R E P O R T   R E S U M E S

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LABORATORY TRAINING EXERCISES 11-18, TEACHER AND STUDENTS' MANUAL. (TITLE SUPPLIED).

GEORGE WASHINGTON UNIV., WASHINGTON, D.C.

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DESCRIPTORS- *LABORATORY MANUALS, *TEACHING GUIDES, ANSWER KEYS, *VOCATIONAL APTITUDE, *MECHANICS (PROCESS), JUNIOR HIGH SCHOOLS, *PREVOCATIONAL EDUCATION,

DEVELOPED AS A PART OF A CURRICULUM PROJECT, DESCRIBED IN VT 004 454, TO HELP YOUNG PEOPLE LEARN BASIC PRINCIPLES AND CONCEPTS OF MECHANICS AND TECHNOLOGY, THIS MANUAL PROVIDES TEACHERS AND STUDENTS WITH INSTRUCTIONS AND QUESTIONS RELATIVE TO EIGHT LABORATORY EXERCISES TO DEVELOP AN UNDERSTANDING OF THE OPERATION OF BASIC MAGNETIC AND ELECTRICAL PRINCIPLES. EXERCISES COVER (11) MAGNETISM, (12) MAGNET CONSTRUCTION, (13) SIMPLE CIRCUITS, (14) SERIES AND PARALLEL CIRCUITS, (15) THREE-WAY SWITCHES, (16) ALTERNATING AND DIRECT CURRENT, (17) A SIMPLE AMPLIFIER AND RADIO, AND (18) A SIMPLE RADIO TRANSMITTER. THE FIRST 10 EXERCISES ARE IN VT 004 470. INSTRUCTOR SUGGESTIONS, ANSWERS TO PROBLEMS AND QUESTIONS, A PLAN OF PROCEDURE FOR EACH EXERCISE, AND EQUIPMENT LISTS ARE INCLUDED. THE TEACHER'S MATERIAL IS ON YELLOW PAGES, THE STUDENT'S ON BLUE. THIS DOCUMENT IS MIMEOGRAPHED AND LOOSELEAF. OTHER RELATED DOCUMENTS ARE VT 004 455 THROUGH VT 004 470. (EM)

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 11

The George Washington University
Education Research Project
1966

MAGNETISM

Objective

To demonstrate how magnets and magnetism work.

Materials

Item No.	Quantity	Description
1	1	Magnet assortment
2	1	Iron Filings
3	1	Shelf, steel (4" x 6")
4	1	Shelf, masonite (4" x 6")
5	1	Shelf, aluminum (4" x 6")
6	1	Shelf, plexiglass (4" x 6")
7	1	Compass
8	1	Electric Magnet
9	1	Materials assortment
10	1	18-inch String
11	2	Pegboard Hooks
12	5	Paper Clips
13	1	Thread

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.

2. Encourage student comment and discussion during the demonstration. Also have one or two students at a time come up to the demonstration table to perform or to repeat Steps in the procedure.

3. The teacher and students may find it very helpful to study the Figures on the printed overlay. These should give some idea of how to set up the materials as well as serve to stimulate questions and discussion.

4. The teacher, in order t initiate and encourage discussion, may wish to ask questions and make comments about the Figures on the printed overlay and the Steps being demonstrated in the procedure.

a. Before doing, Materials attracted by magnets, see if the students already know or can guess which materials in the assortment will be attracted by magnets.

b. As you proceed with, Conductors of magnetism, let the students speculate as to what the outcome will be in each case.

c. See how much the students already know about magnetic lines of force, the Law of the Poles, and how to determine where the poles of a magnet are.

d. See to what extent the students are aware of the use of magnets in their environment, such as door bells, telephone, compasses, loudspeaker, radios, and electrical measuring instruments.

5. If there is time in the class period, the students may wish to try other experiences connected with certain of the Steps in the procedure.

   a. Materials attracted by magnets:
   the students may wish to try out other materials they find in the classroom.

   b. Conductors of magnetism:
   the students may wish to try out other materials, such as a sheet of paper, a piece of stiff cardboard, something made of glass, and objects of their own choice.

   c. The students may wish to try out all the magnets in the kit for lines of force, the Law of the Poles, and locating the poles.

6. In the Step-by-Step Procedure, the terms iron and steel are used interchangeably. The amount of iron or steel in an object varies. Often the metal is an alloy of one or the other of these two. The important thing for the student to know is that the objects attracted by a magnet have some iron or steel in them. Some objects that look like iron or steel have no iron or steel in them at all. Students may discover this when trying to pick up with a magnet, objects such as pins, needles, and nails.

7. The following principles have been demonstrated by this exercise:

   a. Non-metallic materials are not attracted by magnets.

   b. Not all metallic materials are attracted by magnets.

c. Most materials, such as aluminum, plexiglass, and masonite, are good conductors of magnetism, but iron and steel are not good conductors.

d. The ends exert the strongest force of any part of a U-shaped magnet.

e. The lines of force in a magnetic field are strongest at the poles and radiate out from them.

f. Any material that is magnetized and can be suspended so it can swing freely will act like a compass needle.

g. The Law of the Poles states that like poles repel and unlike poles attract each other.

h. All magnets have both N and S poles, no matter what their shape.

8. It is recommended that the teacher show the students how to get the iron filings back into the container after step, Magnetic Lines of Force. This is done by lifting the paper off the magnet and gently bending the paper to form a chute or funnel.

9. Answers to the blanks left in the stated principles in STUDENT'S MANUAL:

S11-1 NOT
S11-2 ATTRACTED
S11-3 STEEL
S11-3 STRONGEST
S11-4 CONCENTRATED
S11-5 NORTH-SOUTH
S11-6 ATTRACT
S11-6 NORTH AND SOUTH

10. Answers to Questions in STUDENT'S MANUAL:

1. Non-metallic
2. metallic
3. metallic
4. conductors
5. poor or not good
6. ends
7. field
8. compass
9. Law of the Poles
10. poles
11. N and S or north and south
12. poles

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 11

The George Washington University
Education Research Project
1966

MAGNETISM

Purpose

This exercise will help you understand how magnets and magnetism work.

Materials

Item No.	Quantity	Description
1	1	Magnet assortment
2	1	Iron filings
3	1	Shelf, steel (4" x 6")
4	1	Shelf, masonite (4" x 6")
5	1	Shelf, aluminum (4" x 6")
6	1	Shelf, plexiglass (4" x 6")
7	1	Compass
8	1	Electric Magnet
9	1	Materials Assortment
10	1	18-inch String
11	2	Pegboard Hooks
12	5	Paper Clips
13	1	Thread

Step-by-Step Procedure

Materials attracted by magnets

1. Spread out the objects in the assortment of materials on a table or desk top. This assortment contains objects made of plastic, paper, metal, wood, and rubber.

2. Select three or four magnets from the assortment of magnets.

3. Separate the objects in the materials assortment into two groups. Put the non-metallic objects in one group and the metallic materials in another.

4. Place each of the magnets near each of the objects in the non-metallic group. Observe that none of these objects is attracted by any of the magnets.

THIS SHOWS THAT NON-METALLIC MATERIALS
ARE ________ ATTRACTED BY MAGNETS.

5. Place each of the magnets near each of the objects in the metallic group. Observe that some metallic objects are attracted by all magnets and that others are not.

THIS SHOWS THAT SOME METALLIC MATERIALS ARE ________ BY MAGNETS AND THAT OTHERS ARE NOT.

Conductors of magnetism

6. Insert the two pegboard mounting hooks in the center of the pegboard with three holes between them.

7. Bend the hooks down so that the shelves when placed on them will be level.

8. Place the 4" x 6" plexiglass shelf on the pegboard hooks.

9. From the group of metallic objects attracted by a magnet, choose one or two and place them on the shelf.

10. From the magnet assortment choose one of the strongest.

11. Hold the magnet against the under side of the plexiglass shelf directly underneath the object.

12. Move the magnet around under the object while holding the shelf in place with your other hand, observing what happens to the object as you do so. Notice the object tries to follow the magnet by sliding or rolling.

13. Substitute the other three shelves (steel, masonite, and aluminum) for the plexiglass one, repeating what you did on the plexiglass shelf, with the same objects (Steps 9-10-11-12). You might also try using two or three shelves of different materials at the same time. Observe what happens in each case. Record your observation on the chart.

Shelf Material	Conduct	Non Conduct	Shelf Material	Conduct	Non Conduct

14. Notice the following:

   a. With the masonite and aluminum shelves, the result is the same as with the plexiglass shelf. These materials are called conductors of magnetism because they allow the force of a magnet to pass through them.

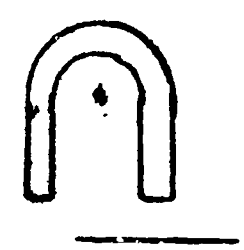
   b. With the steel shelf, observe that when the magnet is moved around under the object, the object does not move at all. Steel is not a good conductor of magnetism because it will not allow the force of a magnet to pass through it easily.

> THIS SHOWS THAT THE FORCE OF MAGNETISM GOES THROUGH SUCH MATERIALS AS ALUMINUM, PLEXIGLASS, AND MASONITE, BUT DOES NOT EASILY PASS THROUGH OBJECTS MADE OF ____________.

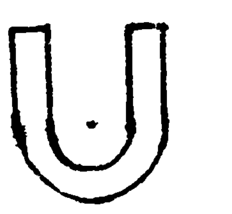
<u>The magnetic lines of force</u>

15. For this step you will need a metal disc from the materials assortment and the small U-shaped magnet. Place the disc on the table.

16. Hold the magnet over the disc, with the ends down as in the diagram. As you lower the magnet toward the disc, you will find that the disc is attracted to the end of the magnet--the disc will jump up off the table tight against the end of the magnet.



17. With the disc in the same position as in Step 14, hold the magnet with the bent side down and lower it toward the disc. Observe that the disc does not stick to the magnet when held in this position. There may be a small amount of attraction, but it is very slight in comparison to the amount of magnetism at the two ends.



> WHEN USING A U-SHAPED MAGNET, THIS SHOWS THAT THE ENDS OF THE MAGNET EXERT THE __________ MAGNETIC FORCE. THIS ALSO SHOWS THAT THE MAGNETIC FORCE IS VERY WEAK AT THE BEND.

18. Choose a magnet and place it under a plain piece of paper.

19. Remove the cap from the plastic container of iron filings and pour some into your hand.

20. Sprinkle the iron filings on the paper over the magnets, as you would salt food. Do not sprinkle too heavily. Notice that the filings form patterns over the magnet.

21. Repeat the above step with a differently shaped magnet and notice the different pattern.

22. Repeat the step with a third type of magnet and again notice the different pattern.

23. Repeat step with the first magnet but lay it on its side or in a different position and notice the change in the pattern.

24. In the case of bar magnets, notice the filings go out from the ends like spokes of a wheel. Between the ends, the lines are more curved when the filings fall further from the area directly between the ends of the magnet.

THIS SHOWS THAT THE LINES OF FORCE IN A MAGNETIC FIELD ARE ________ AT THE POLES OF A MAGNET AND RADIATE OUT FROM THEM.

<u>Law of the Poles</u>

25. Tie a piece of fine thread (about 10 inches) around the middle of each of the bar magnets. Also tie some thread to each of the magnets with a hole. Make a loop in the other end of the string.

26. With your compass determine where north and south are. Be sure the compass is far enough away from any magnets so that the compass needle will not be attracted by them.

27. Suspend each of the magnets prepared in Step 24 from one of the pegboard hooks, one at a time. With a pencil, label the ends of the surfaces of the magnets that point or face north and south. Use an N for the north end, and an S for the south end. The ends of a magnet are referred to as poles.

NOTE: From here on, the north end will be referred to as the N pole and the south end as the S pole.

THIS SHOWS THAT ANY MATERIAL THAT IS MAGNETIZED AND CAN BE SUSPENDED SO THAT IT SWINGS FREELY WILL ACT LIKE A COMPASS NEEDLE BY COMING TO REST IN A ____________ POSITION.

28. Leave one of the bar magnets used in Step 16 on the pegboard hook.

29. Approach the N pole of the suspended magnet with the S pole of each of the other magnets used in Step 26. Observe that the poles attract each other.

30. Next, approach the N pole of the suspended magnet with the N pole of each of the magnets used in Step 26. Observe that the poles repel each other.

31. Approach the S pole of the suspended magnet with the S pole of each of the other magnets. Observe that the poles repel each other.

32. Next, approach the S pole of the suspended magnet with the N pole of each of the other magnets. Observe that the poles attract each other. What you have observed in Steps 28-29-30-31 is known as the <u>Law of the Poles</u>.

THIS SHOWS THAT LIKE POLES
REPEL AND UNLIKE POLES _____
EACH OTHER.

<u>Locating the poles of a magnet</u>

33. Select what seems to be the strongest bar magnet from the assortment. Make sure the ends have been marked to show the N and S poles. (Step 26.)

34. Select several unlabeled magnets of different shapes.

35. Find the poles of one of the unlabeled magnets by bringing the marked magnet near its ends and sides. Observe that you cannot guess the location of the poles just from looking at the shape of the magnet.

36. Repeat Step 34 with the other magnets selected in Step 33. You will discover that in some magnets, the poles are the broad flat surfaces. Observe also that poles are not always located at the ends in some bar magnets.

THIS SHOWS THAT ALL MAGNETS
HAVE BOTH _____ _____ _____
POLES NO MATTER WHAT THEIR
SHAPE.

QUESTIONS

1. _________ objects are not attracted by magnets.

2. Only _________ objects are attracted by magnets.

3. Not all _________ objects are attracted by magnets.

4. Most materials, such as aluminum, plexiglass, and masonite, are good __ _______ of magnetism.

5. Iron and steel are ________ conductors of magnetism.

6. The _________ of a U-shaped magnet exert more magnetic force than the bend.

7. The lines of force in a magnetic _________ are always the same shape.

8. Magnetized materials when suspended so they swing freely will act like a _________.

9. The ______ ______ ______ ______ states that like poles repel and unlike poles attract.

10. All magnets have two ________.

11. All magnets have both _______ and _______ poles.

12. The shape of a magnet does not determine the position of the ______.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 12

The George Washington University
Education Research Project
1966

MAKING MAGNETS

Objective

To demonstrate how to make two kinds of magnets.

Materials

Item No.	Quantity	Description	Source
1	1	Magnet assortment	Magnetism Kit
2	1	Iron Filings	Magnetism Kit
3	1	Compass	Magnetism Kit
4	1	Electric Magnet and Bar	Magnetism Kit
5	1	Spool of copper Wire	Magnetism Kit
6	1	Coil of Insulated Wire	Magnetism Kit
7	10	Paper Clips	Magnetism Kit

Suggestions to the Instructor

1. This is an optional exercise that may be performed if the students show an interest and the time is available.

2. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.

3. To make sure the procedure is being understood, have one or two students at a time come up to the demonstration table to perform or repeat Steps in the procedure.

4. To create and maintain student interest, encourage their comments and discussion during the demonstration.

5. The teacher, in order to encourage discussion, may wish to ask questions and make comments about aspects of the Steps in the procedure.
   a. Relate this exercise to the one before, Exercise 11. See if the students are able to anticipate what will happen in Step 1 of the Step-by-Step Procedure. If they know _what_, see if they know _why_.

b. Relate this exercise to large and powerful magnets used in loading and unloading materials made of steel onto trucks, trains and ships. It is possible some students have observed these at work and will want to tell of their experiences.

6. As with Exercise 11, the terms <u>iron</u> and <u>steel</u> are used interchangeably in this exercise.

7. A new paper clip will have to be used each time Step 1 is performed.

8. If there is time in the class period, the students may be permitted to do additional experiments suggested in Steps 22-23, or any others the teacher and students might think interesting and worthwhile.

9. The following principles have been demonstrated by this exercise:
   a. When an iron (or steel) object is rubbed by a magnet, a change takes place, making it a magnet.
   b. An electromagnet is made by wrapping a piece of iron (or steel) many times with an insulated wire.
   c. The metal in an electromagnet is magnetized only as long as electric current flows through the wire around the metal.
   d. The way the wire of an electromagnet is connected to the terminals of a battery and the way the wire is wrapped around the center, determines the poles of the magnet.

10. Answers to the blanks in the stated principles of the STUDENT'S MANUAL:

    S12-2 <u>MAGNET</u>
    S12-2 <u>CURRENT</u>
    S12-3 <u>MAGNETIZED</u>
    S12-4 CENTER

11. Answers to Questions in the Student's Exercise:
    1. magnet
    2. steel or iron
    3. electric current
    4. poles
    5. direction

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 12

The George Washington University
Education Research Project
1966

MAKING MAGNETS

Purpose

This exercise will show you how to make a magnet and an electromagnet.

Materials

Item No.	Quantity	Description	Source
1	1	Magnet Assortment	Magnetism Kit
2	1	Iron Filings	Magnetism Kit
3	1	Compass	Magnetism Kit
4	1	Electric Magnet and Bar	Magnetism Kit
5	1	Spool of Copper Wire	Magnetism Kit
6	1	Coil of Insulated Wire	Magnetism Kit
7	10	Paper Clips	Magnetism Kit

Step-by-Step Procedure

Making a magnet

1. Straighten out a paper clip.
2. Sprinkle some iron filings on a plain piece of paper.
3. Lay each end of the paper clip wire in the iron filings. Observe that when the wire is lifted from the paper, the iron filings are not attracted to the wire at either end.
4. Select one of the largest and strongest magnets from the magnet assortment. Hold the paper clip wire in one hand. Take the magnet in the other hand and stroke one end of the wire with the magnet. Be sure to stroke the entire length of the wire, raising the magnet when you get to the end and starting back at the other end for the next stroke. Repeat this about 70 or 80 times, making sure to stroke only in one direction and with only one end of the magnet.
5. Hold one end of the wire near the compass needle. Notice that it either repels or attracts the needle, proving that the wire has become a magnet with poles at the ends.

6. Repeat Step 3, observing the change in the wire. If you did Step 4 properly, you will notice that the wire at the ends attracts quite a number of iron filings. You have turned a piece of wire into a magnet.

THIS SHOWS THAT WHEN AN IRON (OR STEEL) OBJECT IS RUBBED BY A MAGNET, A CHANGE TAKES PLACE, MAKING IT A ___________.

Making an electromagnet

7. Remove everything that is on the U-shaped piece of metal except the spool with the wire wrapped around it.

8. Replace one nut on the side of the U-shaped piece of metal with the spool on it.

9. Sprinkle about half the iron filings from the plastic container onto a piece of paper.

10. Place each end of the U in the iron filings. Observe that the filings are not attracted by the U.

11. Attach each of the two ends of the wire coiled on the spool to the terminals or poles of the battery.

> NOTE: Be sure to scrape the brown coating off the ends of the wire so that a good contact is made with the battery terminals.

12. Place the ends of the U in the iron filings. Observe that the poles now attract the iron filings.

THIS SHOWS THAT A PIECE OF IRON (OR STEEL) BECOMES A MAGNET WHEN AN INSULATED WIRE (WHICH IS CONNECTED TO A SOURCE OF ________) IS WRAPPED AROUND IT MANY TIMES.

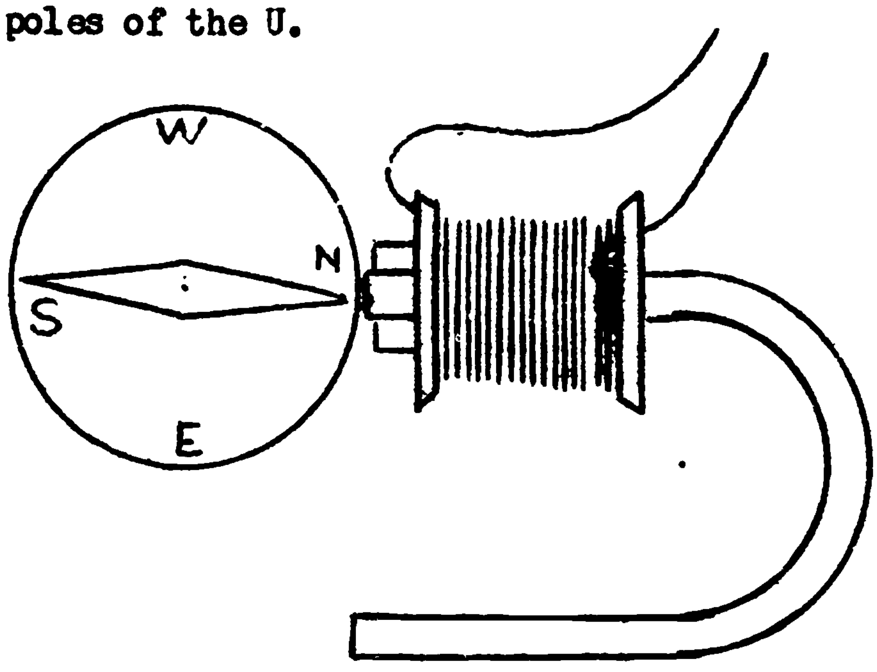
Observe that the coil of wire becomes very warm. Be sure not to leave the wires connected to the battery for very long, as they will become very hot.

13. Repeat Steps 11 and 12. Holding the magnet over a piece of paper, remove one of the wires from the battery. Observe the U is no longer a magnet and that the iron filings fall from the U.

THIS SHOWS THAT AN ELECTROMAGNET'S METAL CORE IS ________________ ONLY SO LONG AS ELECTRIC CURRENT RUNS THROUGH THE WIRES AROUND THE METAL.

14. Again attach the wire, disconnected in Step 13, to the battery terminal.

15. Determine which pole of the magnet is N and which is S by placing the compass directly off the end of one of the poles of the U.



16. Move the compass to the other pole of the U and you will see that the opposite pole of the compass is attracted.

17. Leaving the compass in the same position, disconnect the wires to the battery and change them to the opposite terminals of the battery.

NOTE: The wire that was on the positive (+) terminal should now be on the negative (-) terminal and the negative wire should now be positive.

18. The opposite needle of the compass is now attracted.

19. Repeat Steps 15 and 16, and you will notice that the result is the same every time.

20. Remove the nut from the U and turn the coil end for end.

21. Repeat Steps 15 and 16, turning the coil end for end each time instead of reversing the wires.

Notice that the opposite pole is attracted each time the coil is turned around.

THIS SHOWS THAT THE POLES OF AN ELECTROMAGNET ARE DETERMINED BY THE DIRECTION IN WHICH THE CURRENT FLOWS AROUND THE ______________.

NOTE: Direct current always flows from the negative terminal to the positive terminal.

Additional experiences

22. You may wish to try to magnetize objects other than the paper clip wire, as in Steps 1 through 6. The following are some common objects you might try. You may wish to try other objects of your own selection.
    a. Nail
    b. Needle
    c. Pin
    d. Pegboard Hook
    e. Wire
    f. Lead Weight

23. You may wish to try making electromagnets from objects other than the U. Loop insulated wire many times around metal objects of different shapes, as you did in the <u>Making an electromagnet</u> section of the Step-by-Step Procedure, to see if they become electromagnets. The following are some objects you might wish to try. You may think of other objects.

   a. Nail
   b. Bolt
   c. Metal Bar (In Materials' Kit)
   d. Pegboard Hook
   e. Pencil
   f. Screwdriver

QUESTIONS

1. When a steel object is rubbed by a magnet, a change takes place in the object, making it a ____________.

2. An electromagnet may be made by wrapping a piece of _______ many times with insulated wire and hooking up the wire ends to an electric current.

3. The metal in an electromagnet is magnetized only so long as ________ _______ flows through the wire coiled around the metal.

4. The way the wire of an electromagnet is connected to the terminals of a battery determines the ____________ of the magnet.

5. The poles of an electromagnet can be changed by changing the ________ the current flows around the center.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 13

The George Washington University
Education Research Project
1966

SIMPLE CIRCUIT

Objective

To demonstrate how a simple electric circuit works.

Materials

1. Kit Materials

Item No.	Quantity	Description
1	1	Wired electric panel (See NOTE below.)
2	2	Transformer Hookup Wires
3	5	#428 (GE), 10-12 volt bulb
4	1	110/10 v Transformer with extension cord attached
5	1	Screwdriver

> NOTE: The wired electric panel consists of the following:

Quantity	Description
1	Printed overlay
1	Mounting Board
2	Switches - Single Pole, Single Throw (S.P.S.T.)
1	Switch - Single Pole, Double Throw (S.P.D.T.)
4	Sockets
1	Rheostat
1	Bracket for Rheostat
2	Clips, Fahnestock
15 feet	Hookup Wire
18	Screws and Nuts for Mounting Fixtures

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL starting at the Step-by-Step Procedure section.

2. As an introduction, the following safety precautions in the handling of electricity and electrical appliances should be emphasized:

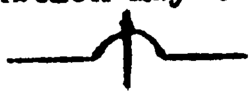
a. The transformer should not be plugged into the 110 volt outlet until all connections are made on the board.
b. Do not touch the bare ends of wire together when they are connected to a power source.
c. Make sure hands are dry when working with electrical circuits.
d. Because of the low voltage that is used in the electrical circuit board there is no danger of shock, but the proper handling of all electrical circuits regardless of voltage is the prime emphasis.

3. Some students will probably notice that the wires on the back of the board do not follow the printed outlines on the overlay; however, it should be pointed out that they are electrically equivalent and if any student wishes to trace the circuits on the back and explain how the various parts are interconnected it would be a good learning experience.

4. The transformer and the rheostat may require an explanation as to their function:
   a. A transformer is a device for either raising or lowering the voltage of alternating current. It will work only on alternating current. In these experiments it is used for lowering the common household voltage of 110 volts to 10 volts (110/10v.). Examples of the use of transformers in the home are in electric train transformers, door bell transformers, and transformers in television sets.
   b. The rheostat is a device for increasing the resistance in an electric circuit. Diagrams have been included in the STUDENT'S MANUAL to help them understand how the rheostat works.

5. Discussion may be encouraged by making comments and asking questions about simple circuits that the students may know about, such as door bells, electric irons, slot cars, electric lamps, and simple light circuit switches.

6. Participation of students is encouraged at all times, and they should be asked to come to the demonstration table in pairs and trace the circuits with a pointer or their fingers. The starting and ending points should be the power supply.

7. An explanation may be necessary as to what the loop means where two wires cross.  Wires are not connected at this point.

8. When the action of the rheostat is being demonstrated, students may be asked to name some uses of this device, such as controlling loudness on television sets, controlling speed on slot cars, and controlling volume on radios. Rheostats were formerly used to dim the lights in theaters, but this function is now done by variable transformers. This is a regular transformer with a control similar to a rheostat that contacts various windings in the secondary to give absolute control of voltage. Students may also mention that dimmers or rheostats are used in homes to dim the lights in dining or living rooms, but this is being done more and more by a solid state or transistorized device.

9. If there is time in the class period, the students may be permitted to do the additional experiences in Steps 35 and 36.

10. The following principles are demonstrated by the procedures of Exercise 11:
    a. A circuit is a path over which electric current travels between the power source and the power consumer.
    b. A switch is a simple device for conveniently completing or breaking an electric circuit.
    c. A rheostat is a device for increasing resistance in electric circuit

11. Answers to blanks in the stated principles of the STUDENT'S MANUAL:

    S13-3 <u>CIRCUIT</u>
    S13-4 <u>SWITCH</u>
    S13-5 <u>RHEOSTAT</u>

12. Answers to Questions in the Student's Exercise:

    1. wire
    2. circuit
    3. socket
    4. transformer
    5. power source or power supply
    6. switch
    7. single pole, single throw
    8. single pole, double throw
    9. breaking or stopping
    10. rheostat
    11. resistance
    12. reduce or cut or diminish or lessen

The George Washington University
Education Research Project
1966

SIMPLE CIRCUITS

Purpose

This exercise will show how a simple circuit orks.

Materials

1. Kit Materials

Item No.	Quantity	Description
1	1	Wired Electric Panel (See NOTE below this list.)
2	2	Transformer Hookup Wires
3	5	#428 (GE) 10-12 volt bulbs
4	1	110/10 V Transformer with extension cord attached
5	1	Screwdriver
6	10 feet	Hookup Wire

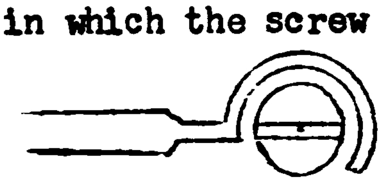
NOTE: The wired electric panel consists of the following:

Quantity	Description
1	Printed overlay
1	Mounting Board
2	Switches--Single Pole, Single Throw (S.P.S.T.)
1	Switch --Single Pole, Double Throw (S.P.D.T.)
4	Sockets
1	Rheostat
1	Bracket for Rheostat
2	Clips, Fahnestock
15 feet	Hookup Wire
18	Screws and Nuts for Mounting Fixtures

Step-by-Step Procedure

Preparing materials and setting up the board

1. Prepare the two transformer hookup wires by removing about 3/4 inch insulation from both ends of each wire.
2. From each 5-foot coil of hookup wire cut two 18-inch pieces. The piece that is left over should be cut into two equal lengths (about 10 or 12 inches).
3. Remove about 3/4 inch insulation from both ends of each of the eight pieces of wire.
4. Open all switches (A, C and E).
5. Place a #428 (GE), 10-12 volt bulb in each of the light sockets (B, D, G and the unmarked light).

> NOTE: In the following steps, when connecting wires to terminals always wrap the wire around the screw in the direction in which the screw is tightened.
>
> 

Working with simple circuits

6. Using two of the 18-inch wires, connect the two brass colored terminals of the unmarked light to the two terminals of the transformer.
7. Plug the extension cord of the transformer into a 110 volt AC (Alternating Current) power outlet. Observe that the bulb burns.
8. Trace the circuit with your finger from the power source (left or right transformer terminal) to the bulb, and back to the transformer (the other transformer terminal).

THIS SHOWS THAT A ___________ IS A PATH OVER WHICH ELECTRIC CURRENT TRAVELS BETWEEN THE POWER SOURCE AND THE POWER CONSUMER.

9. Unscrew the bulb and observe what happens. Notice that now the bulb does not burn. When the bulb is unscrewed, the electric current is stopped at that point. The bulb burns only when the current flows through it.

10. Disconnect the two wires from the terminals of the unmarked light and unplug the transformer.

11. Disconnect the wires to light D and switch C. Bend the wires out so that they are no longer in contact with the terminals.

> NOTE: From here on, whenever you are asked to disconnect wires on the prewired panel, always bend the wire (or wires) out to the side in such a way that you can easily reconnect them later to the same terminal. After completing the exercise, be sure to reconnect all wires.

12. Connect the wire from the left transformer terminal to the left terminal of light D.

13. Use one of the 12-inch wires to connect the right terminal of light D and the bottom terminal of switch C.

14. Connect the other transformer terminal wire to the top terminal of switch C.

15. Plug in the transformer. Note that the bulb does not burn.

16. Close switch C. Notice that now the bulb burns. Closing the switch completed the electric circuit allowing the current to flow from one power terminal to the other.

17. Open switch C. Note that the light does not burn. The circuit is broken by opening the switch.

18. Close switch C again.

19. Unscrew the bulb in light D. Note that the bulb does not burn. Observe that just as an open switch breaks the flow of current, an unscrewed bulb does the same thing. You see that it is easier and takes less time to break the circuit by using the switch.

THIS ILLUSTRATES THAT A ___________ IS A SIMPLE DEVICE FOR CONVENIENTLY COMPLETING OR BREAKING AN ELECTRIC CIRCUIT.

<u>Identifying circuits on the wired panel</u>

20. Disconnect the wires to the switch and lamp socket and unplug the transformer.

21. Check to see that all switches are open.

22. Reconnect the wires to light D and switch C.

23. Check to see that Rheostat F has been turned counter clockwise as far as it will go.

24. Using two 18-inch pieces of wire, connect the terminals of the transformer to the two Power Supply clips in the upper left corner of the board.

25. Plug in the transformer.

26. Push switch E to the upper contact. Observe that light B burns.

27. Trace the circuit by following the lines (solid_______ and dotted ....) from the left terminal of the Power Supply, to light B, to switch E, and back to the Power Supply (right terminal).

28. Close switch E down. Light B goes out. This part of the switch is not a part of the circuit that made light B burn.

29. Push switch E to the upper contacts.

30. Close switch A. Now both lights B and G burn.

31. Open switch E. Light B does not burn but light G continues to burn. They are on separate circuits.

32. Turn Rheostat F counter clockwise as far as it will go. Observe that as the rheostat knob is turned counter clockwise, the light grows dimmer.

33. Turn Rheostat F clockwise as far as it will go. Observe that light G becomes as bright as it was in Step 30. Also notice that the rheostat, in this case, is unlike a switch. It is not used to break the circuit. It is used to reduce the amount of current flowing through the circuit by setting up resistance.

34. Trace the circuit by following the lines (solid______ and broken _ _ _ _ _) from the left terminal of the Power Supply, to switch A, to rheostat F, to light G, and back to the Power Supply (right terminal).

THIS ILLUSTRATES THAT A ________ IS A DEVICE FOR INCREASING THE RESISTANCE IN AN ELECTRIC CIRCUIT.

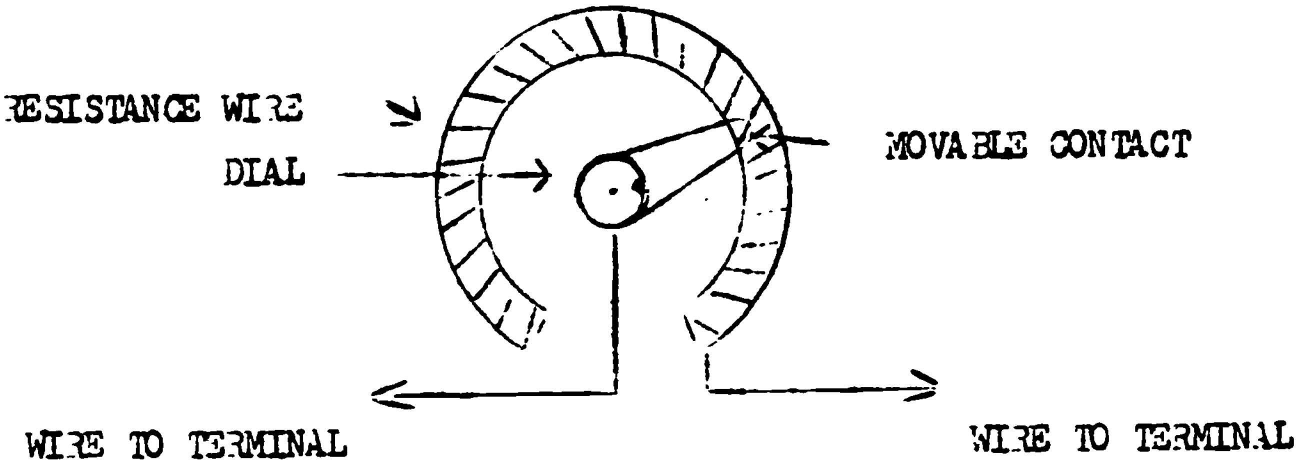


Figure 1. Diagram of Variable Resistance Mechanism of the Rheostat

> NOTE: The rheostat is a variable resistance mechanism that may be adjusted to allow all the current to pass through a circuit or allow varying amounts to pass through. See the diagrams above and below.

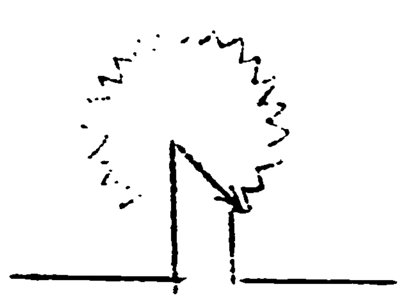


Figure 2

Dial of Rheostat Set for no Resistance

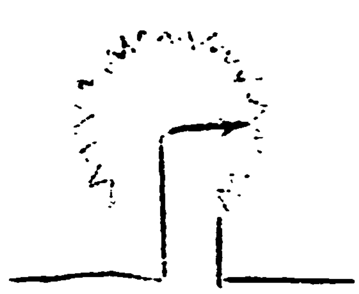


Figure 3

Dial of Rheostat Set for Low Resistance

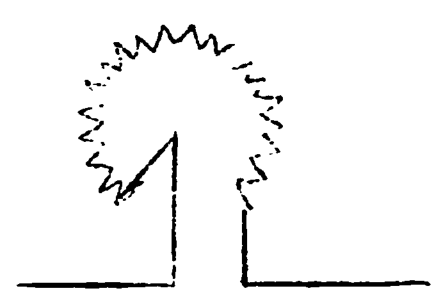


Figure 4

Dial of Rheostat Set for High Resistance

Additional experiences

If there is time, you may wish to try out the following circuit hookups on top of the board using the procedure of Steps 7 through 10.

35. Hookup No. 1

a. Wire #1 (18-inch)
From left terminal of transformer
to right terminal of light B.

b. Wire #2 (12-inch)
From left terminal of light B
to top terminal of switch C.

c. Wire #3 (18-inch)
From bottom terminal of switch C
to right terminal of the transformer.

36. Hookup No. 2

a. Wire #1 (18-inch)
From left terminal of transformer
to left terminal of light G.

b. Wire #2 (18-inch)
From right terminal of light G
to top terminal of switch C.

c. Wire #3 (18-inch)
From bottom termir-1 of switch C
to right terminal o. :he transformer.

QUESTIONS

1. A conductor for electricity made up of one or several strands is called a ___________.

2. The path over which electricity travels to and from the power source is called a ___________.

3. The device into which a bulb is screwed and current may travel is called a _________.

4. A device for stepping up (increasing) or stepping down (decreasing) the voltage of an alternating current power supply source is a _________.

5. To light an electric light bulb, the fixtures and wires must be connected to a _________ _________ .

6. A device for conveniently completing or breaking an electric circuit is the _________.

7. When a switch is named by these initials, S.P.S.T., it is a _______ _________ _________ _________ switch.

8. When a switch is named by these initials, S.P.D.T., we call it a _______ _________ _________ _________.

9. Besides opening a switch, another way of ________ a simple circuit is to unscrew the electric light bulb.

10. A device for increasing the resistance in an electric circuit is the __________.

11. Because the rheostat dial may be adjusted to allow varying amounts of current to pass through the circuit, the rheostat is a variable ____________.

12. A common use of a rheostat is in radios to increase or decrease the loudness because it can ________ the voltage to the speaker.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 14

The George Washington University
Education Research Project
1966

SERIES AND PARALLEL CIRCUITS

Objective

To demonstrate what series and parallel circuits are, and to show how they are different.

Materials

1. Kit Materials

> NOTE: The materials for this exercise are the same as for Exercise 13.

Item No.	Quantity	Description
1	1	Wired Electric Panel
2	2	Transformer Hookup Wires
3	5	#428 (GE), 10-12 volt bulbs
4	1	110/10 V Transformer with extension cord attached
5	1	Screwdriver
6	4	18-inch Wires
7	4	12-inch Wires

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. The teacher may encourage discussion by making comments and asking questions about the common uses of series and parallel circuits the student might know about.
    a. Ask them to give examples of the use of series circuits, such as some Christmas tree lights and some types of street lights.
    b. Ask students to give examples of the use of parallel circuits, such as lights in the home, some Christmas tree lights, and street lights.

c. Discuss differences between the two types of circuits for the same type of usage.

3. As in Exercise 13, it would be well to review and emphasize the importance of observing safety precautions whenever one works with electrical materials or uses electricity. (See TEACHER'S MANUAL, Exercise 13, Page T13-1, Suggestion 2.)

4. Have students come up to the front of the room, one or two at a time, to trace the flow of current through the circuits being demonstrated by following the wires above the board or the lines on the printed overlay. The tracing may be done by using a finger or a pointer.

5. If there is time in the class period, the students may be permitted to do the additional experiences in Steps 53-54.

6. The following are demonstrated by the procedures of Exercise 14:
   a. With a series circuit, the electric current travels over a single path.
   b. When electric lights are connected in series, they share the voltage.
   c. When electric lights (fixtures) are connected in series, the current flows in a single path from one fixture to the next, beginning at the power source, through the fixtures, and ending at the power source.
   d. With parallel circuits, the current travels through two (or more) paths.
   e. Lights arranged in parallel circuits receive their current directly from the power source.

7. Answers to the blanks in the stated principles of the STUDENT'S MANUAL:

   S14-2 <u>SINGLE</u>
   S14-3 <u>SHARE</u> OR <u>DIVIDE</u>
   S14-3 <u>SINGLE</u>
   S14-5 <u>INDEPENDENTLY</u>

8. Answers to Questions in the Student's Exercise:

   1. single
   2. shared
   3. broken or open
   4. parallel
   5. directly or independently
   6. burn or glow or do not go out or are not affected, etc.

The George Washington University
Education Research Project
1966

SERIES AND PARALLEL CIRCUITS

Purpose

This exercise will help you understand what series and parallel circuits are. It will show how they are different.

Materials

1. Kit Materials

NOTE: The materials for this exercise are the same as for Exercise 13.

Item No.	Quantity	Description
1	1	Wired Electric Panel
2	2	Transformer Hookup Wires
3	5	#428 (GE), 10-12 volt bulbs
4	1	110/10 V Transformer with extension cord attached
5	1	Screwdriver
6	4	18-inch Wires
7	4	12-inch Wires

Step-by-Step Procedure

Setting up the board

1. Place a #428, 10-12 volt bulb in each of the light sockets (B, D, G and unmarked).
2. See that all switches (A, C, and E) are open.
3. Turn the rheostat clockwise as far as it will go.

Working with series circuits

4. Disconnect the wires to lights B and D, and switch C.

NOTE: Whenever you are asked to disconnect wires on the prewired panel, always bend the wire (or wires) out to the side in such a way that you can easily reconnect them later to the same terminal. After completing the exercise, be sure to reconnect all wires.

5. Using two of the 18-inch wires, connect the terminals of the transformer with the terminals of light D. Note the brightness of light D.

6. Plug in the transformer and note the brightness of light D.

7. Disconnect the wire to the right side of light D.

8. Using one of the 12-inch pieces of wire, connect the right terminal of light D with the left terminal of the unmarked light.

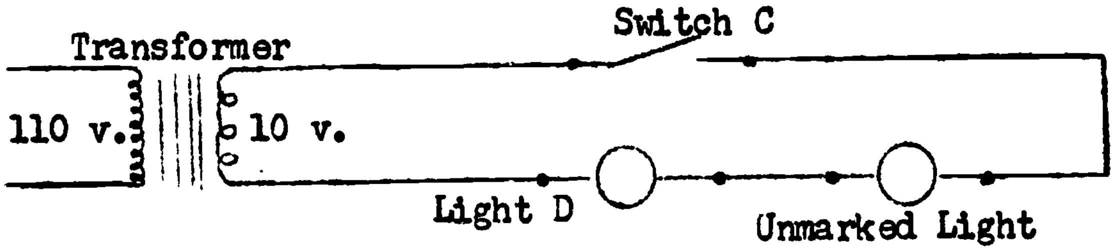
9. Use an 18-inch piece of wire to connect the right terminal of the unmarked light with the top terminal of switch C.

10. Connect the right transformer terminal wire to the bottom terminal of switch C.

11. Close switch C. Notice that both bulbs burn, but not as brightly as before. This is because they are now connected in series.

12. Trace the circuit from one transformer terminal, through the fixtures, and back to the other transformer terminal.

NOTE: This diagram will help you understand this circuit.



THIS ILLUSTRATES THAT IN A SERIES CIRCUIT THE CURRENT TRAVELS OVER A _______ PATH.

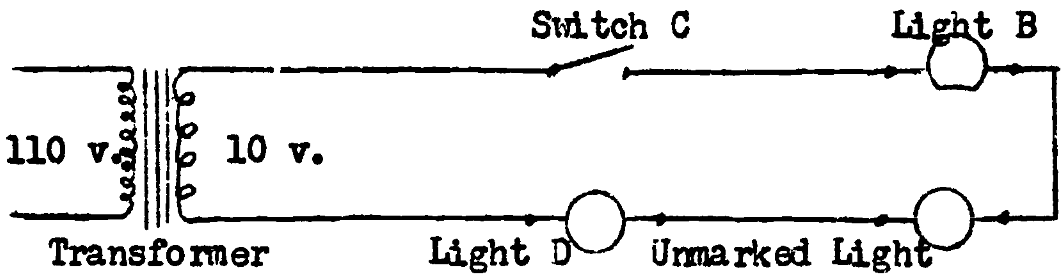
13. Open switch C.

14. Disconnect the wire to the top terminal of switch C and connect it to the right terminal of light B.

15. Using a 12-inch wire, connect the left terminal of light B to the top terminal of switch C.

16. Close switch C. Notice that the three bulbs in this series burn less brightly than the bulbs in the series of two lights.

NOTE: This diagram will help you understand this circuit.



THIS ILLUSTRATES THAT WHEN ELECTRIC LIGHTS ARE CONNECTED IN SERIES, THEY _______ THE VOLTAGE.

17. Unscrew light D. Observe that all lights go out.

18. Tighten light D and unscrew the unmarked light. Observe that again all lights go out.

19. Tighten the unmarked light.

THIS ILLUSTRATES THAT WHEN ELECTRIC LIGHTS ARE CONNECTED IN SERIES, THE CURRENT FLOWS IN A _______ PATH FROM ONE FIXTURE TO THE NEXT, BEGINNING AT ONE TERMINAL OF THE POWER SOURCE, THROUGH THE FIXTURES, AND ENDING AT THE OTHER TERMINAL OF THE POWER SOURCE.

20. Unplug the transformer.

21. Disconnect all wires on top of the board, except the ends of the two 18-inch wires connected to the terminals of the transformer.

22. Reconnect the wires to the terminals of lights B and D, and switch C.

23. Open switch C.

24. Connect the transformer terminal wires to the Power Supply Clips.

25. Plug in the transformer.

26. Close switch A. Throw switch E to the upper connectors. Observe that lights B and G burn with equal brightness. You know from Exercise 13 that lights B and G are in separate circuits.

27. Throw switch E down. Note that light B goes out.

28. Close switch C. Observe that both lights B and D burn dimly. These two lights are now in series and the two bulbs share the voltage.

29. Trace the circuit (solid____ and dotted.... lines) from the left Power Supply terminal to light B, to switch E (lower part), to light D, to switch C, and back to the right terminal of the Power Supply.

30. Open all switches.

31. Unplug the transformer.

Working with parallel circuits

32. Disconnect the two transformer wires from the Power Supply clips.

33. Disconnect the wires to lights D and G.

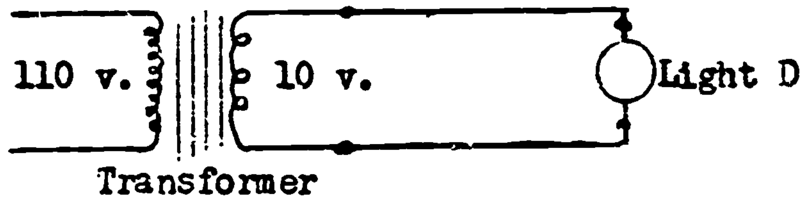
34. Turn the rheostat clockwise as far as it will go.

35. Connect the right terminal transformer wire to the left terminal of light D.

36. Connect the other transformer wire to the right terminal of light D. The light burns.

37. Plug in the transformer and the light will burn.

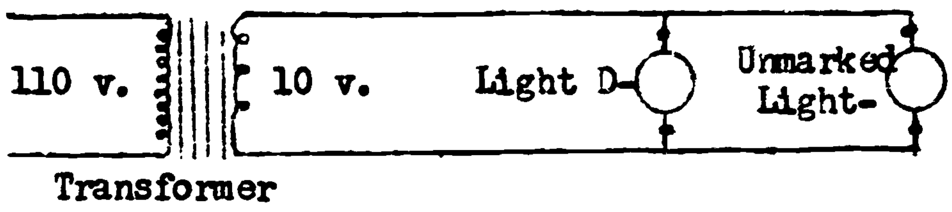
NOTE: This diagram will help you understand this circuit.



38. Leave the transformer wires connected to light D and use one of the 12-inch wires to connect the left terminal of light D to the left terminal of the unmarked light.

39. Use another of the 12-inch wires to connect the right terminals of light D to the right terminal of the unmarked light. The unmarked light burns.

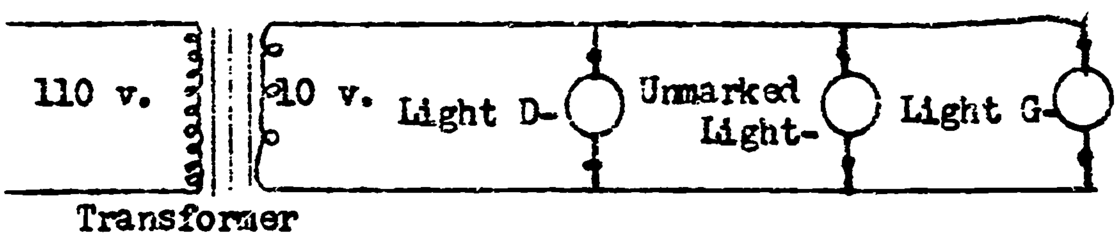
NOTE: This diagram will help you understand parallel circuits.



40. Use another 12-inch wire to connect the left terminal of the unmarked light to the left terminal of light G.

41. Use another 12-inch wire to connect the right terminals of the unmarked light and light G. Light G burns. Observe that all three lights burn about the same. As another light is added to the circuit, the brightness of the other lights is about the same as before.

NOTE: This diagram will help you understand another example of parallel circuits.



THIS ILLUSTRATES THAT WITH PARALLEL CIRCUITS, THE CURRENT TRAVELS THROUGH ________ PATHS.

42. Unscrew the bulb in light D. Notice that the bulbs in the unmarked light and in light G still burn.

43. Tighten the bulb in light D and unscrew the bulb in the unmarked light. Observe that now lights D and G burn.

44. Tighten the bulb in the unmarked light and unscrew the bulb in light G. Now the bulbs in light D and the unmarked light burn.

THIS ILLUSTRATES THAT WHEN LIGHTS ARE ARRANGED IN PARALLEL CIRCUITS, EACH LIGHT RECEIVES ITS CURRENT OF OTHER LIGHTS, DIRECTLY FROM THE POWER SOURCE.

45. Check to see that all switches are open.

46. Unplug the transformer.

47. Remove the four 12-inch wires from the board.

48. Reconnect the panel wires to the terminals of lights D and G.

49. Connect the two transformer wires to the two Power Supply clips.

50. Plug in the transformer.

51. First close switch A, then throw switch E up. Observe that lights B and G burn with about the same brightness when they are on separately or at the same time.

52. Trace the circuits on the marked overlay. Notice that the electric current goes directly to each of these lights from the Power Supply. This is another example of parallel circuits.

<u>Additional experiences</u>

If there is time, you may wish to try out the following series and parallel circuits using the eight pieces of wire.

53. Series circuit hookups. (See section <u>Working with Series Circuits</u>.)
    a. Arrange lights B and G, and the unmarked light in series
    b. Arrange lights D, B and G in series.

54. Parallel circuit hookups. (See section Working with Parallel Circuits.)

a. Arrange the unmarked light, light G, and light B in parallel circuits.

b. Arrange lights D, B and G in parallel circuits.

55. Other hookups you might like to try of your own choice.

> NOTE: Be certain in any hookup that the current must go from the transformer to a light and back to the transformer again.

QUESTIONS

1. The electric current travels over a ________ path in a series circuit.

2. When electric lights are connected in series, the voltage is ________.

3. In a series circuit, if any fixture fails to work, the circuit is ________ and no part of the circuit functions.

4. With ________ circuits, the current travels through two (or more) paths.

5. Lights in parallel circuits receive their current ________ from the power source.

6. When one light in a parallel circuit is disconnected or burns out, the other lights ________.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 15

The George Washington University
Education Research Project
1966

THREE-WAY SWITCHES

Objective

To demonstrate how two single pole, double throw switches can be used to control a light from two different positions.

Materials

1. Kit Materials

> NOTE: The materials for this exercise are the same as for Exercise 14.

Item No.	Quantity	Description
1	1	Wired Electric Panel
2	2	Transformer Hookup Wires
3	5	#428 (GE), 10-12 volt bulbs
4	1	110/10 V Transformer with extension cord attached
5	1	Screwdriver
6	4	18-inch Wires
7	4	12-inch Wires

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. Emphasize that switches D and A are operating as a S.P.D.T. switch, the same as switch E.
3. Switches A and C are never closed or open at the same time. When one is closed, the other must be open.
4. Emphasize the precautions for handling electricity at all times. (Exercise 13, Section 2.)

5. Have students come up to the demonstration unit and travel the flow of electricity through the switches when they are open and closed.

6. Discuss the uses of this type of circuit: top and bottom of stairways, ends of halls, inside and outside garages, etc.

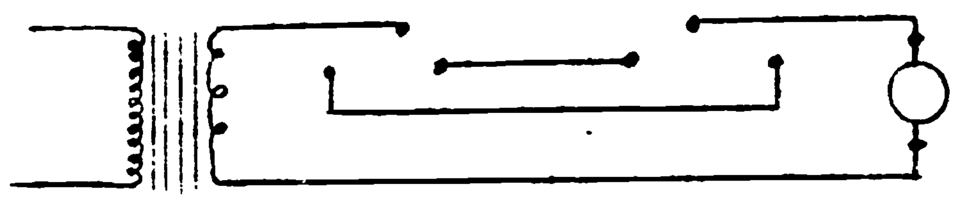
7. This exercise demonstrates the use of two S.P.D.T. switches to control a light from two different points.

8. Answer to blank in the stated principles in the Student's Exercise:

   S15-3 SINGLE POLE, DOUBLE THROW

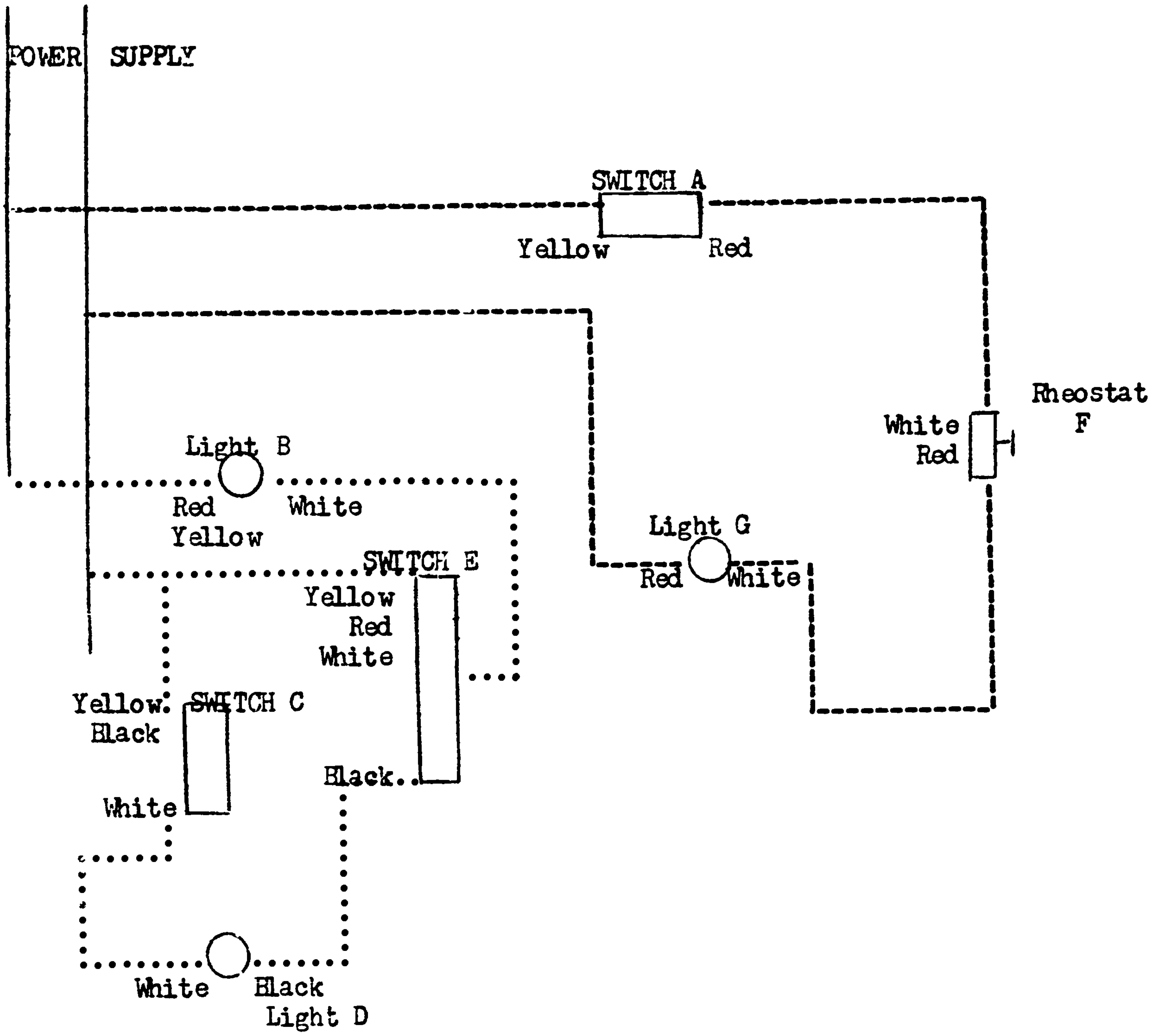
9. Answers to Questions:

   1.



   2. Transformer
   3. Hallways, stairways, garages

10. This is a drawing of the original connection of wires on the circuit board. Check this against your board to see that all wires are reconnected to their original positions. (Drawing on Page T15-3.)


POWER SUPPLY
SWITCH A
Yellow
Red
Rheostat F
White
Red
Light B
Red
Yellow
White
Light G
Red
White
SWITCH E
Yellow
Red
White
Yellow
SWITCH C
Black
White
Black
White
Black
Light D

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 15

The George Washington University
Education Research Project
1966

THREE-WAY SWITCHES

Purpose

To learn how a three-way switch operates.

Materials

1. Kit Materials

NOTE: The materials for this exercise are the same as for Exercise 14.

Item No.	Quantity	Description
1	1	Wired Electric Panel
2	2	Transformer Hookup Wires
3	5	#428 (GE), 10-12 volt bulbs
4	1	110/10 V Transformer with extension cord attached
5	1	Screwdriver
6	4	18-inch Wires
7	4	12-inch Wires

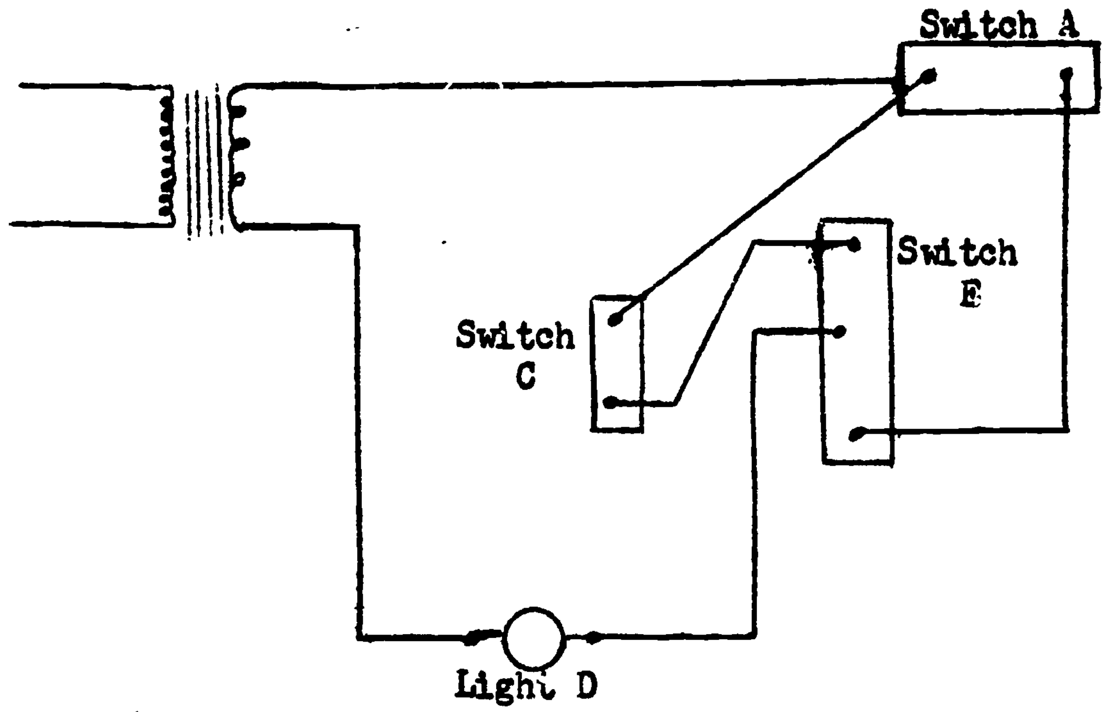
Step-by-Step Procedure

1. Disconnect all wires to switches A-C-E and light socket D.
2. Connect 18-inch wire from left terminal of the transformer to the left terminal of lamp socket D.
3. Connect 18-inch wire from right terminal of transformer to the left terminal of switch A.
4. Connect a 12-inch wire from the left connector of switch A to the upper terminal of switch C.
5. Connect a 12-inch wire from the lower connector of switch C to the upper terminal of switch E.

6. Connect a 12-inch wire from the center of switch E to the right terminal of socket D.

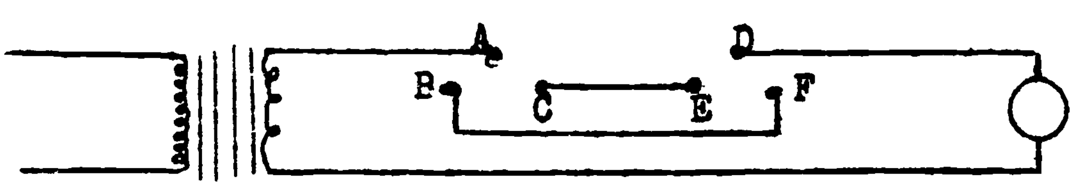
7. Connect a 12-inch wire from the left of switch A to the lower terminal of switch E.

8. Go back and check all wiring to this point before plugging in the transformer. The drawing below is a pictorial view of this circuit. Your wires should be connected the same way.



NOTE: In this exercise switches A and C are operating as a S.P.D.T. The same as switch E. When switch C is open, switch A must be closed. And when switch A is open, switch C must be closed.

9. This is the schematic drawing of this circuit.



You can see from the above drawing that by connecting points A and B and points D and F, that the light will burn. If either of the switches is connected to the other point (CORE), the circuit is broken and the light will go out.

10. Close switch A and move switch E to the lower position. The light will burn.

11. Move switch E to the upper position and the light will go off.

12. Close switch C and open switch A. The light will burn again.

THIS ILLUSTRATES THAT A LIGHT CAN BE CONTROLLED FROM TWO DIFFERENT POSITIONS BY USING TWO ____ ____ ____ ____ SWITCHES.

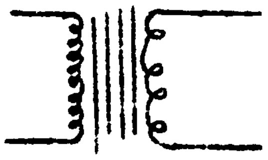
13. Unplug the transformer and remove all the added wires.

14. Replace the original wires to their proper positon.

QUESTIONS

1. Complete the following diagram. Indicate which switches are closed.

2. The drawing below represents a ________________.



3. A circuit using two S.P.D.T. switches could be used to control lights in ____________.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 16

The George Washington University
Education Research Project
1966

ALTERNATING AND DIRECT CURRENT

Objective

To develop an understanding of the difference between alternating and direct current.

Materials

Item No.	Quantity	Description	Source
1	1	Transformer	Electricity
2	5 feet	Wire	Electricity
3	1	Compass	Magnetism
4	1	1/2" diameter Dowel	Friction
5	1	Battery, 6 volt	Electronics
6	1	Earphones	Electronics

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL starting with the Step-by-Step Procedure section.

2. This is an optional exercise that may be performed as the time permits.

3. Student discussion is encouraged at all times and between all steps of the procedure.

4. The students should all be encouraged to come and see the deflection of the compass needle and to listen to the click and buzz in the earphones at the appropriate points in the exercise.

5. Alternating current may be defined as a current of regularly reversing polarity and regularly fluctuating voltage.

6. Direct current is a constant movement of electrons from the negative to the positive pole.

7. The usual current in the United States is 60 cycles per second.

8. Answers to the statements in the STUDENT'S MANUAL:

    S16-2 MAGNETIC

    S16-2 REVERSED

    S16-3 POSITIVE

9. Answers to the Questions in the STUDENT'S MANUAL:

    1. Alternating
    2. 60
    3. diaphram
    4. alternates

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 16

The George Washington University
Education Research Project
1966

ALTERNATING AND DIRECT CURRENTS

Purpose

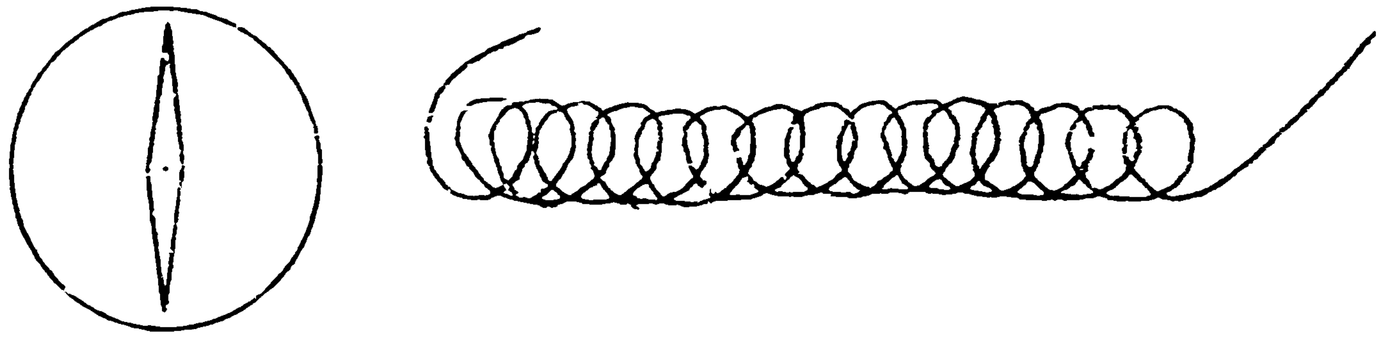
To demonstrate the difference between alternating and direct currents.

Materials

Item No.	Quantity	Description	Source
1	1	Transformer	Electricity
2	5 feet	Wire	Electricity
3	1	Compass	Magnetism
4	1	1/2" diameter Dowel	Friction
5	1	Battery, 6 volt	Electronics
6	1	Earphones	Electronics

Step-by-Step Procedure

1. Remove about one inch of the insulation from the ends of the wire by making a small circular cut and pulling off the insulation.
2. Form a coil of about 15 turns by wrapping the wire around the dowel rod. Start making the coil about 12 inches from the end of the wire and leave 12 inches at the other end.
3. Connect one end of the wire to the positive (+) terminal of the battery.
4. Arrange the coil and the compass so the needle of the compass is at right angles to the center line of the coil. See illustration.



5. Touch the other end of the coil wire to the negative (-) terminal of the battery and hold it there about one-half second.

NOTE: Do not hold the wire on the battery terminal any longer than one-half second or it will ruin the battery.

OBSERVE THAT THE NEEDLE OF THE COMPASS IMMEDIATELY POINTS TOWARD THE COIL. THIS SHOWS THAT YOU HAVE CREATED A ____________ FIELD.

6. Without changing anything else reverse the connection to the battery and carefully observe the action of the compass needle.

THIS SHOWS THAT YOU HAVE ________ THE MAGNETIC FIELD.

7. Now repeat the same experiment but connect the wires to the transformer. Be sure the transformer is plugged in. This time the needle will not move because the alternating pulses of AC at 60 cycles per second do not give the compass needle time to change direction.

8. To prove that there are alternating pulses from positive (+) to negative (-) and back again here is another experiment.

9. Place the compass on top of the transformer. The needle may point in any direction.

10. Plug in the transformer and observe if there is any deflection.

11. Remove the transformer plug and observe any change in the deflection of the needle.

12. Insert and remove the transformer plug several times and observe the deflection of the needle each time when the plug is removed.

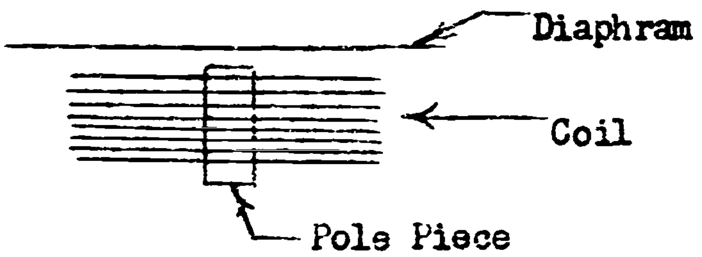
THE NEEDLE OF THE COMPASS WILL FREQUENTLY POINT A DIFFERENT DIRECTION EACH TIME BECAUSE THE IRON CORE OF THE TRANSFORMER RETAINS A SMALL AMOUNT OF MAGNETISM IN THE DIRECTION OF THE CURRENT FLOW AT THE MOMENT THE PLUG IS PULLED.

13. To further show the difference between AC and DC get the earphones from the electronics kit.

14. Attach one earphone plug to the positive (+) terminal of the battery and touch the other plug to the negative (-) terminal.

THE CLICK THAT IS HEARD INDICATES THAT CURRENT IS FLOWING IN ONE DIRECTION ONLY IN THE ELECTROMAGNET OF THE EARPHONES.

The drawing below shows that an earphone is nothing more than an electromagnet with a flat, thin, steel plate over the pole piece. As the magnet is energized by electric current the plate moves and creates a movement of air that is detected by your ears as a sound.



15. Disconnect the earphones from the battery and attach the earphone plugs to the terminals of the transformer. Plug in the transformer and a buzzing sound will be heard.

THIS DEMONSTRATES THAT THE CURRENT IS CHANGING FROM ________ TO NEGATIVE AND BACK AGAIN MAKING THE DIAPHRAM OF THE EARPHONE VIBRATE.

QUESTIONS

1. ____________ current is most commonly used in house wiring.

2. Alternating current changes its polarity or direction of flow ________ times per second.

3. A loud click is heard in the earphones when they are attached to the battery because the ________ is attracted to the pole piece.

4. A buzzing sound is heard in the earphones when they are attached to the transformer because the diaphram moves back and forth when the current __________.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 17

The George Washington University
Education Research Project
1966

SIMPLE AUDIO AMPLIFIER AND RADIO

Objective

To demonstrate how to make a simple audio amplifier and then convert it to a radio.

Materials

Item No.	Label No.	Quantity	Description
1	2	1	Dual Gang Capacitor
2	3	1	IN34 Diode
3	7	1	Battery, 6 volts
4	9	1	Double loop Antenna Coil
5	10	1	2N404 Transistor
6	11	1	220,000 ohm Resistor
7	12	1	22,000 ohm Resistor
8	13	1	.02 Microfarad Capacitor
9		1	Crystal Microphone
10		1	Head Set or Earphones
11		16	Jiffy Clips
12		1	Pegboard (6 2/3" x 11 1/4") with holes 1/2" apart
13		1	Wiring Diagram with holes
14		10 feet	Wire, Antenna

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.

2. After a part has been plugged in, it is difficult to follow the heavy black lines connecting the parts on the diagram. Therefore, the procedure suggests using the second wiring diagram without holes when connecting the parts.

3. It is easy to make an improper connection because of the many lines on the wiring diagram. Emphasize the importance of checking for an improper connection or a connection that has become disconnected. The procedure suggests that someone besides the person making the original connections check the board after all jiffy clips have been put in place.

4. The higher up one is in a building the better the reception usually. There are other factors that may affect the quality of reception also. The farther the receiver is from the radio station the poorer the reception. The longer the antenna is, the better the reception usually.

5. The procedure suggests that the battery be connected last. There are two good reasons for doing this: (a) If there is a loud click in the headset when the second battery terminal is connected to the receiver, there is a greater assurance that all connections have been made, and (b) It is good procedure to connect to the power supply last.

6. If conditions are good these simple receivers will pick up signals quite well; however, if you or your students are unable to recognize speaking or music and are able only to tune in static and other unidentifiable noises, consider your efforts and those of your students as successful.

7. Encourage questions, comments and class discussion during the demonstration. You may discover that the students know quite a great deal more about this subject than you expected.

8. Ask students to list the uses made of radio receivers such as, in the home, automobiles, boats, trains and aircraft, etc. The military uses radio receivers to receive code and voice transmission. Small portable receivers are used in the form of walkie-talkies.

9. Although the materials used in this exercise are in no danger of becoming damaged easily because of the low voltage of the power used, the following precautions for handling electronic materials should be stressed during the demonstration:

    a. Parts should be accurately identified and placed on the wiring diagram and connected properly or problems may be encountered such as:

        (1) the set will malfunction or not work at all.

        (2) the component part improperly connected may be damaged or destroyed.

        (3) one component part improperly placed or connected may damage or destroy other parts in the system.

    b. All electric connections should be carefully cleaned before connecting the parts when constructing circuits.

c. Whenever the instructor or student becomes confused while constructing the set, he should completely disassemble all equipment and start over.

d. Care must be taken to connect batteries properly.

e. Some components are so sensitive that the presence of the human body acts as a capacitor and will alter the reception of the circuit.

10. You and the students may find the schematic diagram helpful in understanding the relationship among parts and in understanding how the amplifier and receiver works. The functions of the simple radio tuner are to receive broadcast signals, select these signals into certain wave lengths and specific signals, and the amplifier is to increase the strength of these signals so that they can be heard through a headset or speaker.

    a. The <u>variable capacitor</u> (tuner) (part #2) selects single transmitted signals from a radio transmitter broadcasting in the local area.

    b. The <u>capacitor</u> (part #13) controls and modifies the signal transmitted to the transistor.

    c. The <u>transistor</u> (part #10) increases the signal before it goes to the resistor.

    d. The <u>resistor</u> (parts #11 and #12) controls and decreases the power of the current going to the headset. It also eliminates irregularity in the power flow to the headset.

    e. The <u>headset</u> (unlabeled) changes the broadcast signal into sound waves which can be heard by the human ear.

11. Answers to the Questions in the STUDENT'S MANUAL:

    1. transistor
    2. microphone
    3. electricity or power
    4. earphones or headset
    5. tuner
    6. voltage

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 17

The George Washington University
Education Research Project
1966

SIMPLE AUDIO AMPLIFIER AND RADIO

Purpose

This exercise will show you how to make a simple audio amplifier and then convert it to a simple radio.

Materials

Item No.	Label No.	Quantity	Description
1	2	1	Dual Gang Capacitor
2	3	1	IN34 Diode
3	7	1	Battery, 6 volts
4	9	1	Double Loop Antenna Coil
5	10	1	2N404 Transistor
6	11	1	220,000 ohm Resistor
7	12	1	22,000 ohm Resistor
8	13	1	.02 Microfarad Capacitor
9		1	Crystal Microphone
10		1	Head Set or Earphones
11		16	Jiffy Clips
12		1	Pegboard (6 2/3" x 11 1/4") with holes 1/2" apart
13		1	Wiring Diagram with holes
14		10 feet	Wire, Antenna

Step-by-Step Procedure

1. Place the wiring diagram of the radio receiver with holes in it on the pegboard so that the holes match the holes in the pegboard.
2. Arrange parts #13 (capacitor), #10 (transistor), #12 (resistor), and #11 (resistor), on the overlay by matching the label number on the part with the corresponding representation of the part on the diagram and plug into place in the pegboard.

> NOTE: Take care in orienting parts so that the terminals correspond with those on the diagram. The straight line on the capacitor, drawing #13, indicates the positive terminal of the capacitor.

Making an audio amplifier

3. Connect the capacitor negative terminal to the base or input of the transistor (point M to H). This brings the signal to the transistor to be amplified.

> NOTE: When connecting jiffy clips, always be sure they contact the terminals firmly and do not touch clips attached to other parts.

4. Connect the input of the transistor (point H) to the resistors (points Q and S). These resistors reduce the amount of current to the transistor.

    5. Connect the emmitter of the transistor (point G) to the 22,000 ohm resistor (point P).

    6. Attach jiffy clips to the two terminals at the end of the cord of the earphones. The earphones convert electrical signals to sound you can hear.

    7. Connect one terminal to the 220,000 ohm resistor (point R).

8. Connect the other terminal of the earphones to the collector of the transistor (point J).

9. Attach jiffy clips to the terminals at the end of the microphone cord.

> NOTE: The terminals of the microphone are separated by a black insulation about 1/16" wide. Be certain the jiffy clips do not touch each other and contact only the separate terminals.

10. Attach the clip at the end microphone terminal to the capacitor (point N).

11. Attach the other clip to negative battery terminal or point R.

CHECK LIST #1: Use the following check list to be sure that your connections are made properly.

Point	to	Point	Check
M		H	
H		Q	
H		S	
G		P	
Earphone		R	
Earphone		J	
Microphone		N	
Microphone		R	

12. Have someone else also check over your connections for you.

13. Connect the negative (-) side of the battery to the 220,000 ohm resistor (point R) by inserting the wire from the battery into the hole in the top of the battery.

14. Connect the positive (+) side of the battery to the 22,000 ohm resistor (point D).

15. Gently tap the microphone and listen in the earphones. You should hear the tapping clearly. Have someone talk into the microphone and see if you can understand them.

> NOTE: If the amplifier does not seem to work immediately, disconnect the battery and check over all your connections.

16. After trying the amplifier and assuring yourself that it works, disconnect the microphone from points M and N and the battery from points P and R.

Adding a radio tuner to the amplifier

17. Place parts #2 (dual gang capacitor), #3 (diode), #9 (double loop antenna coil), on the pegboard by matching them to the holes and the representation of the part.

18. Compare Figures 1 and 2 on Page S17-7.

Detector and tuning section (Figures 1 and 2)

19. Notice the antenna coil and the dual gang capacitor are connected in parallel. These parts select the signal from the air.

20. Using jiffy clips, connect these parts in parallel by following the wiring diagram (points A to F, C to E, B to D).

21. Connect the one gang of the capacitor to the diode, (points E to K). The diode detects the radio signal.

22. Connect the diode to the capacitor (points L to N). This capacitor will only allow radio signal to pass.

23. Connect your antenna to the antenna coil (point A). This can be done by doubling the wire over and pushing down the hole in the terminal.

> NOTE: The longer your antenna is, the better the reception will be. You might try attaching your antenna to a window screen or a television antenna. Do not allow the antenna wire to touch the ground.

CHECK LIST #2: Use the following check list to be sure that your connections are made properly.

Point	to	Point	Check
A		F	
C		E	
B		D	
E		K	
L		N	
Antenna		A	

24. Have someone else check over your connections for you.

25. Connect the negative (-) side of the battery to the 220,000 ohm resistor (point R) by pushing it in the hole in the top of the terminal.

26. Connect the positive (+) side of the battery to the 22,000 ohm resistor (point P) by pushing it in the hole in the top of the terminal.

27. Slowly tune the variable capacitor to see how many stations are being received.

28. Disconnect the battery when the set is not in use.

NOTE: Reception conditions vary considerably. Distance from the station, power of the station, and height above ground affect the signal. Flourescent lights and other types of interference may cause static in the radio.

QUESTIONS

1. The ________ amplifies the signal.

2. The ________ converts sound waves into electrical power.

3. The battery furnishes ________ to the set.

4. The ________ change electrical power into sound waves.

5. The ________ section detects and separates the radio signal being received.

6. The resistors limit ________.

RADIO RECEIVER

FIGURE 1

WIRING DIAGRAM

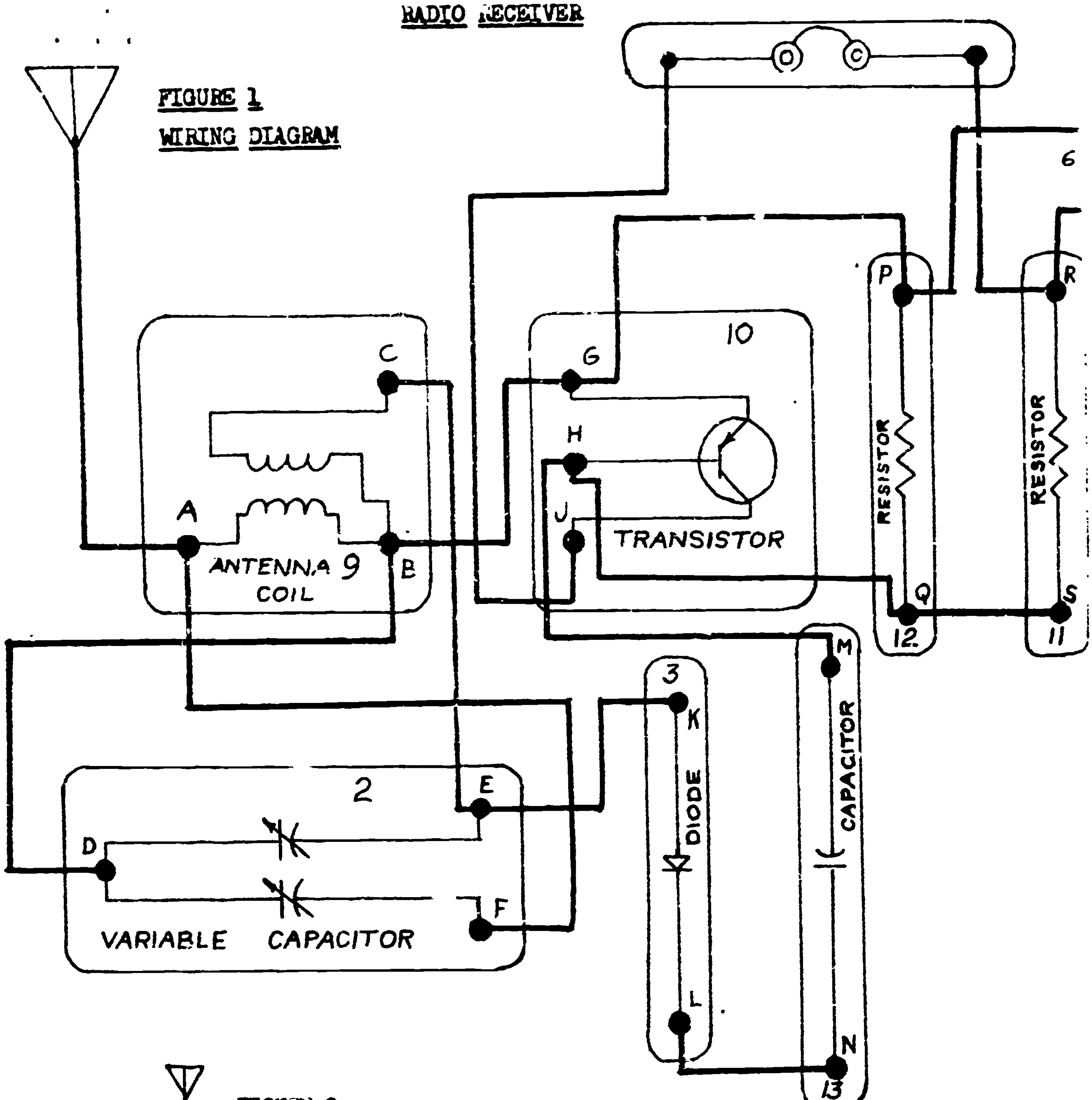
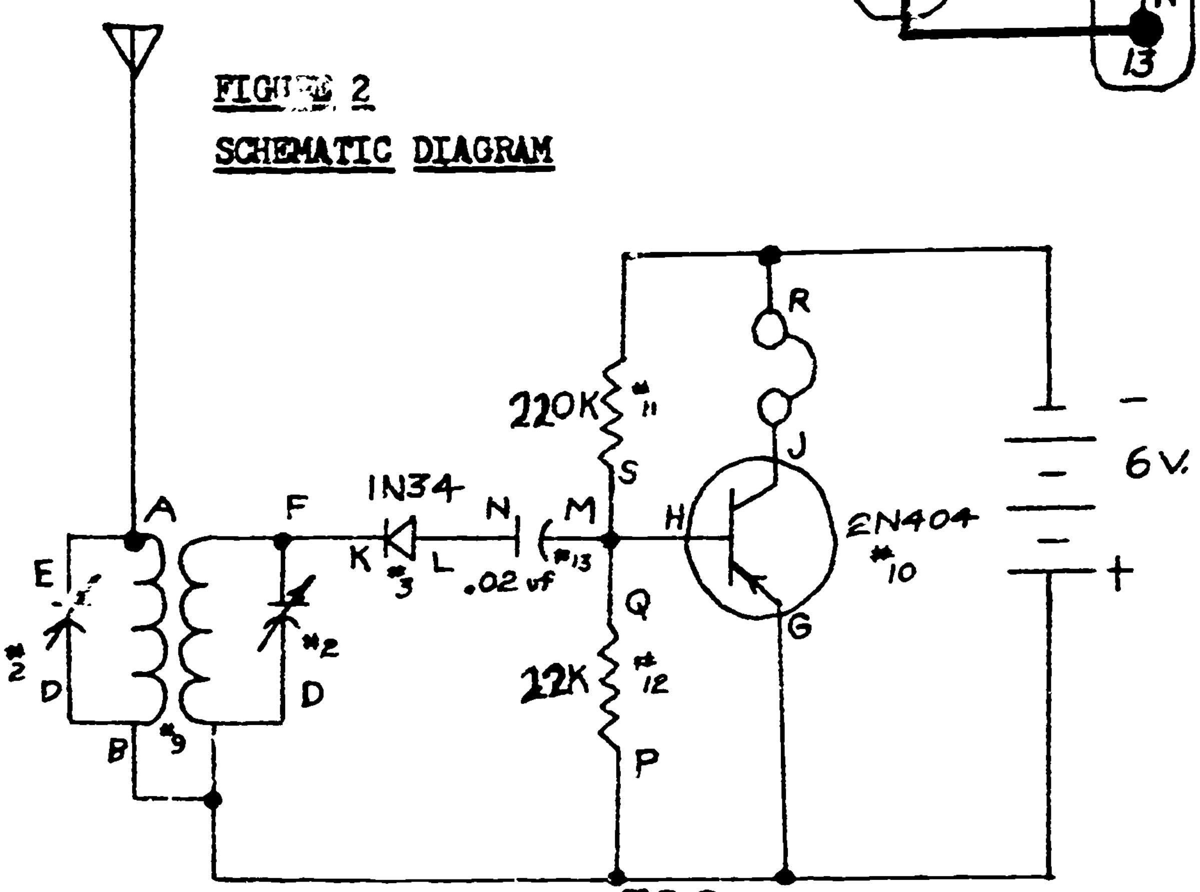


FIGURE 2

SCHEMATIC DIAGRAM



Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 18

The George Washington University
Education Research Project
1966

SIMPLE RADIO TRANSMITTER

Objective

To demonstrate how to make a simple radio transmitter.

Materials

> NOTE: There are no component changes in this kit.

Item No.	Label No.	Quantity	Description
1	1	1	365 Micro Microfared Variable Capacitor
2	2	1	Oscillator Coil
3	3	1	250 Microfared Capacitor
4	4	1	2N1086A Transistor
5	5	1	2.2 Milihenry R.F. Choke
6	6	1	56,000 ohm Resistor
7	7	1	Battery, 6 volts
8	8	1	47 Micro Microfared Capacitor
9	9	1	18,000 ohm Resistor
10	10	1	1,000 Microfared Capacitor
11	11	1	100 Microfared 6WVDC
12	12	1	Carbon Microphone
13	13	1	AR153 Transformer
14	14	1	Battery Holder
15		1	Battery, Flashlight, 1 1/2 volts
16		21	Jiffy Clips
17		1	Pegboard (6 2/3" x 11 1/4" with holes 1/2" apart)
18		1	Wiring Diagram with holes

> NOTE: This exercise will require a piece of wire for an antenna and a radio receiver not provided in the original materials. A piece of wire from Exercise 12 may be used. A longer antenna can be made by splicing several pieces of wire together. Small radios are in such common use today that it should not be difficult to find one among the students or in the school.

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.

2. Again, as with Exercise 17, the procedure of this exercise suggests using the second wiring diagram without holes and with connecting parts indicated when connecting the parts with jiffy clips.

3. Also, this exercise recommends that someone besides the person wiring the board check to see that all connections have been made according to the wiring diagram to ensure that the connections have been made properly.

4. Encourage the students to ask questions, make comments and participate in class discussion during the demonstration. Some students may wish to tell of experiences they may have had seeing or using radio transmitters and receivers.

5. Precautions for handling electronic materials should be emphasized in this exercise as in Exercise 17. See TEACHER'S MANUAL, Exercise 17, Page T17-3, Suggestion 10.

6. It might be well to tell the students during the demonstration that all types of radio transmitters send a known signal on a certain wavelength at a specific signal strength for certain times. All transmission stations have to meet Federal Communications Commission requirements about the strength of transmitted signals, and the wavelength used. However, a transmitter of very limited range like this one does not have to be licensed if used in a school program.

7. Ask students to list the uses made of radio transmitters, such as, portable transmitters used as walkie-talkies, telephones in cars, telephones in airplanes, and radio telephones on boats and ships, etc.

8. The schematic diagram may prove helpful in giving the student a better understanding of the relationship among parts and in understanding how the transmitter works.

a. The microphone (part #12) produces the signal which goes through the set and is transmitted.

b. The resistors (parts #6 and #9) control and limit the current passing through the set.

c. The capacitors (parts #3, #8, and #10) control and modify the signal.

d. The batteries (part #7 and an unlabeled flashlight battery) and holder (part #14) power the set and the carbon microphone.

e. The transistor (part #4) increases the signal strength.

f. The coil (part #2) modifies, increases and maintains a single transmission signal.

g. The tuner (part #1) isolates a single signal for transmission out through the antenna.

9. Answers to the questions in the STUDENT'S MANUAL:

   1. antenna
   2. transistor
   3. radio frequency or signal generator
   4. modulation

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 18

The George Washington University
Education Research Project
1966

SIMPLE RADIO TRANSMITTER

Purpose

This exercise will show you how to make a simple radio transmitter.

Materials

Item No.	Label No.	Quantity	Description
1	1	1	365 Micro Microfared Variable Capacitor
2	2	1	Oscillator Coil
3	3	1	250 Microfared Capacitor
4	4	1	2N1086A Transistor
5	5	1	2.2 Milihenry R.F. Choke
6	6	1	56,000 ohm Resistor
7	7	1	Battery, 6 volts
8	8	1	47 Micro Microfared Capacitor
9	9	1	18,000 ohm Resistor
10	10	1	1,000 Microfared Capacitor
11	11	1	100 Microfared 6WVDC
12	12	1	Carbon Microphone
13	13	1	AR153 Transformer
14	14	1	Battery Holder
15		1	Battery, Flashlight, 1 1/2 volts
16		21	Jiffy Clips
17		1	Pegboard (6 2/3" x 11 1/4" with holes 1/2" apart)
18		1	Wiring Diagram with holes

NOTE: This exercise will require a piece of wire for an antenna and a radio receiver not provided in the original materials. A piece of wire from Exercise 12 may be used. A longer antenna can be made by splicing several pieces of wire together. Small radios are in such common use today that it should not be difficult to find one among the students or in the school.

Step-by-Step Procedure

1. Place the wiring diagram with holes in it on the pegboard so that the holes match the holes in the pegboard.
2. Arrange the parts on the overlay by matching the label number on the part with the corresponding representation of the part on the diagram and plug into place in the pegboard.
3. Take care in orienting parts so that the terminals correspond with those on the diagram (parts #1, #2, #4, #13 and #14).
    4. Place the 1 1/2 volt flashlight battery (part #15) into the holder (part #14). The battery snaps into the holder easily but take care to snap it in so that the positive (+) and negative (-) ends of the battery match the positive and negative ends of the holder.
    5. Compare the wiring diagram on page S18-8 with the schematic diagram on page S18-9. Notice the numbers on the parts and compare them with the placement of parts on the wiring diagram. The schematic indicates which parts are wired together while the wiring diagram shows the placement of the actual wires. The points A, B, C, etc. are indicated on the wiring diagram. Remove this page from the manual and keep it in front of you.

<u>The radio frequency signal generator</u>

6. Starting with the variable capacitor (#1) connect a jiffy clip to the top on the oscillator coil (#2), point A to point B.

> NOTE: When connecting jiffy clips always be certain they fasten snugly and they do not touch other clips that are not connected to the same terminal.

7. From the end of the oscillator coil (point C), connect a jiffy clip to point D on the capacitor #3 (point D).

8. Connect the other terminal of the oscillator coil (point E) to the variable capacitor (point F). This completes the section of the transmitter that generates the radio signal.

Radio frequency amplifier section

9. From the oscillator coil (point E), connect to the capacitor #8 (point G). This capacitor only allows radio frequency signals to pass through to the transistor.

10. Connect the other terminal of the capacitor (point H) to the input or base of the transistor #4 (point K).

> NOTE: If you are following the lines for the wires on the drawing under the parts, you will see that this is not exactly as shown; but tracing the wires you will see it is simply a short way of wiring these parts.

11. Connect the emmitter of the transistor (point J) to the resistor #9 (point N).

12. From the resistor (point N), connect to the capacitor #10 (point O).

13. Connect the capacitor #9 (point O) to the capacitor #11 (point P).

14. Connect the resistor #9 to the capacitor #10 (points S to R).

15. Connect the capacitor #10 (point R) to the transformer #13 (point Y).

16. Connect the capacitor #11 (point Q) to the transformer #13 (point X). These parts (#9, #10, #11), are used to limit and modify the current to the transistor.

> NOTE: There are three terminals on one side of the transformer and two terminals on the other side. The side with three terminals must be away from the edge of the pegboard and parallel to capacitor #11.

17. From the base or input of the transistor #13 (point K) connect to the resistor #6 (point T).

18. Connect the collector of the transistor (point L) to the RF choke #5 (point U). This choke prevents radio frequency current from flowing back to the battery.

19. Connect the resistor #6 to the RF choke (points V to W).

20. Connect the collector of the transistor (point L) to the capacitor #3 (point M). This completes the amplification of the radio signal.

The modulation section

21. Connect the transformer #13 (point Z) to the battery holder (point BB).

22. Connect the other terminal of the transformer (point AA) to the microphone. This section of the transmitter changes the radio signal that has been generated from a steady current to one that varies or modulates as your voice or input sound varies.

NOTE: The carbon microphone has two brass colored rings on the back. The wires will have to be held against these rings when you are talking into the microphone.

23. Connect the negative (-) terminal of the battery (point CC) to the other connection of the microphone.

24. A piece of wire is needed for the antenna. This can be as short as four inches or as long as 30 feet.

25. The large 6-volt battery (part #7) does not need to be plugged into the pegboard but located wherever most convenient.

26. Do not connect the battery until someone has checked your wiring to make sure all connections have been made as shown in the diagram. Use the following check list to be sure your connections are correct.

CHECK LIST

Point	to	Point	Check
A		B	
C		D	
E		F	
E		G	
H		K	
J		N	
N		O	
O		P	
S		R	
R		Y	
Q		X	
U		T	
L		U	
V		W	
L		M	
Z		BB	
AA		Microphone	
CC		Microphone	

27. Connect your transmitter to the power supply, the 6-volt storage battery (part #7). Be sure you know which terminal is negative (-) and which is positive (+) before connecting it. The negative terminal is in the center and the positive terminal is in a corner.

28. Connect the positive (+) terminal to part W of the choke, the negative (-) terminal to point R of the capacitor #10.

29. Turn on a commercially produced radio receiver and tune to a quiet spot between stations.

30. Turn the knob on the variable capacitor (part #1) until you hear a signal over the radio. Tap (with pencil or finger) or blow into the microphone to assist in tuning. After you have tuned the variable capacitor, try transmitting a voice signal over the microphone.

NOTE: If the radio receiver is moved farther away, it will be necessary to re-tune the variable capacitor to make the signal stronger.

31. If there is time in the class period repeat Steps 29 and 30 and substitute the radio receiver made in Exercise 17 for the commercially made radio. You may not be able to pick up the signal from the transmitter on this set as the power may be too weak and you have no way of increasing it as you could with the volume control dial on the other radio.

32. Disconnect the battery when the set is not in use.

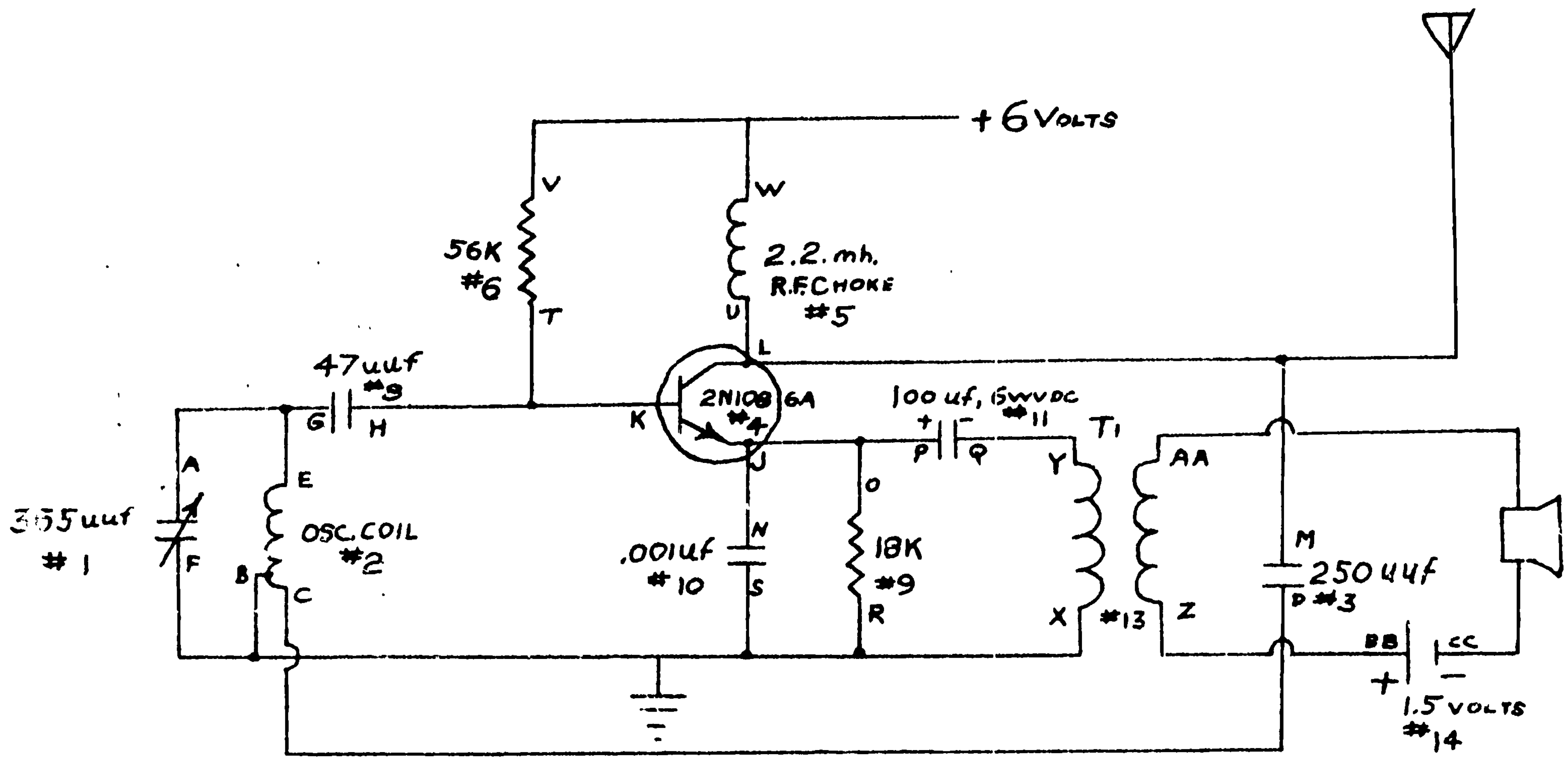
QUESTIONS

1. The ________ radiates the signal from the transmitter.

2. The ________ amplifies the signal.

3. The oscillator coil and the variable capacitor make up the ________ ________ section of the transmitter.

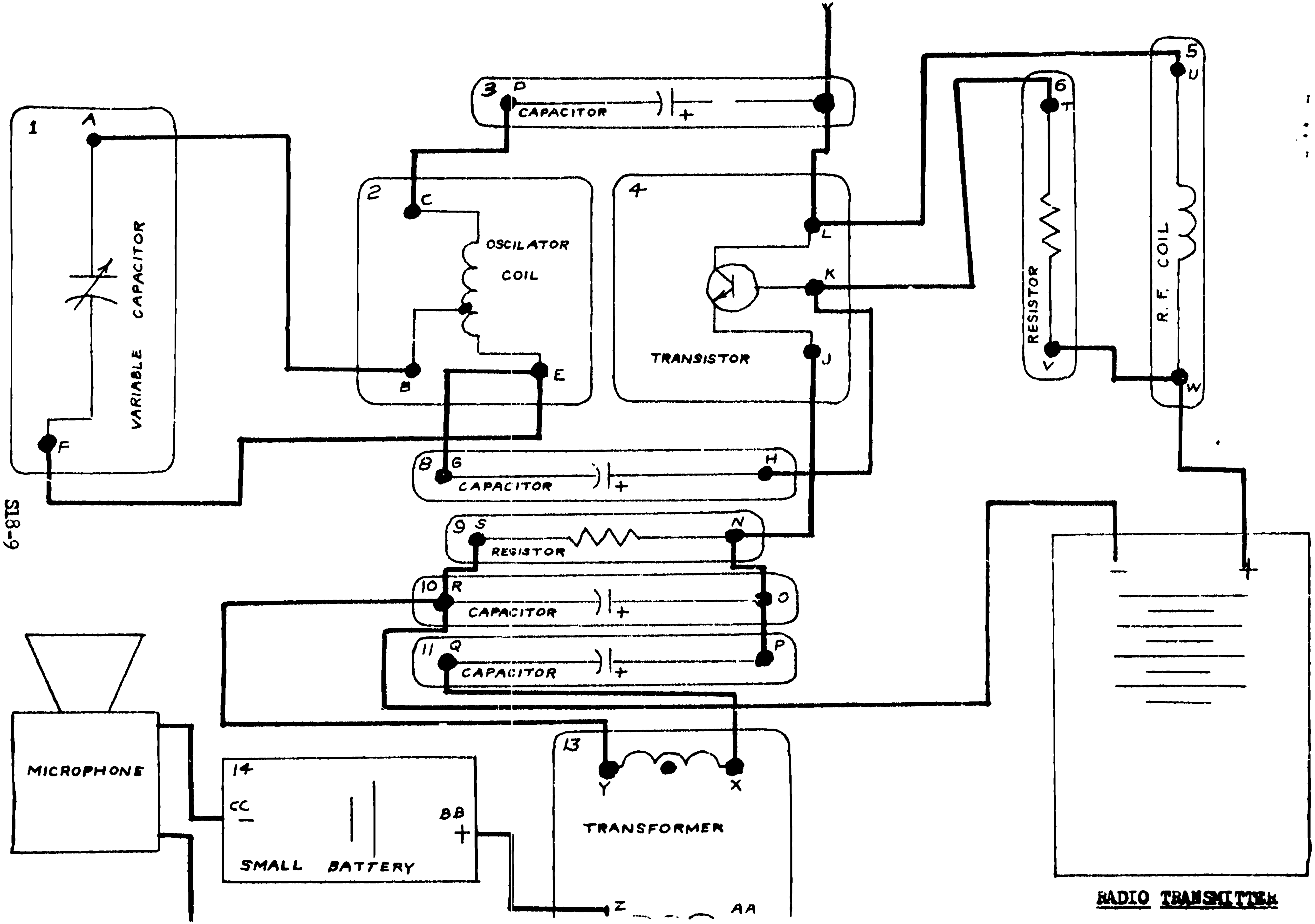
4. The microphone and the transformer make up the ________ section of the transmitter.



SL8-8

RADIO TRANSMITTER

SCHEMATIC DIAGRAM



RADIO TRANSMITTER

S18-9