28 E-M Induction and Generators ♡

When a wire is moved in a magnetic field, a voltage is induced, providing that the wire is moved so that it cuts the magnetic field lines.

You can reverse the direction of the voltage by

- moving the wire in the opposite direction, or by
- reversing the direction of the magnetic field.

You can increase the voltage by

- moving the wire more quickly, or by
- using a stronger magnetic field.

When a magnet is moved into a coil of wire, a voltage is induced.
You can make it larger by

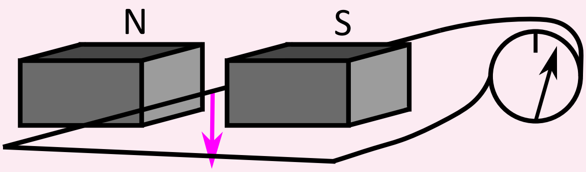
- moving the magnet more quickly,
- using a stronger magnet, or by
- using a coil with more turns of wire on it.

You can reverse the direction of the voltage by

- moving the magnet in the opposite direction, or by
- using a magnet magnetized the other way.

In fact, the voltage is proportional to the magnetic field strength, the speed of movement across the field lines, and the length of wire in the field. This means that, if there is no relative motion (the magnet is stationary in the coil, or the wire is stationary in the magnetic field) no voltage is induced – no matter how strong the field is (providing the field strength is not changing). Generators are mechanical devices (with wires and a magnetic field) so that mechanical work done on the generator (usually to turn it) enables the generator to do electrical work on the circuit (and light bulbs). The work done on the generator or by moving a wire across the field, does not reduce the energy stored in the magnetic field. Any energy transferred comes from the work done in moving the wire and not from the magnetic field itself.

28.1 A long wire, connected to a centre-zero galvanometer, is moved downwards perpendicular to a magnetic field. The field is between two permanent magnets, with opposite poles facing each other. While the wire is moving, the galvanometer needle moves to the right.

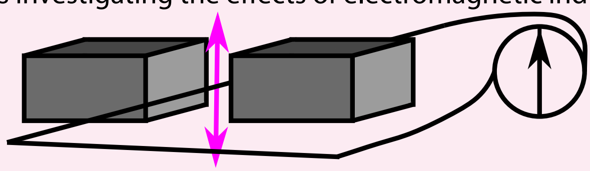


(a) How would the pointer of the galvanometer move if the wire was moved up through the magnetic field?

(b) What would be the induced current in the conductor if it was held stationary in the centre of the magnetic field?

(c) State three ways of increasing the deflection of the pointer on the galvanometer when the wire is moved through the magnetic field.

28.2 A pupil is investigating the effects of electromagnetic induction.



They move a conducting wire up and down parallel to the faces of the two permanent magnets, expecting the pointer on the galvanometer to show a deflection. However, the pointer does not move. The meter is working and sensitive enough for the experiment. There are no breaks in the wires. What must be wrong?

28.3 Suppose $+1.5$ mV is induced when a wire is moved between the poles of a large permanent magnet at a speed of 0.20 m/s from left to right. What voltage would you expect when: *[Hint: for an explanation of solving proportionality questions turn to P16]*

(a) the speed is increased to 0.40 m/s?

(b) the speed is 0.3 m/s, but the wire is moved from right to left?

(c) the original experiment is repeated with a magnet four times as strong?

28.4 Suppose $+2.7$ V is induced when the North pole of a magnet is inserted into a 200-turn coil at a speed of 1.5 m/s from above. What voltage would you expect if

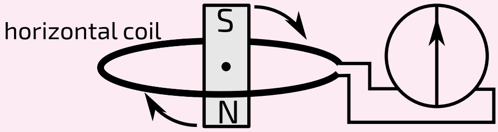
(a) the coil had 450 turns on it?

(b) the magnet were moved into the 200-turn coil at 8.4 m/s?

(c) the South pole of the magnet were moved into the 200-turn coil at 4.5 m/s?

(d) the North pole of a magnet with $1\,000\times$ the strength was held still inside the coil?

28.5 A simple electrical generator is made by mounting a magnet (shaded) in a coil of wire, with the magnet continuously rotating slowly about a horizontal axis. It is connected to a meter which can read positive and negative voltages. One quarter of a turn later from the position shown on the diagram, the meter shows a positive voltage of 1.5 V.



(a) What will the meter show one half of a turn later still? (i.e. three quarters of a turn on from the position shown in the diagram?)

(b) What will the meter show when the magnet is back in the position shown in the figure?

(c) What two things would happen if you turned the magnet twice as quickly?

(d) How could you modify the design so that larger voltages were induced without needing to change the speed of the rotation?