3.16.4.2: Faraday's Law Simulation

In this simulation you can experiment with Faraday's law. One important application is also shown; a moving coil microphone. Magnetic flux is defined to be the amount of magnetic field passing through a given area and has units of webers where $1\ \mathrm{Wb} = 1\ \mathrm{Tm}^2$. The technical definition of Faraday's law says that a changing magnetic flux (ϕ) causes an electromotive force (***emf*** in volts). If there is a circuit, that emf will cause current to flow, just like a battery. A second law, ***Lenz's law***, says that the current flow will be in a direction opposite to the change that induced the current flow. The current direction is shown two different ways; one is by the arrow in the meter which is attached to the coil. The other is an arrow which appears below the coil when the current flows.

Simulation Questions:

1. Run the simulation and slowly drag the magnet back and forth through the coil. What happens to the emf (shown in the graph and in the box below) when the north pole of the magnet moves into the coil? Which way does the needle on the meter point?
2. What happens to the emf when the north end of the magnet moves away (to the right) from the coil? Which way does the needle point in this case?
3. What happens to the emf if the magnet is not moving?
4. When the magnet is close to the coil but not moving, the emf is zero. What about the flux (ϕ)? This is the essence of Faraday's law, the flux has to change for an emf to occur.
5. Choosing the reverse button allows you to drag the coil instead of the magnet. Run the simulation after clicking the reverse button. Does it make a difference in the graphs if you move the magnet or the coil? Explain.
6. Now choose the coil button and run the simulation. As we saw earlier in this chapter, a coil with current flowing in it will have a magnetic field. Is there a difference in the emf graph if you drag a current-carrying coil through the stationary coil instead of a magnet? Explain.
7. Now choose the microphone button and run the simulation. This is a simulation of a moving coil microphone. In this type of microphone a small coil is attached to a flexible diaphragm. When sound waves hit the diaphragm it causes the coil to vibrate near a stationary magnet. The changing flux in the coil causes a current to flow due to Faraday's law. It is this current that is amplified and sent to loudspeakers or recorded on tape or digital recording (see the next chapter). You can change the sound wave frequency. How does this affect the frequency of the emf shown in the graph?

Summary

Ohm's law says voltage acts as a kind of potential energy that will cause charge to flow if there is a path (a circuit). The number of charges in a circuit remain fixed but they carry electrical energy which is turned into other useful forms of energy (light, heat, sound, etc.) by components in the circuit (light bulb, toaster, stereo). Currents cause magnetic fields. If a current finds itself in a magnetic field caused by some other source (magnet or other current) it will feel a force unless it moves parallel to the magnetic field. This is the basis of an electric motor. Faraday's law says a *changing* magnetic field through an area (or equivalently, a changing area with constant field) will cause a voltage. This is the mechanism behind electric generators, credit cards, metal detectors, computer hard drives, etc.

Questions on Faraday's Law:

1. Why is a generator coil harder to turn when it is generating electricity than when it does not?
2. A magnet falling through a narrow copper tube will slow down, even though copper is not magnetic (your instructor may have demonstrated this in class). Explain why this happens.
3. Does your car burn more gas when you run the head lights than if the lights are off?
4. When you swipe a credit card the reader gets information from a strip on the back of the card. Explain how that works.
5. Most traffic lights are connected by a small computer chip to a wire embedded in the road which detects the presence of a car. How does this work?
6. The metal detectors at airport security can detect non-magnetic metals such as aluminum. Explain how that works.
7. Information is contained on your computer hard drive as a series of small magnetic fields (hard drives have iron particles embedded in them so that different regions can be magnetized). The read head consists of a small coil of wire that is located very close to the disk and can be moved around to reach different parts of the disk. Explain how the read head detects the information. Would this work if the disk were not spinning?
8. Explain how a generator works.

9. What is the difference between an electric motor and an electric generator?
10. Why don't transformers work with direct current (DC)?
11. Why is power transmitted at high voltages (and low current) over long distances?
12. What is Faraday's law?
13. A transformer with 10 turns in the primary and 100 turns in the secondary will convert an AC voltage of $5\ \mathrm{V}$ to $50\ \mathrm{V}$. Explain why this doesn't contradict conservation of energy.
14. A pickup for an electric guitar consists of a small metal coil of wire wrapped around a magnet. Due to Faraday's law current is induced in the coil if the magnetic field near the pickup changes. Will this type of pickup work with nylon or other, non-metal strings? Explain.
15. Suppose a metal string is vibrating at $100\ \mathrm{Hz}$ in front of the pickup described in the previous question. What frequency will the induced current in the coil have as a result of Faraday's law?