11.1 - Electromagnetic Induction

Nature of science:

Experimentation: In 1831 Michael Faraday, using primitive equipment, observed a minute pulse of current in one coil of wire only when the current in a second coil of wire was switched on or off but nothing while a constant current was established. Faraday's observation of these small transient currents led him to perform experiments that led to his law of electromagnetic induction. (1.8)

Understandings:

- Electromotive force (emf)
- Magnetic flux and magnetic flux linkage
- Faraday's law of induction
- Lenz's law

Applications and skills:

- Describing the production of an induced emf by a changing magnetic flux and within a uniform magnetic field
- Solving problems involving magnetic flux, magnetic flux linkage and Faraday's law
- Explaining Lenz's law through the conservation of energy

Theory of knowledge:

- Terminology used in electromagnetic field theory is extensive and can confuse people who are not directly involved. What effect can lack of clarity in terminology have on communicating scientific concepts to the public?

Utilization:

- Applications of electromagnetic induction can be found in many places including transformers, electromagnetic braking, geophones used in seismology, and metal detectors

Aims:

- **Aim 2:** the simple principles of electromagnetic induction are a powerful aspect of the physicist's or technologist's armoury when designing systems that transfer energy from one form to another

Guidance:

- Quantitative treatments will be expected for straight conductors moving at right angles to magnetic fields and rectangular coils moving in and out of fields and rotating in fields
- Qualitative treatments only will be expected for fixed coils in a changing magnetic field and ac generators

Data booklet reference:

- $\Phi = BA\cos\theta$
- $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$
- $\varepsilon = Bv\ell$
- $\varepsilon = Bv\ell N$

RMS

The way to find the *average* of a regularly alternating voltage is called the **root mean square.** The AC rms values are equivalent to the constant DC values that would dissipate the same power.

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

The reason for using the rms values for AC current and voltage is that power consumption doesn't depend on the peak voltage (and peak current); rather, it depends on the rms values, since they are an average.

$$P = V_{rms} I_{rms} = I_{rms}^2 R = \frac{V_{rms}^2}{R}$$

If a resistor is connected to an AC supply, the following relationship holds:
$V_{rms} = I_{rms} R$
$V_0 = I_0 R$

This relationship shows that I and V are proportional to each other and in phase. In AC circuits there are components called capacitors and inductors which change the phase relationship between I and V.

Charging a capacitor

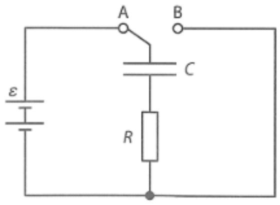


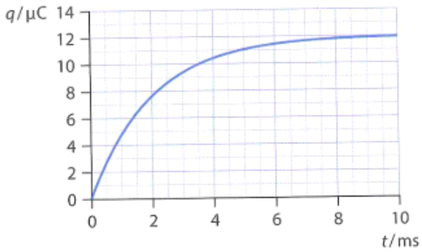
Figure 11.38 Circuit for charging and discharging a capacitor. When the switch is at A the capacitor charges. When at B it discharges.

If the switch is moved to position A, the capacitor will charge. After the capacitor has charged, moving the switch to B the capacitor will discharge through the resistor R.

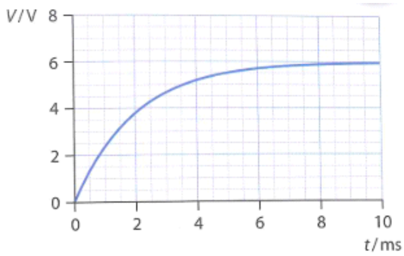
When the switch is moved to A, the charge on the capacitor plates will increase. In **Figure 11.38** the current is clockwise, meaning that the current is counter-clockwise. This makes the bottom plate negative. The potential difference across the capcaitor plates will become equal to the emf ε of the battery.

Three types of graphs:

q vs t



V vs t



I vs t