



Indoor Environment – Electromagnetic Radiation

Purpose:

To increase the students' awareness of the sources of electric and magnetic fields and the potential for adverse health effects from prolonged exposure to elevated levels.

Time estimate:

- ½ to 1 hour

Module Objectives:

1. Understand the basics of electricity
2. Understand that the body communicates through electricity
3. Understand that the heart operates on electricity
4. Understand that the body is electrically conductive
5. Understand magnetic fields – definition, sources, and measurement procedures
6. Understand electric fields – definition, sources, and measurement procedures

Vocabulary:

- Ammeter
- Body Voltage
- Conductor
- Current
- Electric field
- Electrical panel
- Electron
- Gaussmeter
- Magnetic field
- Voltage
- Voltmeter

Supplies:

Plastic tubing (conductor)	Chick peas (electrons)
½" coupling (switch)	Cereal box (electric panel)
Romex wire	Voltmeter – Body voltage set up
Ammeter – clamp-on	Gaussmeter
E-field sensor	Electric disk
Extension cord – split wire	Signs: voltage, ammeter, switch, lamp, conductor

Student handouts:

- Vocabulary (combined with the Indoor Air Quality module)
- Room-to-room inspection (combined with the Indoor Air Quality module)

Overview:

- Step 1: Define electricity
- Step 2: Body electric
- Step 3: Adverse health effects
- Step 4: Magnetic fields
- Step 5: Electric fields



Step 1: Define Electricity

Setup: Need four volunteers: each will wear the appropriate sign.

Voltage will stand near the electrical panel and hold one of the $\frac{5}{8}$ " plastic tubing. As directed, Voltage will get peas from the electrical panel (source of electrons) and force them into the plastic tubing (conductor).

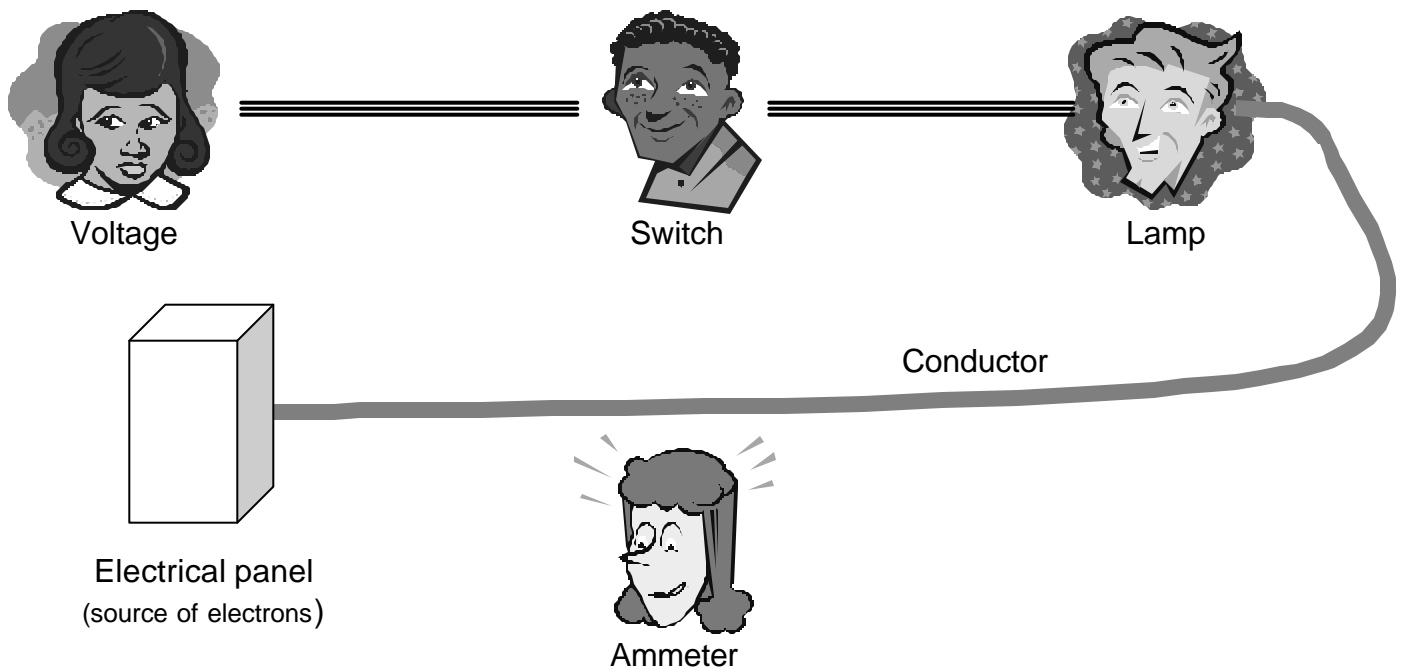
Switch will hold two pieces of plastic tubing and one $\frac{1}{2}$ plastic coupler. When the switch is open the two pieces of tubing will be separated, when the switch is closed, the coupler will be used to connect the two pieces together.

Lamp will be positioned to the left of the switch and initially will just hold the tubing loosely. The lamp sign will reflect both On and Off positions. When the Lamp is On and the switch is closed, the Lamp will periodically apply pressure to the tubing, creating a resistance to the current flow.

Ammeter will loosely hold the plastic tubing near the area where there is a mark around the girth of the tubing that will make counting easier. The Ammeter will count the electrons as they pass.

Plastic tubing should be completely filled with peas with additional peas stored in the "electrical panel" box.

Electrical panel box can be a cereal box partially filled with peas.



Explanation:

Electricity is the flow of electrons, called *current*, through a conductor that makes a complete circuit. *Electrons* are small negatively charged particles that circle around the nucleus of an atom. Because the electrons in metals are easily excited so that they will move, most *conductors* are made of metal; however, water and minerals can also be good conductors.

In our model, the plastic tubing represents the metal conductor. The peas inside the tubing represent the electrons. The circuit starts at the *Electrical Panel*, or the source of the electrons. Discuss with the class about their electrical panels at home. Briefly explain that the actual source of electrons is from a power



plant and comes to their electrical panel over the high voltage transmission and distribution lines. Ask them on their way home to observe these lines.

Next, let's discuss the purpose of the *Ammeter*. An ammeter is used to measure current, that is the flow of electrons through the conductor. Our ammeter is going to count the number of electrons that he/she sees pass through the tube.

Voltage, who is next, will collect electrons from the Electrical Panel and insert them into the tubing to apply pressure to the electrons and force them to move. Voltage is the force that causes current.

Switch has all of the control. When the switch is open, there can be no current flow, and therefore the lamp will be off. When the switch is closed, the plastic tubing is connected completing the circuit and the electrons are allowed to flow freely. *Demonstrate with the switch open and with the switch closed. In each case, have Ammeter call out the counts (zero, zero, zero, ... and 1, 2, 3, ...).*

Lamps function when current flows through the filament. Have you ever looked into a light bulb when it is not on and seen the small coil of wire. This wire is the filament and it causes resistance or impedes current flow. As it does this, it gets hot and when hot gives off light. It has to get hot before you have light, so there may be a slight delay from when current is allowed to flow – switch is on – until there is light. In our model, *Lamp* will periodically apply resistance and therefore slow down the current. *Demonstrate with the Lamp and Switch on, and Lamp and Switch off. In each case, have Ammeter call out the counts.*

After coming passed the ammeter, the circuit returns to the electrical panel for a complete circuit. Electrons that originally left the electrical panel will eventually return. Remember, to have electricity you must have a complete path – the electrons, or current flow out, around the loop, and then back to the source. That is, if the *Switch* allows them to.

Step 2: Body Electric

Explanation:

Our body runs on electricity. Our *brain* communicates with the nerves and muscles using electricity. These electrical impulses tell the muscles when to contract and relax, while our eyes, ears and skin translate received stimuli into electrical impulses to send to the brain.

According to PBS:

Although not a "brain scan" as the term is usually used, the EEG, or electroencephalograph, deserves mention as one of the first -- and still very useful -- ways of non-invasively observing human brain activity. An EEG is a recording of electrical signals from the brain made by hooking up electrodes to the subject's scalp. These electrodes pick up electric signals naturally produced by the brain and send them to galvanometers (instruments that detect and measure small electric currents) that are in turn hooked up to pens, under which graph paper moves continuously.

Our *hearts* also work off of electricity. Electrical currents are generated when the heart beats.

According to PBS:

Cardiologists treat patients with conditions of the heart, blood vessels, and circulation. To evaluate a patient's condition, cardiologists use tests such as the electrocardiogram (EKG), which graphically records electric currents generated by the heart.

Step 3: Adverse health effects

Explanation:

Because our body is 50-70% water with a high mineral content, it is highly *conductive*, that is, when exposed to a voltage, a current will flow through the body. When it is voltage from the brain it is a good thing to have current, but when it is from an external source, the current may be too high to be healthy and at a minimum disturb the body's communication.



At night, the body is directed by the brain to recover, for cells to regenerate, and the body to rest. If exposed to high levels of electricity during sleep, the brain's communication may be negatively affected and prevent the body from "recovering" as it should.

Some people develop symptoms when they experience long-term exposure, especially at night, to elevated levels of electricity, such as: headaches, hyperactivity, nightmares, depression, fatigue, eyestrain, and muscle cramps.

In our world, what are possible sources of electricity to which you might be exposed to for several hours during the day?

- Cell phones
- Cell towers
- TV's
- Computers
- Video games
- Fluorescent lights

Therefore, to be healthy, we should limit our exposure as much as possible, especially at night.

Step 4: Magnetic Fields

Setup: Use the electricity model of Step 1. In addition, plug in the electric disk using the split-wire extension cord.

Explanation:

Whenever there is current flow, a *Magnetic field* will develop as rings around the conductor. The direction of the rings depends on the direction of current flow. Since the current flows away from the source through the electrical appliance, or lamp, and then back to the source, the magnetic field that develops around each leg of the wire will be in different directions. *Use the paper plates to visually show these rings around the conductor in Step 1.* In between the wires, note that the arrows flow in the same direction; these will combine to have a high magnetic field between the wires.

Now look what happens when the two wires are placed adjacent to one another. *Use the paper plates around both wires.* Look at the direction of the arrow flows outside of the two wires, they are in opposite direction and will cancel each other. Thus, though all current flow will lead to magnetic fields, if the outgoing and incoming wires in a circuit are adjacent to one another, the fields will be cancelled.

This is a piece of wire that is normally used in home wiring (*show the Romex wire*). Note that the two conductors are contained within one plastic sheath. That way, they will always be adjacent to one another, and if properly installed, will prevent high magnetic fields to not create adverse health effects that might disturb the body's communication.

Magnetic fields are measured with an instrument called a Gaussmeter. To not have any adverse health effects the reading on the Gaussmeter should be less than 0.2 milliGauss. *Without turning on the electric disk, pick up the split-wire extension cord. Hold the wires apart and use the Gaussmeter to measure the magnetic field – ask a student to assist. Make sure the single wire is held across the top of the Gaussmeter.* As we slowly bring the wires together, note how the strength of the magnetic field decreases until it reaches the lowest level where the wires are together. *It may be helpful to use the paper plates to visually show the rings on the extension cord.*

It is impossible to count the electrons flowing in the wire, let's measure the current flow in the extension cord using an Ammeter. Since a clamp-on ammeter is based on magnetic fields, then we can only measure current flow through the single wire. *Set the ammeter to AC and measure the current in one leg and attempt to measure with both wires through the loop – ask a student to help. Should measure about 11milliamps with a single strand and ~0 with both.*

See this black box that provides the power to this disk, it is called a transformer and is a source of high magnetic fields. However, note that when I'm close to the transformer the field is extremely high, but as I



get further away how quickly the field decreases. *Use the Gaussmeter to identify other possible sources of magnetic fields in the room, as the students point them out.*

Other sources of magnetic fields in a home are anything that use current, such as televisions, computers, monitors, video games, refrigerators, voltage transformers for cell and portable phones, fluorescent lights, and even on the copper plumbing pipes.

Remember to be healthy there should be less than 0.2 milliGauss in your bedroom while you are sleeping. Can you think of anything in your bedroom or on the other side of the wall from your bed that might cause high magnetic fields? Think about whether it would be possible to move these further away, or move your bed.

Are there any areas in your classroom that you shouldn't sleep because of the high magnetic fields?

Step 5: Electric Fields

Setup: Use the electricity model of Step 1. In addition, plug in the electric disk using the split-wire extension cord.

Explanation:

Electric fields are a bit harder to identify. Electric fields are present whenever there is voltage. This can be a wire or an appliance, such as a lamp, radio, computer or TV. In our model, when the switch is open there will be an electric field between *Voltage* and the *Switch*. When the switch is closed, there will also be an electric field between the *Switch* and the *Lamp*. An electric field will start at the conductor or appliance, and radiate outward in all directions like a hairy ball. *Use the paper plate and show how the electric field would look from the conductor between Voltage and Switch on the model of Step 1 (the switch should be open).* Now close the switch and note that the electric field would also be between the *Switch* and the *Lamp*.

Now turn on the electric disk. Note that the source of the electric field is in the middle of the disk, but see how it radiates out in all directions. Every electrical appliance and wire has a similar electric field branching outward. Electric fields can be detected with an E-field sensor. *Use the E-field sensor and show how to work it to identify sources of electric fields in the room. Ask the students to discuss sources of electric fields that they see.*

Now let's observe the impact of an electric field on the body. Note how that when I touch the disk, the field is actually attracted to my conductive body. Not only the voltage from the disk, but also the voltage from the extension cord and other electric sources will create a "voltage" in my body. To measure the Body Voltage we use a Voltmeter. *Ask for a volunteer and setup to test for Body Voltage. Have the student hold the brass bar and read the voltmeter. Demonstrate to the class how the voltage changes the closer the student is to the electric disk, and even reaching 200V when he/she touches the disk, and then show how the voltage drops as the student steps away from the disk. The further away, the lower – but make sure that other electric fields are not influencing the results.*

To properly rest at night your body voltage should be less than 0.2V. What are some things that are near your bed that might cause you to have a high body voltage at night? Bedside lamps, radios, extension cords, computers, stereos, video games, etc. These should be unplugged at night, or at least moved away from your head. Additionally, for some people, the electric fields from the wires in the wall can have a negative effect, and these individuals should consider sleeping with their heads in the middle of the room.

Are there any areas in your classroom that you shouldn't sleep because of high electric fields?

What is your body voltage?