raft resource area for teaching
www.raft.net

Curriculum topics:

- Electricity
- Magnetism
- Electromagnetism
- Motors
- Experimental Variables
- Energy and Matter
- Cause and Effect

Subject:
Physical Science

Grade range: 4 – 12

Who we are:

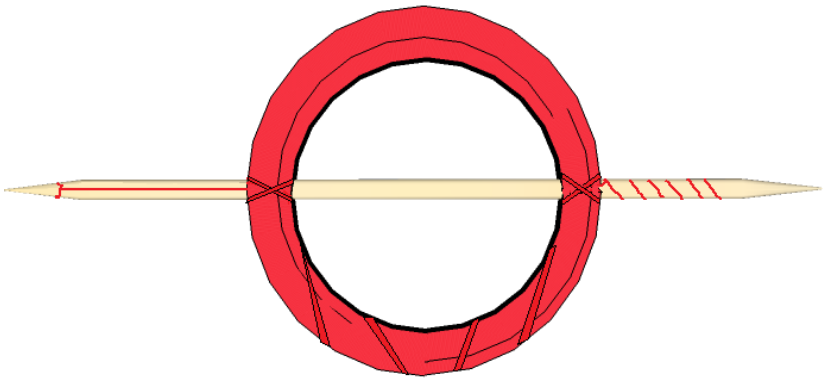
Resource Area for Teaching (RAFT) helps educators transform the learning experience through affordable "hands-on" activities that engage students and inspire the joy and discovery of learning.

For more ideas and to see RAFT Locations

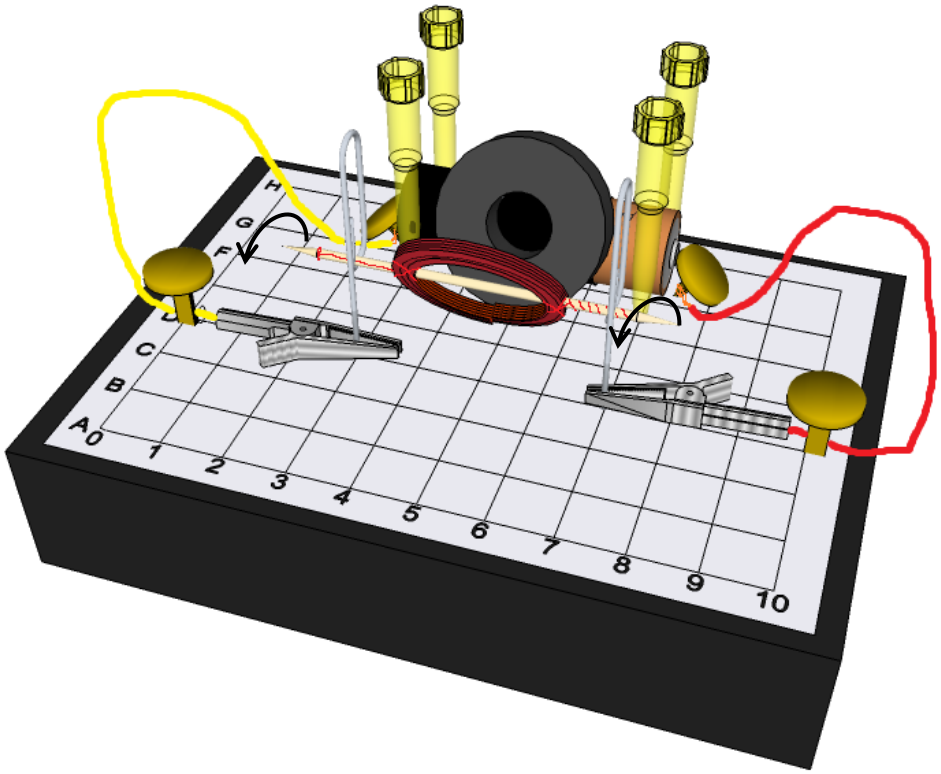
www.raft.net/visit-raft-locations

SIMPLE MOTOR

The simplest coil motor - a coil on a toothpick!



Skewer a coil of magnet wire to create a simple spinning motor! A spinning rotor needs an axle that is rigid with the ends in perfect alignment. Difficult to arrange with wire that is flexible enough to form a coil, but automatically provided by a toothpick! The motor converts electrical energy into kinetic energy – the energy of motion.



http://www.raft.net/raft-idea?isid=725

Materials required

Per Simple Motor unit:

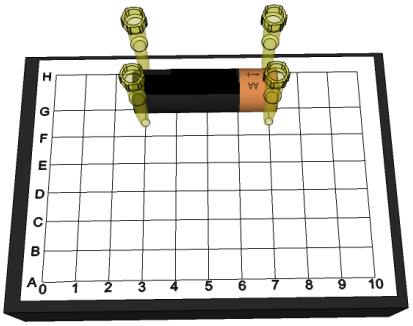
Safety tip: Wash hands after handling electrical components.

- Foam base, at least ~9 cm x 13 cm (3½" x 5"); ~3 cm (1⅛") thick
- Paper grid – ¼ of blackline master (download a 4-copy master of the grid at www.raft.net/raft-idea?isid=725)
- Plastic pipette tips, 5 cm (2") long, 4
- Alligator test lead, cut in half; and cut ends stripped, ~2.5 cm (1")
- Toothpick, round the whole length, 1
- Brass-plated paper fasteners, ~2.5 cm (1") long, 4
- Magnet wire, 28 gauge, 1.5 m (60") long – formed into a coil (see note below)
- 1 bulb + socket (not LED) from a holiday mini-light set (cut apart and ends stripped)
- Paperclips, regular size (#1), 2
- Ring magnet, ~3 cm (1⅛") diameter, 6 mm (¼") thick
- Sandpaper, fine grit, ~2 cm x 5 cm (1" by 2")
- Index card section, ~8 cm x 1.5 cm (3"x5/8")
- Battery, AA, (AAA, C, or D will also work)

Coiling magnet wire: *Requires fine motor skills & attention. If needed, have an adult make coils in advance.* When handling wire work slowly & carefully to avoid kinks. Wrap the wire around a 2.5 cm (1") form (such as a cork or C size battery), leaving a 7.5 cm (~3") lead on each end. Once the coil is complete, twist the two leads together twice, gently, close to the coil. Carefully slide coil off the form.

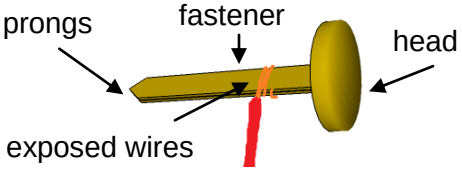
How to build it

Suggestion: Do ***Electromagnetic Exploration*** or ***Hopping Coil*** activities before building the ***Simple Motor*** at starting at step 7.

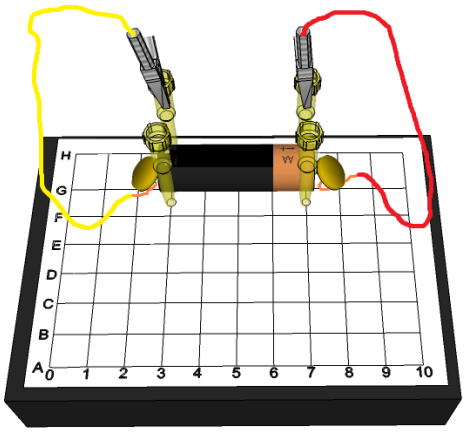


Creating the Base

1. Place the paper grid on foam. Insert a pipette tip ~ 1/3 of the way into the foam block through the paper at (3, H) and (7, H).
2. Place a battery on row G against the 2 inserted pipette tips. Insert a pipette tip on column 3 and on column 7 right next to the battery as shown.
3. Remove the insulation from the end of one alligator test lead. Twist the exposed fine wires to give them a rope-like appearance. Repeat with 2nd alligator test lead.

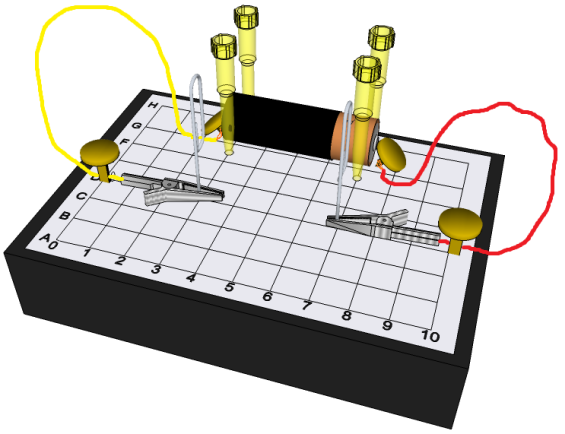


4. Insert the very end of one set of twisted wires in between the prongs of a brass paper fastener, near the head of the fastener. Wrap the bare wires several times around the 2 prongs. Repeat for the other lead and a 2nd fastener.



5. Insert the prongs of one of the wrapped fasteners at a point very close to one end of the battery and at a slight angle toward the battery. Push the fastener into the foam block until the head of the fastener makes contact with the metal end of the battery. Repeat with the other wrapped fastener, at the other end of the battery. Make sure to keep clips from touching!
6. To test the connection to the battery, touch the alligator clips to the bare leads of a low voltage (1.5 - 2.5 volt) bulb. The bulb should light. Finish by attaching clips to separate pipette tips.
7. Unbend the outer end of a paperclip to form a "9" shape. Repeat with a second paperclip. Insert the pointed ends of the paperclips ~2 cm (3/4") into the foam at the points (3, D) & (7, D). Turn the paperclips so the short side is nearest the battery – with the loop openings facing each other.

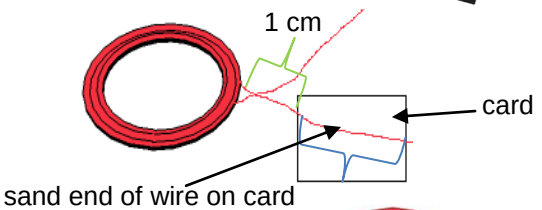
8 Unclip an alligator clip and clip the tip to the nearest paperclip just above where the paperclip exits the foam block. Repeat for the other alligator clip and paperclip.



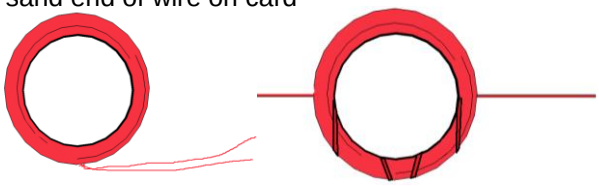
9 Spread the prongs of a third fastener and insert into the foam on both sides of a wire as it comes of the back of the alligator clip jaws to hold the lead in place (see illustration). Repeat with another fastener and alligator clip.

Forming the Rotor

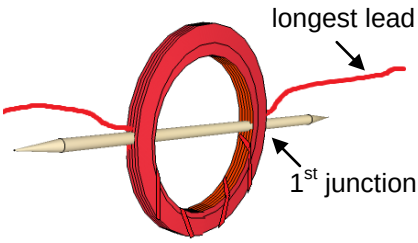
10 Carefully hold the coil and sand the loose leads starting about 1 cm (3/8”) from the coil to the ends until a bright “new penny” copper color is seen on all sides. Simple sanding method: Lay the loose end of the magnet wire on a card and rub sandpaper over the wire. **Rotate wire to sand all sides.**



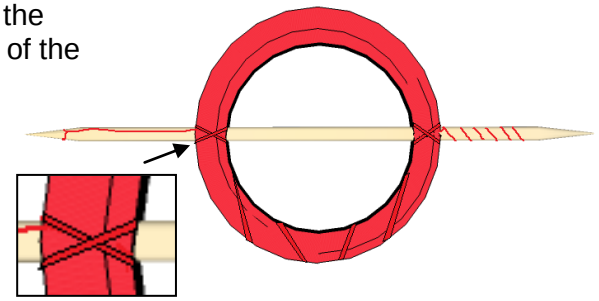
11 Bend the coil’s twisted leads section until the twisted part lies next to the coil, as shown.



12 Wrap one of the loose leads, 1 or 2 turns only, around the coil, moving away from the twisted ends for a little less than ¼ of the coil’s circumference. Repeat with the other coil lead, but going in the other direction around the coil. Stop when the lead is on the opposite side of the coil, as shown.



13 Insert the toothpick into the coils so the toothpick bisects the coil at points just below the leads. Using the loose lead with the longest remaining length, wrap the lead in an x-pattern around the coil and toothpick junction (to secure coil to the toothpick) and then wrap the lead around the toothpick going away from the coil. Space the loops around the toothpick about 1 to 2 times the thickness of the wire apart.

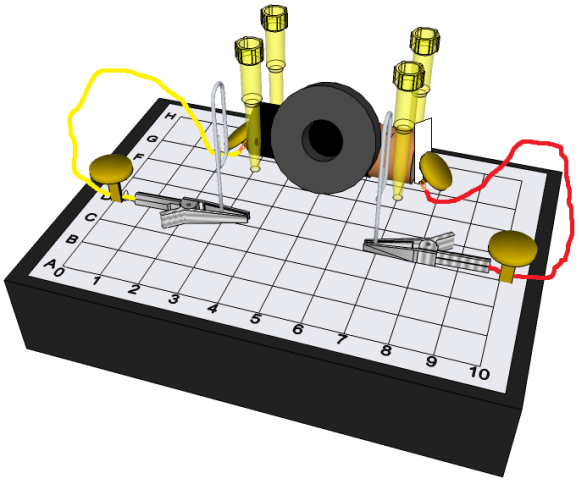


14 Wrap the remaining loose lead in an x-pattern around the other coil/toothpick junction (to secure the coil). Lay the rest of the lead alongside the length of the toothpick, making a gentle ¼ turn as the wire reaches the tip of the toothpick. Make a few tight turns of the lead at the very tip to hold the wire in place along the toothpick. Cut off any excess lead.

Final Steps

15 Put a card in between the flat end of the battery and the head of the fastener. Lay the ring magnet against the side of the battery facing the paperclips.

16 Insert the ends of the toothpick into the loops of the paperclips and adjust as needed so the toothpick is parallel to the foam block and the coil can spin freely. See illustration on page 1.



Tip – bend one paperclip slightly outward to make it easier to remove, adjust, and replace the rotor.

Curriculum Standards:

Energy can be transferred from place to place & converted between different forms (Next Generation Science Standards: Next Generation Science Standards, Grade 4, Physical Science 3-2 & 3-4; High School, Physical Science 3-3)

Electric or magnetic interactions between objects not in contact with each other (Next Generation Science Standards: Middle School, Physical Science 2-5)

Magnetic forces and interactions (Next Generation Science Standards, Middle School, Physical Science 2-3)

Electric Current Creates a Magnetic Field (Next Generation Science Standards: High School, Physical Science 2-5)

Compare Multiple solutions (Next Generation Science Standards: Middle School, Engineering Design 1-2 & 1-4)

Test variables (Next Generation Science Standards: Grades 3-5, Engineering Design 1-3)

Science & Engineering Practices (Next Generation Science Standards: Grades 4 – 12)

Additional standards at: http://www.raft.net/raft-idea?isid=725

To do and notice

Remove the card and press the head toward the battery to make a good contact. Give the coil a quick spin. If the circuit works, the coil will continue to spin. The position of the bare wire along the length of the toothpick, in relation to the coil's opening, may need to be adjusted so that the wire touches the paperclip, completing the circuit, when the coil faces the magnet.

Troubleshooting – Having the coil spin well will require some "fine tuning". Adjustments can include reversing the face of the magnet that faces the coil, slightly turning the paperclips so the loops touch different parts of the bare wires on the toothpick, and moving the loops around one end of the toothpick closer together or farther apart. Check to see if there is anything keeping the coil from spinning smoothly.
See **Troubleshooting Tips** at http://www.raft.net/raft-idea?isid=725

The science behind the activity

Electromagnetism and Electrical to Kinetic Conversions

The coil will become an electromagnet when a conductive path, a circuit, is created from one end of the battery, through the wires, paperclips, and coil, to the other end of the battery. When electrons move along the loops of wire a magnetic field is created around the coil. That magnetic field disappears when the electrons stop moving due to a break in the circuit. If the magnetic pole of the energized coil is facing the same magnetic pole ("like pole") of the permanent magnet, then the pivoting coil will rotate as it is repelled away from the magnet. If the coil were constantly connected to the battery, then once the opposite magnetic poles faced each other, the attractive forces between the coil and magnet would stop the coil from turning. In order to continue spinning the conductive path has to be broken when the opposite poles face each other. The Simple Motor rotor has a spiral lead on one side that effectively creates a continuous electrical contact to the paperclip as the rotor spins. To break the circuit – the other end of the rotor has a straight wire running along one side of the toothpick. When the straight wire touches the paperclip the circuit is completed and the coil energized. When straight wire moves away from touching the paperclip, as the rotor turns, then only the wooden toothpick, an insulator, touches the paperclip, breaking the circuit and de-energizing the coil.

Learn more

What would happen if a second magnet were placed on the opposite side of the coil from the original magnet? How would the poles of the magnets need to be orientated to speed up the spinning coil? What would happen if 2 batteries were used in the circuit, in series or in parallel?

Related activities: See RAFT Idea Sheets:

Electromagnetic Exploration - http://www.raft.net/ideas/Electromagnetic Exploration.pdf

Hopping Coil - http://www.raft.net/ideas/Hopping Coil.pdf

Speaker in a Cup - http://www.raft.net/ideas/Speaker in a Cup.pdf

Resources

Visit www.raft.net/raft-idea?isid=725 for "how-to" video demos & more ideas!
See these websites for more information on the following topics:

- **How an Electric Motor Works** - http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/mothow.html