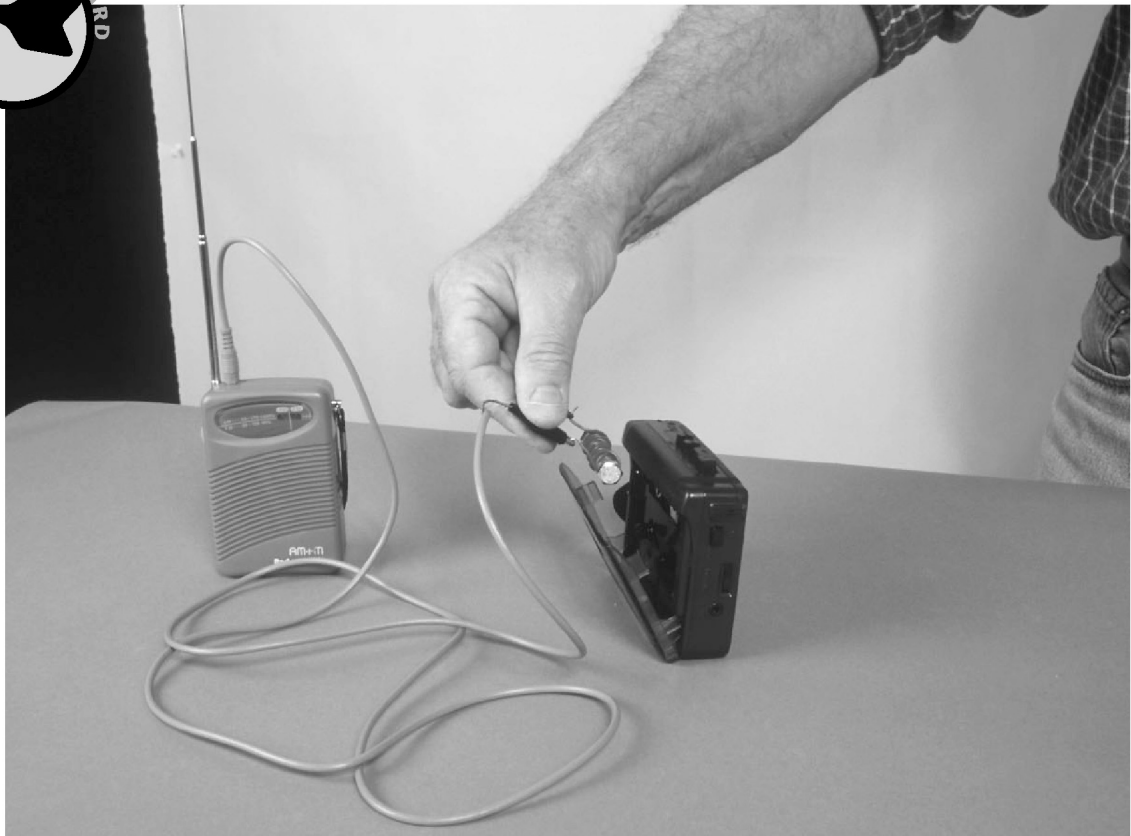


# Modulated Coil

## Hear the magnet!

Using a simple electromagnet, you can wirelessly transfer the sound from a radio to the speaker of a tape player.



## Materials

- wire stripper or knife
- about 3 ft (1 m) of insulated wire (e.g., RadioShack #20 or #22 solid copper wire with plastic insulation)
- steel bolt, about  $\frac{1}{4}$ -in diameter and 2 in long (nut optional); exact size of bolt is not critical
- audio cable, 6 ft (2 m),  $\frac{1}{8}$ -in phone plug on one end and two alligator clips on the other (e.g., RadioShack #42-2421; a phone plug is sometimes called a mini plug)
- small radio with headphone jack (e.g., RadioShack #12-799)
- portable tape cassette player with speaker (if the player doesn't have its own speaker, you'll have to have the headphones on)

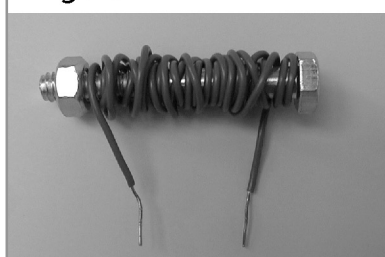
## ASSEMBLY

**1** Use a wire stripper or knife to remove about half an inch (1.2 cm) of the plastic insulation from each end of the wire. (If you happen to have enamel-insulated wire instead of plastic-insulated wire, use sandpaper to remove the enamel.)

**2** If you have a nut for the bolt, screw it onto the end of the bolt. It may help keep the wire that you're about to wrap onto the bolt in place, but it isn't essential.

**3** Start wrapping the wire around the bolt, leaving about an inch (2.5 cm) of wire free on the starting

**Figure 1**



*Coil wrapped around bolt*

end of the wire. Begin as close as you can to one end of the bolt and proceed toward the other end. When you reach the other end, start another layer and proceed back toward

the original end, but keep wrapping in the same direction (i.e., clockwise or counterclockwise, whichever direction you began with; see figure 1). If you reverse the direction of your wraps, you'll cancel the effect of the wire you wrapped initially. Keep wrapping the wire around the bolt, building up multiple layers if necessary, until you have at least 20 wraps. When you've finished wrapping, leave another inch (2.5 cm) of wire free.

**4** Attach the two alligator clips on the audio cable to the ends of the wire on the bolt.

## To Do and Notice

Turn on the radio and find a radio station with a strong, clear signal. Adjust the volume to medium-high. Plug the phone plug on the audio cable into the headphone jack on the radio. When you do this, you will no longer hear the radio, since the signal is being fed to the headphone circuit instead of to the speaker.

Be sure there is no tape in the tape player, and then press the play button. Adjust the volume control on the tape player to medium-high. Since there is no tape in the player, you should not hear any significant sound.

Bring the wire-wrapped bolt near the head of the tape player. You should hear the sound from the radio station playing through the speaker of the tape player. (Remember: If the tape player doesn't have its own speaker, you'll need to have the headphones on.)

## What's Going On?

The radio sends an electric current through the audio cable and through

the coils of wire wrapped around the bolt. The wire-wrapped bolt becomes an electromagnet, with the strength of its magnetic field determined in part by the size of the current flowing through the coils. Because the current carries an audio signal, it varies in strength, causing the magnetic field of the electromagnet to vary also.

The head of the tape player is essentially a device for detecting very small variations in a magnetic field. Normally it detects variations in the magnetic field on the audiotape as the tape travels by. In this case, however, it senses the fluctuating magnetic field in the coils of wire wrapped around the bolt.

## So What?

The "T" mode of a hearing aid, which is designed to be used with a telephone, works on the principle of magnetic field coupling demonstrated by this snack. A telephone has a magnet whose field varies with the oscillations of the sound signal. A hearing aid, like the head of the tape recorder in the snack, detects small variations of the magnetic field. This fluctuating mag-

netic field induces current in the pickup coils of the hearing aid, and the current is converted to sound. This "T" mode eliminates the annoying high-pitched audio feedback to the hearing-aid microphone that is often present and can be made worse by covering the hearing aid with the telephone headset.

## Going Further

### *Iron Versus Air*

In principle you could use the coil of wire alone, without the bolt. You would then have an electromagnet with an air core rather than an iron core. The iron core, however, greatly intensifies the magnetic field. What would you have to do to achieve the same effect with an air core? Check your reasoning by building an air-core electromagnet.

## References

Rathjen, Don. "Trick of the Trade: Modulated Coil," *The Physics Teacher*, Vol. 36, No. 7, October 1998, p. 416.