Rationale:
According to the new California Science Standards, electricity and magnetism are important science concepts for 4th grade students. While the new science standards have not yet been implemented in most schools, these modules were designed to complement these standards. Specific science standards addressed in this Electricity and Magnetism lesson plan are:

3rd grade:
- Energy can be carried from one place to another by electric current.
- Students are asked to predict the outcome of a simple investigation and compare the result with the prediction.
- Students are asked to collect data in an investigation and analyze the data to develop a logical conclusion.

4th grade:
- Students know the role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones.
- Electrical energy can be converted to light (also heat and motion).

Disclaimer: Some of the procedures for the activities contained in the lessons have been adapted from various resources listed throughout the module.

Part 4: Magnetism, Electricity, and Work

Objectives:
After participating in the program Electricity and Magnetism, Part 4, students will be able to:
- explain that a magnetic field changing with time produces a current in a wire
- describe how the current produced in a wire by a moving magnetic field changes direction as the motion changes direction
- report that the current produced in a wire by a moving magnetic field will vary in magnitude as the number of coils is varied and if a magnetic core is used
- recognize that movement (of a diaphragm of a speaker or the rotor of a motor) can be produced by forcing a current through a coil near a stationary permanent magnet
- describe how electric power may be generated by causing a magnet to move near a coil of wire

Lesson Notes:
1. Students should see a deflection of the ammeter needle when the permanent magnet is moved near the coil. This is indicating that a current is made to flow by the movement of the magnet near the wire. When the magnet is held stationary, the current falls back to zero. What
determines the magnitude and direction of the current flow? (Speed of
the movement should affect the magnitude of the current produced. As
the motion of the magnet is reversed, the sign of the current on the meter
or the direction of current flow is reversed.)

2. How does the current change when you change how fast you move
the magnet? (If the magnet is moved quickly, a higher current is
obtained than if it is moved more slowly. Thus the current is proportional
to the speed with which the magnet is moved.)
What happens when you repeat the exercise with the large nail inside
the coil? (With the nail inside the coil, any movement of the magnet near
the coil produced a much larger current.)
What is the effect of using a coil with a different number of turns? (When
a coil with a different number of turns is used, similar magnet speeds will
produce a current proportional to the number of turns in the coil. Coils
with more turns will have higher currents that coils with fewer turns.)

3. Do we see complementary behavior if the magnet is held stationary
and a current is made to flow through the coil? (Yes. This principle can
be reversed by holding the magnet stationary and moving the coil with
respect to it. All that matters is the movement of the magnet relative to
the coil. This can be accomplished with the coil/ammeter setup. The
small speakers also demonstrate this effect. When current is made to
flow through the speaker coil (by connecting the battery), the coil is made
to move because of the interaction of the magnetic fields of the current in
the wire and the permanent magnet. The movement of the coil causes
the movement of the diaphragm since they are attached – this produces
sound. The current must change in order to produce the movement.
That is why the coil only moves when the circuit is closed or opened. A
steadily flowing current is equivalent to a stationary magnet near a coil –
no movement is produced.)

4. How does the motor work? (In the case of the motor, the current is
forced through the coil by connecting the battery. This induces a
magnetic field in the coil which interacts with the permanent magnet
below it. The coil will be pushed in one direction or the other by this
magnetic force. The coil feels this magnetic push until the insulated part
of one lead breaks the circuit. Gravity and inertia will cause the coil to
continue to rotate until the bare side of the wire again completes the
circuit and gives the coil another push in the same direction. In this
manner the coil can be made to rotate for quite a while. If the circuit
were not broken during one half of the revolution of the coil, the coil
would experience a torque in the opposite direction during this half cycle.
In this case the coil would not rotate but would rock back and forth. This
circular motion of the motor’s rotor can be used to do work in various
types of machines.)

5. What would we have to do to generate electricity? (Electrical power
can be generated by rotating a permanent magnet near a coil of wire.
This is the basic principle utilized by our power companies to generate
electricity for our everyday consumption.)
We use many sources of mechanical power to rotate the magnet in order
to generate our electricity. Students are asked to think of some and/or
propose some. (Some methods that have been tried are water
(hydroelectric plants), steam (generated by burning oil, coal, natural gas, etc.), and wind.)

Answers to the worksheet are located in the file: E&M_4_wksht_key.

References and Extension Ideas:

The following resources were used in developing this lesson plan. Some of the activities were adapted from these sources. Many ideas for extension activities can be found in them as well.

2. www.beakman.com
3. Foss Magnetism and Electricity Module
4. www.freeweb.pdq.net/headstrong/mag.htm
5. www.freeweb.pdq.net/headstrong/mag2.htm
6. www.pausd.palo-alto.ca.us/k6science/electric/e_tips.html
7. www.edtech.kennesaw.edu/web/electric.html
8. Exploratorium Science Snackbook or www.exploratorium.edu/snacks/
9. www.pbs.org/kcta/newtons/12/electric.html
11. www.pbs.org/wgbh/nova/specialfx/fxguide/fxmsht2.html
15. www.chss.montclair.edu/~pererat/pertel.html
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