Mission 8
Building a Radio Receiver

Hearing the Radio Waves That Surround You!

There are messages traveling through the air right now–thousands of messages. Can you hear them? Listen! Your ears cannot receive these signals, but by using your brain you can construct a technological device that will enable you to hear these messages.

You have the job of building a working AM radio, using just a few simple materials. A high standard of craftsmanship is necessary for the radio to work. Aim to make your radio look like the class model that has already been built. Use the class model to check your construction technique and your electrical connections.

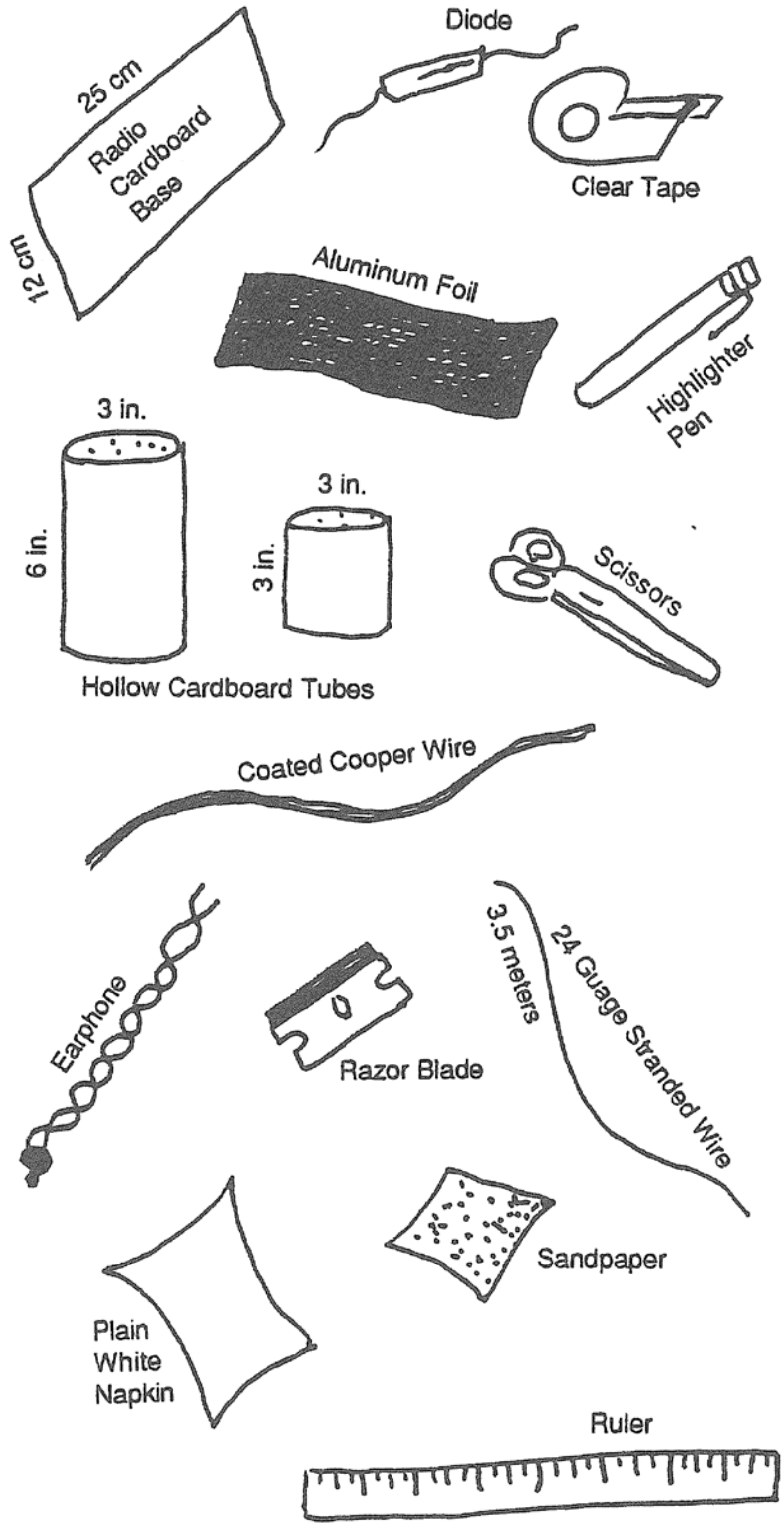
Step 1–Organizing the Job

As each step of the job is completed, use the highlighting pen to check it off by coloring through the instructions.

Gather your materials and lay them out at your work area. Check off each item when you have identified it.

- Radio cardboard base: 25 cm x 12 cm
- Two pieces of 3-inch-diameter hollow cardboard tubing:
  15.25 cm length
  7.5 cm length
- 16 meters of 24-gauge solid copper wire (enamel coated)
- 3.5 meters of 24-gauge stranded wire
- Diode
- Crystal radio earphone
- Highlighter pen
- Aluminum foil
- Clear tape
- Small piece of extra-fine sandpaper
- Sheet of white paper
- Scissors
- Single-edge razor blade or X-acto® knife
- Meter stick
- Grocery bag

Figure–8.1.


Diode
25 cm
Radio
Cardboard
Base
12 cm
Clear Tape
Aluminum Foil
Highlighter
Pen
3 in.
6 in.
3 in.
3 in.
Scissors
Hollow Cardboard Tubes
Coated Cooper Wire
3.5 meters
24 Guage Stranded Wire
Earphone
Razor Blade
Sandpaper
Plain
White
Napkin
Ruler

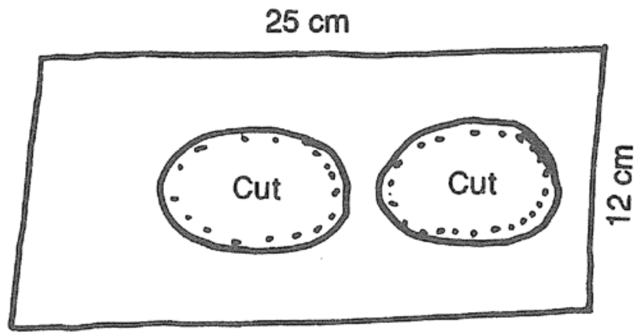
Step 2–Building the Base

a. Cut the cardboard radio base to size: 25 cm x 12 cm.

b. Trace around the outside of the hollow cardboard tube to make two circles on the radio base as shown on diagram.

c. Use a cutting tool to cut out both circles just inside of the pencil line. This guarantees your cardboard tubes will have a tight fit.

Figure–8.2.



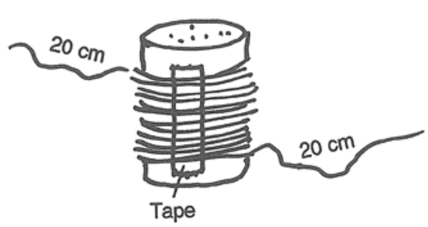
Step 3–Building the Coil

a. Tape the coated copper wire to the top of the short cardboard tube, leaving 20 cm of extra wire overhanging the tube for connection purposes later.

b. Begin to wrap the wire tightly around the tube, making sure that the wire fits snugly, but doesn't overlap, Don't let your wire come uncoiled! You can tape down a few coils at a time with transparent tape as you work.

c. Leave 20 cm of the wire overhanging the tube at the other end. Tape the entire coil in place so that it doesn't come apart.

Figure–8.3.



Step 4–Building the Variable Capacitor

a. Cut a piece of aluminum foil 10 cm x 25 cm to fit around the bottom half of the tall cardboard tube. Make sure that the ends of the foil overlap just a little bit.

b. Starting 1 cm up from the bottom of the tube, tape the entire overlapping edge of the foil together. Tape the exposed edge of the foil all the way around the center of the tube.

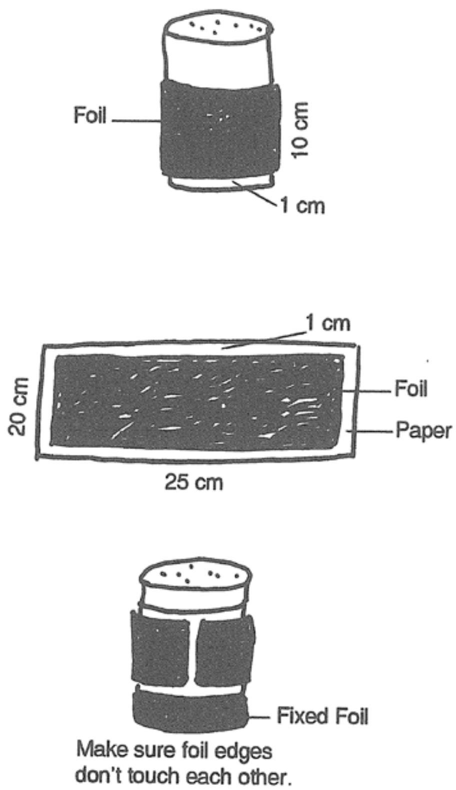
c. Cut a second piece of foil 20 cm x 25 cm.

d. Cut a piece of white paper 1 cm wider than the second piece of foil on all of the four sides.

e. Tape the foil to the paper. There should be a white border of paper visible all the way around the foil rectangle.

d. Wrap this foil-paper piece around the upper portion of the cardboard tube, with the white paper next to the tube. Tape the paper ends together. This piece must be able to move up and down over the bottom piece of aluminum. It cannot be too tight, and it cannot be too loose. The top aluminum foil cannot touch either the bottom aluminum foil or itself where it wraps around the tube.

Figure–8.4



Step 5–Building the Electrical Connecting Strips

a. Cut one piece of aluminum foil 15 cm x 15 cm.

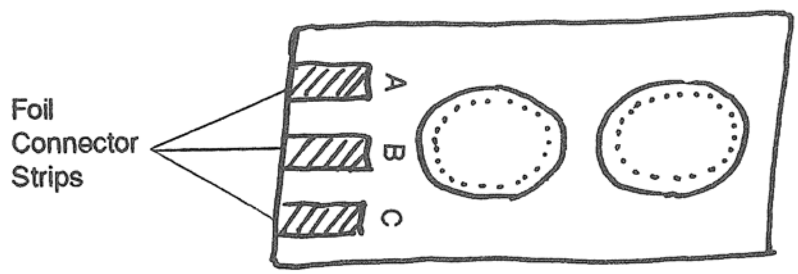
b. Fold the aluminum foil piece in half. Fold it in half a second time, and then fold it in half a third time, forming a long strip of aluminum foil.

c. Cut the long strip of aluminum foil into thirds, forming three connector strips. Each of these connector strips is now 5 cm long.

d. Tape each connector strip to the cardboard radio base as shown in the diagram, leaving room where wire can later be inserted.

e. Label A, B, and C as shown in the diagram.

Figure–8.5.



Step 6–Assembling Your Radio

a. Insert the coil into the center hole of the radio base. It should fit tightly Make sure that the two overhanging wires can reach the connector strips.

b. Turn the radio base upside down. Tape the tube in place with strips of tape from inside the tube outside to the base.

c. Take the loose end of the wire closest to connector strip A and cut off any extra wire so that it just reaches to connector strip A. Sand 2 cm of enamel coating (insulation) off the end of the wire. Do the same to the other wire, making sure that it is long enough to reach connector strip C.

d. Secure the variable capacitor to the radio base in the same way that you did the coil. Make sure that the fixed piece of aluminum is at the bottom.

e. Cut 15 cm of stranded wire. Strip 1 cm of plastic insulation off each end of the wire.

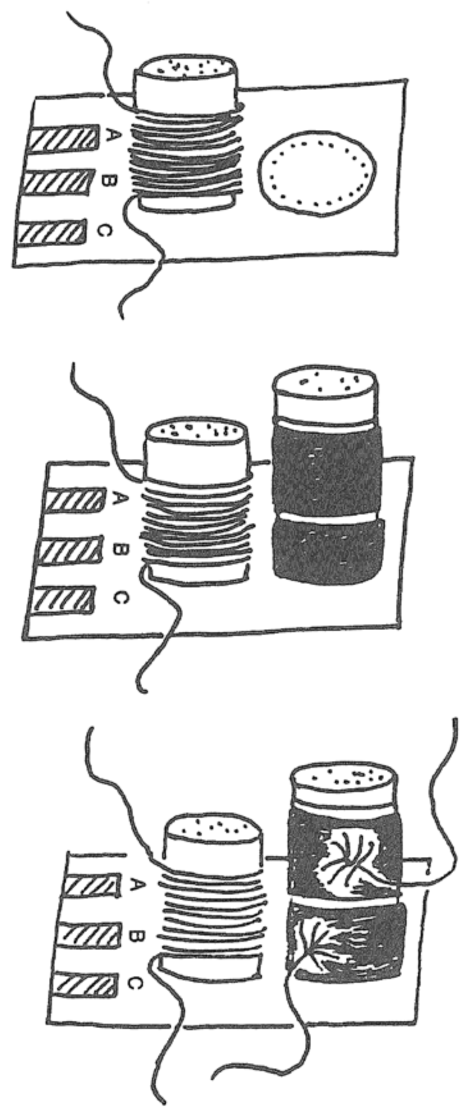
f. Carefully spread out the strands of tiny wires on one end like a fan and tape them firmly to the fixed piece of aluminum foil on the bottom of the variable capacitor.

g. Cut 20 cm of stranded wire. Strip 1 cm of plastic insulation off each end of the wire. Fan out the strands of tiny wires on one end and tape them firmly to the sliding piece of foil.

h. Cut 2 m of stranded wire for the antenna. Strip 1 cm of plastic insulation from both ends.

i. Cut 1 meter of stranded wire to use as a ground wire. Strip 1 cm of plastic insulation from both ends.

Figure–8.6.



Step 7–Making the Electrical Connections

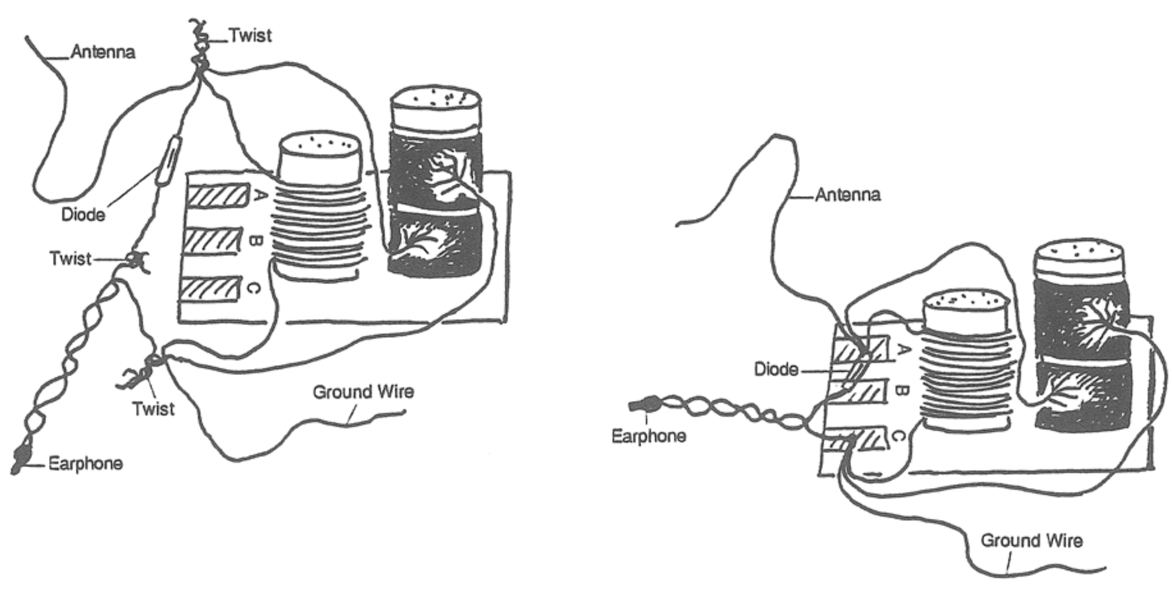
a. Twist together the following wires:
   one end of antenna wire
   one end of coil wire (sanded)
   one end of wire from bottom half of variable capacitor
   one end of diode
   After these wires are twisted, carefully tape them down to connector strip A.

b. Twist together the following wires:
   other end of diode
   one earphone wire
   Tape to connector B.

c. Twist together the following wires:
   one end of ground wire
   other earphone wire
   other end of coil wire (sanded)
   one end of wire from top half of capacitor
   Tape to connector strip C.

Believe it or not, once you make the final connection, your radio is "on"! There is no on/off switch like a normal radio would have, because there is no battery.

Figure–8.7.



Step 8–Testing Your Radio

a. Double check all of your connections and compare your radio to the one your teacher has on display in the room.

b. Find a place to hook up your antenna wire, preferably up high. If your teacher has set up an antenna wire that goes out of your room through a window, hook the end of your antenna wire to the end of your teacher's antenna wire. Make sure the plastic insulation has been stripped off the end of your antenna wire. Attach the ground wire to a pipe or metal radiator at a place where the paint is missing.

c. Very slowly move your variable capacitor up and down on the larger cardboard tube. The variable capacitor allows you to change stations. If you don't get any stations in one location, unhook your antenna and ground wire and move to another location.

d. Make sure that all your connections are correct and you have tested out your radio in several locations around the room, in case of difficulty.

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How Does a Radio Work?

What Is Radio?

Everyone knows that light can travel quickly from place to place, and can pass effortlessly through the vacuum of space. In the past, simple attempts were made to use light to send messages, by flashing mirrors or using a shutter on a shipboard lantern. However, at the end of the last century, European scientists such as Heinrich Hertz and Guglielmo Marconi began to experiment with sending messages with "light" of much lower frequency (or longer wavelength). We refer to this "light" as radio waves. Our eyes don't respond to low-frequency electromagnetic radiation, so we don't see radio waves. But radio waves and light are the same phenomenon; they differ only in their wavelength.

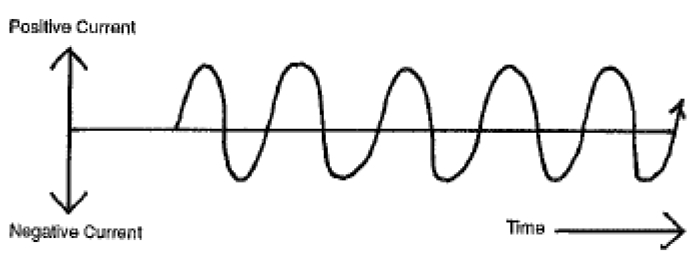
How Do You Make Radio Waves?

Radio waves are generated any time you have a changing electric current. If you simply shake an electron, for example, you generate a radio wave (albeit a weak one). If an electron just sits there, or moves steadily down a wire as a direct current, no waves are radiated. You have to change its motion.

Heinrich Hertz did this by making electric sparks, which shakes up a lot of electrons in a random kind of way. This works (have you ever heard the static on your radio when a lightning bolt flashes nearby?), but it causes radio waves at all sorts of frequencies. It's a bit like trying to make a pure, musical note by hitting a jungle gym with a hammer.

A better way is to use electronic circuits to move lots of electrons all together (a sort of electronic, country line-dance) in a rhythmic pattern that makes a pure radio "tone." In a circuit like this, called an oscillator, the current is always changing; it looks like Figure 8.8.

Figure 8.8–Oscillating Current.



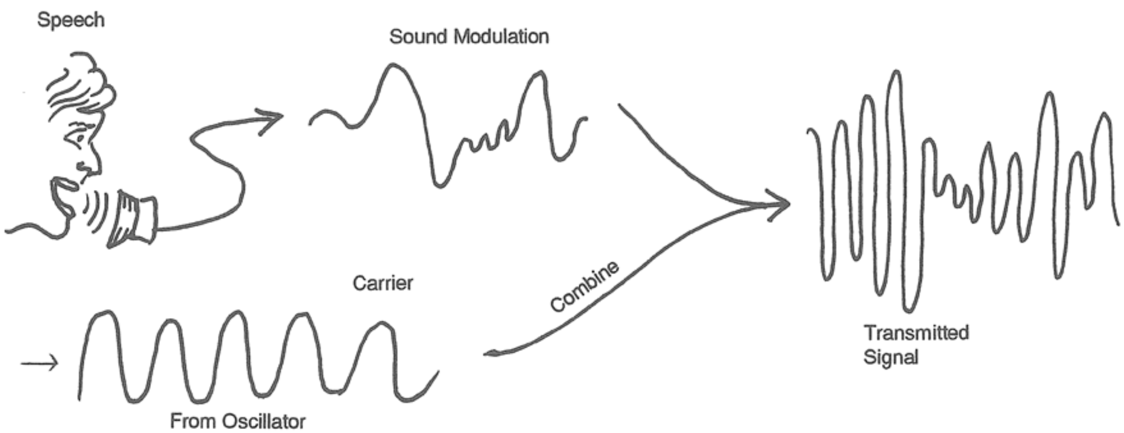
An AM radio station has an oscillator that changes the direction of the electron dance about a million times a second. That is why such stations have frequencies on the dial like "810" or

"1400," which stand for 810 kilohertz (810,000 changes of direction or cycles per second) or 1400 kilohertz (1,400,000 cycles per second).

Adding the "Top 40" (do kids even know or care what a Top 40 is anymore?)

The high-frequency oscillator used at an AM station generates a pure, radio tone. Unfortunately, listeners would quickly get bored if their receivers only produced this monotonous note, so the engineers have figured out how to modify, or "modulate" the pure radio tone (which is called a "carrier") with the sound of today's Top 40 or a newscaster's voice. The modulations are produced by a microphone, which converts sound waves into another changing electrical current, which is then added to the radio carrier, as in Figure 8.9.

Figure 8.9–Converting Sound Waves to Electrical Current.



How a Radio Receiver Works

An antenna, either sticking out the top of your radio (or car) or built inside, picks up radio signals and causes electrons in the wire connected to the antenna to dance synchronously with the signal. But that's not good enough to make a radio receiver, because 1) the antenna is sensitive to all radio stations, not just the one you want to listen to, and 2) you are not interested in the carrier, only the modulation, and you want this changed into sound waves so you can listen to your favorite music group or broadcaster.

The simplest kind of receiver is called a crystal set, and consists of four major sections:

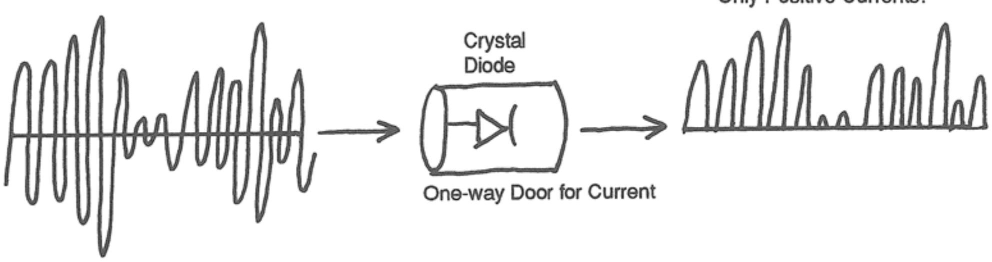
1. **The antenna.** This can be a long piece of wire which picks up radio signals. It helps a lot if you also have a "ground," which is another piece of wire that is connected to a metal fixture that sticks into earth. In the wire that joins the antenna and the ground, the incoming radio waves from the transmitter force the electrons to do a dance that mimics the one produced in the radio transmitters.

2. **A tuning circuit.** This consists of a coil of wire and a capacitor (two metal plates, close together; you can also make a capacitor with two pieces of aluminum foil, separated by a

sheet of paper or some other insulator). What does the tuning circuit do? It picks out the carrier wave at one station's wavelength–the one that you wish to listen to–and sends that signal on to the next part of the receiver. It is connected to the tuning knob in larger receivers. You can seek out another station by changing either the coil or the capacitor.

3. **The detector.** Because the current in the antenna is oscillating both forward and backward, if we sent this signal directly to an earphone you wouldn't hear anything, because the positive and negative currents would cancel out on average, producing no sound! Instead, we force the signal from the tuning circuit through a detector (in this case, a crystal diode) which only allows current to pass in one direction (see Figure 8.10). After passing the diode, the average value of the current is not zero, and we can send the signal onto the final section of the radio, the earphone.

Figure 8.10–The Detector.



4. **The earphone.** This is the part of the radio that converts the changing currents into sound (see fig. 8.11). It undoes what the microphone originally did to convert sound into changing electric currents. The earphone accomplishes this with a thin piece of metal (a diaphragm) next to a small electromagnet. When the current from the detector passes through the electromagnet, it turns it into a varying magnet which pulls on the metal diaphragm, causing it to vibrate and make the sound you hear. The very rapid current changes caused by the radio carrier are too fast (about one million changes per second!), for the diaphragm, but the slow moving changes due to the music are not. So you don't hear the carrier, but you do hear the Top 40. A complete crystal radio receiver is shown in figure 8.12.

Figure 8.11–The Earphone.

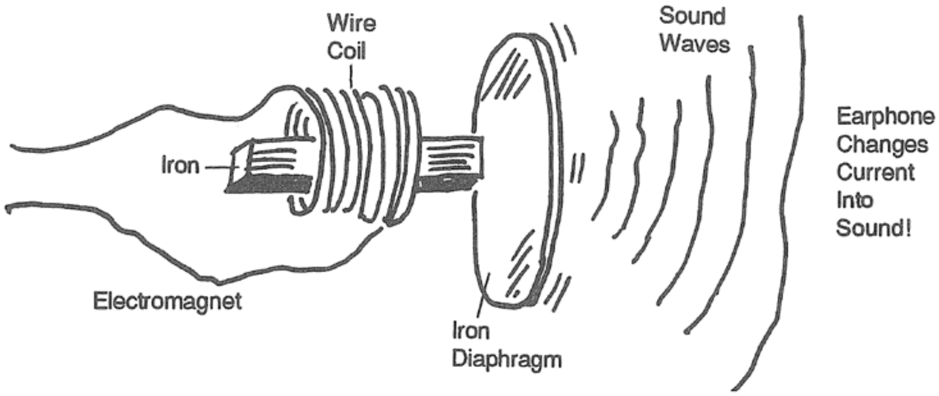
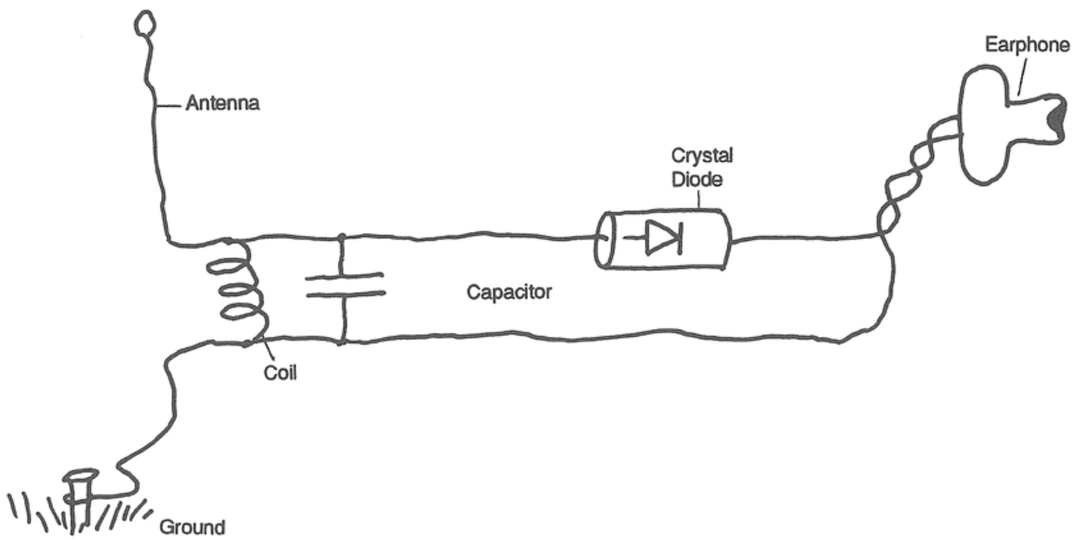


Figure 8.12–The Radio Receiver.



Troubleshooting the Crystal Radio Receiver

1. Check the hook-up to make sure the circuit diagram given in the lesson was followed. It does not matter if you have reversed the direction of the crystal diode, and interchanging where the antenna and ground are connected does not matter either.

2. Make sure that the earphone works. Try connecting it to the terminals of a battery (any 1 volt or even a 9 volt battery can be used). You should hear a clicking sound in the earphones as you make the connection.

3. It is very important that the crystal radio receiver has an adequate antenna and ground. The antenna should be a long piece of wire that can be hung out the window or strung across the room. The ground wire should be taped or wrapped onto a bare spot on a radiator or some other piece of plumbing.

4. The tuning circuit, which consists of the coil and capacitor, is the most fallible element of the radio. The inductance of the coil is sensitively dependent on the number of turns and the diameter of the tube on which it is wound. If the tube is smaller than described in the lesson, increase the number of turns of the coil (*e.g.*, if the tube is 30 percent smaller, increase the number of wire turns by 30 percent; if the tube is larger, decrease the number of turns accordingly).

5. Slide the tuning capacitor up and down to find different stations. Often, the crystal set will only receive one or two strong stations in a particular area. Hunt carefully for a strong station before giving up. Home quality hi-fi earphones hooked up to the receiver are more sensitive and better at shutting out ambient noise than the simple earphones described in the lesson, and these may make station selection easier.

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Mission 8
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Radio Technology–Worksheet

Name: ______________________________ Date: ______________________________

1. Where does the power or energy come from to make your radio work?

2. Is your reception better in particular areas of your room or outdoors? Explain why:

3. Does your antenna work better when you press your fingers on the connection point? Why do you think this is so?

4. Take your antenna off. Can you get any stations now? Describe what happens and why you think it happens:

5. Take off the ground wire. Can you still get any stations? Describe what happens and why you think this happens?

6. What is your radio actually receiving? Where is this “information” coming from?

7. If there are radio waves in the room right now, why do you think we cannot hear them without the aid of a device like a radio?

8. What is the carrier?

9. Why is the carrier modulated?

10. While testing your radio, fill in the table shown below. To fill in the column “Distance to Bottom of the Variable Capacitor,” use a metric ruler that shows millimeters. Put the zero end of the ruler against the base of the radio, and measure to the bottom of the variable capacitor to the nearest millimeter. Record the distance on your chart. Different stations will be a few millimeters apart. This varies with the strength of the incoming signal. Strong signals will take up a wider band of space on the variable capacitor. Can you tell which radio stations you are receiving? List their call numbers and/or call signs in the last column.

Table 8.23

Station	Distance to Bottom of the Variable Capacitor	Your Location in the Room	Number and/or Call Sign of the Radio Station
1			
2			
3			
4			

5			
6			
7			
8			
9			
10			
11			