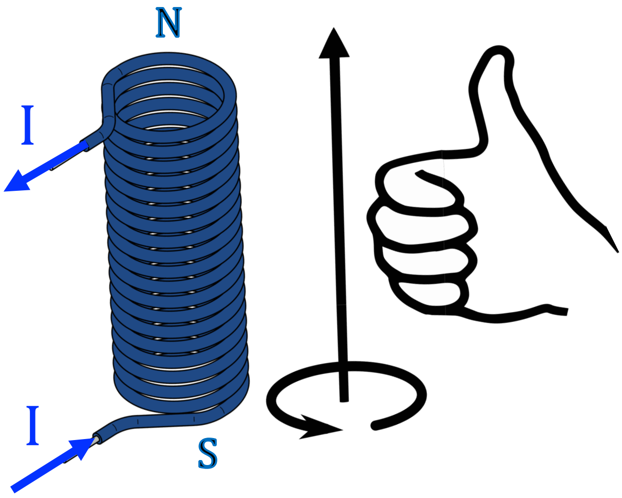
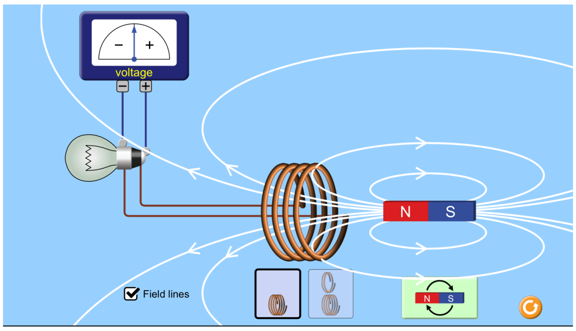
7.14 Electromagnetic induction

When we pass an electric current through a coil of wire, a magnetic field is generated which has the same shape as that of a bar magnet. One end becomes a magnetic north (N) pole, and one becomes a magnetic south (S) pole.



To determine which end is a N pole, wrap your fingers of your right hand in the direction the current is looping. Your thumb should point towards the N pole of the magnet.

We can <u>induce</u> an emf across the coil of wire if we move the coil in a magnetic field. Run the following simulation:
https://tinyurl.com/nm5mw59



Check the field lines box.

(1)✐Now move the magnet towards the solenoid, from right to left. What do you notice about the induced emf?

(2)✐From the direction of current flow through the bulb (and coil), work out the polarity of the pole closest to the bar magnet.

(3)✐Move the magnet away from the coil. What do you notice about the induced emf?

(4)✐From the direction of current flow, work out the polarity of the pole closest to the bar magnet.

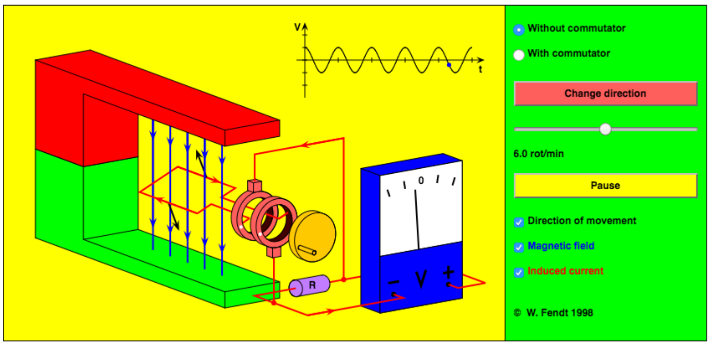
Lenz's law

Lenz's law states that *'the direction of the current is always such as to oppose the change that causes the current'*.

In the simulation, above, you should have found that a current was induced that produced a magnetic polarity for the solenoid that opposes the motion of the bar magnet.

Faraday's law

Run the following simulation:
http://www.walter-fendt.de/html5/phen/generator_en.htm



We see a conducting loop turning in a magnetic field. There is an induced emf, because the magnetic flux through the loop is changing as it rotates.

The magnetic flux ϕ is given by the following expression:

$$\phi = BA\sin\theta$$

where B=magnetic flux density, A=area of loop, θ=angle of loop to field direction.

(5)✏At what angle is the magnetic flux a maximum?

(6)✏At what angle is the magnetic flux zero?

If there is more than one loop (so, a coil), the expression for 'magnetic flux linkage' becomes:

$$N\phi = NBA\sin\theta$$

where N is the number of loops (or 'turns').

$N\phi$ is called the 'flux linkage'.

Faraday's law states that *'the induced emf in a coil is equal to the rate of change of flux linkage through the coil'*.

The expression for the induced emf is given by:

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

The minus sign in this expression indicates that the emf is such as to oppose the change that caused it.

(7)✏What effect would doubling the number of turns have on the maximum induced emf?

(8)✏What effect would doubling the speed of rotation have on the maximum induced emf?

As we have seen, above, the flux linkage for a coil is given by the expression:

$$N\phi = NBA\sin\theta$$

If the coil is rotated at a constant angular speed ω $(= 2\pi f)$, the resulting emf will be sinusoidal:

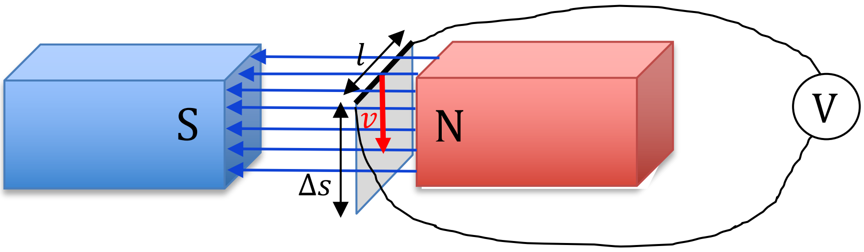
$$\varepsilon = \varepsilon_0 \sin\omega t$$

where $\varepsilon_0 = maximum\ emf = NBA\omega$.

(9)✏A coil of 100 turns and a cross sectional area of 3cm^2 is rotated at 50Hz in a magnetic field of 500mT. What is the maximum emf produced?

A moving conductor in a magnetic field

As we have seen in 7.12, if a wire cuts through lines of magnetic flux, an emf is produced across the ends of the wire.



The emf is given by the expression:

$$\varepsilon = -\frac{\Delta\phi}{\Delta t} = -\frac{BA}{\Delta t}$$

If a length l of wire is moved a distance Δs, then the area (A) ‘cut’ is:

$$A = l\Delta s$$

(10)✐Substitute for A in the expression for emf.

(11)✐Show that the emf is given by the expression:

$$\varepsilon = -Blv$$

where v=speed of movement.

(12)✐A 2cm length of wire is moved at constant speed at right angles to a magnetic field with flux density B=200mT. An emf of 0.23V is produced across the wire. What speed is the wire being moved at?