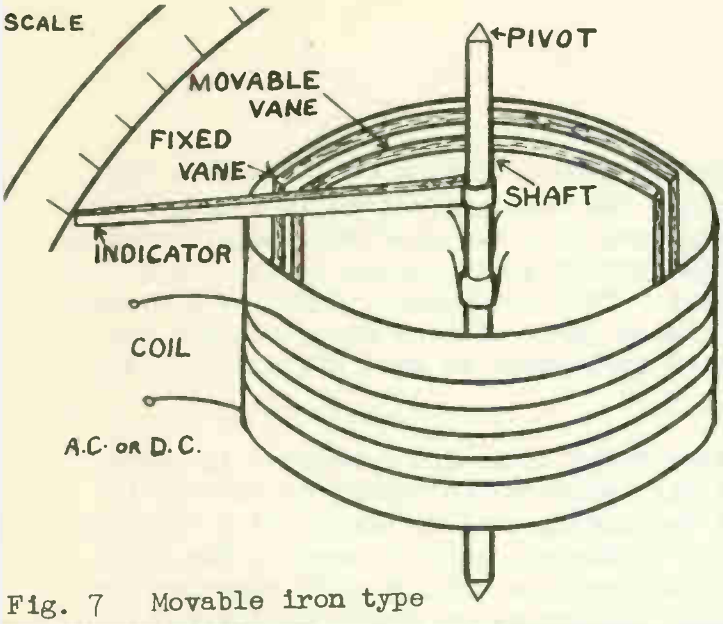


Fig. 7 Movable iron type

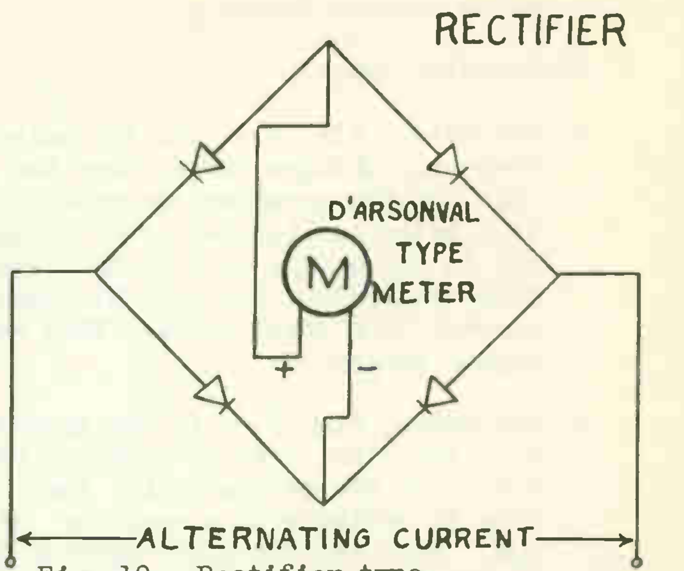


Fig. 10. Rectifier type

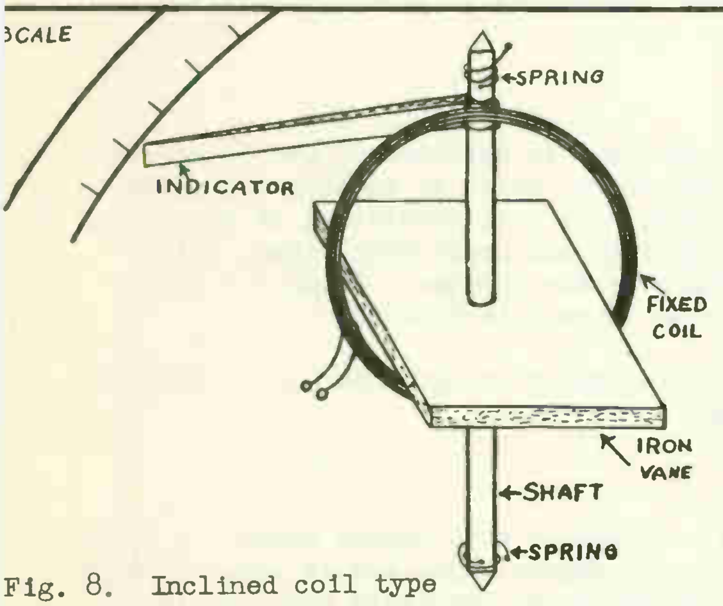


Fig. 8. Inclined coil type

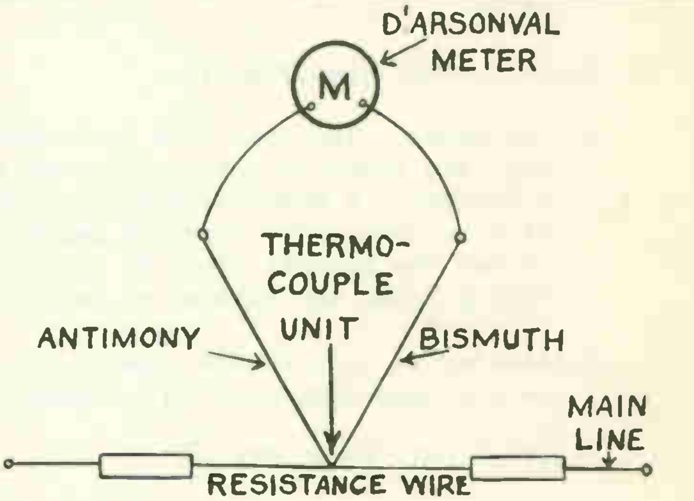


Fig. 11. Electrothermal type

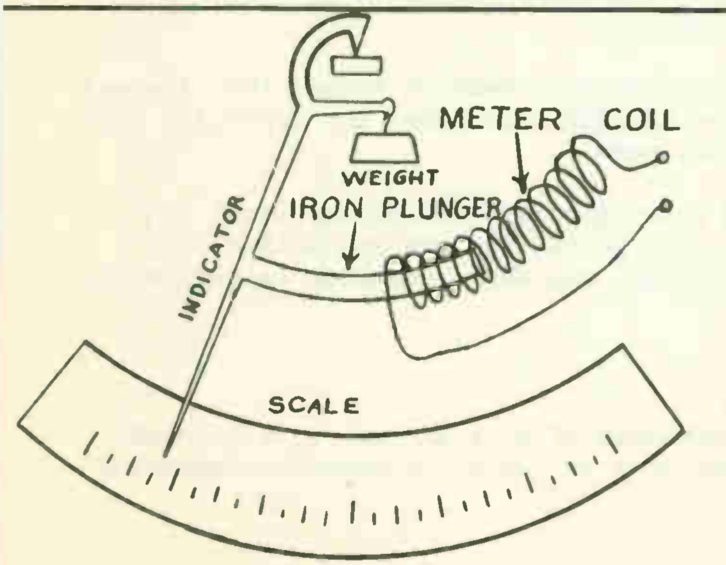


Fig. 9. Plunger type

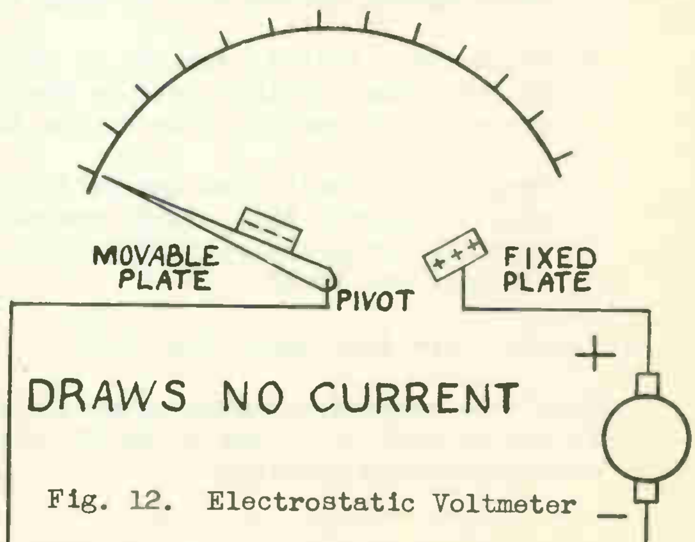


Fig. 12. Electrostatic Voltmeter

C. Alternating Current Meters

1. Dynamometer types

a. Voltmeter, Fig. 5 -- The d-c galvanometer cannot be used on AC because the frequency changes faster than the needle can move, resulting in a zero reading. If the permanent magnets are replaced with two electromagnets, however, this meter can be used on AC since the current would change in the field coils and in the moving coil at the same time. This instrument, known as a dynamometer voltmeter, has coil windings of many turns of fine wire to limit the current to a small value. This type of instrument is most efficient in the higher ranges.

b. Wattmeter, Fig. 6 -- if the dynamometer field coils are connected in series with the line, like an ammeter, they will measure the amount of current by acting on the moving coil. Then, if the moving coil is connected across the line in series with a resistor, like a voltmeter, it will measure the voltage. That is, the field current and the armature voltage will together turn the moving coil and pointer to indicate instantaneous power, calibrated in watts.

2. Movable iron type, Fig. 7.

a. Voltmeter - Two iron bars or "vanes" are used in this meter. One is stationary; the other is attached to the meter shaft, which is in turn connected to a pointer. A magnetic field is furnished by a coil consisting of many turns of fine wire. The bars are magnetized alike and repel each other, which causes the movable piece to rotate and move the pointer. A small spiral spring holds the pointer at zero when no current is flowing.

b. Ammeter -- this is the same as the a-c voltmeter except that its winding may be a single loop made of a copper bar.

3. Inclined coil type, Fig. 8.

a. Ammeter - this type has a stationary coil set at a 45 degree angle. A light iron vane is also set on the shaft at a 45 degree angle and it tries to turn so it is parallel to the lines of force set up by the field coil, while a small spiral spring acts to keep it back.

b. Voltmeter - this is similar to the inclined coil ammeter except that instead of iron vane, another coil is used, wound with fine wire, the two coils being connected in series. The action is the same.

c. Damping - a small aluminum paddle is sometimes fastened to the shaft and made to operate in a closed chamber. The paddle resists any motion, and tends to bring the pointer to rest quickly, thereby preventing it from swinging back and forth.

4. Plunger type iron vane, Fig. 9.

This is a variation depending on the attraction of an iron core by a solenoid. It can be used on either AC or DC, either as a voltmeter or ammeter, depending on the solenoid winding.

5. Rectifier Types, Fig. 10

   a. Copper oxide - this type of meter permits measurement of alternating current or voltage with a d-c meter. It employs a small copper-oxide full-wave rectifier to change the AC to DC. The current flows from the oxide to the copper but not from the copper to the oxide.

   b. Electrothermal, Fig. 11 -- another way to change AC to DC so that a d-c meter can be used is by electrothermal action. The effect of either a-c or d-c current in the resistance wire heats the junction of the two unlike elements (thermo-couple).

6. Electrostatic voltmeter, Fig. 12.

   This type of voltmeter actually draws no current, its operating depends upon the force existing between two charged bodies. When hooked across a source of supply one of the plates becomes charged positively, the other negatively. The attractive force between these charged bodies causes the plates to be pulled toward each other, the deflection being balanced by the tension of a spring. The higher the voltage, the greater the deflection.

D. Precautions

1. Use the right kind of meter.

2. Use the right range.

3. Use the right connections.

4. Use meters away from electrical disturbances.

E. Summary Problem

1. Given a 28-ohm 1 ma. meter movement, what size shunt must be used to make this meter read 0 to 25 amperes?

EDISON THREE WIRE SYSTEMS

Objective

To learn more about three wire systems and to learn advantages in the use of this type of a system.

References

____

____

Lesson Content

A. Definition

The Edison 3-wire system may be used with equal success in AC or DC, but sometimes the name is a bit confusing. The original EDISON 3-wire system was DC; present Edison 3-wire systems may be either AC or DC (See Fig. 1A and 1B)

B. Wire Saving Advantage

The Edison three wire system permits a saving of over 50% in copper and it has the advantage of two different voltages.

Example:

A load of 12000 W. at 120 Volts - Distance 1000', Fig. 2A.

$$I = \frac{12000\ W}{120E} = 100 \text{ amps.}$$

#1 Wire Cap. 100 amps.
253 lbs. per 1000'
253 x 2 = 506 total lbs. copper

In Fig. 2B the 12000 watt load has been connected in a 3-wire circuit.

$$I = \frac{6000W}{120E} = 50 \text{ amps.}$$

$$\text{or} \quad I = \frac{12000}{240} = 50 \text{ amps.}$$

#6 Wire Cap. 50 amps.
79.5 lbs per 1000'

79.5 x 3 = 238.5 lb copper
506 - 238.5 = 267.5 lb copper saved.

C. Polarization.

Polarization of a wiring system refers to the identification and marking of the neutral wire from the time it leaves the source, which is the generator in DC or the transformer in AC, throughout its entire course to the wiring device.

Identification, so important in Edison 3-wire work, is accomplished by the following rules of better wiring practice set up by the N.E.C. art. 200.

"Polarity Identifcation of Systems and Circuits" summarized as:

1. Dark colors are used for hot or ungrounded wires and should not be used for a neutral or grounded wire.
2. Light colors are used for insulation coloring for the neutral or grounded wires. Conductor is usually white in color.
3. Fixture or socket terminals are identified by using brass or dark screws for hot and white metal screws for neutral.

Some advantages of the above method of identification are:

1. It does away with fusing the neutral wire.
(To understand this statement it might be well to review balanced and unbalanced systems).

2. Example of a balanced load on a perfectly balanced three wire system each of the outside wires carry the total load - neutral wire nothing, Fig.1B

3. Example of an unbalanced load, in a three wire system when the load is unbalanced, one of the outside wires will carry the total load. The remaining two wires, one of which is the neutral, will carry the total load divded between them and the division may or may not be equal. Fig. 3

4. Unbalanced load and open neutral - Fig. 4 is an unbalanced three wire system, When the neutral wire breaks, the lightly loaded side will receive too much voltage causing damage or burn out to the appliance due to surge current.

Resistance of each lamp = 100 ohms

$\frac{100}{4} = 25\,\Omega$ resistance in lower section

$\frac{100}{4} = 50\,\Omega$ resistance in upper section

$25+50 = 75\ R_t$ (Total resistance).

$I = \frac{E}{R} = \frac{220}{75} = 2.93\ I_t$ (Total amperes)

$E = IxR - 2.93 \times 25 = 73\,v$ and $2.93 \times 50 = 147\,v$

73+ 147 = 220 volts across entire load.

5. Polarization tends to encourage the use of the Edison 3-wire system. The three wire system can be used for power and lighting loads where the same must be had from one service, such as residences of one or two stories, small business establishments, etc.

6. Polarization does away with the insulating of the individual fixtures, Fig. 6.

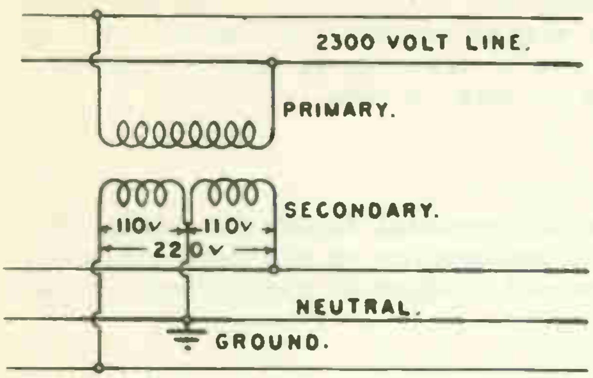


Fig. 1A a 3-wire AC system

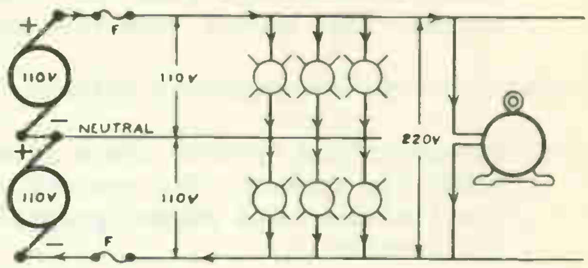


Fig 1B A 3-wire DC system

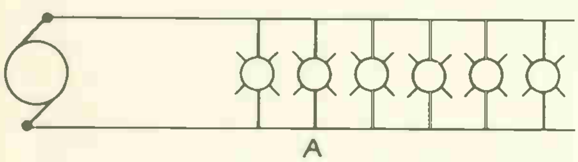


Fig. 2A Six lamps connected to a 2-wire system

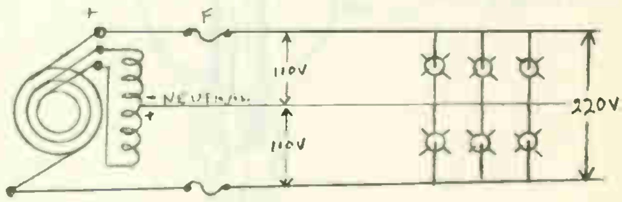


Fig. 2B Six lamps connected to a 3-wire system using a balance coil.

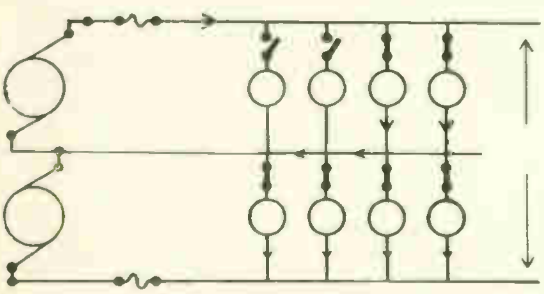


Fig. 3 an unbalanced 3-wire system with a solid neutral.

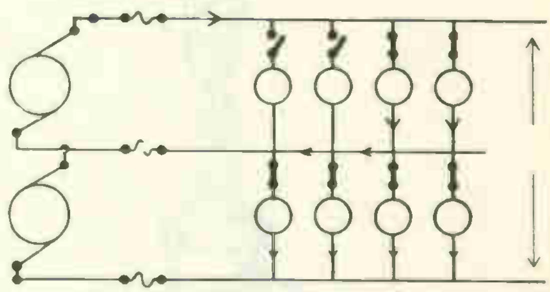


Fig. 4 An unbalanced 3-wire system with an open neutral.

a) It is only possible to insulate the canopy and fixture stem from the outlet box. So should a ground occur there is a good possibility someone will receive a shock. Now with the line fused for 15 amperes, as soon as current exceeds that amount, the fuse opens and no harm is done.

7. Reduces life and property hazards.

a. Non-polarized systems are a great cause of personnel injury especially to those who work on "hot systems". If all systems new or old reconditioned, are installed and marked properly, fires and mishaps of various natures will not develop.

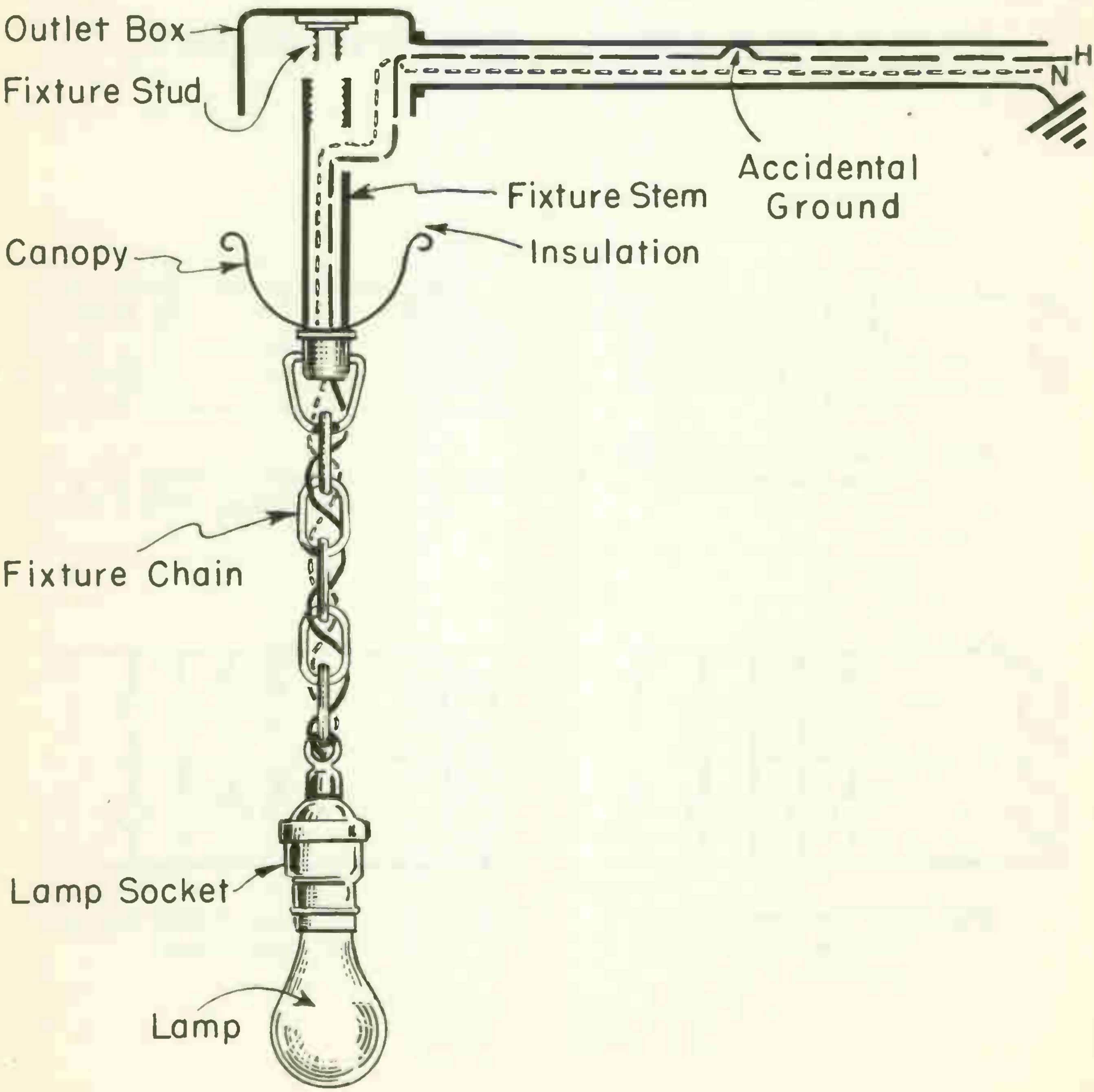


Fig. 6

WIRE CALCULATIONS

Objective

To learn the methods of determining the sizes of electrical conductors, the factors that determine the resistance of conductors and the use of copper wire tables.

References:

Bureau of Standards, Circular #31 - "Copper Wire Tables". National Electric Code.

Lesson Content

A. Wire Definition

A wire, as used in electrical work, is defined by the American Standards Association as a slender rod or filament of drawn metal.

B. Wire Sizes

1. How determined

Wire is available in different sizes to accommodate different values of current. Tables are published showing the current carrying capacity in amperes of various sizes of wire.

2. How named

Wire is manufactured or drawn in various sizes. The system of sizes most commonly used in the United States is called the American Wire Gauge (A.W.G.).

C. Wire Measurements

1. Micrometer

One method of measuring wire is by means of a micrometer, a precision instrument of the caliper type, which gives the diameter of round wire in thousandths of an inch. Thus, if we take a piece of copper wire almost half an inch thick and measure it carefully with a micrometer, we might get a reading such as 0.460 which means that it is 460/1000 of an inch in diameter. A wire this size is given an A.W.G. number of 0000, usually written 4/0 and pronounced "four ought". It is the largest size of wire that has an A.W.G. number; larger wires are measured in a unit called "circular mils". A micrometer, in the hands of one skilled in its use, will give very accurate results but its use in practical electrical work has a number of disadvantages.

2. Wire Gauge

Another instrument commonly used in electrical work for measuring wire sizes is called a "wire gauge". Fig. 1. While not as accurate as a micrometer, especially in measuring odd sizes, the wire gauge is cheaper, more rugged in construction and much easier to use. All the insulation is carefully removed from the wire, then the wire is inserted in one of the large holes in the gauge, and drawn through the slot leading from the hole. If the wire passes through the slot too easily, it is tried in the next smaller slot and so on, until one is found through which the wire passes snugly without binding. Then we look at the edge of the hold through which the wire was passed and find, on one side of the wire gauge, the diameter of the wire in thousandths of an inch. On the other side of the gauge, opposite the same hole, we find the A.W.G. number of this size wire. For example #14 wire would have a diameter of .064 on one side and the number 14 on the other.

D. Units of Measurement

1. The "mil"

Since the largest size of wire with a gauge number is only .460 inch in diameter, it is obvious that the ordinary linear system of yards, feet and inches is inadequate for this small measure unless we wish to continually worry over decimals and fractions. Hence, a smaller unit of linear measure is used in connection with wire sizes. This unit is called a "mil" and it is equal to one one-thousandth of an inch. (.001). In other words, one inch is equal to 1,000 mils. By the use of this unit, number 4/0 wire would have a diameter of 460 mils, and number 14 wire would have a diameter of 64 mils, both fractions and decimals being eliminated.

2. The circular mil (CM)

The current carrying capacity of wire is based on its "circular mil area" rather than on its diameter, and the circular mil area is found simply by squaring the diameter, the formula being: $A=d^2$.

For example, the area of 4/0 wire would be 460x460 or 211,600 CM. The current capacity of 4/0 is 225 amperes.

3. The square mil (SM)

Circular mils are used only for round conductors or wires. Conductors which are square or rectangular in shape (known as bus) are measured in square mils. To find square mils we use the following formula: A (in S.M.) equals side X side.

That is, we multiply one side of our bus by the other side. For example, a square bus measuring 25 mils on each side would have an area of 25 x 25 or 625 square mils; a rectangular bus (20 mils wide and 40 mils long would have an area of 800 square mils. If the bus size is given in inches or fractions of an inch, we should first convert these measurements to mils then multiply. Thus a bus measuring $\frac{1}{2}$ inch by $\frac{1}{4}$ inch would be the equivalent of 500 mils by 250 mils so the area would be 250x500 or 125,000 square mils. See Fig. 2.

NOTE: If the ventilation is average, bus capacity is rated at 1,000 amperes per square inch. With forced ventilation, as much as 1,300 amperes per square inch may be allowed, while, if the ventilation is poor, the current should be limited to 800 amperes per square inch.

4. Comparison of square mils and circular mils

If we draw a square with sides exactly one mil in length Fig. 2B and inscribe a circle inside of that square, the circle will have a diameter of one mil, and, according to our formulas, the area of the square will be one square mil, while the area of the circle will be one circular mil.

We know however, the the square we have drawn contains a greater actual area than the inscribed circle, because of the corners which the circle cuts off, so it is apparent that a square mil is larger than a circular mil. As a matter of fact, the circle's area is only 0.7854 times that of the square, which means that we can always convert circular mils to square mils by merely multiplying the circular mil area by figure 0.7854; conversely, we can change square mils to circular mils by dividing the square mils by 0.7854, the important thing being to know whether we should multiply or divide. We can always remember this by keeping in mind the fact that a square mil is larger than a circular mil, so there will be more circular mils and less square mils in any given area. If we are seeking the larger number we divide by 0.7854 and if we are seeking the smaller number, we multiply by 0.7854.

E. Resistance of Conductors

Copper is one of the best low-loss conductors. If we disregard silver, which is too expensive for most purposes, copper can be called the best electrical conductor. Its nearest rival, so far as wire is concerned, is aluminum, which is sometimes preferred because of its lighter weight. A comparison is given below.

	CONDUCTIVITY (Based on Silver)	TENSILE STRENGTH IN LBS. per Sq. Inch.
Copper (annealed)..........	96% to 99%	30,000 to 65,000
Copper (hard-drawn)........	92% to 96%	30,000 to 65,000
Aluminum	54% to 63%	24,000 to 55,000

The difference in tensile strength is negligible but the conductivity is important. In general we can say that, for equal conductivity, aluminum will be two A.W.G.'s larger than copper, but will have only 48% of the weight of the copper.

In the past aluminum was not popular because it was difficult to solder, but special solder is now available which makes soldering easy. There is little difference in the cost of aluminum solder and ordinary solder. A new copper-aluminum alloy wire has been developed combining strength and flexibility.

F. Factors Determining Resistance

The resistance of a conductor is determined by such factors as temperature, size and kind of material. Some of these things affect resistance directly, others inversely.

1. Temperature (T)

It has been found by experiment that when we increase the temperature of a metal conductor, the resistance of the conductor is proportionately increased. The reverse is true with gases, electrolytes, and carbon.

2. Length (L)

The length of a conductor affects its resistance. If we had a number of identical cubes of metal, measuring one inch in each direction and have a resistance of one ohm each, we would find that if we placed two of these cubes end to end and passed current through them the resistance would be two ohms. A line of four cubes would have a resistance of four ohms, and a line of 100 cubes would have a resistance of 100 ohms.

Resistance varies directly with the length (L).

3. Area (A)

Now let us take two of these cubes and place them next to each other so that we will be passing the current through the widest portion (area of 1 x 2 or two square inches). This is the same as passing the current through two one ohm resistors connected in parallel and we know that the current will divide equally among the equal resistors, the total resistance being equal to the value of one resistor (1 ohm) divided by the number of paths (2) or one-half ohm. That is, when the area is doubled the resistance will be cut in half. Similarly, if we place four of these cubes together, making an area of four square inches, we would have a total resistance of only one-fourth ohm, so we see that:

Resistance varies inversely with the area.

Since the area of a round conductor, in circular mils is equal to the diameter squared, we can also say that:

Resistance varies inversely with the square of the diameter.

4. Kind of material (K)

The "Specific Resistance" of any material is stated in terms of the resistance of a piece of this material one foot long and having a cross-sectional area of one circular mil. A piece this size is known as a "mil foot", or "circular mil foot". Since a piece of copper one foot long with a cross-sectional area of one circular mil will have a resistance of 10.4 ohms, we say that copper has a Specific Resistance of 10.4, or in other words, "K" for copper is 10.4. Specific Resistances (K) for several common metals are listed below.

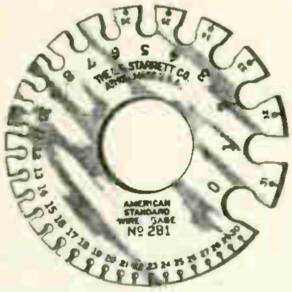
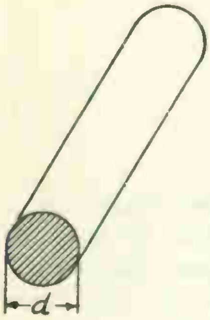
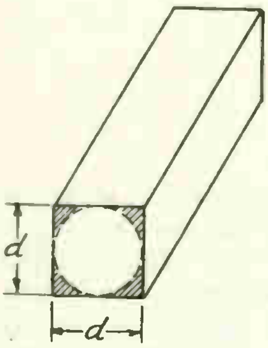


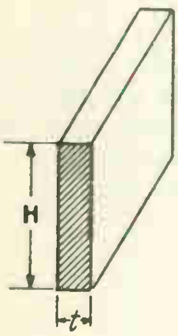
Fig. 1 A wire gauge of this type is commonly used to determine the size of wires for various uses.



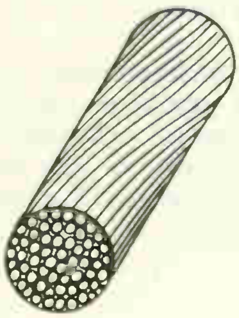
A



B



C



D

Fig. 2. Electrical conductors are commonly made in the several shapes shown above. Note particularly the comparative areas of round and square conductors as shown at "B".

Single Conductor in Free Air
(Based on Room Temperature of 30°C., 86°F.)

Size A.W.G.	Area, circular mils	No. wires	Diam. each wire, inches	Rubber Type R Type RW Type RU (14–6)	Rubber Type RH
18	1,624	Solid	0.0403	3	
16	2,583	Solid	0.0508	6	
14	4,107	Solid	0.0641	20	20
12	6,530	Solid	0.0808	25	25
10	10,380	Solid	0.1019	40	40
8	16,510	Solid	0.1285	55	65
6	26,250	7	0.0612	80	95
4	41,740	7	0.0772	105	125
3	52,640	7	0.0867	120	145
2	66,370	7	0.0974	140	170
1	83,690	19	0.0664	165	195
0	105,500	19	0.0745	195	230
00	133,100	19	0.0837	225	265
000	167,800	19	0.0940	260	310
0000	211,600	19	0.1055	300	360
	250,000	37	0.0822	340	405
	300,000	37	0.0900	375	445
	350,000	37	0.0973	420	505
	400,000	37	0.1040	455	545
	500,000	37	0.1162	515	620
	600,000	61	0.0992	575	690
	700,000	61	0.1071	630	755
	750,000	61	0.1109	655	785
	800,000	61	0.1145	680	815
	900,000	61	0.1215	730	870
	1,000,000	61	0.1280	780	935
	1,250,000	91	0.1172	890	1,065
	1,500,000	91	0.1284	980	1,175
	1,750,000	127	0.1174	1,070	1,280
	2,000,000	127	0.1255	1,155	1,385

Fig. 3 - This very convenient table gives the current carrying capacity for the various sizes of wire, and also their diameter and area in circular mils.

Silver .... 9.8 ohms	Copper .... 10.4 ohms
Iron ....63.4 ohms	Aluminum .... 17.2 ohms
German Silver ....128.3 ohms	

Resistance varies directly with the kind of material

5. Constructing the formula.

To summarize, there are four factors affecting the resistance of a conductor; length, area, kind of material (these three having a pronounced effect) and temperature, which has a proportionately smaller effect. Since temperature has such a small effect, it is convenient to assume that the temperature will remain constant at 68° Fahrenheit, and base our formula on the other three variables; length, area, and type of material. So, since the length of a conductor and the material from which it is made have a direct effect on a resistance, we put these values above the line, and since the area of the conductor has an inverse effect we put it below the line. The resulting formula will be:

$$R = \frac{KL}{A}$$

G. Copper Wire Tables

When designing a wiring installation and the allowable line drop has been computed, the allowable resistance in the wiring can be readily computed by means of Ohm's Law. This resistance, the length of the wire, and the copper constant will then be known factors, leaving "A" or the cross-sectional area of the conductor to be computed. This can be done with the above formula, $R=KL/A$, or, putting the same formula another way, $A=LK/R$. This area however, gives us no idea of the weight, A.W.G., or specific resistance per thousand feet of the conductor having this area. This information can be found in an ordinary copper wire table, such as is illustrated in Figs. 3 and 4.

Since weight varies directly with the area, remember that as the current-carrying capacity of a wire is increased and therefore the area is increased the weight of the wire per foot of length will also be increased and additional support will be needed for the wire. In addition, copper wire prices are based upon the weight of the metal in the wire, a consideration which will in itself show the importance of determining wire calculations accurately.

Gauge Equivalents with Weights and Resistances of Standard Annealed Copper Wire

B. & S. American Wire Gauge No.	Diameter In Inches	Area Circular Mils	Ohms at 68 deg. Fah.			Feet		Pounds			B. & S. American Wire Gauge No.
			Per 1,000 Ft.	Per Mile	Per Pound	Per Pound	Per Ohm	Per 1,000 Ft.	Per Ohm	Per Mile	
0000	0.460	211600.	0.04906	0.25903	0.000077	1.56122	20497.7	640.51	12987.	3380.	0000
000	0.40964	167805.	0.06186	0.32664	0.00012	1.9687	16255.27	507.95	8333.	2680.	000
00	0.3648	133079.	0.07801	0.41187	0.00019	2.4824	12891.37	402.83	5263.	2130.	00
0	0.32486	105534.	0 09831	0.51909	0.00031	3.1303	10223.08	319.45	3225.	1680.	0
1	0.2893	83694.	0.12404	0.65490	0.00049	3.94714	8107.49	253.34	2041.	1340.	1
2	0.25763	66373.	0.1563	0.8258	0.00078	4.97722	6429.58	200.91	1282.	1060.	2
3	0.22942	52634.	0.19723	1.0414	0.00125	6.2765	5098.61	159.32	800.	840.	3
4	0.20431	41743.	0.24869	1.313	0.00198	7.9141	4043.6	126.35	505.	665.	4
5	0.18194	33102.	0.31361	1.655	0.00314	9.97983	3206.61	100.20	318.	528.	5
6	0.16202	26251.	0.39546	2.088	0.00499	12.5847	2542.89	79.462	200.	420.	6
7	0.14428	20817.	0.49871	2.633	0.00797	15.8696	2015.51	63.013	126.	333.	7
8	0.12849	16510.	0.6529	3.3	0.0125	20.0097	1599.3	49.976	80.	264.	8
9	0.11443	13094.	0.7892	4.1	0.0197	25.229	1268.44	39.636	50.	209.	9
10	0.10189	10382.	0.8441	4.4	0.0270	31.8212	1055.66	31.426	37.	166.	10
11	0.090742	8234.	1.254	6.4	0.0501	40.1202	797.649	24.924	20.	132.	11
12	0.080808	6530.	1.580	8.3	0.079	50.5906	632.555	19.766	12.65	105.	12
13	0.071961	5178.	1.995	10.4	0.127	63.7948	501.63	15.674	7.87	82.9	13
14	0.064084	4107.	2.504	13.2	0.200	80.4415	397.822	12.435	5.00	65.5	14
15	0.057068	3257.	3.172	16.7	0.320	101.4365	315.482	9.859	3.12	52.1	15
16	0.05082	2583.	4.001	23.	0.512	127.12	250.184	7.819	1.95	41.3	16
17	0.045257	2048.	5.04	26.	0.811	161.22	198.409	6.199	1.23	32.7	17
18	0.040303	1624.	6.36	33.	1.29	203.374	157.35	4.916	0.775	26.0	18
19	0.03589	1288.	8.25	43.	2.11	256.468	124.777	3.899	0.473	20.6	19
20	0.031961	1021.	10.12	53.	3.27	323.399	98.9533	3.094	0.305	16.3	20
21	0.028462	810.	12.76	68.	5.20	407.815	78.473	2.452	0.192	12.9	21
22	0.025347	642.	16.25	85.	8.35	514.193	62.236	1.945	0.119	10.24	22
23	0.022571	509.	20.30	108.	13.3	648.452	49.3504	1.542	0.075	8.13	23
24	0.0201	404.	25.60	135.	20.9	817.688	39.1365	1.223	0.047	6.44	24
25	0.0179	326.	32.2	170.	33.2	1031.038	31.0381	0.9699	0.030	5.12	25
26	0.01594	254.	40.7	214.	52.9	1300.180	24.6131	0.7692	0.0187	4.06	26
27	0.014195	201.	51.3	270.	84.2	1639.49	19.5191	0.6099	0.0118	3.22	27
28	0.012641	159.8	64.8	343.	134.	2067.364	15.4793	0.4837	0.0074	2.56	28
29	0.011257	126.7	81.6	432.	213.	2606.959	12.2854	0.3835	0.0047	2.03	29
30	0.010025	100.5	103.	538.	338.	3287.084	9.7355	0.3002	0.0029	1.61	30
31	0.008928	79.7	130.	685.	539.	4414.49	7.72143	0.2413	0.0018	1.27	31
32	0.00795	63.	164.	865.	856.	5226.915	6.12243	0.1913	0.0011	1.01	32
33	0.00708	50.1	206.	1033.	1357.	6590.41	4.85575	0.1517	0.00076	0.803	33
34	0.006304	39.74	260.	1389.	2166.	8312.8	3.84966	0.1204	0.00046	0.634	34
35	0.005614	31.5	328.	1820.	3521.	10481.77	3.05305	0.0956	0.00028	0.504	35
36	0.005	25.	414.	2200.	5469.	13214.16	2.4217	0.0757	0.00018	0.400	36
37	0.004453	19.8	523.	2765.	8742.	16659.97	1.92086	0.06003	0.00011	0.317	37
38	0.003965	15.72	660.	3486.	13772.	21013.25	1.52292	0.04758	0.00007	0.251	38
39	0.003531	12.47	832.	4395.	21896.	26496.237	1.20777	0.03755	0.00004	0.199	39
40	0.003144	9.88	1049.	5542.	34823.	33420.63	0.97984	0.02992	0.000029	0.158	40

This very complete table of data for copper conductors will often save you a great amount of time if you become familiar with its use, and refer to it for the information it contains. It will be a good plan to compare the sizes, areas and resistance of a number of the more common sized wires given in this table. This will help you to understand the gauge numbers and in making selections of proper conductors for various jobs in the future.

H. Summary Questions

1. What is the ratio between a circular mil and a square mil?

2. What is the square mil area of a #6 round wire?

3. What four factors determine the resistance of a conductor?

4. Is the resistance of a tungsten filament incandescent lamp higher or lower when no current is flowing in the lamp?

5. The resistance of a small carbon filament lamp is measured with an ohmmeter. When the lamp is put in a circuit so that current flows through it, will its resistance be the same, higher, or less?

6. Determine the proper size conductor to carry a load of 20 ampere over a two-wire circuit, 100 feet in length, with not more than a three-volt drop.

7. What size copper wire must be installed to supply power to a shop situated 1280 feet away, having twenty-six 60-watt, 110 volt lamps, and one ten horse-power, 220-volt motor, allowing a 12% drop in a line? The source voltage is 250 volts.

8. What is the length of a silver wire wound on a resistance spool if its resistance is 50 ohms? The wire is #20 A.W.G.

9. Find the resistance of 1,000 feet of iron wire having an area of 10,000 CM.

10. What will the voltage be at the distant end of the circuit supplying twenty 40-watt 110-volt lamps with power, if the wire is #14 A.W.G. copper? The source voltage is 110 volts and the distance between source and demand is 50 yards.

11. If two 60-watt, 120 volt lamps are connected to the distant end of a 150-foot line, what size copper wire in CM is required to limit the voltage drop to two volts?

12. A load of ten appliances (110E) drawing 10 amperes each is located 200 feet from a source voltage of 224 E. Allowing a line drop of four volts, what size copperwire would be required? Give the answer in CM.

JOB SECTION STUDENT MANUAL

COYNE ELECTRICAL SCHOOL

CHICAGO, ILLINOIS

TABLE OF CONTENTS

JOB SHEETS

ELECTRIC SHOCK

By Frederick Strange Kolle, M. D.
From "Standard Wiring" for Electric Light and Power by H. C. Cushing, Jr.

1st. Lay the patient on his back.
2nd. Move the tongue back and forth in the mouth by seizing it with a handkerchief or the fingers, while working the arms to induce respiration.
3rd. Don't pour anything down the patient's throat.
4th. . Try to cause the patient to gasp by inserting the first and second fingers in the rectum and pressing them suddenly and forcibly toward the back.
5th. If possible, procure oxygen gas, and try to get it into the lungs during the efforts at artificial respiration.
6th. Get a doctor as quickly as possible.
7th. Treat the body as though it had been under water, by trying to obtain artificial respiration.

The above items have been arranged in the manner given, to avoid the immediate necessity of reading that which follows, in cases of emergency. It is quite natural to realize, that the victim of shock must be pulled out of circuit or disconnected from the wires carrying the current. To do this, a stick of dry wood, a piece of dry cloth, a coat or soft felt hat, may be used. It will be understood, therefore, that means are taken, more or less familiar to the electrical man, for removing the body from continued danger of this kind; the best to use being, of course, rubber gloves for this purpose, if convenient.

Air in the Lungs.—The patient must be made to breathe at once. To accomplish this, lay him on his back with a coat under his shoulders to throw out the chest. Then, lift the arms over the head and back again, until they press against the chest. This process will force air in and out of the lungs, as required. A second party ought to assist in pulling the tongue forward, when the arms are raised above the head, and let it fall back when the arms press against the chest.

Rate of Breathing.—The rate of breathing produced artificially should be about sixteen times a minute; a little more or less will not affect the general result.

Jaws Locked.—If the jaws are locked by the clenching of the teeth, force them open with a knife or spoon handle, or their equivalent, so that the tongue can be seized and moved as described.

Effect of Tongue on Teeth.—By the rubbing of the lower side of the tongue on the under row of teeth, the patient is apt to gasp automatically, and thus fill the lungs with air. The fact that an effect of this kind is possible is a good sign, and should be produced at intervals of a few seconds, if possible.

Time of Keeping Up Artificial Respiration.—The operations indicated should not be discontinued for a long time. In many cases an hour or more is required before the body begins to resume its natural functions, as shown by the beginnings of ordinary breathing.

Throat Free.—The throat must be free to admit air, when the lungs are inhaling, by the upward movement of the arms. The movement is similar to that transpiring during the process of yawning and stretching the arms above the head. The inhalation must be made as deep as possible, and the operations leading to it continued with systematic care until results are visible. Filling the throat with the back of the tongue at the wrong time, will mean failure. Therefore, the movement of the tongue back and forth must be intelligently performed.

Paper Cone for Oxygen Gas.—An inhaling cone may be made of paper, the larger end over the patient's face, and the smaller end or stem attached to the oxygen tank by means of a piece of rubber pipe. A little oxygen in the lungs causes a strong heart action and operates to revive very quickly.

Friction of the Limbs.—Rubbing of the body is a secondary means of hastening the blood circulation. The inactivity of the lungs and heart are due to a temporary paralysis or shock caused by the passage of the current. The removal of this condition means resuscitation, part of which process may be carried out by massage of the body and limbs.

General Character of the Treatment.—As may have been noted in reading this popular version of the means of assisting recovery from shock by electricity the general drift is in the direction of getting the patient to breathe and his heart to beat strongly. Other legitimate ways may be tried, but they must not be so heroic as to induce death during so critical a condition. It is better to follow accepted methods than irrational experiments. The above program should be followed out until a physician takes charge of the case.

Basic Electricity and Circuits.

PROCEDURE GUIDE
(Job Section)

Supplementary jobs, beyond those called for in your course have been provided. These jobs will be of value to you in case you should desire to perform extra jobs.

The required jobs should be covered in order as follows:

Job No.	Title	Date Completed
1-3.	Simple Circuits	....
2-4.	Series Circuits	....
3-5.	Parallel Circuits	....
4-6.	Series and Parallel Combinations	....
5-7.	Circuit Wiring	....
6-9.	Ohm's Law Problems	....
7-11.	Voltage Drop	....
8-12.	Voltage Drop around a Circuit	....
9-13.	Voltage Drop in Series	....
10-14.	Voltage Drop in Combination Circuits	....
11-18.	Relay Circuits	....
12-19.	Railway Crossing Signal System	....
13-20.	Relay Motor Control	....
14-21.	Annunciator Systems	....
15-22.	Duplex Relay Controlled System	....
16-1.	Common Splices	....
17 to 24-30.	Wiring Lighting Control Systems	....

NOTE: Please date each job as it is completed and recorded on your job card so that both you and your instructor can keep a check on your progress.

WIRE SPLICING

Objective:

To obtain practice in making some of the common splices used in electrical work.

Average Time:

Tools, Equipment and Materials

- 1 Pliers - side cutters
- 1 Bundle wire
- 1 Soldering copper
- 1 Stick solder

Related Information

A. Purpose of a splice

A splice is made to join or unite wires in a circuit where it is impossible to have a continuous run and where the circuit branches off for various equipment.

B. Requirements of a splice.

The National Electrical Code requires that a splice be both mechanically and electrically secure without the aid of solder.

A splice must have a sufficient number of turns (not less than 5) and all turns should be close together to give good mechanical strength.

NOTE: Solderless connectors and lugs, also the proper tools for attaching them are manufactured for practically all sizes of wires. Be sure to use the size and type approved for the installation. Wire nuts are a great help in fixture installation, but there again, be sure to follow the local code rules.

C. Cleaning the wires for splicing.

Use a knife to remove the rubber insulation and trim it like you would sharpen a pencil. Be very careful not to nick the wire because that reduces the size of the conductor and increases the resistance. Use back edge of blade to scrape the dirt off of the wire, being careful not to remove the tinned surface of the wire.

D. NOTE: The insulation can be crushed between the handles of a pair of side cutters and then stripped from the wire without damaging the wire.

D. Making the splice

Practice using your side cutters to make the turns and twists and thus save your fingers.

E. Soldering the splice

Do not file the soldering copper - To remove pits, use an emery stone or whetstone, use the stone only when the copper is cold. Soldering copper must be clean well tinned and hot. Use rosin and sand or a sal ammoniac block to clean surface of the soldering copper after it is hot. Be sure the solder is free from acid.

Use non-acid flux for all electrical soldering.

Place the soldering copper under the splice for a quick and easy job, because heat naturally travels upward.

Soldering spreads a very thin layer of tin over the clean copper surface which prevents oxidation and corrosion of the splice, thereby maintaining the conductivity of the splice.

F. Taping the splice.

Rubber tape must be stretched on, to cover all bare metal. It is to take the place of the insulation removed.

Friction tape is wrapped on, to protect the rubber tape and must extend at least $\frac{1}{2}$ inch out over the injured or frayed braids, but must end back on itself because friction tape will not stick to the braid.

G. Commonly used splices

1. Pigtail splice - used at outlet boxes and junction boxes. Ends of wires must extend 6 to 8 inches out of the box to allow for making this splice. The number of ends that can be pigtailed together is limited only by safety and space.
2. Western Union splice - made where two ends join in open work only.
3. Common Tee or Tap splice - made where a branch is tapped off from a run in open or temporary wiring and where there will not be any stress or pull on the tap.
4. Knotted tee or tap splice - used for tapping onto a run in open or temporary wiring and there will be a pull on the tap.
5. Stranded Tap splice - used for tapping off from a temporary run of stranded flexible conductor. Open work only.
6. Fixture splice - Fixtures are usually wired with stranded conductors at the factory. This fixture splice is used when the fixture is hung to join the stranded conductor onto the solid conductor extending from the outlet box.

Precautions

1. Any burn or scratch, however slight, should be reported to the nurse at once.

2. Be extra cautious with tools, careless handling may result in injury. Keep the work away from your face.

Procedure Steps

1. Clean the insulation from one end of each of five wires. The exposed cleaned bare wire should be about $2\frac{1}{2}$ inches long.

2. Make a two wire pigtail splice, Fig. 1.
When making the pigtail splices, remember you will have at least 6 inches of wire at the outlet box, so with one hand grasp all wires for one splice and hold together parallel with each other. With side cutters in your other hand, grip ends of the bare wires and twist toward the insulation.

3. Make a three wire pigtail splice.

4. To make fixture splice, strip about $1\frac{1}{2}$ inches of insulation from another solid conductor, then strip about 2 inches off the end of a stranded conductor. Follow the procedure shown on example boards for fixture splice.

5. Make the two different tap or tee splices, Fig. 2, being careful to strip out approximately 5/8 inch on existing or running line. The bare end of the tap wire or junction wire should be at least 4 inches in length. Excess can be clipped after finishing splice.

6. Make stranded tap splice.

7. Make the western union splice, Fig. 3, by first stripping and cleaning 4 inches from the end of #14 wire. Follow each step carefully being sure to have no less than three and no more than five twists. CAUTION: Be sure to wrap the ends so that on each wire there will be a very small space from the last wrap to the insulation, otherwise a weak spot results. Wrap at least five no more than ten turns. Refer to Fig. 3D.

   NOTE: After completing the foregoing six splices, have them checked by the instructor who will then direct you to the soldering section.

8. Solder all splices and have them checked by the instructor.

9. Tape with rubber tape, three splices selected by the instructor. The rubber tape covers all metallic parts only.

10. Have the taping job checked by an instructor.

11. Tape, with friction tape, the three splices that have been taped with rubber tape.

    NOTE: Use only enough tape to do a proper job.

12. Get the final check on the job.

13. Answer the following questions.

    a. What is a splice? Connecting 2 or more wires for a circuit

    b. Which of the splices just completed would be used in installations using conduit, non-metallic, and armored cable work. Pigtail Splice.

    c. What is the purpose of solder? What is soldering flux? To make the solder flow evenly & take the oxidation off the wires
    Solder is to make a solid connection

    d. Where do we use rubber tape? Why is it used? To insulate the wires.
    After making a splice

    e. Why use friction tape? Should friction tape be used without rubber tape? No.
    To take the place of the braid

14. Have instructor check answers for final grade.

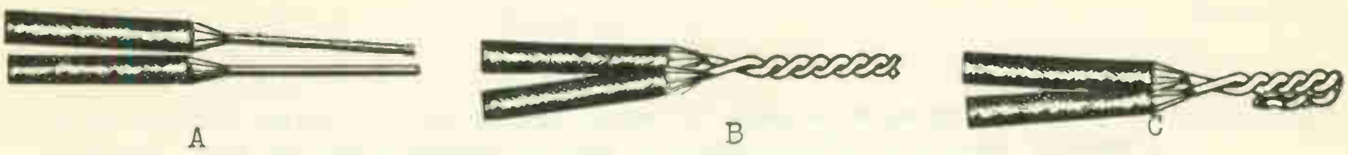


Fig. 1 Steps to be followed in making a pigtail splice.

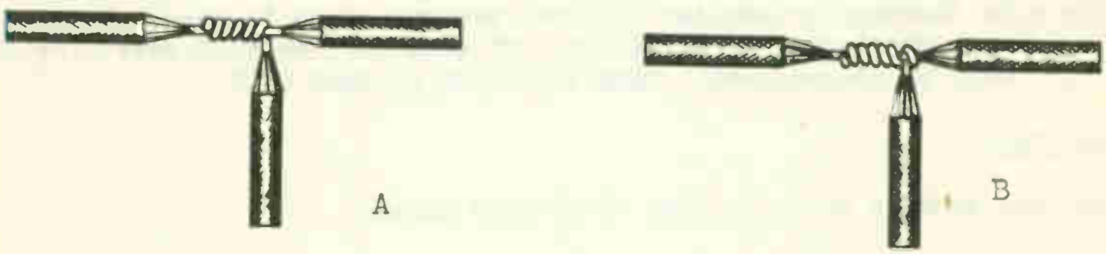


Fig. 2 Tap and tee splices

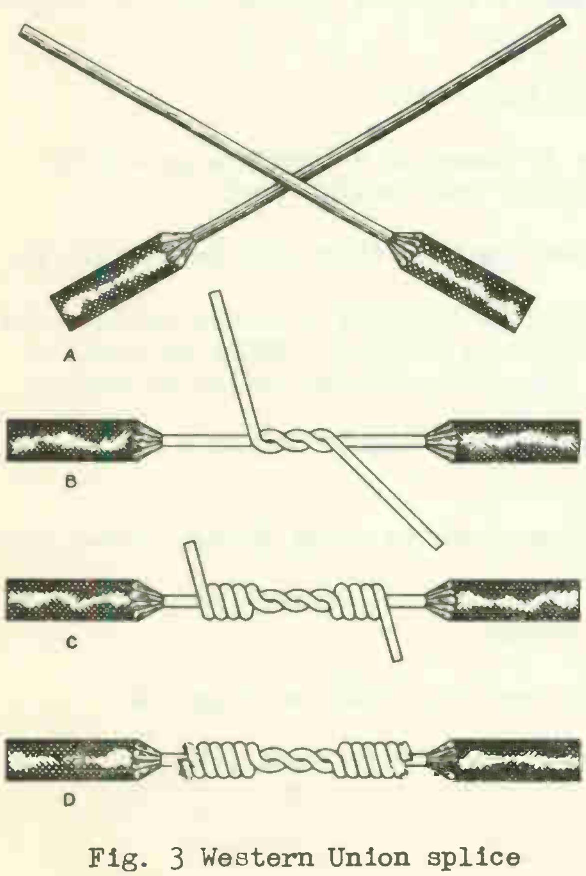


Fig. 3 Western Union splice

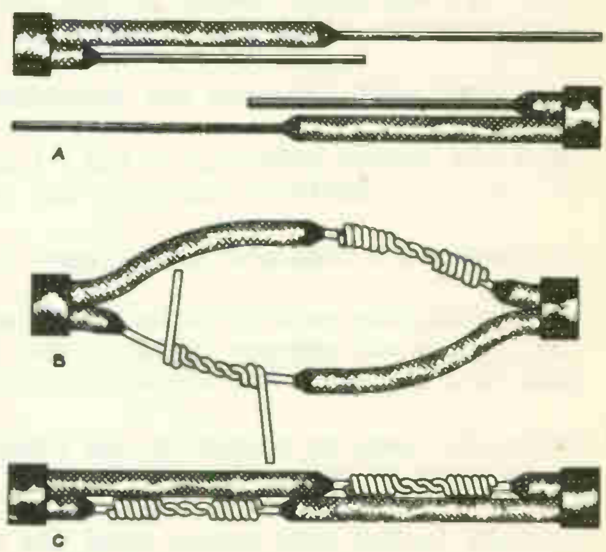


Fig. 4 When making splices in pairs of conductors they should be staggered as shown above so each splice will be close to good insulation on the other wire.

Job No. 3

Basic Electricity & Circuits

SIMPLE CIRCUITS

Objective - To gain a working knowledge of basic electrical circuits, simple switches, commonly used electrical symbols, and to become familiar with the elements of circuit diagram tracing.

References:

3 open Switches
3 bells
1 battery
#30 wire

Tools, Equipment & Materials

Bundle of #30 C.C. Wire

Precaution - Be thoroughly familiar with the various steps in the procedure, so maximum knowledge can be gained. If each step is followed, no difficulty will be encountered. TAKE YOUR TIME, DO NEAT WORK.

Procedure Steps

1. Review the symbols shown on page 22 of this manual.
2. Study Fig. 3 to learn equipment needed and how it is to be connected.
3. Make a complete material list of all equipment including the approved symbol for each part.
4. Test all equipment needed on the job and make a complete switch terminal chart. For procedure check Fig. 1 and Fig. 2.
5. Have your work approved and initialed by an instructor.
6. Mark the source polarity on Fig. 3 and see if there is a complete path from (+) to (-). Encircle and mark the terminals of each switch used.
7. If there is a complete path, trace it in lead pencil; this will be circuit #1.
8. If no complete path is shown, dot the switch, to indicate a closed switch, and then trace all current paths in the same color as the dot. NOTE: Be sure to make tracing neat, the arrows very small, and use a minimum number of arrows.
9. Write the name or number of the circuit beside the diagram and show the color arrow used to trace it.
10. Proceed in the same manner with the remaining circuits using colors listed below:

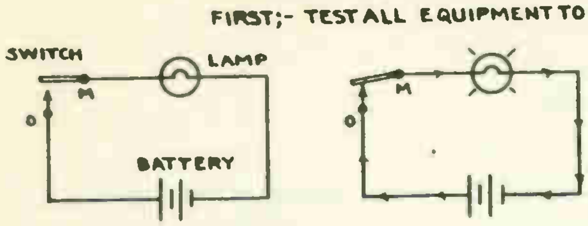
    Circuit #1 lead pencil
    Circuit #2 red
    Circuit #3 blue
    Circuit #4 Orange
    Circuit #5 green

11. Wire the job, Fig. 3 ONE STEP AT A TIME and test each step as completed.
12. Have an instructor check your work and give you credit on your job card.

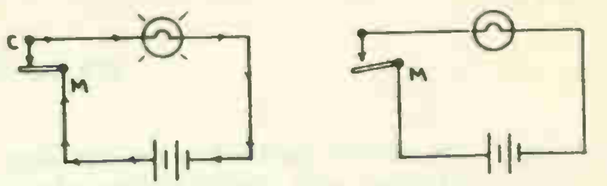
M O C	O M C	C M O	M O	M O	M O

TO LEARN CIRCUITS YOU MUST PROCEED BY STEPS AS FOLLOWS:-

FIRST;- TEST ALL EQUIPMENT TO BE WIRED. (ARROWS INDICATE CURRENT).



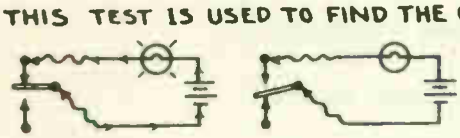
IF THE LAMP LIGHTS WHEN THE BUTTON IS PRESSED, IT IS AN OPEN CIRCUIT SWITCH HAVING OPEN AND MOVING CONTACTS.



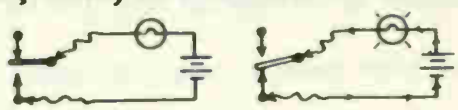
IF THE LAMP GOES DARK WHEN THE BUTTON IS PRESSED, IT IS A CLOSED CIRCUIT SWITCH HAVING CLOSED AND MOVING CONTACTS.

Fig. 1 The above diagrams show the normal positions and the pressed positions for the two single circuit type of push button switches.

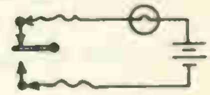
THIS TEST IS USED TO FIND THE CLOSED, MOVING, AND OPEN CONTACTS ON A DOUBLE CIRCUIT SWITCH.



PLACE THE TEST LEADS ON ANY TWO TERMINALS OF THE SWITCH. IF THE TEST LAMP LIGHTS, THE LEADS ARE CONNECTED TO THE CLOSED AND MOVING CONTACTS. PRESSING SWITCH WILL CAUSE THE LIGHT TO GO OUT. THE REMAINING TERMINAL IS FOR THE OPEN CONTACT.



CONNECT TEST LEADS TO A DIFFERENT PAIR OF TERMINALS AND PRESS BUTTON. IF TEST LAMP LIGHTS, THE LEADS ARE CONNECTED TO THE OPEN CONTACT AND THE MOVING CONTACT. THE REMAINING TERMINAL IS FOR THE CLOSED CONTACT.

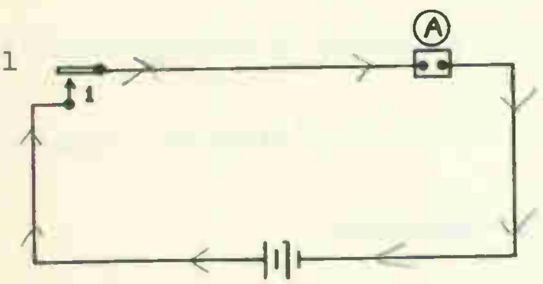


IF LAMP DOES NOT LIGHT WHETHER BUTTON IS PRESSED OR NOT THE TEST LEADS ARE CONNECTED TO THE OPEN CONTACT AND THE CLOSED CONTACT.

THE TERMINAL COMMON IN BOTH TESTS IS CONNECTED TO THE MOVING CONTACT.

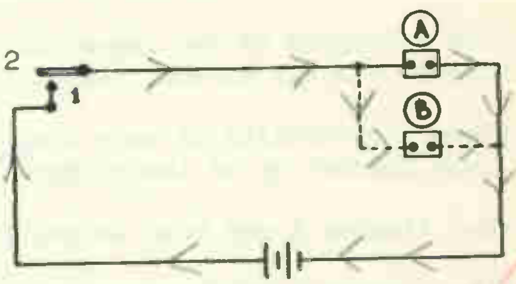
Fig. 2 The above diagrams show the normal and abnormal (pressed) positions of the double circuit type switch.

1



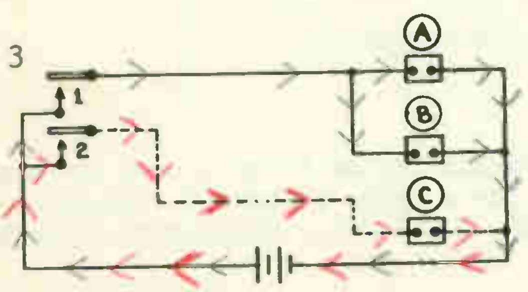
A simple practical circuit.

2



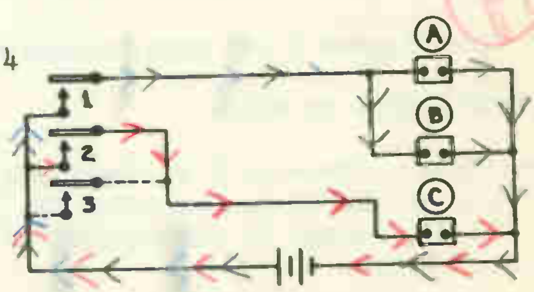
Open circuit switch used to control 2 bells in parallel

3



#1 Switch controls bells A & B.
#2 " " bell C.

4



#1 Switch controls A & B
#2 & #3 Switches control C.

Fig. 3 Wire each of the steps shown. Have part 3 checked and also part 4. You must trace each of the 4 shown.

SERIES CIRCUITS

Objective: To obtain practice in drawing schematic diagrams using proper symbols, wiring, and tracing the circuits.

References:

Average Time Required: 2 hours

Procedure Steps

1. Refresh your memory by reviewing the job on simple circuits.
2. On the following page make a complete switch terminal chart.

   NOTE: Draw all diagrams neatly, in the space provided, and use a straight edge or ruler.
3. Draw a diagram of two lamps connected in series and controlled by an open circuit switch. (Identify this diagram with the letter A.)
4. Draw a diagram of two lamps and a bell all connected in series and controlled by an open circuit switch. (Identify as B.)
5. Draw a diagram of a lamp and a bell connected in series controlled by an open circuit switch (Identify as C).
6. Draw a diagram of two lamps and two bells all connected in series controlled by an open circuit switch. (Identify as D.)
7. Trace the circuits of each diagram and have the finished diagrams and material lists checked by an instructor.
8. Wire diagram A and have instructor check for operation.
9. Wire diagram B and have instructor check for operation.
10. Wire diagram C and have instructor check for operation.
11. Wire diagram D and have instructor check for operation.

QUESTIONS - True or False

Instructions - Place an X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F (X) Chicago is the capitol of U.S.A. 02. T (X) F ( ) Washington DC is the Capitol of U.S.A.

(Continued on page 169)

1. T (X) F ( ). The source voltage is applied to all parts as a group in a series circuit.

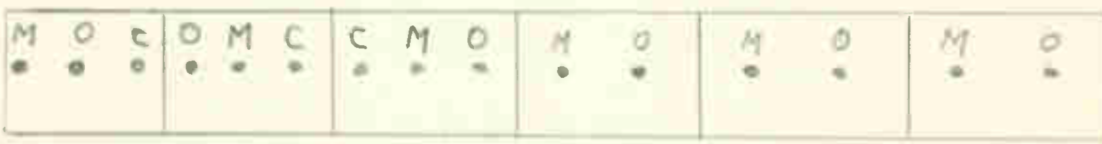
2. T (X) F ( ). The current will be the same in all parts of a series circuit.

3. T (X) F ( ). If one piece of equipment burns out all others will stop, in a series circuit.

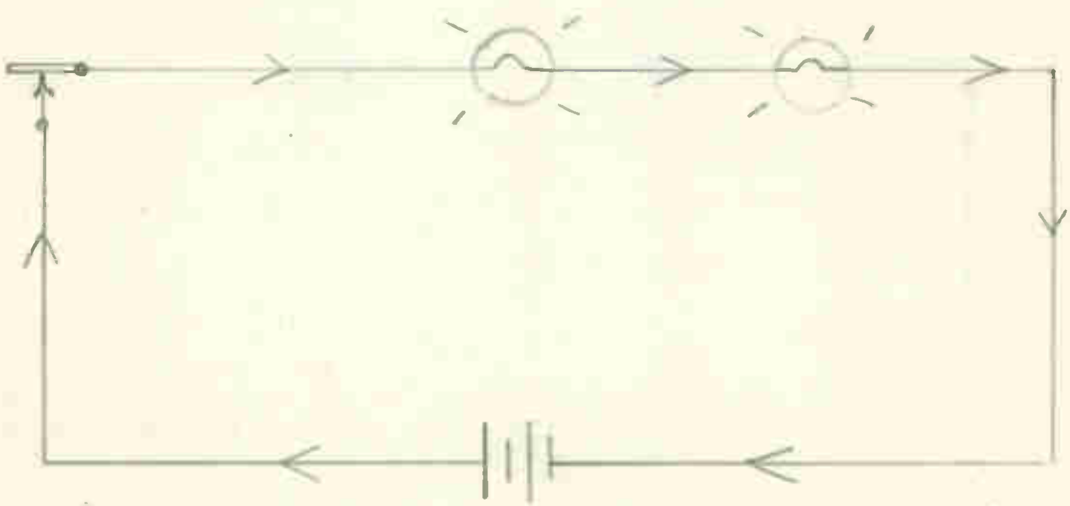
4. T (X) F ( ). A good circuit should contain the following parts; source, load, means of control, and the necessary conducting medium.

5. T (X) F ( ). It is good wiring practice to keep the control equipment in the hot lead if possible.

6. T (X) F ( ) The sum of the separate voltage drops in a series circuit is equal to the source voltage.

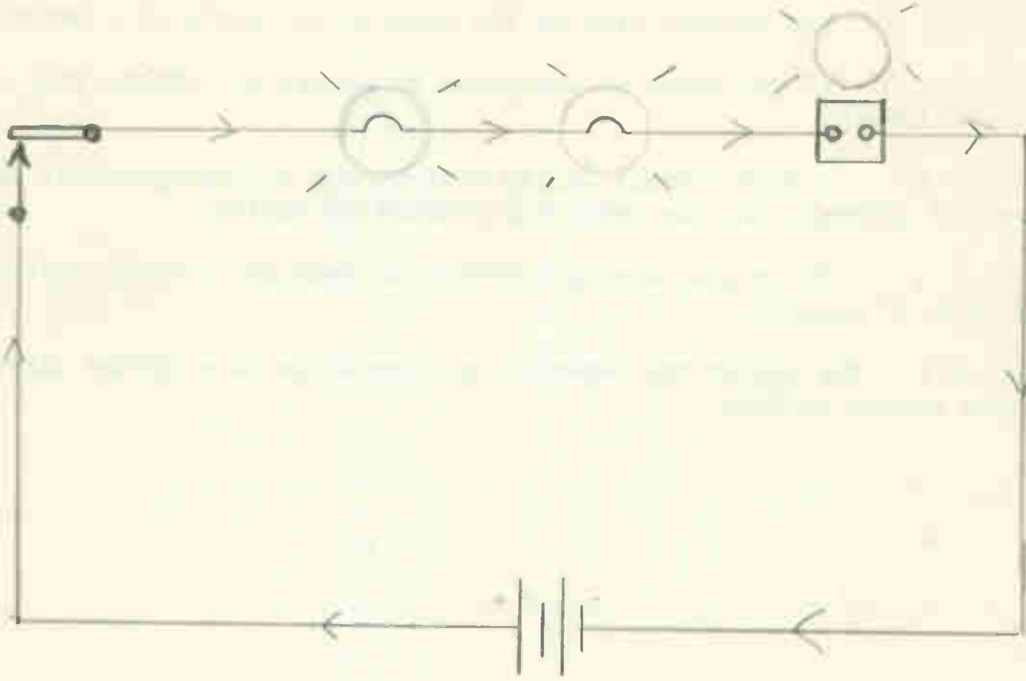


A



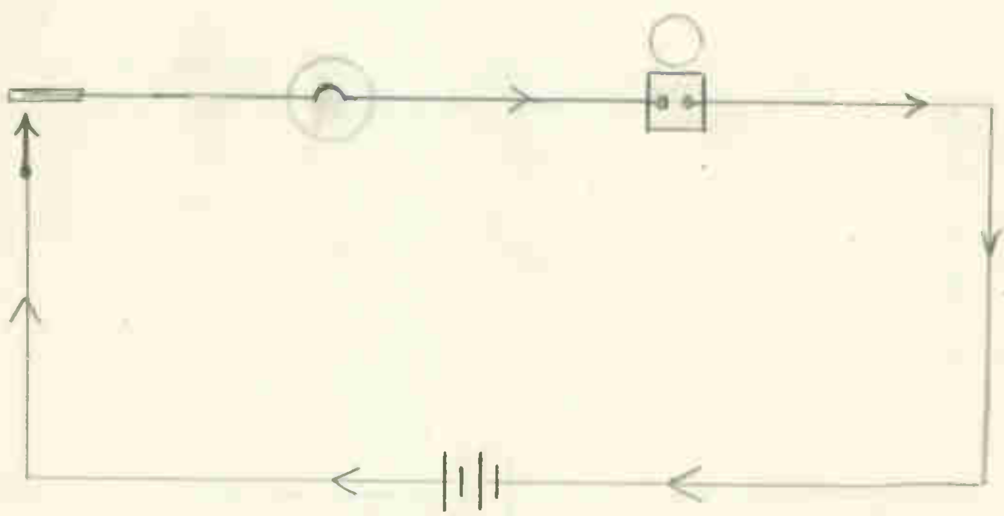
1-switch (open circuit)
2 Lamps
1-Battery
1-battery
#30 wire

B



1 switch
2 lamps
1- bell
1- battery
#30 wire

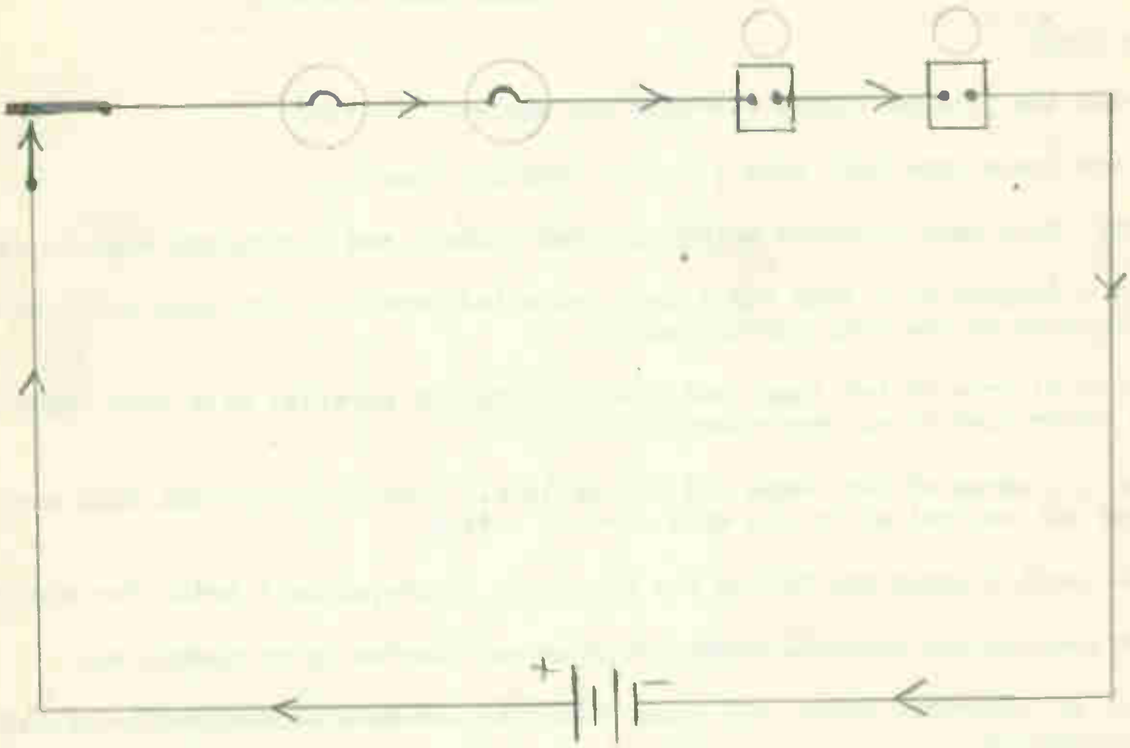
C



1 switch
1 lamp
1 bell
1 battery
#30 wire

RJK

D



1 switch (open circuit type)
2 - Lamps
2 - bells
1 - battery
#30 wire

PARALLEL CIRCUITS

Objective: To gain knowledge obtain practice in wiring and tracing simple parallel circuits.

References:

Average Time Required: 2 hours

Procedure Steps

1. Review the jobs on simple circuits and series circuits.

2. In the space provided, make a switch terminal chart.

   NOTE: Make neat diagrams using approved symbols and a straight edge or ruler.

A 3. Draw a diagram of a lamp and a bell connected parallel with each other and all controlled by one open circuit switch.

B 4. Draw a diagram of two lamps and a bell connected parallel with each other and all controlled by an open circuit switch.

C 5. Draw a diagram of two lamps and two bells all connected parallel with each other and controlled by one open circuit switch.

6. Trace each diagram and follow the procedure in preparing a print for wiring.

7. ~~Have your switch terminal chart and diagrams checked by an instructor.~~

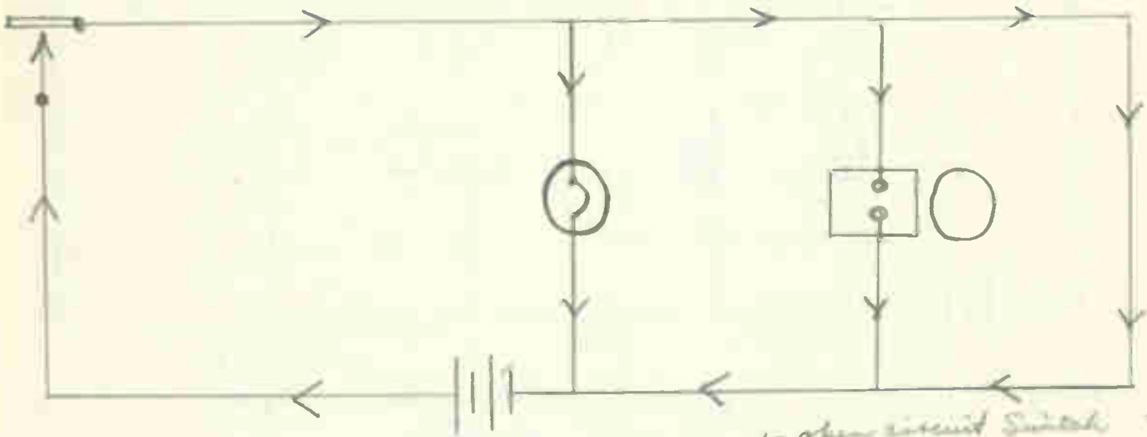
8. Wire, in numerical order, all three circuits. ~~and have each circuit checked by an instructor.~~

9. Have your job card punched by an instructor upon completion of the third circuit.

QUESTIONS - True or False (See instructions for Job No. 4).

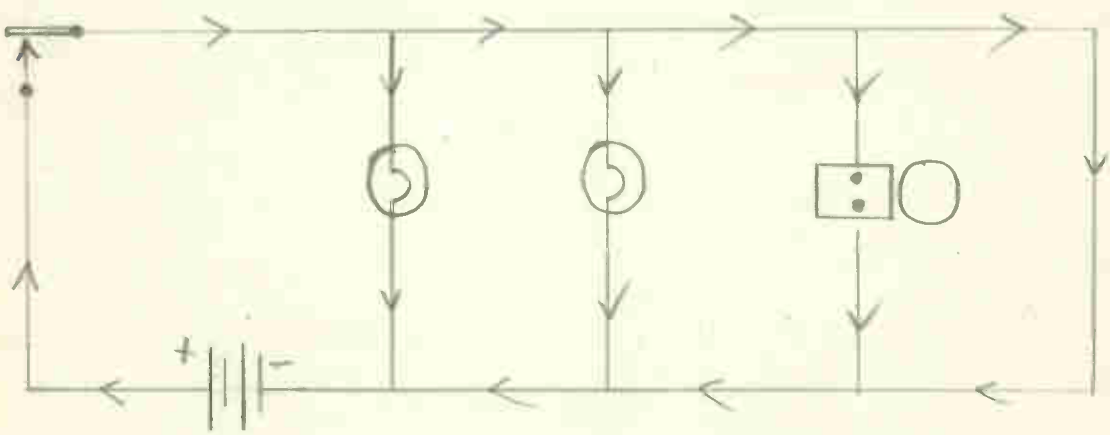
1. T (X) F ( ) When all like terminals are connected together, the connection is known as a parallel connection.
2. T (X) F ( ) The same voltage is applied to all branches of a parallel group.
3. T (X) F ( ) If a wire is connected parallel or shunt with one lamp of a parallel group, the connection would be termed a "short circuit".
4. T (X) F ( ) Open circuit switches are usually connected parallel with each other.
5. T ( ) F (X) Closed circuit switches are usually connected parallel with each other.
6. T (X) F ( ) There is never any connection between the closed and open contacts of the same double circuit switch.
7. T ( ) F (X) If a parallel connected lamp burned out, the remainder of the circuit would be deenergized.
8. T (X) F ( ) For good wiring practice, switches or other control apparatus should be connected in the hot lead if possible.
9. T (X) F ( ) The amount of current passing through each of the parallel paths, will be in proportion to the relative resistance of the various paths.

A



1- open circuit Switch
1- Lamp
1- Bell
1- Battery
30 wire

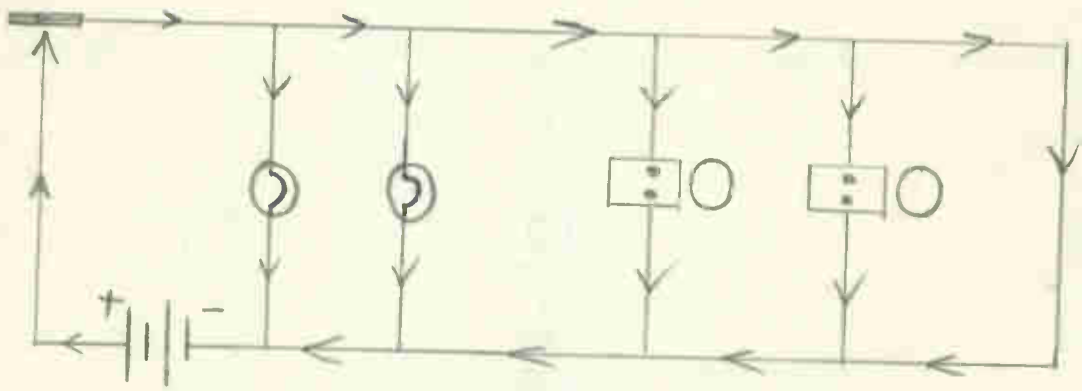
B



1-open circuit switch
2- Lamps
1 - Bell -
1 - battery
30 wire

C

RBK



1- open circuit switch
2- Lamps
2- bells
1- battery
#30 wire

M O C	O M C	C M O	M O	M O	M O

D

SERIES AND PARALLEL COMBINATIONS

Objectives: To obtain practice in wiring and tracing series and parallel circuits.

References:

Average Time Required: 2 hours

NOTE: Jobs 3, 4, & 5 must be finished before starting this job.

Procedure Steps

1. Review the principles of series and parallel circuits.

2. Make a switch terminal chart, at the top of the following page.

3. Make all diagrams neatly, using about ½ page for each diagram.

A 4. Using ruler and compass, draw a diagram of two parallel paths, each path containing a lamp and a bell in series and one path controlled by a closed circuit switch and the entire combination controlled by an open circuit switch.

B 5. Draw a diagram of one lamp controlled with open circuit switches located at 3 different places. (Use three colors to trace the circuits).

C 6. Draw a diagram of one lamp in series with a lamp and bell in parallel and all controlled by an open circuit switch.

D 7. Draw a diagram of a lamp connected parallel with two bells in series controlled by one open circuit switch.

8. Trace each diagram in the correct manner.

9. Test all switches and show them on the terminal chart; have diagrams and terminal chart checked by the instructor.

10. After the check is completed, wire the diagrams one at a time and have each completed diagram checked by the instructor for operation.

NOTE: Credit will be indicated on your job card after you finish all diagrams and answer the following questions.

QUESTIONS = True or False (See instructions for Job No. 4)

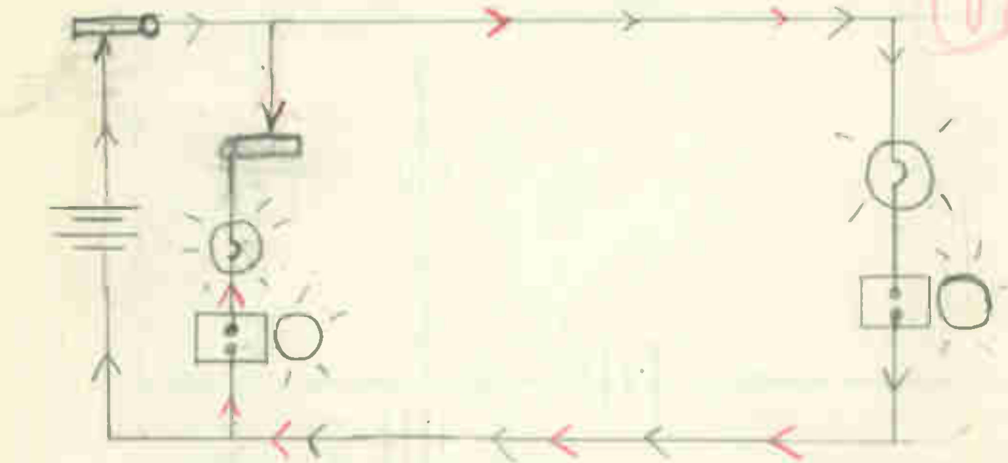
1. T (X) F ( ) The current in a series circuit is the same in all parts.
2. T (X) F ( ) The current in a parallel circuit divides according to the resistance values of the various branches.
3. T (X) F ( ) The general rule to follow for two simple type, single circuit pushbutton switches is: For connections where more than one closed circuit switch is to be used, it is best to use a series connection.
4. T ( ) F (X) Where one resistor is connected in series with a parallel group of resistors, any resistor of the parallel group is considered in series with the lone series resistor.
5. T (X) F ( ) A machine or appliance circuit may be considered, any complete wiring system controlled by one switch.

Job No. 6

M O C	O M C	C M O	M O	M O	M O

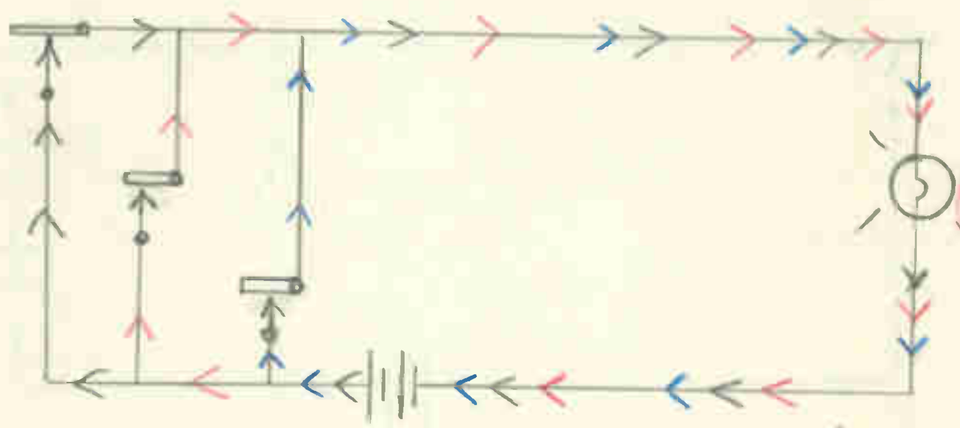
A

RJK



2 switches (open circuit) 1 (closed.
3 Lamps
1 Battery
#30 wire

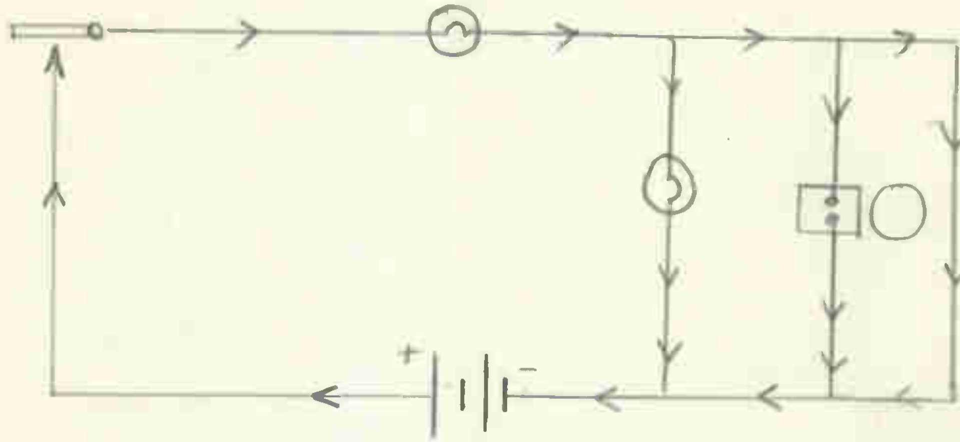
B



RJK

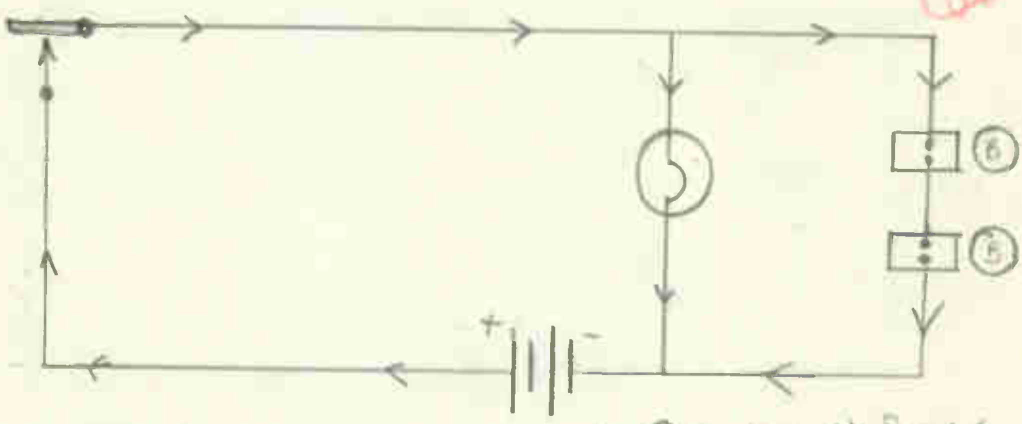
1 - Lamp
3 - open circuit switches
1 - Battery
30# wire

C



1 - open circuit switch
2 - Lamps
1 - Bell
1 - Battery
#30 wire

D



1 - Open circuit Switch
1 - Lamp
2 - Bells
1 - Battery
#30 wire

CIRCUIT WIRING

Objective

To gain additional practice in circuit wiring and reading circuit diagrams.

References:

Average Time Required:

NOTE: Jobs 3 and 4 must be completed before starting this job.

Procedure Steps

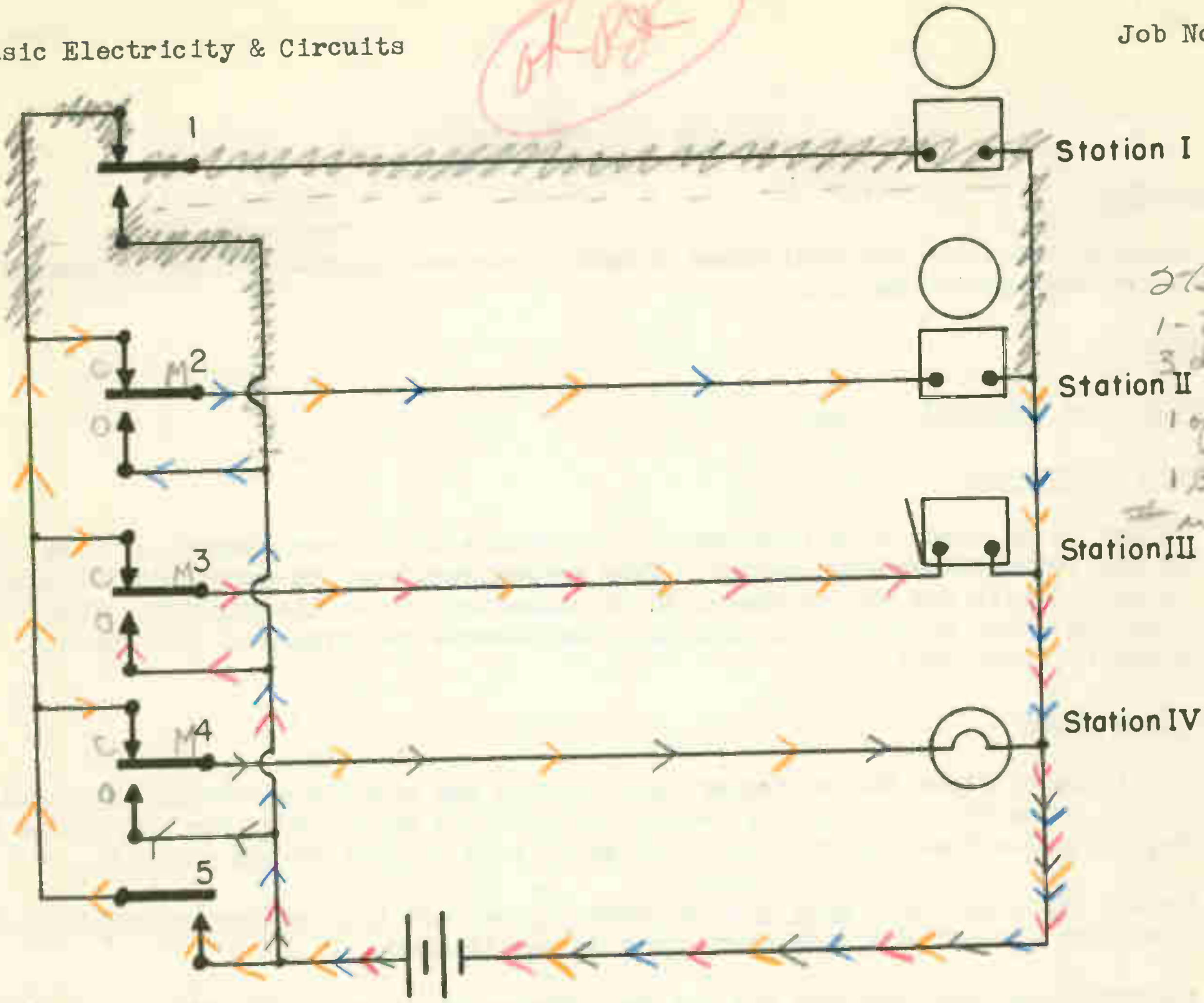
1. Study the wiring diagram, Fig. 1, to determine the materials needed on this job, noting the switches and their connections.
2. Make a complete switch terminal chart and material list.
3. Trace the circuits, Figs. 1 & 2, (use correct colors).
4. Wire the circuit for Fig. 1, one step at a time and test each step as completed.
5. Have an instructor check your work for operation and corrections of the tracing.
6. Wire the circuit for Fig. 2 in the same manner and have it checked.
7. After completing both of the diagrams, Fig. 1 & 2, answer the following questions and have credit allowed on your job card.

QUESTIONS - True or False

Instructions - Place and X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F ( ) Chicago is the capitol of U.S.A. 02. T( ) F ( ) Washington DC is the Capitol of U.S.A.

1. T (X) F ( ) Fig. 2 can be arranged so there are only two wires between stations.
2. T (X) F ( ) This is permissible in some cases.
3. T (X) F ( ) It is possible to arrange a return call system similar to Fig. 2 so there will be only one wire between stations.
4. T (X) F ( ) Disadvantage of the system mentioned in question 3, is that two sources are required.
5. T (X) F ( ) An open circuit push button system can be used on the above system.

C	O	M	C	M	O	M	O	C



2 Buzzers
1 - Lamp
3 double circuit Switches
1 open circuit Switch
1 Battery
wire

Fig. 1 This selective station call system shows the use of various switches with switch 1 to 4 inclusive calling the corresponding station, while switch 5 calls all stations.

2 - Buzzers
2 - double circuit Switches
1 - Battery
#Chip wires

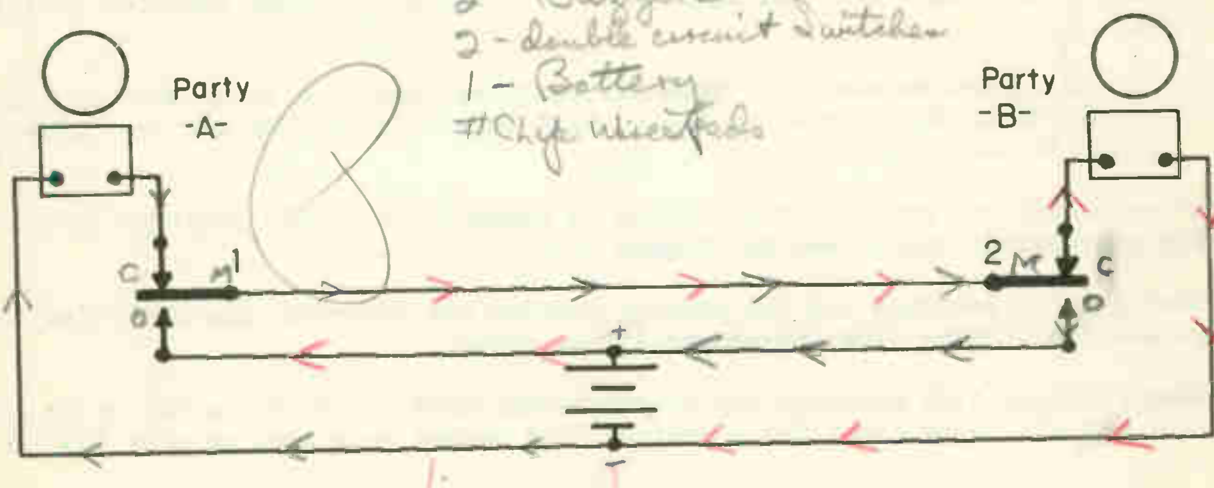


Fig. 2 A return call system using double circuit switches connected so that switch #1 calls party B and switch #2 calls party A.

OHM'S LAW PROBLEM

Objective:

To learn to calculate the resistance values of various lengths of wire by use of the voltmeter-ammeter method.

Reference:

Average Time Required: 2 hours

Related Information

The method often used in calibrating the resistance of various lengths of wire is called the voltmeter-ammeter method. This method requires the ammeter to be connected in the circuit and the voltmeter to be connected across the circuit. Then by applying Ohm's Law to the known readings, the unknown resistance of the various parts can be found easily.

Procedure Steps

1. In diagram A place the voltmeter leads across the circuit as shown. With switch 2 open, draw the leads slowly toward the opposite end of the line and notice that the voltmeter does not vary because there is no current in the circuit.

2. Repeat the experiment with both switches closed and take voltmeter readings at positions indicated by the heavy dots on the diagram.

3. Record these five readings and the two ammeter readings in the spaces provided beside diagram A.

NOTE: This proves that when current is flowing in the wire the voltage drops as the length of line is increased.

4. In diagram B, with both switches closed, place the voltmeter leads together on one line wire, then draw the negative (-) lead slowly away from the positive lead.

NOTE: In this case, we could say that the positive lead is a reference point and if placed on the diagram as shown, will be considered the most positive (+) point in the circuit.

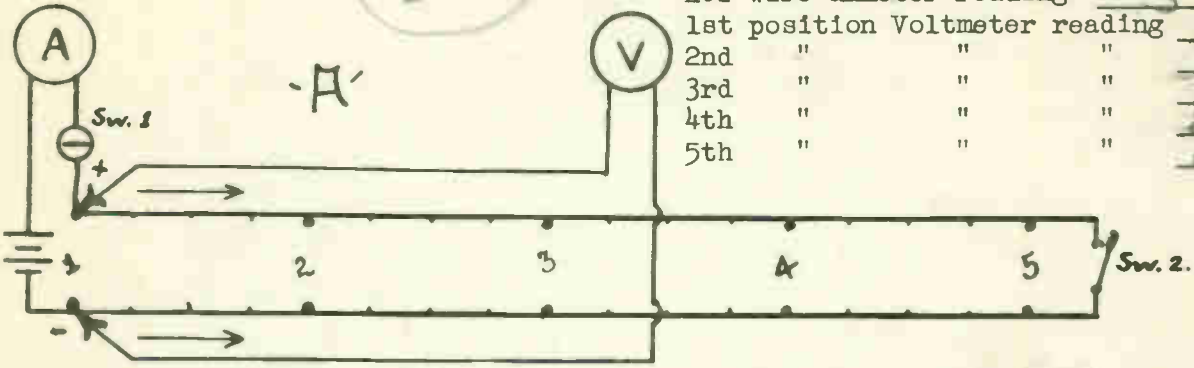
5. As each numbered point on the diagram is passed, record the readings obtained in the appropriate spaces beside diagram B.

6. When all ten readings and the ammeter reading are recorded, use Ohm's Law to calculate the various wire length resistance values.

7. When finished with readings and calculations, have all work checked by an instructor, who will also check the questions, and record your work on your job card.

$\frac{E}{I \times R}$ OHMS LAW

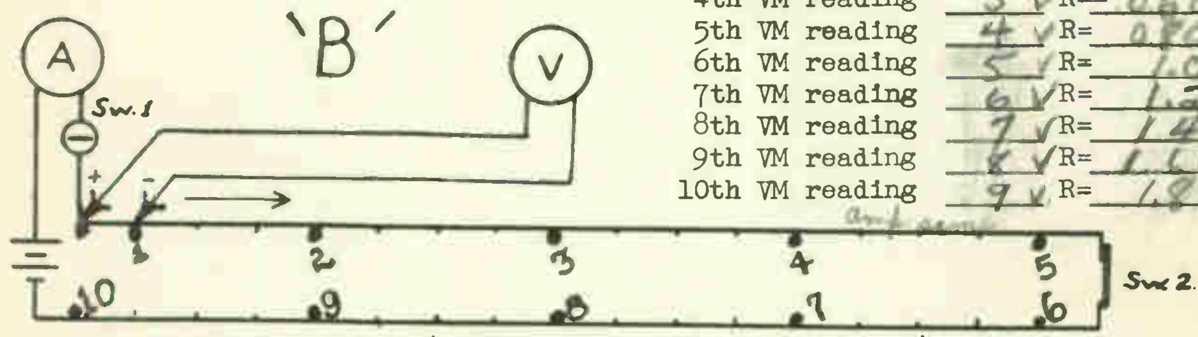
OK



COLD wire ammeter reading	5.4
HOT wire ammeter reading	5
1st position Voltmeter reading	9 ✓
2nd " " "	7 ✓
3rd " " "	5 ✓
4th " " "	2.5 ✓
5th " " "	.05 ✓

Ammeter reading 5

1st reading on VM	.02 ✓	R=	.04 Ω
2nd VM reading	1 ✓	R=	.020
3rd VM reading	2 ✓	R=	.040
4th VM reading	3 ✓	R=	.060
5th VM reading	4 ✓	R=	.080
6th VM reading	5 ✓	R=	1.00
7th VM reading	6 ✓	R=	1.20
8th VM reading	7 ✓	R=	1.40
9th VM reading	8 ✓	R=	1.60
10th VM reading	9 ✓	R=	1.80



QUESTIONS - True of False (See instructions for Job No. 7).

1. T ( ) F (X) As the temperature of a wire increases the resistance decreases.

2. T ( ) F (X) The current remains the same from the time the circuit is connected until the line wires become hot.

3. T (X) F (X) The source voltage is equal to the sum of the differences between the various points around a circuit.

4. T (X) F ( ) The smallest divisions on the voltmeter on this job represents 0.2v

5. T (X) F ( ) The "B" part of this job could be considered as a series connection of resistance.

$$R = \frac{E}{I} = \frac{9}{5} = 1\tfrac{4}{5}$$

1.80

OHM'S LAW

Objective

To gain further knowledge in the use of Ohm's Law, especially on a parallel connected equal value resistance group.

References:

Average Time Required:

Related Information

Some of the formulae to be remembered in solution of parallel connected resistors are:

If the resistors are parallel,- $R_t = \frac{R1 \times R2}{R1 + R2}$

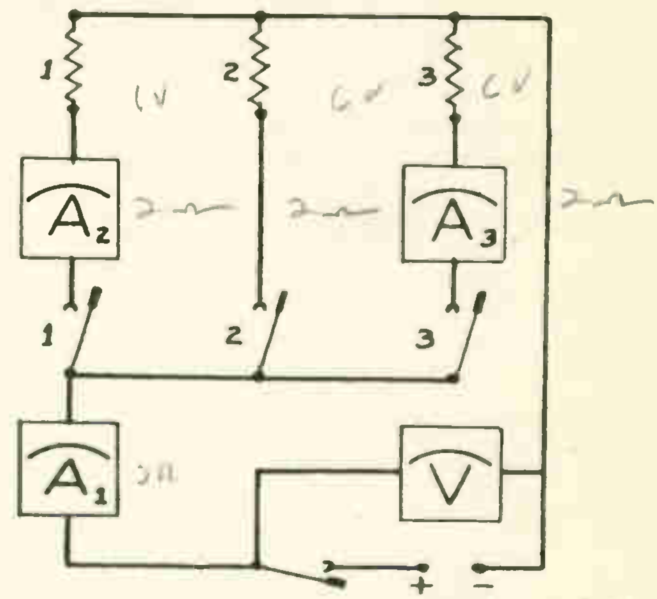
It should be noted that this formula will work for only two resistors at any one time, and may be used for either equal or unequal resistor values. If it is known that the resistors are the same value a short cut may be used -

$$R_t = \frac{\text{R of one resistor}}{\text{number of like resistors}}$$

Procedure Steps

1. Take the readings carefully on the various ammeters and record the values in the proper spaces.
2. After completing the ammeter readings, take the voltmeter reading at full load and at no load.
3. Write in your explanation as to why there is a difference in the voltmeter readings in problem 4.
4. After all readings have been double checked by you, work out and supply the necessary formula in obtaining the answers to problems 10, 11, 12, & 15.
5. Complete all other problems to the best of your ability, and have the instructor check your work and punch your job card.

APPLICATION OF OHM'S LAW



1. When sw. 1 is on:

   Ammeter 1 reads __1__ amps.
   " 2 " __1__ amps.
   " 3 " ____ amps.

   When sw. 1 and 2 are on:

   Ammeter 1 reads __2__ amps.
   " 2 " __1__ amps.
   " 3 " __0__ amps.

   When sw. 1, 2, and 3 are on:

   Ammeter 1 reads __3__ amps.
   " 2 " __1__ amps.
   " 3 " __1__ amps. } 5A

2. The Voltmeter reading with no resistors connected (no load) is __7 V__. 6V/3Ω
3. The Voltmeter reading with all resistors connected. (full load) is __6 V__.

Stop

4. The cause for the difference in voltmeter readings is __Increase in resistance causes an increase in current__
5. The Voltmeter is connected __parallel__ with the load.
6. Ammeter 1 is connected __series__ with __all__ resistors.
7. Switches 1, 2, and 3 are connected __parallel__ with each other.
8. The master switch is connected __series__ with switch 1, 2, and 3.
9. R-1, R-2, and R-3 are connected __parallels__ with each other.

SHOW FORMULAE IN OBTAINING ANSWERS TO THE FOLLOWING: $I_T = I_1 + I_2 + I_3 = 3 + 1 + 1 = 5$ Amps

10. The total resistance is __1 1/3__
11. The resistance of each resistor is __2 Ω__ 2 Ω = 1 1/3 3 Paths
12. If the resistors were connected in series with each other the total resistance would be __6 Ω__
13. The purpose of an ammeter is to measure __Current__
14. The purpose of a Voltmeter is to measure __pressure in Volts__
15. The total wattage when all switches are on is __18W = I X E__

W

• • • •

VOLTAGE DROP

Objective: To learn what voltage drop means and how to us it.

Related Information

Voltage drop and IR drop are the same thing. A voltmeter can be used to measure voltage drop. In other words, a certain voltage can be used to force current through a resistance and to measure the value of this difference of pressure we use a voltmeter.

Procedure Steps

1. Study diagram A and B and notice the similiarity between the water analogy and an electrical system.

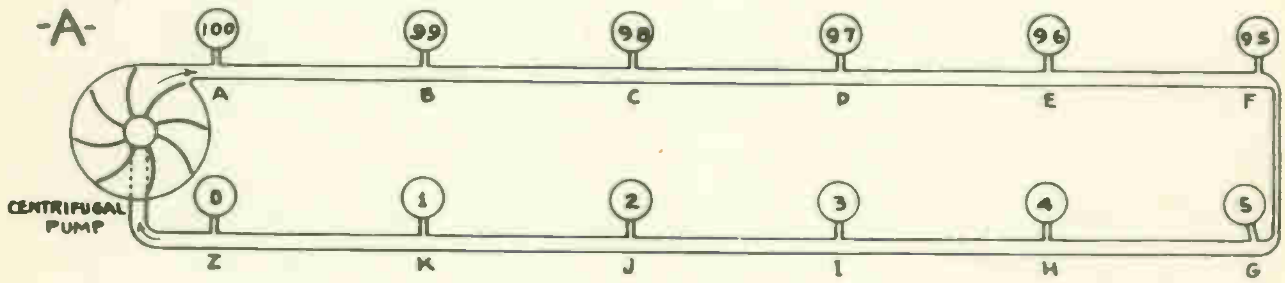
2. Answer each question with all of its parts.

NOTE: Where a question asks, at which point is the higher pressure and gives a choice of several answers, encircle the correct answer.

3. After finishing the first two sets of six questions each, proceed with the questions under Figs. C and D.

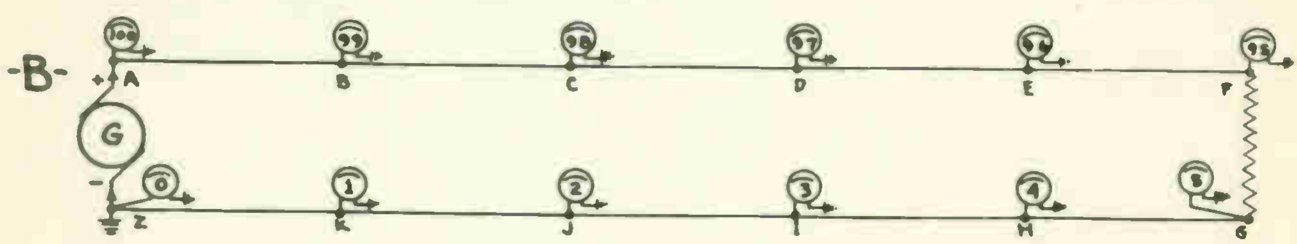
4. When finished with all parts, have an instructor check the accuracy of your work and punch your job card.

-A-

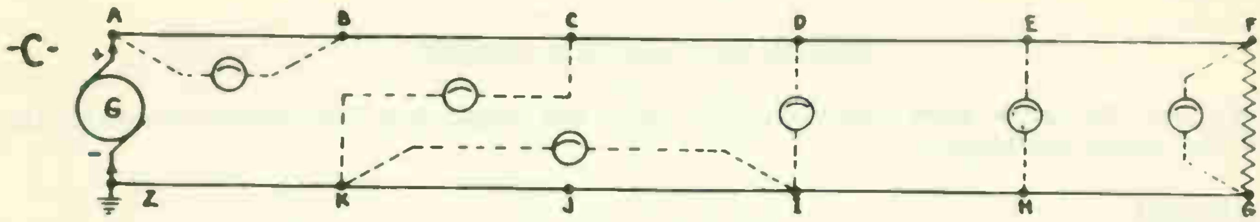


1. Which point is at the higher pressure? A or B, J or I, B or D, K or A. ________
2. What is the difference in pressure between A-B, B-D, C-F, F-G, F-J, A-Z? ________
3. What is the drop in pressure from A-B, C-E, F-G, H-K, E-H, E-G, D-I? ________
4. What is the total pressure drops around the circuit ? ________
5. Is the sum of the pressure drops equal to the applied pressure? ________
6. What is the pressure rise in pounds from Z to A? ________

-B-



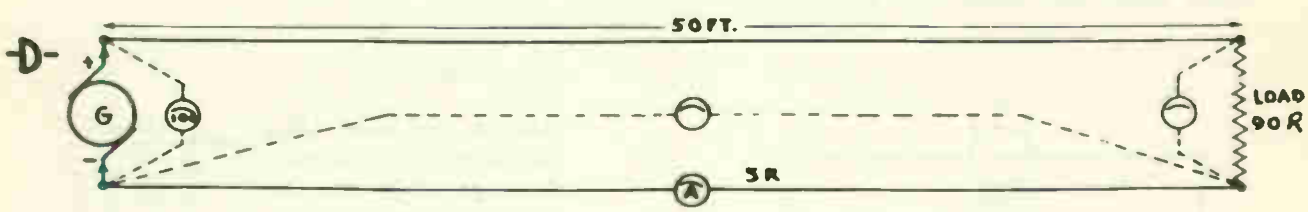
1. Which point is at the higher pressure? A or B, J or I, B or D, K or A. ________
2. What is the difference in electrical pressure between A-B, B-D, C-F, E-G? ________
3. What is the drop in pressure from A-B, C-E, E-F, F-G, K-Z, H-K, A-F? ________
4. What is the sum of the electrical pressure drops around the circuit?? ________
5. Is the sum of the pressure drops equal to the applied pressure? ________
6. What is the pressure rise in volts from Z to A? ________



Assume same conditions as shown in (B). Mark readings on the different meters

Questions - True or False

1. T ( ) F ( ) A is at a higher electrical pressure than B?
2. T ( ) F ( ) A is more positive than B?
3. T ( ) F ( ) Voltage indicates: Difference in pressure.
4. T ( ) F ( ) J is at a lower electrical pressure than K?
5. T ( ) F ( ) J is more negative than K?
6. T ( ) F ( ) The difference in pressure between D and H is 93v.



1. What is the current in amperes? .... ________
2. What is the voltage drop per 10 feet of line? .... ________
3. What is the total line voltage drop .... ________
4. What voltage is applied to the load? .... ________
5. Does the load voltage plus the line drop equal the applied voltage? ________
6. Mark in the readings on the different meters shown.

VOLTAGE DROP AROUND A CIRCUIT

Objective: To learn more about voltage drop and comparing Kirchhoff's Voltage law with the meter readings:

References:

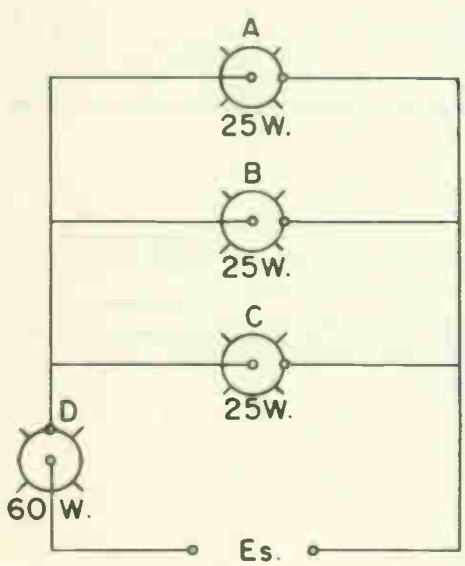
Average Time Required:

Related Information

Remember that the sum of all the voltages in a closed path will be equal to the source voltage. A series circuit, however, may contain sections with two or more parallel circuits. The voltage drop across a parallel section should be added to the voltage drop across other sections which make up the main series circuit. The sum of the voltage drops across the separate sections will equal the source voltage.

Procedure Steps

1. Study the A-B-C-D lamp combination, Fig. 1, and determine what is in series or parallel with what other part.
2. Select the proper example or demonstration equipment in the shop and test the voltage at the source of the example board.
3. Record your readings as taken, following the directions given in charts 1, 2, & 3.
4. Answer all the related questions and record the answer in the true-false blanks, according to directions.
5. Have an instructor check the accuracy of your work and he will punch your job card when you have satisfactorily completed the job.



1 - All lamps on:-

Source Voltage (E_s) 120V
Voltage drop across A 50V
Voltage drop across B 50V
Voltage drop across C 50V
Voltage drop across D 70V

2 - Lamp A off; Lamps B & C on:-

Source Voltage (E_s) 120V
Voltage drop across A 0V
Voltage drop across B 70V
Voltage drop across C 70V
Voltage drop across D 50V

3 - Lamps A & B off; C on:

Source Voltage (E_s) 120V
Voltage drop across A 0V
Voltage drop across B 0V
Voltage drop across C 100V
Voltage drop across D 20V

QUESTIONS - True or False

Instructions - Place an X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F (X) Chicago is the capitol of U.S.A. 02. T (X) F ( ) Washington DC is the Capitol of U.S.A.

1. T (X) F ( ) Lamps A, B, C are connected parallel with each other.
2. T ( ) F (X) If any of the above mentioned lamps are turned out all others will stop operating.
3. T (X) F ( ) Lamp D is connected in series with all other lamps and if loosened in the socket will stop current to the 3 other lamps.
4. T ( ) F (X) If lamps A, B, C are disconnected lamp D will still burn.
5. T (X) F ( ) If all lamps are connected as the diagram shows, then lamps A and B are disconnected, lamp D will become dimmer.
6. T (X) F ( ) With all lamps out and then C and D are connected, lamp D will become brighter when lamps B & A are connected.
7. T (X) F ( ) As lamps A & B which were formerly connected in the circuit with C and D, are turned off, the voltage drop across C increases.
8. T (X) F ( ) The sum of the voltage drops around a closed path is always equal to the source voltage.
9. T ( ) F (X) In this job, the low wattage lamp lights up brighter than the higher wattage lamp, because of the higher resistance in the lower wattage lamps. This will always show up in two different lamps in series connected across a source.

Job No. 13 | Basic Electricity & Circuits

VOLTAGE DROP IN SERIES

Objective

To learn about voltage drops in series and to learn to take difficult meter readings correctly.

References:

Average Time Required:

Procedure Steps

1. Take special note of the method of connection of the lamps A-B-C and determine how many circuits are included.

2. Select an appropriate example board in the shop for use when taking voltage readings.

3. Plug in the circuit, and check and record the source voltage value in proper space on voltage chart.

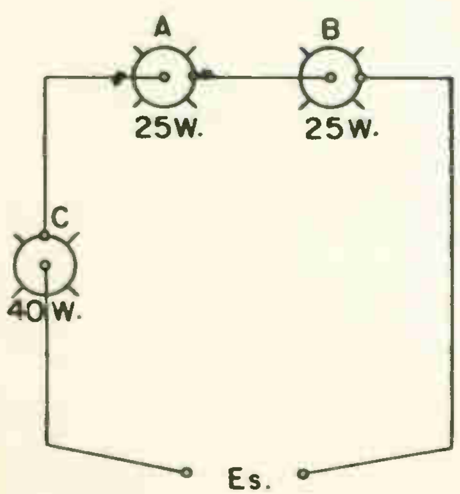
4. Check each lamp or resistance unit and determine if any two are the same.

   NOTE: You will notice that lamps A & B are of the same wattage value and therefore should read identical values if the lamps have the same voltage rating.

5. Measure and record the voltage drop across each lamp in proper space on voltage chart.

   NOTE: It is possible the meters may read differently and the cause may be attributed to loose connections, dirty contacts, incorrect reading of meter or age of lamp.

6. Answer the questions and have the instructor check the accuracy of your work and record credit on your job card.



VOLTAGE DROP

All lamps on:-

Source Voltage (E_s) 120V
Voltage drop across A 50V
Voltage drop across B 50V
Voltage drop across C 20V

QUESTIONS - True or False

Instructions - Place an X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F (X) Chicago is the capitol of U.S.A. 02. T (X) F ( ) Washington DC is the Capitol of U.S.A.

1. T (X) F ( ) All of the lamps are connected in series with each other.
2. T (X) F ( ) If lamp C is off, lamps A & B will be off.
3. T (X) F ( ) The current through all lamps will be the same.
4. T ( ) F (X) The voltage drops across all lamps will be the same because the current through each lamp is the same as any other.
5. T (X) F ( ) The voltage drops across A-B-C and the line drop will add up to the source voltage.
6. T ( ) F (X) The lamps will not give proper light unless the applied voltage is low.
7. T ( ) F (X) The lamps will give proper light if the applied voltage is 500 volts.
8. T (X) F ( ) The watts consumed by any lamp is equal to the actual applied voltage times the actual current through the lamp.
9. T (X) F ( ) A 115/230 volt test unit can be built by taking two 115 volt 15 W lamps and connecting them in series.
10. T (X) F ( ) The above unit will glow to normal brilliance when connected across a circuit of 230 volts.

VOLTAGE DROP

Objective

1. To gain practice in voltage drop problems.
2. To gain practice in taking meter readings.

References:

Average Time Required:

Related Information

The voltage drops in a closed path when added together will equal the source voltage. If in your jobs, there is a slight discrepancy in the sum total and Es, it may be attributed to loose connections, incorrect reading of meter, line voltage drop, or other intervening factors such as age of lamp, etc.

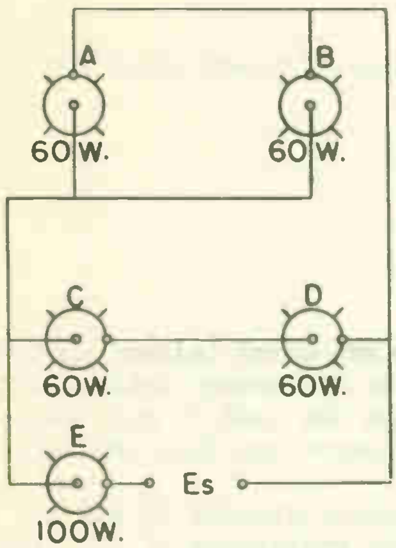
Procedure Steps

1. Study the diagram carefully to determine each lamp relation to all others in the circuit.
2. Select the appropriate example board on the benches in the shop.
3. Test the equipment already connected and also the voltmeter.
4. Check the lamps to see if the proper sizes are in the proper receptacles according to the diagram on the next page.
5. With the circuit board connected to the source of supply, check the source voltage (Es) and record this data in the proper space in chart I.
6. Follow directions for the remainder of chart I and record each meter reading in its appropriate space.
7. Make circuit changes as directed in chart II and record the values obtained in the proper blanks.
8. Make circuit changes as directed, chart III and take the readings, recording them as obtained in the proper spaces.

   NOTE: Please note that lamps C and D are the same size and that the voltage drops across lamps C & D are approximately the same.

9. When finished with all readings, answer the questions.
10. Have your work checked by an instructor and credit recorded on your job card.

VOLTAGE DROP



Voltage Charts

I All Lamps On:-

Source Voltage (E_s)	120V ✓
Ed across A	30V
Ed across B	30V
Ed across C	20
Ed across D	20
Ed across E	90

II Lamps A & B On:
Lamps C & D Off:-

Source Voltage (E_s)	120 V ✓
Ed across A	50V
Ed across B	50V
Ed across C	0V
Ed across D	0V
Ed across E	70 V

III Lamps A & B Off:
Lamps C & D On:

Source Voltage (E_s)	120V ✓
Ed across A	0V
Ed across B	0V
Ed across C	50V
Ed across D	50V
Ed across E	20V

QUESTIONS - True or False

Instructions - Place an X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F (X) Chicago is the capitol of U.S.A. 02. T (X) F ( ) Washington DC is the Capitol of U.S.A.

1. T (X) F ( ) Lamps A & B are connected parallel with each other.
2. T ( ) F (X) Lamp E is connected in series with all other lamps in this circuit.
3. T (X) F ( ) With lamps A & B disconnected, we could consider lamps C-D-E in series.
4. T (X) F ( ) Assuming the conditions as in question 3, the voltage drop across E would be lower than the voltage drop across C or D.
5. T (X) F ( ) Lamps C & D are connected in series with each other, but parallel as a group with lamp A or B.
6. T (X) F ( ) When all lamps are connected, the brightest of the five lamps will be lamp E, because all current for the other lamps must pass through lamp E.
7. T (X) F ( ) When lamp A is turned out, it will have no effect on the brightness of lamp B.
8. T (X) F ( ) The sum of all of the voltage drops in a closed path is equal to the applied voltage (E_s).
9. T ( ) F (X) If another lamp is added to a parallel group of lamps operating at the distant end of a long line (500') the voltage drop across that parallel group will decrease.
10. T ( ) F (X) If conditions were as in question 9 the parallel addition of the extra lamp at the load, would increase the line voltage drop.

LINE VOLTAGE DROP AND POWER LOSS PROBLEM

Objective

To gain knowledge of some of the properties or characteristics of power lines and the changes that take place as a load is added or increased.

References:

Average Time Required:

Related Information

Referring to the diagram below, if a voltmeter reading is taken as at (a) and another as at (b), the sum of the two readings should be equal to the difference between the source voltmeter reading and the load voltmeter reading, when the load is on. This difference in voltage is known as LINE VOLTAGE DROP. Both source and load ammeters read alike because they are in series with each other.

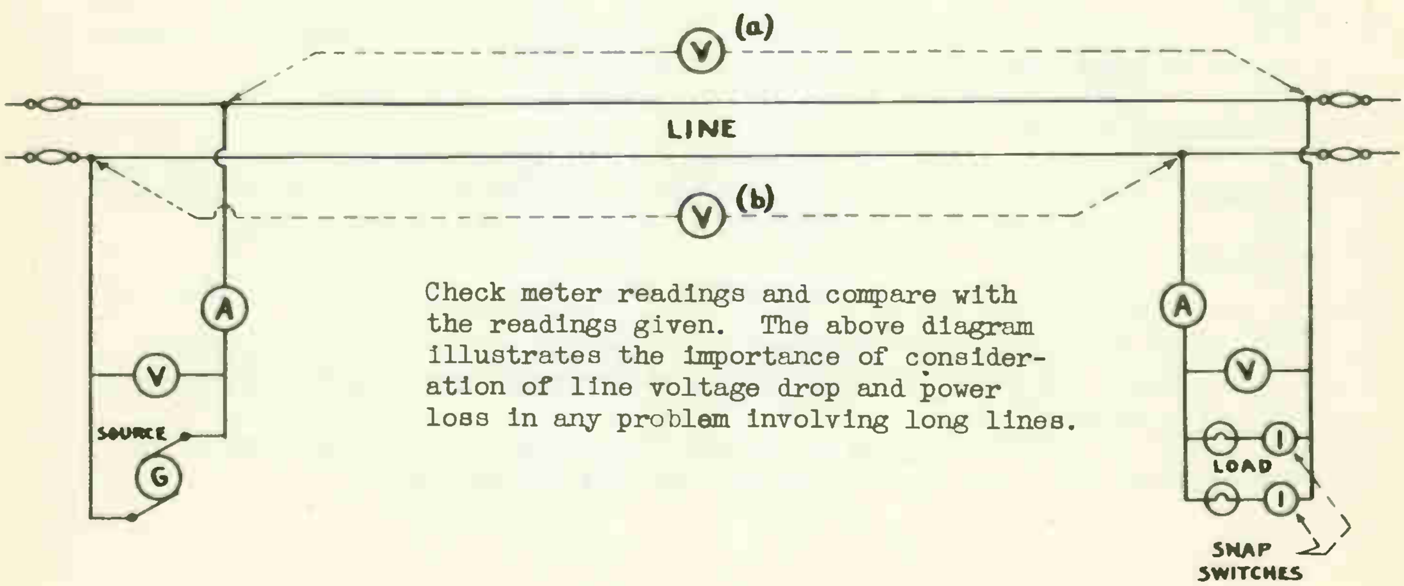
VOLTAGE DROP - difference in pressure between two points along a circuit (I x R).

LINE VOLTAGE DROP - voltage used to force current through the resistance of the line wires only. It is measured in volts.

LINE POWER LOSS - the power consumed by the line due to heating. It is measured in watts.

Procedure Steps

1. Study the example that has been worked out for you. Notice the various parts and the substitution in the various formulae.
2. Take the readings required and enter them in the proper spaces in the work charts.
3. Follow the example and work out all parts according to the readings you have obtained.
4. Substitute, in the proper spaces, the formula and enter the data in the chart.
5. When finished with formulas substitutions and all readings, have your work checked by an instructor.



Check meter readings and compare with the readings given. The above diagram illustrates the importance of consideration of line voltage drop and power loss in any problem involving long lines.

NUMBER OF LAMPS	SOURCE E	SOURCE I	LOAD E	LOAD I	LINE DROP	LINE LOSS	TOTAL W	LOAD W	LINE R	TOTAL R	LOAD R
NONE	120	0	120	0	0	0	0	0	-	-	-
ONE	120	.8	114	8	6	4.8	96	91.2	7.5	150	142.5
TWO	120	1.6	108	1.6	12	19.2	192	172.8	7.5	75	67.5

FORMULA	VALUES FOR ONE LAMP	VALUES FOR TWO LAMPS
Line Voltage Drop = Es - El	120 - 114 = 6v.	120 - 108 = 12v.
Line Power Loss = I x Ed	0.8 x 6 = 4.8w	1.6 x 12 = 19.2w
Total W = I x Es	0.8 x 120 = 96w	1.6 x 120 = 192w
Load W = I x El	0.8 x 114 = 91.2w	1.6 x 108 = 172.8w
Line R = Ed ÷ I	6 ÷ 0.8 = 7.5 ohms	12 ÷ 1.6 = 7.5 ohms
Total R = Es ÷ I	120 ÷ 0.8 = 150 ohms	120 ÷ 1.6 = 75 ohms
Load R = El ÷ I	114 ÷ 0.8 = 142.5 ohms	108 ÷ 1.6 = 67.5 ohms

Es = Source voltage El = Load voltage Ed = LINE voltage drop

WORK CHARTS

NUMBER OF LAMPS	SOURCE E	SOURCE I	LOAD E	LOAD I	LINE DROP	LINE LOSS	TOTAL W	LOAD W	LINE R	TOTAL R	LOAD R
NONE											
ONE											
TWO											

APPLY FORMULAS, SUBSTITUTE THE PROPER VALUES, AND ENTER BELOW.

FORMULA	VALUES FOR ONE LAMP	VALUES FOR TWO LAMPS
Line Voltage Drop =		
Line Power Loss =		
TOTAL W =		
LOAD W =		
LINE R =		
TOTAL R =		
LOAD R =		

RELAY CIRCUITS

Objective

To obtain practice in the use of relays.

References: Average Time Required

Related Information

The relay (magnetic switch) can be used for the following applications: control circuits which are distant from the operating point, control high voltage or high wattage circuits by means of low voltage or low wattage circuits, and to obtain a variety of control operations which are not possible with ordinary switch controls.

Tools Equipment, and necessary Materials: #30 wire and items mounted on the bench.

Procedure Steps

1. Study the equipment for this job and learn by reference to diagram A how it is to be connected.
2. Make a complete switch terminal chart and a relay switch terminal chart.
3. Place both terminal charts at the head of the sheet on the opposite page.
4. Trace the circuits and name them in the provided spaces.
5. Place the colored arrow used to trace the circuits ahead of the name given.
6. Systematically, wire the job one branch at a time and test each branch as it is completed.
7. When finished with the above step, prepare circuit B by repeating steps 4 and 5.
8. Have circuit A checked by an instructor and have the instructor also check the second diagram (B) with its material list before beginning to wire the second.

   NOTE: The next diagram's tracing and its corresponding material list will be checked by the instructor before the diagram is wired. The first check made by the instructor will be for terminal charts, material lists and circuit tracing and naming as well as the wiring on wiring diagram A. He will at the same time check your second diagram so that you may proceed to the next.

9. Repeat above procedure with circuits C and D, when satisfactorily completed with the first.
10. Answer five questions which follow and then have an instructor check your work.

QUESTIONS - True and false (See instructions on previous jobs).

1. T ( ) F ( ) A relay is a manually operated switch.
2. T ( ) F ( ) A relay is an indicator, or may be used to indicate which part of the circuit has been disturbed or where the call originated.
3. T ( ) F ( ) The counter torque spring is used to act as a returner of the moving part or armature of the relay to the normally closed contact.
4. T ( ) F ( ) Attraction of the iron part or moving contact is brought about by the magnetic attraction caused by current through the coils.
5. T ( ) F ( ) A stick or holding circuit can be created in any open circuit relay by connecting the open bridge contact in series with the coil and armature and all in series with a source.

A #1 Control Ckt. > Black
Power Ckt. > Red

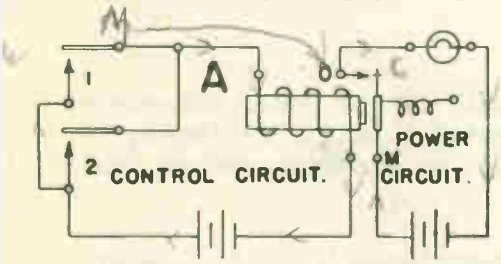
B Control Ckt. > Black
Power Ckt. > Red

D #1 Starting Ckt. > Black
Stick Circuit > Red

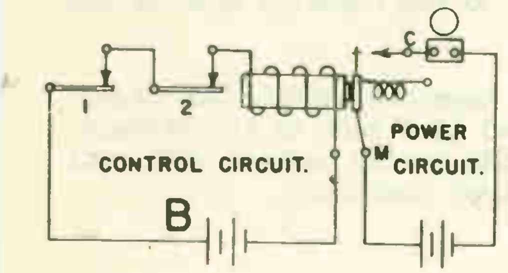
C Lamp or Alarm > Black
Control or Reset Ckt. > Red
Holding or Stick Ckt. > Blue

D #2 Starting Ckt. > Blue
#3 " " > Orange

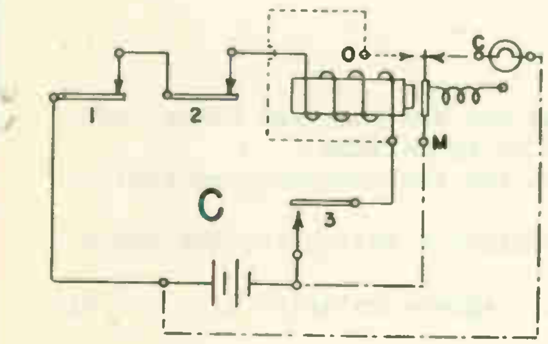
RELAY CIRCUITS.



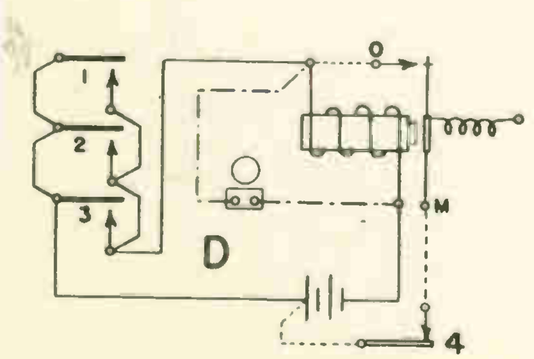
MATERIAL LIST	SYMBOL



MATERIAL LIST	SYMBOL



MATERIAL LIST	SYMBOL



MATERIAL LIST	SYMBOL

☐☐☐☐

RAILWAY CROSSING SIGNAL SYSTEM

Objective

To learn the principles of a railway crossing alarm signal system.

References:

Average Time Required

Related Information

This railway crossing alarm system is used on steam, diesel, or any other non-electric system. The system cannot be used as shown for elevated electric railways, third rail systems, or any other system where the rails act as a common return for energy supplied for the trains prime movers.

When no train is on the track current will pass through Resistance R and the relay coil C back to the source or battery. This will cause the coil to energize bringing the moving contact of the relay switching apparatus over to the normally open bridge contact, and the all clear signal will come on.

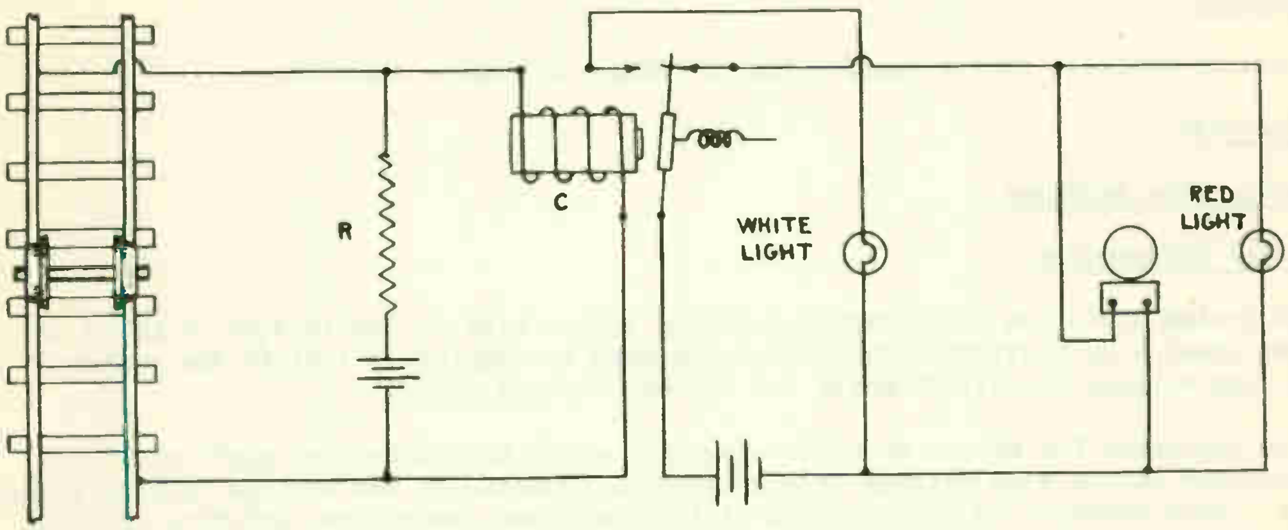
When a train appears on the track, the rails are shorted together causing the majority of the current to be bypassed through the resistor and line back to the battery. This action will deenergize the relay and the spring on the moving contact will pull the armature over to its normal position, against the closed contact.

Tools Equipment & Materials

Use your #30 CC pushback wire.
A shop table position with the necessary parts needed.

Procedure Steps

1. Study the diagram to determine the materials needed and how they are connected.
2. Trace the circuits and show the colored arrow used to trace them.
3. Test all equipment needed and make a terminal chart for the necessary mechanical and magnetic switches.
4. Wire the job, one circuit at a time, and use an open circuit switch for the track and train wheel combination switch.
5. Mark down in the proper spaces under the diagram a complete material list for all materials needed on the job.
6. Answer the questions and have an instructor check your completed work, wiring, and questions and punch your job card.



MATERIAL LIST

CIRCUITS AND COLOR TRACED

____ Low resistance track circuit
____ Danger signal circuit
____ High resistance relay circuit
____ Safety signal circuit

QUESTIONS - True or False (See instructions on previous jobs)

1. T ( ) F ( ) This railway signal can be used for any type of railway system.
2. T ( ) F ( ) The resistor R acts as a current limiter in both the high resistance relay circuit and the low resistance track circuit.
3. T ( ) F ( ) Its main use is to limit the current to a safe value when a train is on the track.
4. T ( ) F ( ) A double circuit relay must be used for this job.
5. T ( ) F ( ) The same source of current supply may be used for this system.
6. T ( ) F ( ) A broken axle in the train, would likely break the low resistance track circuit and the safety signal lamp would show all clear.
7. T ( ) F ( ) The relay should be of a comparatively high resistance (50 to 100 ohms)

RELAY MOTOR CONTROL

Objective

To obtain practice in the application of relays to remote controls.

References:

Average Time Required:

Related Information:

This system shows how to control a motor of either high or low voltage by means of three start-stop positions. Two relays are used to completely isolate the controlled high voltage circuit from the low voltage control circuit.

It is desirable for motors or other apparatus where the controlled portion of the system may handle high voltage or high wattage by means of low voltage control equipment. Such examples as motor driven milling machines, conveyors, printing presses, lathes, multiple drilling machines, and even overhead crane equipment can be easily started and stopped by means of this simple control.

Tools, Equipment & Materials

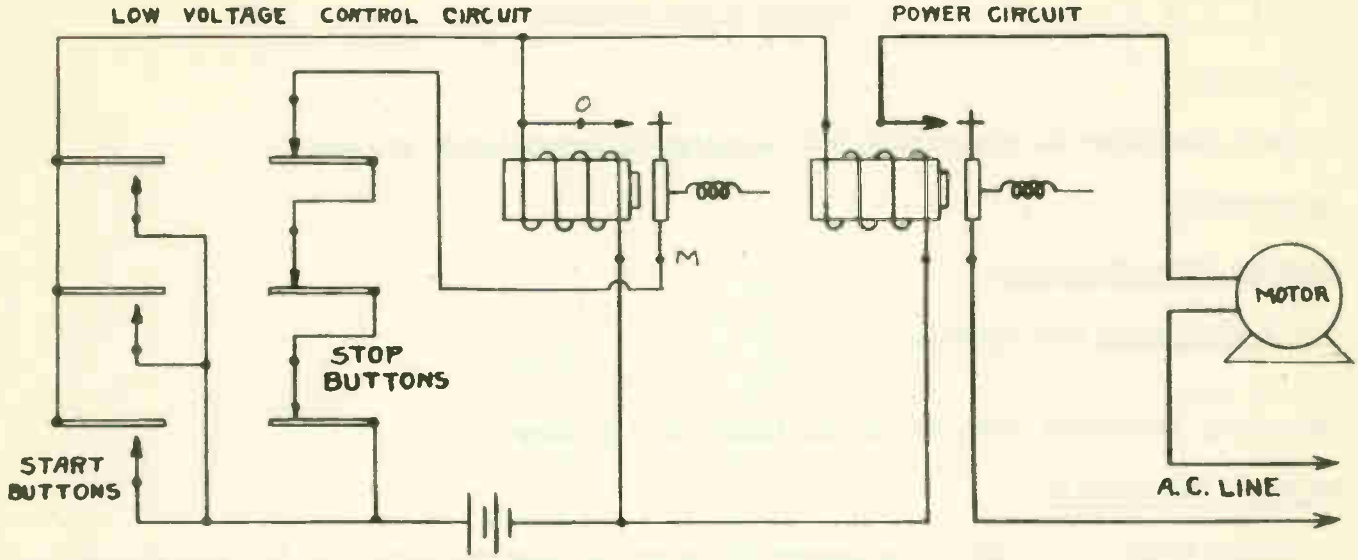
#30 CC wire - Shop table containing all the equipment including the motor.

Procedure Steps

1. Study the diagram used on this job.
2. Trace the circuits in proper colors and show arrow used to trace those circuits.
3. Test all the equipment needed on the job and make a complete terminal chart for all mechanical and magnetic switches.
4. Wire the job systematically and test each completed circuit for operation.

   NOTE: Many possible troubles and trouble sources may be eliminated by using a system of wiring and also checking each finished circuit before proceeding with next circuit.

5. Make a complete material list in the provided space on the next page.
6. Answer the questions and have your work checked. The instructor will punch your card if the work is satisfactory.



MATERIAL LIST

CIRCUITS AND COLOR TRACED

____ 1)
____ 2) Starting Circuits
____ 3)

____ Stick or Holding Circuit
____ Power or Motor Circuit

QUESTIONS - True or False

Instructions - Place an X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F (X) Chicago is the capitol of U.S.A. 02. T (X) F ( ) Washington DC is the Capitol of U.S.A.

1. T ( ) F ( ) A relay may be used for this type job as long as it is an open circuit type and a proper source is applied to cause operation of that relay.
2. T ( ) F ( ) The open circuit switches are connected parallel with each other.
3. T ( ) F ( ) Closed circuit switches are connected in series with each other so that the stick or holding circuit may be broken at any point.
4. T ( ) F ( ) The relay coils on the two different relays are connected in series with each other.
5. T ( ) F ( ) The two relay coils are connected parallel with each other.
6. T ( ) F ( ) To obtain a stick or holding circuit the open bridge contact, coil and armature of the same relay must be connected in series with the source of current supply.
7. T ( ) F ( ) In order to make an approved 3 position control using push button switches, 3 wires must be used between the switch boxes.

ANNUNCIATOR SYSTEMS

Objective

To gain practice in connecting and testing an annunciator system.

References:

Average Time Required:

Tools Equipment and Materials:

#30 CC wire
Necessary equipment mounted on the table in the shop.

Related Information

An annunciator is a signaling apparatus operated electromagnetically, and serves to indicate whether current exists in one or more circuits. It is usually employed in connection with electric bells, buzzers or lamps (A.S.A. 95.50.015).

The circuit shown is an alarm or signal system using an annunciator, A, and a drop relay, D (drop switch), to provide a continuous alarm until the relay is reset by hand.

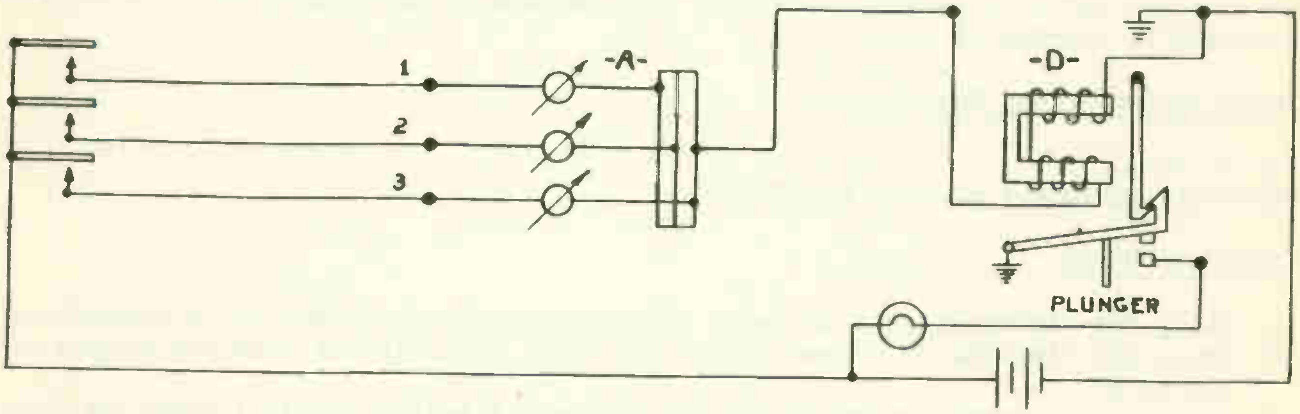
Procedure Steps

1. Study the diagram to determine what equipment to use and how it is connected.
2. Trace the circuits in proper colors and show the colored arrow used to trace each circuit. Name each circuit and its purpose in the system.
3. Test all equipment needed on the job and make a switch terminal chart as well as the drop relay and annunciator terminal chart.
4. Wire the job and test each completed section to insure operation without faulty wiring of one part affecting the system.
5. Make a complete material list in the space provided on the next page.
6. When all work is finished have an instructor check both the job and your answers to the questions. If satisfactory he will punch your job card.

QUESTIONS - True and false (See instructions on previous lessons).

1. T ( ) F ( ) The annunciator is actually an indicator of call or disturbance in the system.
2. T ( ) F ( ) The drop relay's drop contact terminal will not work in the upside down position. In other words, it must depend on gravity for operation.
3. T ( ) F ( ) The common return terminal of the annunciator paired with any other terminal on the annunciator when energized, will drop only one shutter.
4. T ( ) F ( ) Current for the signal or alarm circuit must actually pass through the metal frame of the drop relay.
5. T ( ) F ( ) The biggest problem of maintenance of an annunciator system is repairing the wiring, armature spring, and shutter.
6. T ( ) F ( ) You can use annunciators for an elevator call system, burglar protection, and fire alarm connected equipment.

ANNUNCIATOR SYSTEMS



MATERIAL LIST

CIRCUITS & COLOR USED

____ 1)
____ 2) Annunciator Circuits
____ 3)

____ Lamp or Alarm Circuit

DUPLEX RELAY CONTROLLED ANNUNCIATOR SYSTEM

Objective

To gain practical experience on annunciator systems.

References:

Average Time Required:

Related Information

Two relays are used to give a greater flexibility to this type of control.

CAUTION

A common source of supply may be used for this job but care must be taken to finish the various parts or sections one at a time because of the danger of short-outs if too much is started at once.

Tools Equipment and Materials:

#30 CC Wire
Necessary equipment already mounted

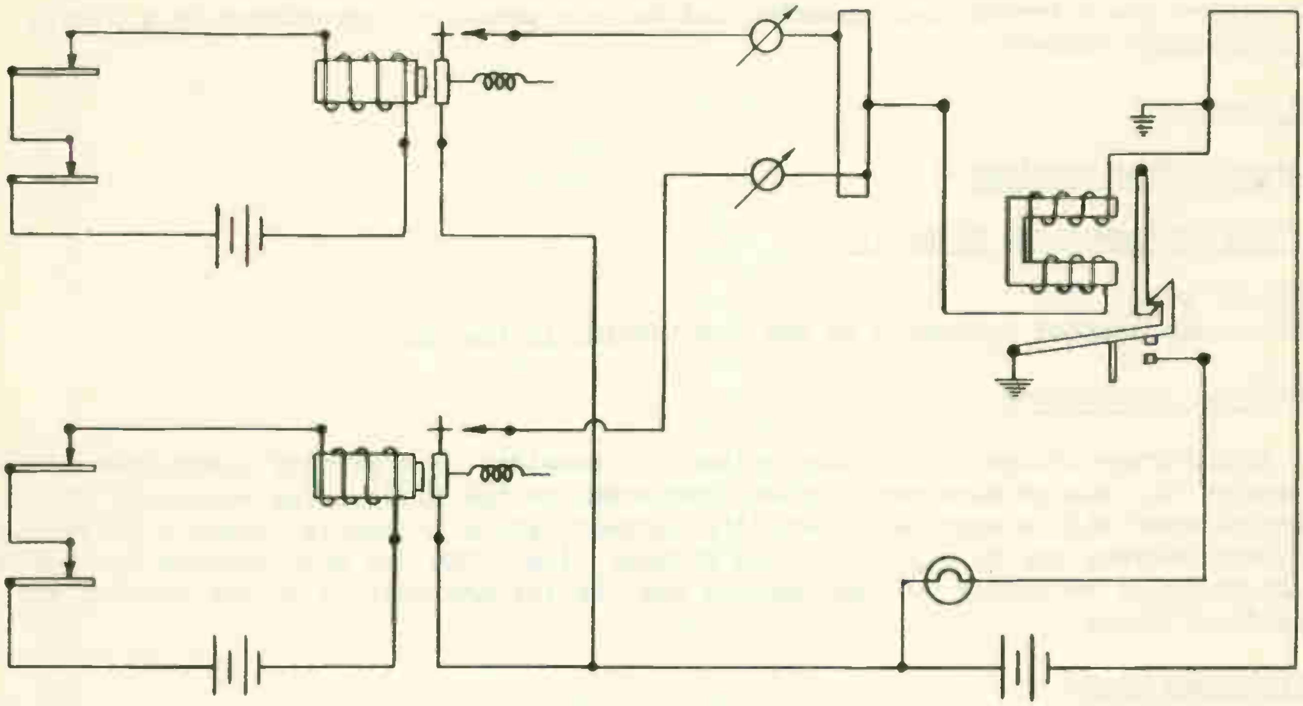
Procedure Steps

1. Study the wiring diagram to learn the equipment used and how it is connected.
2. Trace the circuits in proper colors and label each circuit with its proper tracing color.
3. Test all equipment needed on the job and make a switch terminal chart as well as the annunciator and drop relay terminal charts.
4. Also show the terminal charts for the two closed circuit relays, at the bottom of the next sheet along with the other charts made in step 3.
5. Wire the job and test each completed section to insure operation with no trouble in the wiring.
6. Make a complete material list and place in provided space on the next page.
7. Answer the following questions, have all work checked by an instructor.

QUESTIONS - True or False (See instructions on previous jobs).

1. T ( ) F ( ) This two section alarm or signal system could protect two or more floors, buildings, or departments because the closed circuit switches could be in door jams, window frames or other likely disturbed areas.
2. T ( ) F ( ) If an audible signal is desired instead of the visual signal shown, a bell may be substituted.
3. T ( ) F ( ) A foil band made of aluminum or other light metal can be used for show window protection.
4. T ( ) F ( ) If the spring tension is weak on either relay armature, that circuit may not function properly.
5. T ( ) F ( ) This system could be installed satisfactorily, for two people with a maid or butler. The servant would be able to tell which party called by observing the dropped number in the annunciator box.

DUPLEX RELAY CONTROLLED ANNUNCIATOR SYSTEM



MATERIAL LIST

CIRCUITS AND COLOR USED

____	Relay Circuit No. 1
____	Annunciator Circuit No. 1
____	Lamp or Alarm Circuit
____	Relay Circuit No. 2
____	Annunciator circuit No. 2

TRANSFORMER PRINCIPLES AND APPLICATIONS

Objective

To learn how a transformer operates and to gain practical experience in a simple transformer connection.

References:

Average Time Required:

Tools Equipment and Materials

#30 CC wire
Necessary mounted equipment on the work tables in the shop.

Related Information

A transformer changes AC voltage values. It consists of a primary (connected to the source) and one or more secondaries (connected to the load). The secondary of any transformer will always be alternating current, while in special cases a pulsating direct current may be applied to the primary side. The two main factors upon which the value of secondary voltage depends are the voltage applied to the primary and the ratio of turns.

Procedure Steps

1. Study the wiring diagram and determine the equipment to use.
2. Trace the circuits in proper colors and show, in the space provided, the colored arrow used to trace each circuit.
3. Test all equipment needed on the job and make a terminal chart for the switches and place it in the proper space at the bottom of the page.
4. Make a complete material list and place it in the provided space.
5. Wire the job and test each completed circuit.
6. When finished, answer the questions below and have all of your work checked by the instructor.

QUESTIONS - True or False

Instructions - Place an X in the space following the letter T for a true statement. Place an X in the space following the letter F for a false statement. Example - 01. T ( ) F (X) Chicago is the capitol of U.S.A. 02. T (X) F ( ) Washington DC is the Capitol of U.S.A. (Refer to page 251)

1. T ( ) F ( ) The connections you have made to the transformer are tied to the low tension side of the transformer.

2. T ( ) F ( ) Any winding can be used for the primary of a transformer provided the correct voltage and frequency are applied.

3. T ( ) F ( ) Output power is equal to input power minus losses in windings and core due to heat.

4. T ( ) F ( ) Transformer ratio means a comparison of the primary to secondary in current, voltage, or turns of wire.

5. T ( ) F ( ) All transformers have a primary and secondary but may not have high tension and low tension.

6. T ( ) F ( ) The induced voltage of a transformer is opposite in polarity that of the applied voltage.

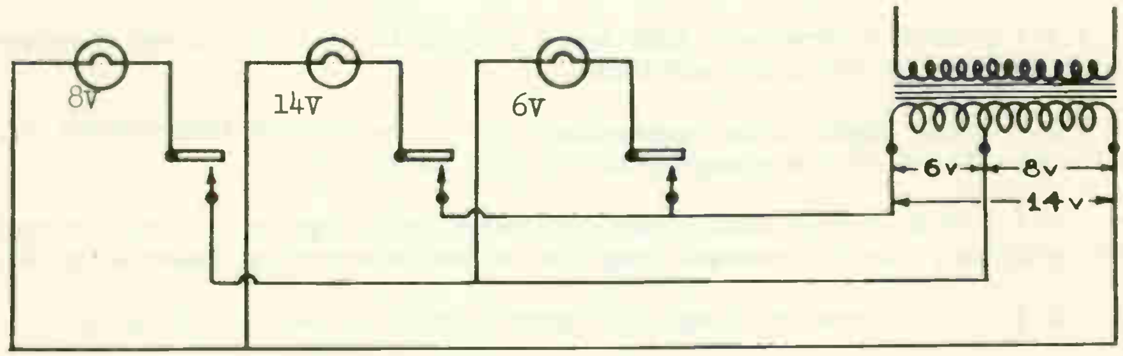
7. T ( ) F ( ) Transformers are used in AC - DC radio sets to supply various necessary voltages for operation of that radio set.

8. T ( ) F ( ) The laminated iron core in a transformer serves as a magnetic coupler, flux concentrator, and it acts to limit or confine the eddy currents induced in the iron.

9. T ( ) F ( ) The secondary of any transformer is always the side to which the load is attached.

10. T ( ) F ( ) The high tension winding is known as the high voltage winding. The low tension winding is known as the low voltage winding.

11. T ( ) F ( ) When a voltage is stepped up by means of the transformer, it causes the current to be stepped down.



MATERIALS LIST

____

____

____

____

CIRCUITS AND THE COLOR USED

______ 6 Volt Lamp Circuit
______ 14 Volt Lamp Circuit
______ 8 Volt Lamp Circuit

T E R M I N A L C H A R T

FLUORESCENT LAMPS

Objective

To learn the operating principles of a simple fluorescent lighting circuit and its component parts.

References:

Average Time Required:

Tools Equipment and Materials

Materials board containing all necessary equipment except the starter and lamp.

Procedure Steps

1. Connect the block wiring diagram (next page) together in a neat manner.
2. Trace the starting circuit and the operating circuit.
3. Make a complete detailed material list for the job.
4. Using #14 RC black and #14 white wire, wire the job.

NOTE: Strict polarization of a wiring system must be observed.

5. When wiring is finished, recheck and then answer the following questions before the instructor gives you a lamp and starter.
6. When your work is satisfactory, an instructor will punch your job card.

QUESTIONS True and False

1. T ( ) F ( ) The lumen output of a 40 Watt (3500°) fluorescent lamp is 2320 lumens.

2. T ( ) F ( ) Each fluorescent lamp has a very thin coating called phosphors on the inside surface of the glass envelope.

3. T ( ) F ( ) The light color temperature of a fluorescent lamp varies as the chemical composition of the phosphorous coating is varied.

4. T ( ) F ( ) With proper auxilliary equipment including an external current control resistor, the fluorescent lamp can be satisfactorily operated on DC.

5. T ( ) F ( ) A fluorescent lamp will operate just as well on DC as AC.

6. T ( ) F ( ) The no-blink starter has an additional element (bimetallic) which acts to prevent high preheat current to flow through the ballast, if a lamp is unsuccessful in starting because of defect or exhaustion.

7. T ( ) F ( ) The average 40 Watt fluorescent lamp life is about 2500 hours.

8. T ( ) F ( ) The fluorescent lamp has the standard Edison screw base.

9. T ( ) F ( ) A starter is used as a switch in this type of circuit to connect the heating coil elements in series for starting operation.

10. T ( ) F ( ) A ballast coil preforms the following functions in the fluorescent

lamp circuit: Preheats electrodes liberating many free electrons, provides a surge potential to start the arc, and prevents the arc current from exceeding the set limit for a certain size lamp.

11. T ( ) F ( ) Three types of automatic starters are; thermal, glow, and no-blink.

12. T ( ) F ( ) Fluorescent ballasts and other equipment have been designed for frequencies of 25 to 400 cycles. The lower the frequency the smaller the ballast.

13. T ( ) F ( ) Fluorescent lamps operate most efficiently at temperatures between 70° and 90°F.

14. T ( ) F ( ) To operate fluorescent lamps on DC without a reverse starting switch will cause one electrode to burn out while the other is nearly new.

15. T ( ) F ( ) When these lamps are operated on AC, what keeps the lamp glowing when the cyclic zero points are reached. It must be the holdover effect of the phosphors.

16. T ( ) F ( ) Stroboscopic effect is noticed principally on the single lamp a-c circuits.

17. T ( ) F ( ) The eleven most popular fluorescent lamp sizes are: 6, 8, 13, 14, 15, 20, 25, 30, 40, 85, and 100 Watt sizes.

18. T ( ) F ( ) The most popular colors of the fluorescent lamp family are: daylight (6500°K), white (4500°K), standard white (3500°K) warm white (3000°K), soft white (2500°K), blue, green, gold, pink and red.

19. T ( ) F ( ) The bulb type number denotes the lamp's diameter size in 1/8ths of an inch.

20. T ( ) F ( ) Other type lamps in the fluorescent class are low brightness, instant-start, slimline, and circline.

ELECTRIC TROFFER TYPE SIGN

Objective

To gain practical experience with the connections of this sign and to learn the various effects obtainable.

References:

Average Time Required:

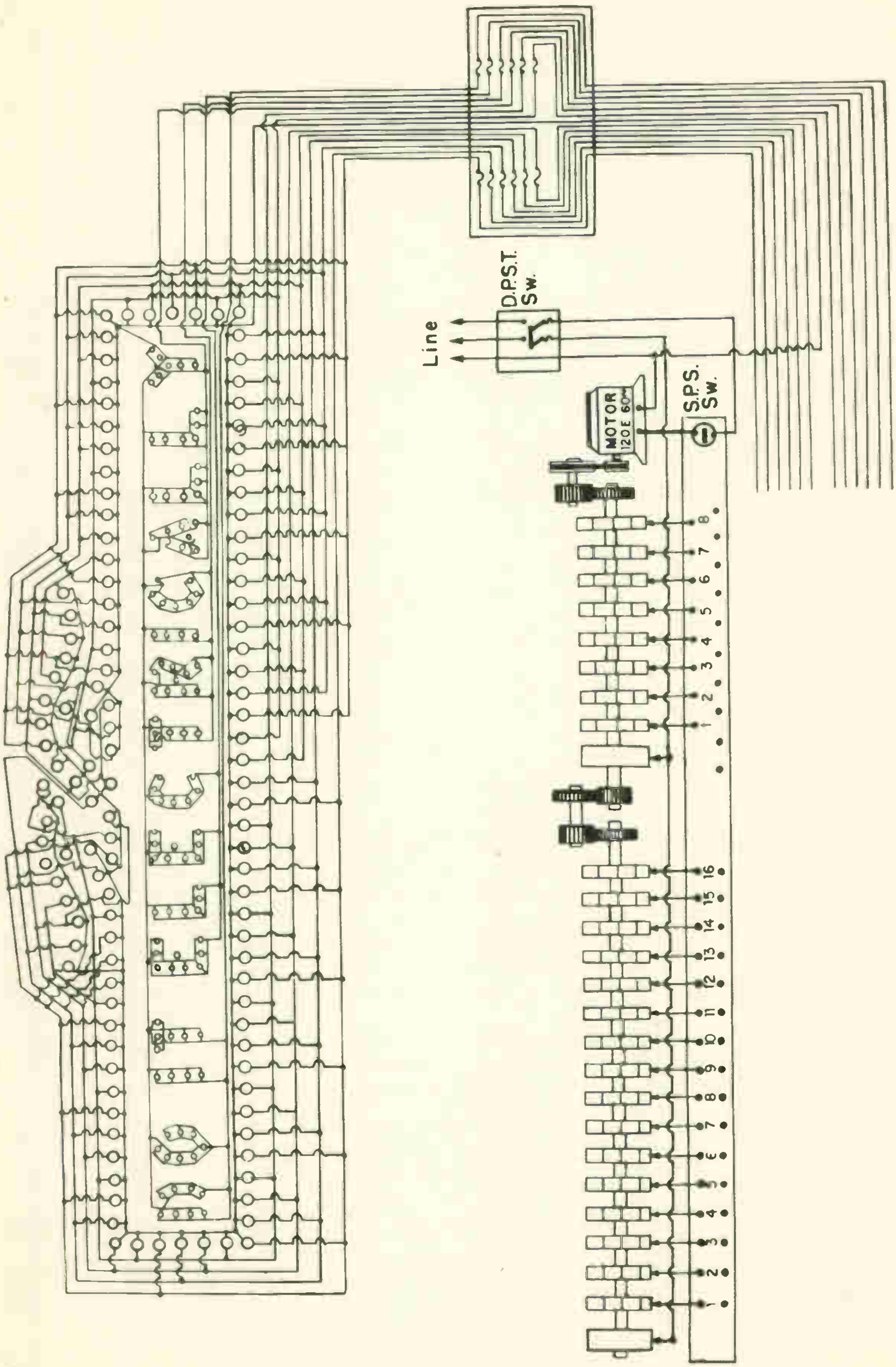
Tools, Equipment, and Materials

Procedure Steps

1. Test the controller or flasher to identify the terminals.
2. Connect the border so the entire border will have a clockwise rotation.
3. Connect the "D O I T E L E C T R I C A L L Y" for the speller and flash effects.
4. Make a material list for the parts and list the purpose of each.
5. List the main troubles encountered with this type sign.
6. When finished, have your work checked by an instructor.

QUESTIONS - True and False

1. T ( ) F ( ) The purpose of an electrical sign is to attract attention and for advertising.
2. T ( ) F ( ) The border effect on a sign may be added to attract attention to the message.
3. T ( ) F ( ) The reading distance (effective) of this sign will be increased to approximately 1500' or more depending upon the size of letters.
4. T ( ) F ( ) Removing the troffers around the letters decreases the reading distance.
5. T ( ) F ( ) The maintenance problems for this sign would probably be contacts, controller, motor, wiring and sign in that order.
6. T ( ) F ( ) This sign uses an Edison 3-wire type of a service.
7. T ( ) F ( ) The motor used on this sign controller is $\frac{1}{4}$ HP at 115 volts.
8. T ( ) F ( ) The wire used for controller wiring is #14 WP.
9. T ( ) F ( ) Probably the greatest disadvantage of this controller is the exposed arcing.
10. T ( ) F ( ) The border lamps are low wattage lamps and they are all connected on one branch circuit.


D.P.S.T.
Sw.
Line
S.P.S.
Sw.
MOTOR
120E 60~
8
7
6
5
4
3
2
1
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

EXPOSED LAMP TYPE ELECTRICAL SIGNS

Objective: To gain experience with electrically operated signs

References: Average Time Required:

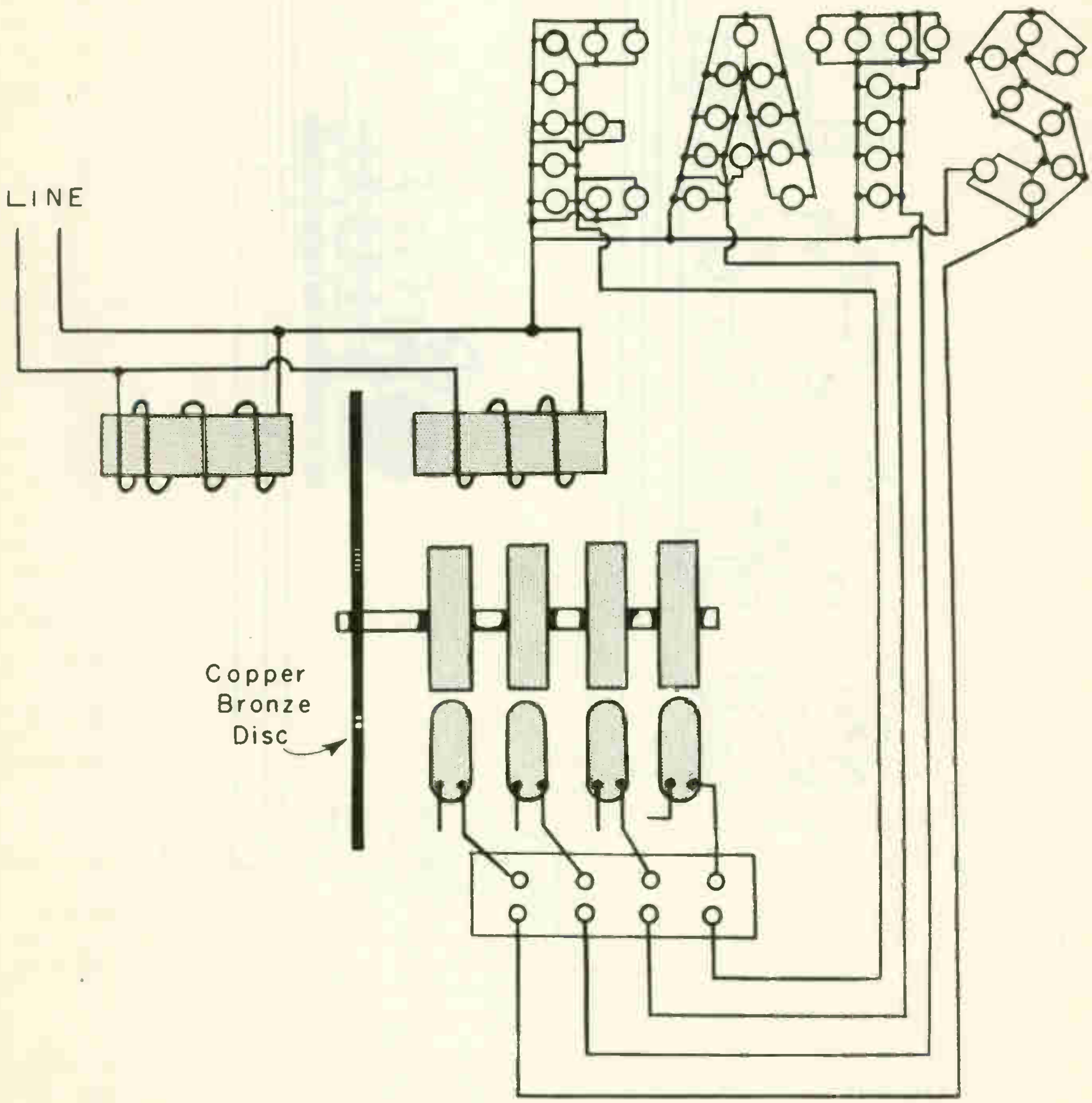
Tools, Equipment, and Materials:

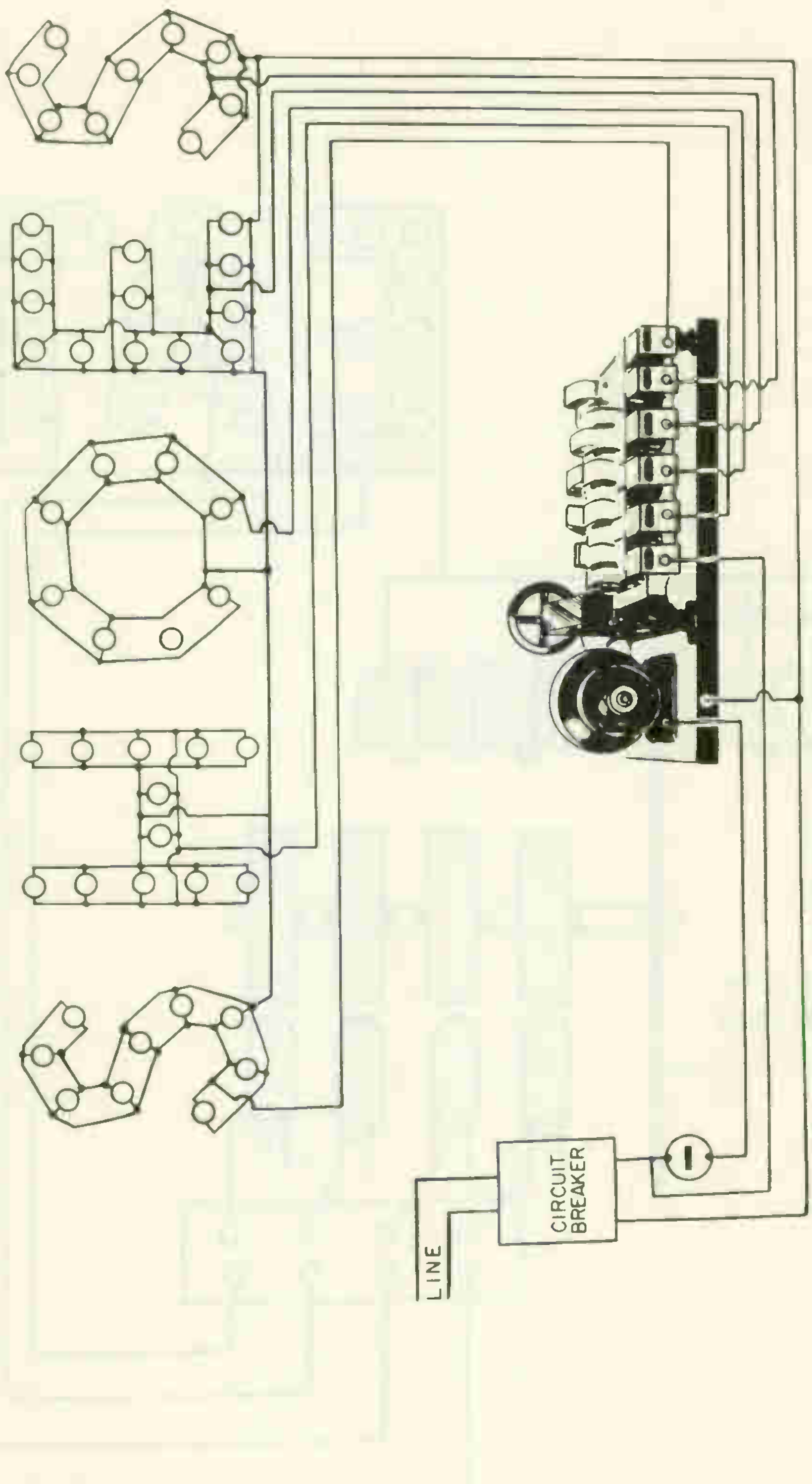
Procedure Steps

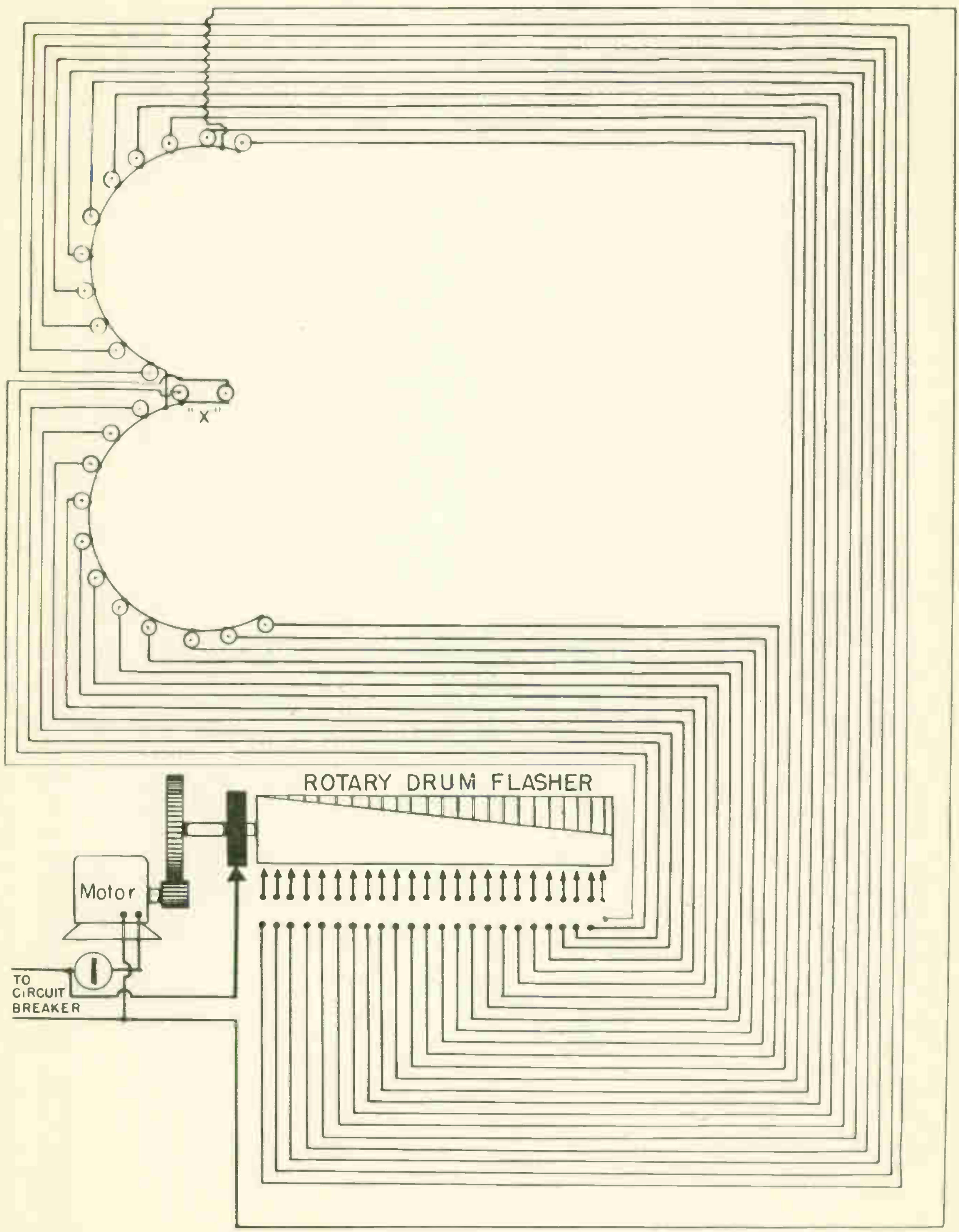
1. After obtaining your requisition from the desk, PRINT your name and student number along with today's date in the provided spaces at the top.
2. Present the requisition slip to stockroom window #1.
3. Check the materials received, with the material list on the end of the box.
4. Choose one of these signs (A) E sign (B) EATS sign (C) SHOES sign and use the corresponding diagram.
5. Begin testing the controller or sign flasher so as to determine their terminals and the connections made to each terminal.
6. Wire the signs in such a manner that the message is spelled out in proper order.
7. Write detailed information next to the diagram as to materials needed, purpose of parts, motor data, and observations.
8. When finished with any one part of diagram, have your work checked by the instructor who will also check your questions.

QUESTIONS - True and False

1. T ( ) F ( ) The sign you have just wired is an exposed lamp type that has an effective reading distance of 250' or less.
2. T ( ) F ( ) A big advantage of an electric sign is that it is cheaper to operate, because the lamps are not on all of the time.
3. T ( ) F ( ) The flasher used on this type of sign is rated in amperes per contact.
4. T ( ) F ( ) The size lamp used for this type of sign should not be over 25 watts each.
5. T ( ) F ( ) The advantage of the mercury flasher is that the circuit is made and broken in a vacuum, adding to the life of the sign flasher.
6. T ( ) F ( ) It is not necessary to polarize the wiring system to the sign control equipment.
7. T ( ) F ( ) A total load of 3 kw or over requires a three wire system.
8. T ( ) F ( ) The circuit breaker to this sign is connected in the neutral side of the line.
9. T ( ) F ( ) The cost of operation of this sign can be calculated by taking the number of lamps and the size of each and the hours operated, times cost per kwh.
10. T ( ) F ( ) The cost of operating the sign you have just wired is $1.32, when we figure the lamps on 1/3 of the time, 50 hours period, and $0.05 per kwh.
11. T ( ) F ( ) To be effective, the sign must be cleaned periodically.
12. T ( ) F ( ) Lamp changes and maintenance must be considered in the cost of operation of this sign.
13. T ( ) F ( ) The silhouette type of sign has a lesser effective reading distance than these exposed lamp types.
14. T ( ) F ( ) The speller effect is used in all modern sign work.


LINE
Copper
Bronze
Disc


CIRCUIT BREAKER
LINE


"X"
ROTARY DRUM FLASHER
Motor
TO
CIRCUIT
BREAKER

DRY CELL CONNECTIONS

Objective

To learn the various methods of connecting #6 standard dry cells so as to obtain different totals of voltage and current capacity.

References:

Average Time Required:

Tools Materials & Equipment

Related Information

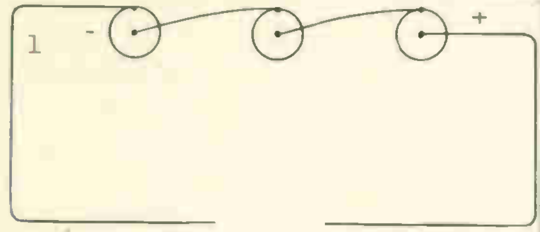
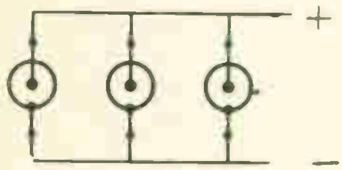
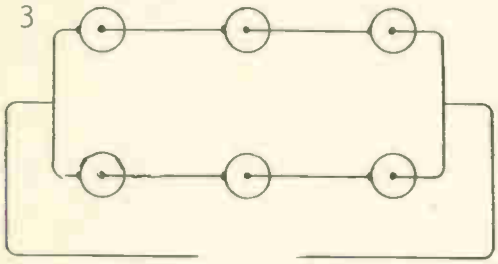
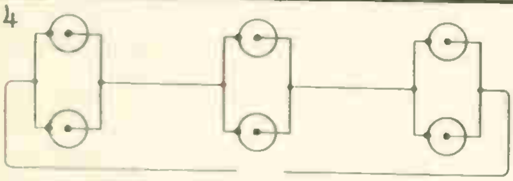
The particular cell we are referring to here is a standard #6 dry cell which has the following rating: 1.5v, 20Ih, 30 Wh (max. constant drain $\frac{1}{4}$ amp).
By connecting cells in parallel, we can increase the current capacity (Ih) of the unit. By connecting cells in series, we increase the voltage output of the unit. By connecting cells in a series-parallel-series, called a network combination, the overall work can be increased by increasing both current and voltage.

Procedure Steps

1. Study over the examples 1 - 4 to determine how each cell adds to the final voltage and current capacity.
2. Review the jobs on series and parallel circuits to refresh your memory on what constitutes series or parallel connections.
3. Make a sketch in position 5 of 4 series connected cells.
4. Show final voltage, amperehours, and watt-hours for the connection (step 3).
5. Draw a diagram of 5 parallel cells in position 6.
6. Show final result as in Step 4.
7. Continue in the described manner for the remaining two examples:
   position 7-draw and show the final result for 4 series 3 parallel.
   position 8-draw and show the final result for 3 parallel 4 series.
8. Answer the following questions and have the instructor check your work.

QUESTIONS - True or False (See instructions on previous jobs)

1. T ( ) F ( ) The standard dry cell is a primary cell.
2. T ( ) F ( ) As soon as this cell is manufactured, it will furnish current.
3. T ( ) F ( ) The voltage of a cell is largely dependent upon the types of elements used in cell construction.
4. T ( ) F ( ) The current capacity of any cell depends upon the size of the plates or elements.
5. T ( ) F ( ) In a series-parallel connection of cells, the voltage and current capacity are increased.
6. T ( ) F ( ) In a parallel-series connection of cells, the current capacity and voltage decreases.
7. T ( ) F ( ) An element may be considered any lone material of the earth such as iron, copper, zinc, lead, etc.
8. T ( ) F ( ) The electrolyte of a standard dry cell is sal-ammoniac and water.
9. T ( ) F ( ) Increasing the strength of the electrolyte, increases the voltage of the cell.
10. T ( ) F ( ) The so called dry cell actually has about 3.4 fluid ounces of water in it, but will still operate in any position.

1  3 Series 4.5v 20Ih 90wh	5
2  3 parallel 1.5v 60Ih 90wh	6
3  3 Series - 2 parallel 4.5v 40 Ih 180wh	7
4  2 parallel - 3 Series 4.5v 40Ih 180 wh	8

☐☐☐☐

LOCAL BATTERY TELEPHONE

Objective: To learn the principles of telephony.

References: Average Time Required

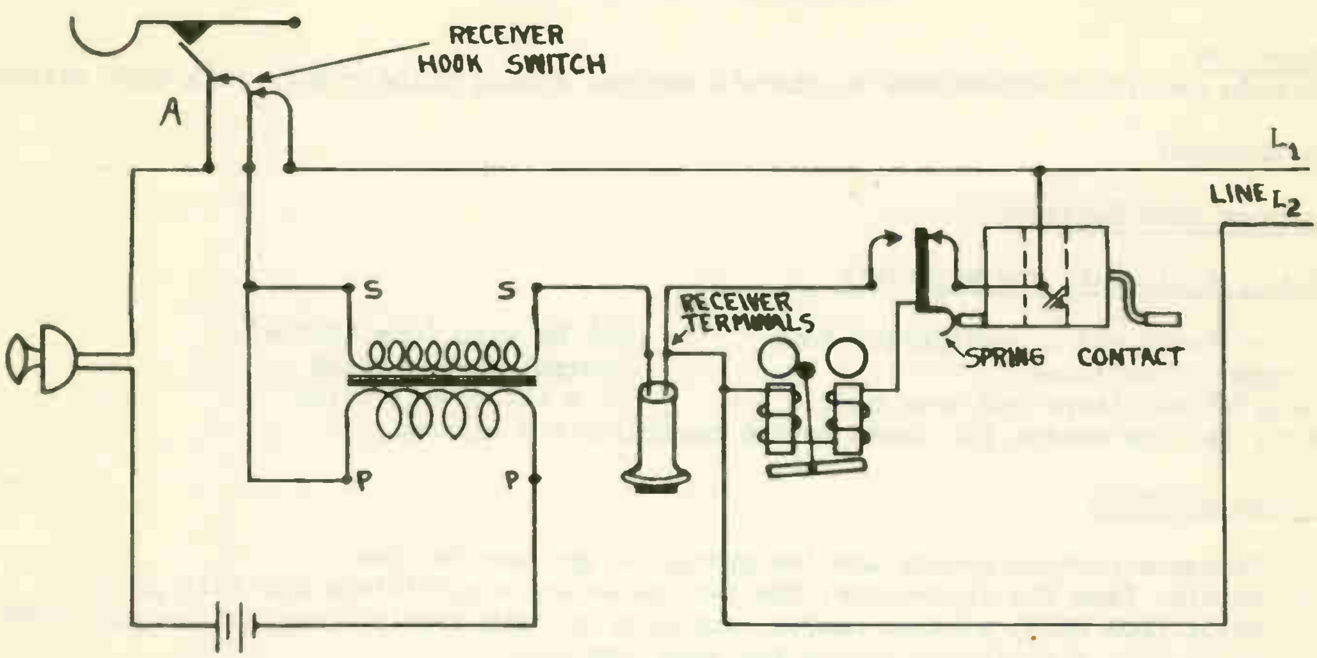
Tools, Materials, & Equipment: 1 complete board of parts for a local battery telephone.

Procedure Steps

1. Study the diagram carefully to determine equipment used, its purpose in the circuit, and how it is connected in the circuit.
2. Trace each circuit in order with proper color, and show the type of current, ac or dc, in that circuit.
3. Make the necessary polarization of the battery known, and mark the terminals on the double-circuit switch on the end of the hand operated a-c generator.
4. Make a complete material list of the different parts used and state the purpose of each one, in the provided space.
5. Wire the job one step at a time, and complete each circuit separately.
6. Apply the following five tests to determine whether all parts are connected properly:
   a. Place fingers on L_1 and L_2 and crank the magneto a few turns. If the magneto circuit is properly connected you will feel a slight tingle.
   b. Lift the receiver and listen while cranking the magneto a few turns; if a vibration is heard the receiver circuit is properly connected.
   c. Place a jumper wire across L_1 and L_2 and remove the connection to the magneto open terminal. The bell should ring when the magneto is operated.
   d. Replace wire on the open terminal and crank the magneto again; the bell should not ring.
   e. With the jumper still on the line connections, whistle or blow air past the transmitter and you should hear that sound in the receiver if the transmitter circuit is connected properly.
7. Having tested each part of the circuit, remove jumper across the lines and answer the following questions.
8. Call the switchboard, and the instructor will check your work.

QUESTIONS -True or False (See instructions of previous jobs)

1. T ( ) F ( ) The purpose of the iron core in the induction coil is to reduce magnetic leakage by making a low reluctance path for magnetic lines of force.
2. T ( ) F ( ) The direction of current in the secondary winding of the induction coil depends upon the direction of the secondary winding and also the direction the secondary is cut by lines of force.
3. T ( ) F ( ) The permeability of the iron core in the induction coil must be high, because the iron core will conduct lines of force easily.
4. T ( ) F ( ) The polarized bell is high resistance, compared with the other parts in the telephone circuit.
5. T ( ) F ( ) The receiver and polarized bell both have three artificial magnets for operation, namely: Permanent, electro, and temporary.
6. T ( ) F ( ) The capacitor in the common battery or central energy type telephone acts as a block to DC and permits AC for ringing and receiver circuits.
7. T ( ) F ( ) The first law of magnetism states that like poles repel and unlike poles attract each other.
8. T ( ) F ( ) There is nothing magnetic about the operation of the transmitter.



Color	Circuit	Type Current
	BELL CIRCUIT	
	TRANSMITTER CIRCUIT	
	RECEIVER CIRCUIT	
	MAGNETO CIRCUIT	

MATERIAL LIST AND FUNCTION OF EACH PART

SWITCHES AND CIRCUIT WIRING

Objective

To gain practical experience in circuit control wiring using rotary snap type switches.

References:

Average Time Required

Tools, Equipment, and Materials

Kit of tools and a combination lock
5 types of switches
Receptacles, lamps and drop cord
#14 RC wire (one bundle)
Control wiring board
$\frac{1}{2}$" x 18" dowell stick

NOTE: Red the entire job sheet before beginning the wiring.

Procedure Steps

1. Choose a partner or ask the instructor to get one for you.
2. Obtain, from the instructor, the two necessary requisitions for this job.
3. PRINT YOUR NAME, student number, and date on both requisitions and present them to the No. 1 stockroom window for your supplies.
4. CHECK all of your equipment as soon as it is received, with the complete listing on the end of each box. If you are short, or material is other than in good order, bring same to attention of stockroom personnel.
5. Choose, and sign up for a locker in the department containing the control wiring board and the dowell stick.

NOTE: You are held responsible for that locker and its contents until you have finished with the last job.

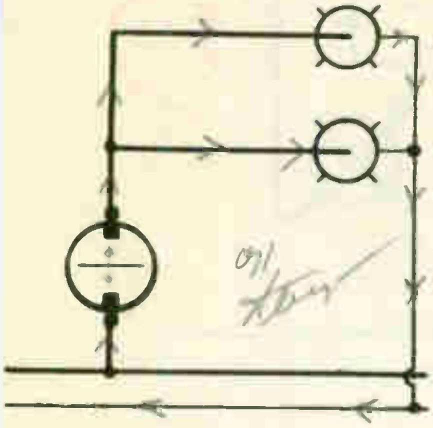
6. Dot the switch in the proper color showing the contacts which will complete the various circuits.
7. Trace all job diagrams with single arrows before wiring the circuit.
8. Trace all Fig. A's at the instant the hot wire is positive.
9. Trace all Fig. B's at the instant the neutral wire is positive.

NOTE: Hot wires are marked in heavy lines on the diagrams - Neutral wires are marked in light lines on the diagrams.

10. Make material list, wire all jobs in proper order and have each part checked by the instructor, for operation and material list including proper symbol for switches used (FIg. C).

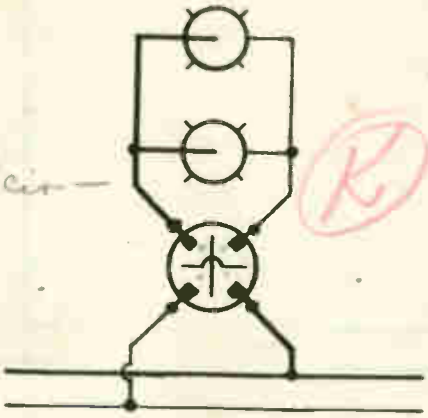
11. Begin wiring Fig. A and remember the following good wiring practices:
    a) All wires will be placed in the conduit.
    b) Only pigtail splices will be used in the outlet boxes.
    c) Wire will be placed around screw terminal in a clockwise direction.
    d) Only one wire under any terminal screw.
    e) Hot wire will always be connected to the center receptacle terminal.
    f) At least 6" of wire should be left extending out of each outlet box.
    g) Limit the wires in a pigtail to four, wherever possible.
    h) Never run a single wire in a conduit, except, for grounding connections at the distribution panel or meter box.
    i) Limit the number of #14 wires, to 4 in $\frac{1}{2}$" conduit.

31



A single-pole switch used to control two lights in parallel.

FIG. A



A double-pole switch used to control two lights in parallel

FIG. B.

R

Single Pole Switch........ $
Double Pole Switch....... $2
Three Way Switch......... $3
Four Way Switch.......... $4
Electrolier Switch .... $E

FIG. C

MATERIAL LIST

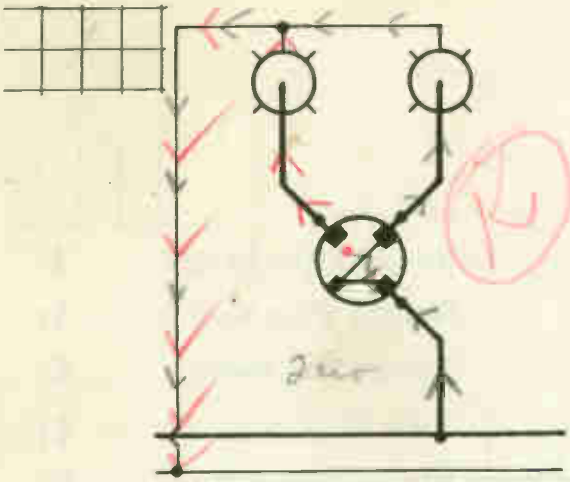
1 Handy Box
1 - 4" Octagon outlet Box
2 - 3 " "
1/2" Conduit
6 - 1/2 Locknuts
6 - 1/2 Bushings
1 - Duplex receptacle
1 - Single Pole Snap switch
2 - Sign Receptacles
2 - Sign " Covers
1 - Extension Cord
2 - 15 W Lamps
#14 Rubber Covered Wire

MATERIAL LIST

1 Handy Box
1 - 4" Octagon Outlet Box
2 - 3 " "
1/2 " Conduit
6 - 1/2 Locknuts
6 - 1/2 Bushings
1 - Duplex Receptacle
1 - Double Pole Snap Switch
2 Sign receptacles
2 " " covers
1 extension cord
2 - 15 W lamps
#14 Rubber Covered Wire

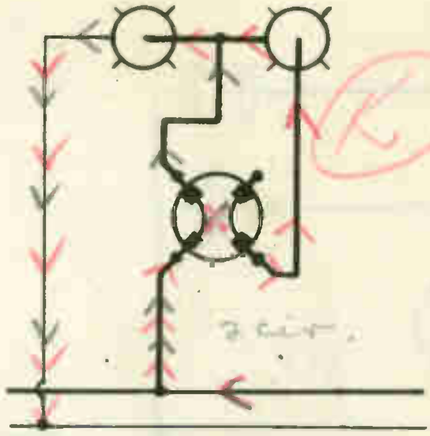
QUESTIONS:

1. T (X) F ( ) In the two diagrams above, the same voltage is applied to both lamps in the same diagram, regardless of the current.
2. T (X) F ( ) If one lamp in either figure was taken out, the other lamp would remain lighted as brightly as before.
3. T (X) F ( ) A double-pole switch is used mainly for portable work.
4. T (X) F ( ) A single-pole switch can be used for single place control circuits.
5. T ( ) F (X) Polarization of a wiring system, means the identification of the hot wire.



A 3-way switch used to control 2 lights alternately. One or the other will be lighted.

FIG. A



A 4-way switch used to control one light only, or 2 lights in series.

FIG. B

MATERIAL LIST

1 handy Box
1-4" Octagon Outlet Box.
2-3" " " "
6-1/2" Locknuts
6-1/2" Bushings
1-Duplex receptacle
1-3 way Snap switch
2-Sign receptacles.
2-" Covers
1-Extension Cord
2-15 W. Lamps
#14 Rubber Covered Wire.

MATERIAL LIST

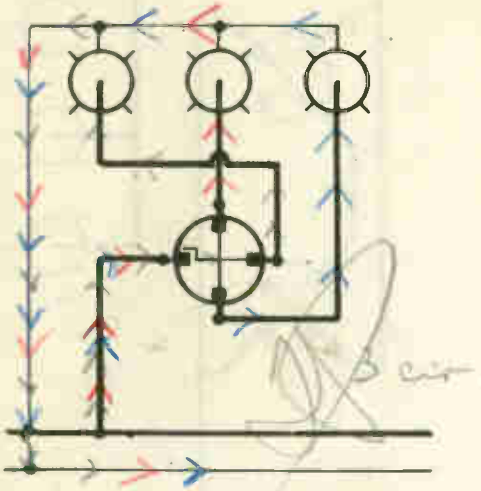
1 handy Box
1-4" Octagon Outlet Box.
2-3" " "
6-1/2 Locknuts.
6-1/2" Bushings.
1-Duplex receptacle
1-4 way Snap Switch
2 Sign receptacle.
2-" Covers
1 Extension Cord
2-15 W. Lamps.
#14 Rubber Covered Wire

QUESTIONS:

1. T (X) F ( ) Fig. A illustrates a simple store night light system using only one switch.
2. T (X) F ( ) A three-way switch is a non-indicating switch.
3. T (X) F ( ) Four-way non-indicating switches can be used as 3-way switches; Fig. B could use a three-way in place of a four-way provided the source was connected to the shunt.
4. T (X) F ( ) Three-way and four-way switches are usually used in pairs or at least in numbers of more than one.
5. T ( ) F (X) A three-way switch cannot be used as a single-pole switch.

(33)

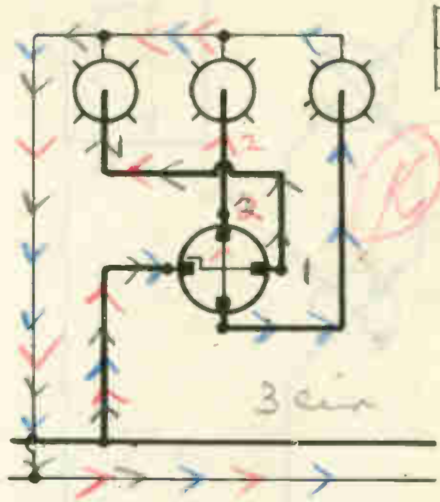
NOTE: Two of the many possible electrolier switching arrangements are shown below:



Electrolier switch used
to control three separ-
ate lights from one place.

1st position lamp #1 on
2nd " " #2 "
3rd " " #3 "
4th " all off.

FIG. A



Electrolier switch used
to control three separ-
ate lights from one place.

1st position lamp #1 on.
2nd " " #1 and #2 on.
3rd " " #1, #2 and #3 on.
4th " " #ll off.

FIG. B

NOTE: Check your switch carefully and determine which of the above you have.
(MATERIAL LIST - Same for either circuit).

1 Handy Box
1 - 4" Octagon Outlet Box
2 - 3"
8 - ½ Lock nuts
8 - ½ Bushing
1 - Duplex receptacle
1 - Electrolier switch
3 - Sign receptacles
3 - 1.6 Covers
1 Extension Cord
3 - 15 W. Lamps
#14 Rubber Cover Wire

Handy Box
1 4" Octagon Outlet Box
2 3"
8 - ½ Lock nuts
8 - ½ Bushings
1 Duplex receptacle
1 Electrolier switch
3 - Sign receptacles
3 - " "
1 Extension cord
3 - 15 W. Lamps
Rubber Cover Wire
Conduit

QUESTIONS:

1. T (X) F ( ) In wiring this job, I used the switch as indicated in Fig. A.
2. T (X) F ( ) The electrolier switch is used for lighting control, heat control, and for motor control.
3. T ( ) F (X) It makes no difference where the hot wire is connected on an electrolier switch.
4. T ( ) F (X) The electrolier switch has a permanent shunt in the base of the switch.
5. T (X) F ( ) In electric fans, the various speed controls can be obtained by means of electrolier switches.

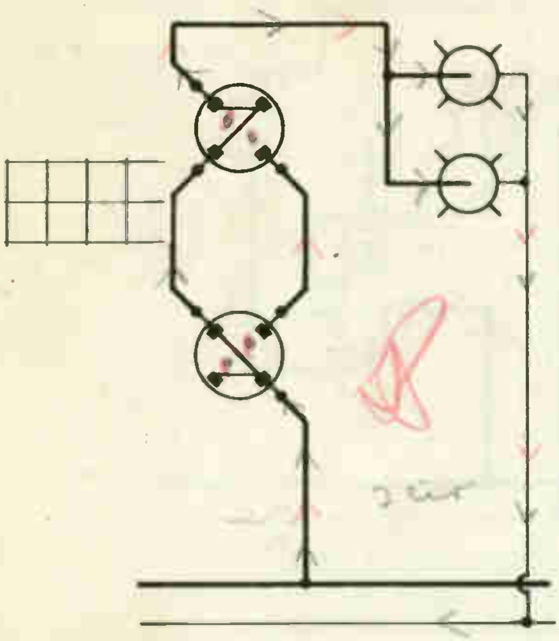


FIG. A This circuit is the "Standard" method for two-place control using two 3-way switches and is approved by the Code for for 110v.

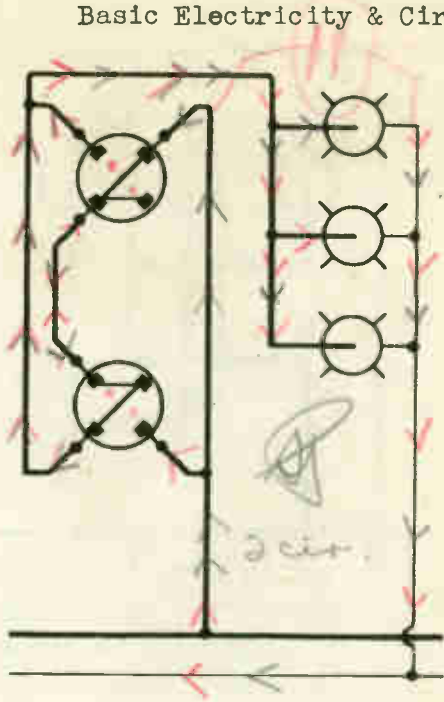


FIG. B This shows another method of controlling lights from 2 places.

MATERIAL LIST

1 handy Box
1-4" Octagon Outlet Box
3-3" " "
8-1/2 Locknuts
9-1/2 Bushings
1-Duplex receptacle
2-3 way Snap Switches
3-Sur receptacles
3-Std. Cleats
1-Extension cord
2-15 W. Lamps
#14 Rubber Cover wire
Conduit

MATERIAL LIST

1 handy Box
1-4" Octagon Outlet Box
4-3" " "
10-1/2" Locknuts
10-1/2" Bushings
1-Duplex receptacle
2-3 way switches
3-Sur receptacles
3- " " Covers
1-extension cord
3-15 W. Lamps
#14 Rubber Covered wire
Conduit

QUESTIONS:

1. T (X) F ( ) It is not permitted by the NEC to break both sides of the line with 3 way switches. Page 31
2. T (X) F ( ) The neutral wire should always be left unbroken so as to reduce shock hazard at the load.
3. T (X) F ( ) Fig. B shows a method where a permanently hot receptacle could be placed near the top switch without installing extra wire from the switch closer to the source.
4. T (X) F ( ) When desiring control for a light from two places it is best to use two three-way switches.
5. T (X) F ( ) For more than two place control, a four-way must be added.

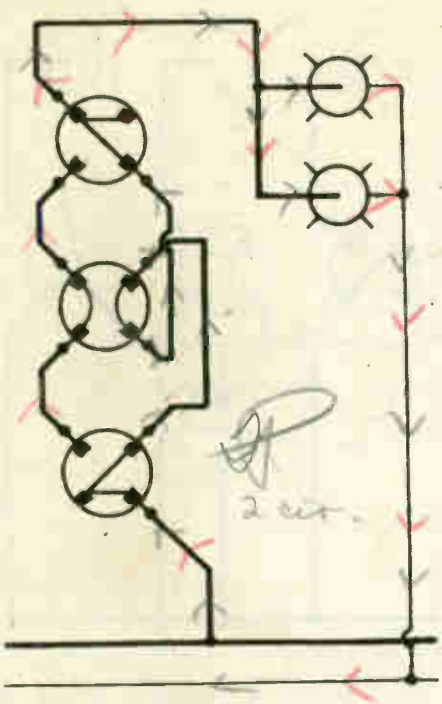


FIG. A Method used to control one or more lights from three places.

MATERIAL LIST

1 Handy Box.
1-4" Octagon Outlet Box
4-3" " " "
10 1/2 Locknuts
10 1/2 Bushings
1- Duplex receptacle
3- 3way Switches
1-4 way "
2 Sign receptacles
2 " Covers
1 extension cord
2-15 W. Lamps
#14 rubber covered wire
Conduit.

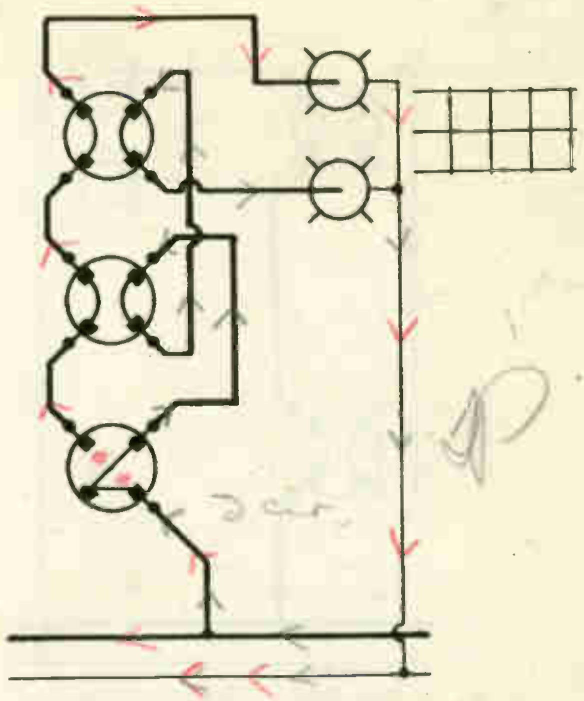


FIG. B This diagram shows how to control each light alternately from three different places.

MATERIAL LIST

1 Handy Box
1-4" Octagon Outlet Box
4-3" " "
10 1/2 Locknuts
1 1/2 [illegible]
1 Duplex [illegible]
2- 4 way Switches
1 [illegible]
2 Sign [illegible]
2 " Covers
1 extension cord
2 15 W. Lamps
#14 rubber covered wire
Conduit

QUESTIONS:

1. T (X) F ( ) The switch requirement for a job giving seven place control of a group of ceiling lights, would be two three-way and the rest four-way switches.
2. T (X) F ( ) Fig. B represents a practical circuit for operating the two separate lamp circuits alternately.
3. T (X) F ( ) These two circuits are polarized.
4. T (X) F ( ) To properly connect four-way systems of switches, the opposite terminals of the four-way switch, are connected to the next four-way's opposite terminals.
5. T ( ) F (X) Double-pole switches are the same as four-way switches.

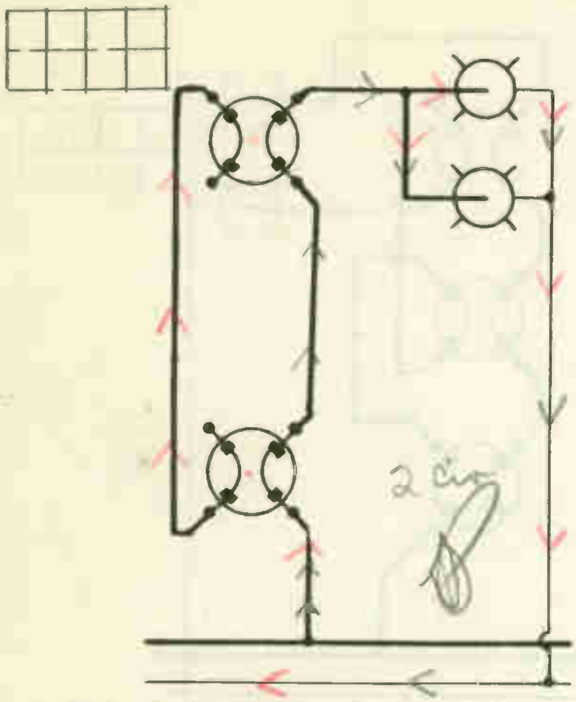


FIG. A Possible circuit used to control two lights in parallel from two places using two 4-way switches.

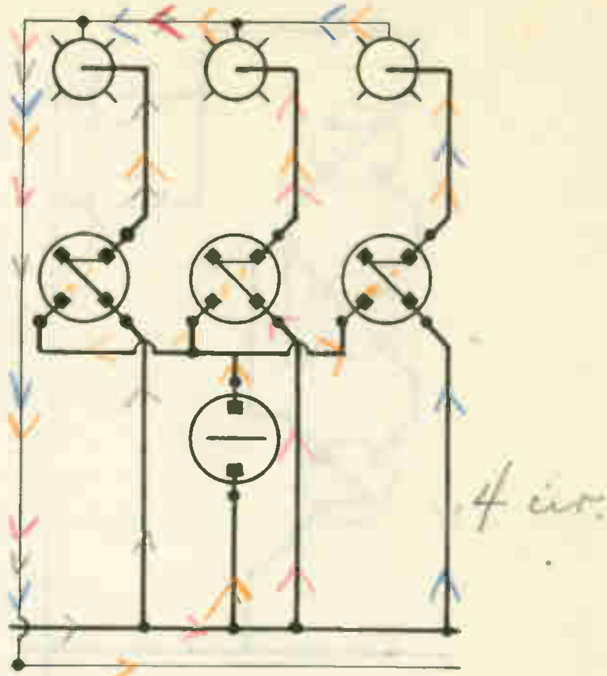


FIG. B This shows 3 lights, each one individually controlled from one place, using a three-way switch as a single-pole switch. The one single-pole switch is used as a master switch When the master switch is on; the other lights cannot be turned off.

MATERIAL LIST

1 Handy Box
1-4" Oblong Outlet Box
3-3" " " "
8-1/2" Locknuts
8-1/2 Bushings
1 Duplex receptacle
2-4 way snap switches
2- Sign receptacles
2- Sign Cords
1- Extension Cord
2- 15 W. Lamps
#14 Rubber covered wire
Conduit

MATERIAL LIST

1 Handy Box
1-4" Oblong Outlet Boxes
6-3" " "
14-1/2 Locknuts
14-1/2 Bushings
1 Duplex receptacle
3-3way Snap Switches
1- Single Pole Snap Switch
3- Sign receptacles
3- Sign Cords
1- Extension Cord
3 15 W. Lamps
#14 Rubber Covered wire
Conduit

QUESTIONS:

1. T (X) F ( ) The four-way switches in Fig. A are used as 3-way switches.

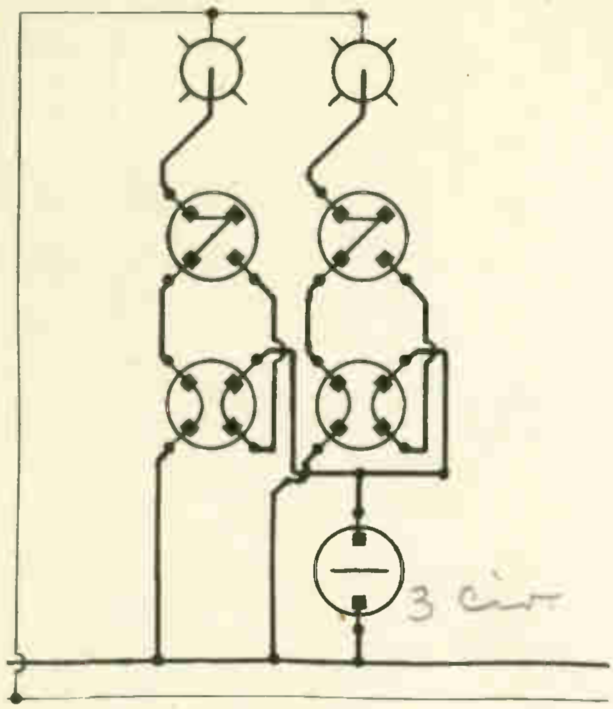
2. T (X) F ( ) Any 3-way switch may be substituted for a four-way switch.

3. T (X) F ( ) Any 4-way switch may be substituted for a 3-way switch.

4. T (X) F ( ) Fig. B shows a master switch connection where it might be desired to keep all lights on, as a form of burgler protection.

5. T (X) F ( ) Three-way switches are the only switches with permanent shunts.

37



MATERIAL LIST

FIG. A When the single-pole switch is open, each of the 2 lights may be controlled from 2 places. When the single-pole switch is closed, all the lamps will remain lighted regardless of the position of the other switches.

QUESTIONS:

1. T ( ) F ( ) The above figure shows a two place control system with a master switch.
2. T ( ) F ( ) A four-way switch could be substituted for either 3-way switch.
3. T ( ) F ( ) If the two lamps are turned on and off by means of the single pole switch, the lamps are operated in parallel.
4. T ( ) F ( ) With the master switch on, no lamp can be controlled by its switches.
5. T ( ) F ( ) A double-pole switch can be substituted for either four-way switch.