Electromagnetic induction and Faraday's laws

Teachers' notes

These notes supplement a workshop on the video called ***Teaching Electromagnetic induction and Faraday's laws*** by Brian Gray and the Solon Foundation. You find the video at www.scienceteachingalive.com.

Here are a few important ideas to keep in mind when you teach this section.

1 Faraday's law

You can induce a potential difference (called a voltage or an "emf") in a coil by *changing* the magnetic flux through a coil; the **size** of the emf is proportional to the rate of change of magnetic flux through the coil. In other words, the faster you change the flux, the bigger the emf. A fast change in a large flux will cause a bigger emf than a change in a small flux, so you can make the flux bigger by using a stronger magnet, putting an iron core inside (the iron core multiplies the magnetic field) and adding more turns of wire (so that the flux-change pushes current in more turns of wire).

The emf will push a current around the coil; the **direction** of the emf pushes a current that creates a new magnetic field that opposes the change in magnetic flux. In other words, if you increase the magnetic flux through a coil, the coil gets a current that tries to decrease the flux. If you decrease the flux, the coil gets a current that tries to increase the flux. (This second paragraph is also called Lenz's Law.)

2 Student misconceptions

Students often form the misconception that if you put a magnet into a coil, the coil produces a voltage. This is not true; the coil produces a voltage only while the magnet is moving. No motion of the magnet means no current.

3 Power stations

Power stations have generators that spin coils of wire and magnets past each other. But to spin the coils and magnets needs huge amounts of energy. This energy comes from turbines and the turbines get their energy from steam at high pressures and temperatures. And where does the steam gets its energy? From burning coal, or nuclear reactions, or mirrors that concentrate the Sun's energy onto energy-collectors.

4 Why is it hard to spin the coils of wire past the magnets?

You might wonder why it takes so much energy to spin the coils of wire past the magnetic field. You might think that the coil should spin easily, if you oil the bearings. Well, the generator coil does spin easily provided that you don't draw any current from the generator. But when you draw current, things change.

Think of a small generator that you may find in people's homes or in a shop. The generator has a petrol-powered engine. As soon as you connect a load to the generator, such as lights or a fridge, you hear the engine of the generator slow down and begin to work harder.

Figure 1 *A petrol-engined generator.*

The reason lies in Lenz's law. When you draw a current from the moving coil, that current itself produces a new magnetic field around the wires, and that field acts against the force that is spinning the coil of wire. The voltage that pushes this current is called the "back-emf" .

5 What you find inside a bicycle generator

Try to find a bicycle generator and open it up to show the students what's inside. (Probably you'll have at least one student who is willing to do this for you. He or she will need pliers, a small adjustable spanner and a small screw-driver.)

Figure 2 shows you the parts of the system. The generator (often called a dynamo) is clamped onto the bicycle frame and a spring presses the roller against the back tyre. As the wheel turns, the roller spins and generates alternating current. In the photo you see two wires; usually there is only one wire and the top wire is replaced by the conducting metal frame of the bicycle.

The dynamo/generator has no slip-rings because the coils don't move. Instead, the magnet spins between the coils. This is the way big power-station generators are designed, too.

Figure 2 *The complete system, without bicycle frame.*

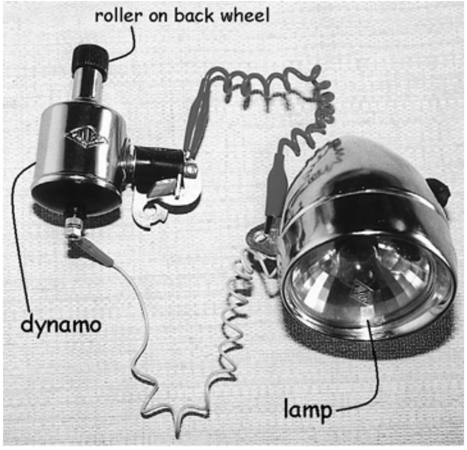

Figure 3 *The dynamo consists of four magnets glued together and four coils of wire that do not move .*

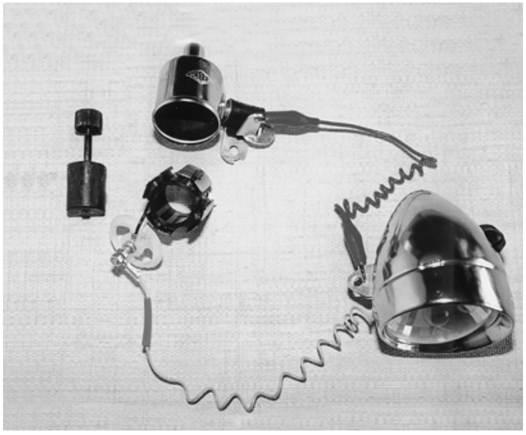

Figure 4 *The coils of wire do not move but the magnets spin past the wires.*

These are links to some useful websites:

http://www.youtube.com/watch?v=AgZHqfIBkUI *The magnetic field inside a coil of copper wire*

http://www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway/energy_resources/generating_electricityrev1.shtml This BBC site has an animation of a hand moving a magnet in and out of a coil; you can make it move and see the effect on an ammeter.

http://macao.communications.museum/eng/exhibition/secondfloor/moreinfo/2_4_1_ACGenerator.html This is a comprehensive description of what happens when a coil spins in a magnetic field. It shows the effect of the changes in the angle between the coil and magnetic field.

http://www.bbc.co.uk/schools/gcsebitesize/science/add_ocr_pre_2011/electric_circuits/mainsproducedrev3.shtml This BBC website has 5 pages for students, covers generators **and transformers**, and has interactive calculation exercises

The picture of the portable generator is free of copyright and the source is http://commons.wikimedia.org/wiki/File:Generac_Portable_Generators.png