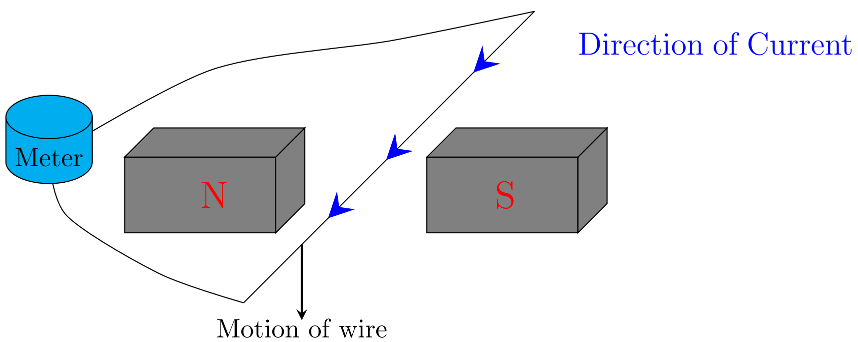
Electromagnetic Induction

1 Generating Electricity



When a conductor is moved through a magnetic field an emf is **induced** across the ends of the conductor

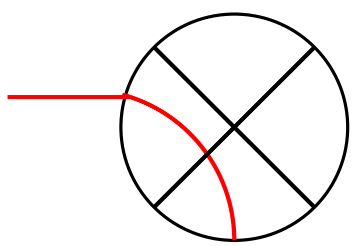
The emf will be greater when:

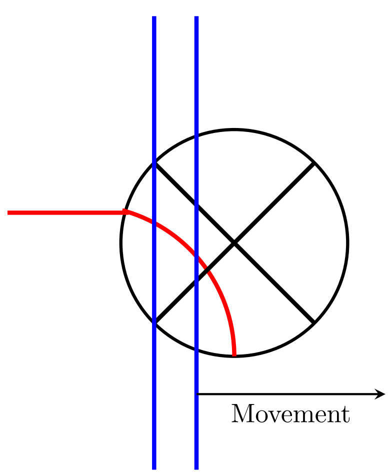
- The conductor is moved more quickly
- The magnetic field is stronger
- There is a longer length of conductor in the magnetic field

No emf will be induced if the conductor is parallel to the field lines

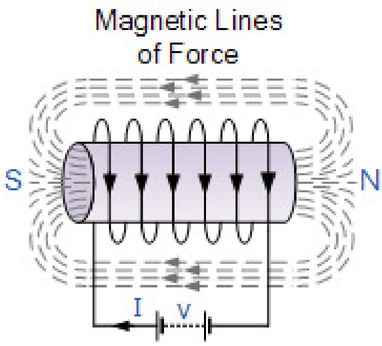
A current will flow if the conductor is part of a complete circuit

1.1 Explaining electromagnetic induction





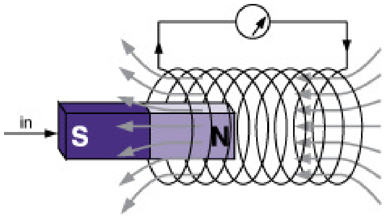
2 The laws of electromagnetic induction



North Pole - Anticlockwise current flow
South Pole - Clockwise current flow

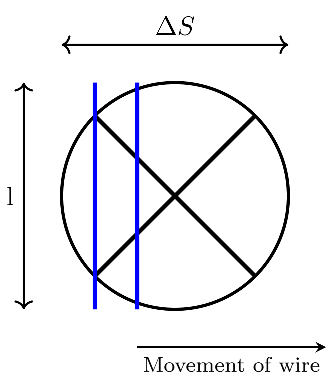
3 Lenz's law

The direction of the induced emf is always such as to oppose the change that is causing it.



As the magnet is pushed into the coil it induces an emf in the coil, this produces a magnetic field which opposes the potion. When removing the magnet the polarity will be inversed.

4 Faraday's law



$$\begin{aligned}\text{Work done} &= F \times S \\ &= BIl \times \Delta S\end{aligned}$$

Charge transfer, $Q = I \times \Delta t$

$$\epsilon = \frac{\text{Work done}}{\text{Charge}} = \frac{BIl \times \Delta S}{I \times \Delta t} = \frac{BA}{\Delta t}$$

B=Magnetic flux density=$\frac{\phi}{A}$
ϕ = Magnetic flux

$$\epsilon = \frac{\phi}{\Delta t}$$

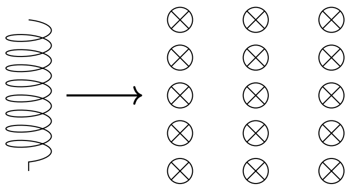
Faraday's law of electromagnetic induction is equal to the rate of change of flux(linkage) through the circuit.

Flux linkage refers to coils, $N\phi$ replaces ϕ where N is the number of coils.

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

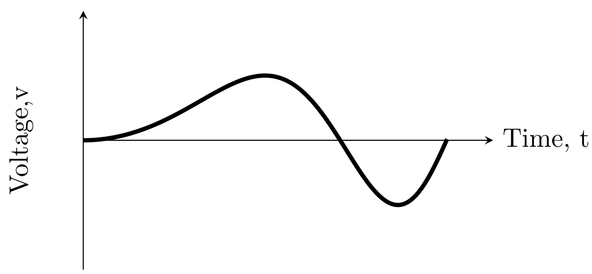
This equation may need to be expanded depending on the example

4.1 Example



$\epsilon = -N\frac{B\Delta A}{\Delta t}$

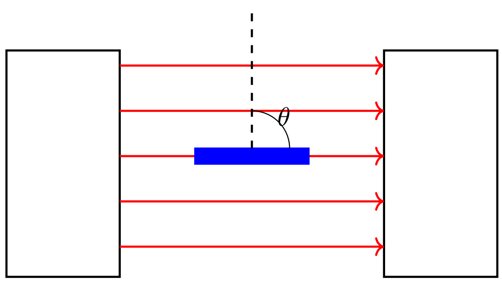
4.2 Magnets being dropped through a coil



1st peak - Wide, low
2nd peak - High, narrow

This is because the magnet accelerates, meaning the entry takes more time, and as it is travelling at a lower velocity on entry, the rate of flux cutting, and so the voltage is lower than the exit.

5 EMF induced in a rotating coil

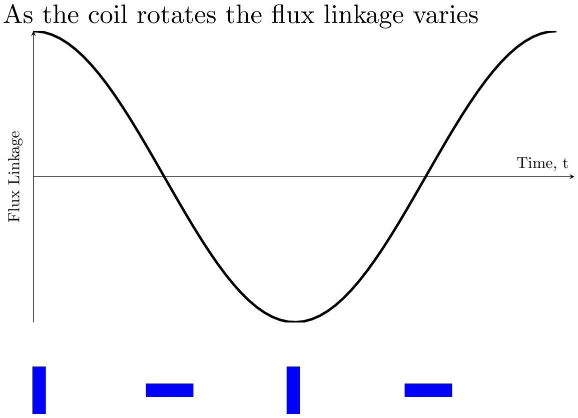


θ = The angle between the field lines and a line perpendicular to the coil

$$\text{Flux passing through the coil: } \phi = BA\cos\theta$$

$$\text{Flux linkage: } N\phi = BAN\cos\theta$$

As the coil rotates the flux linkage varies



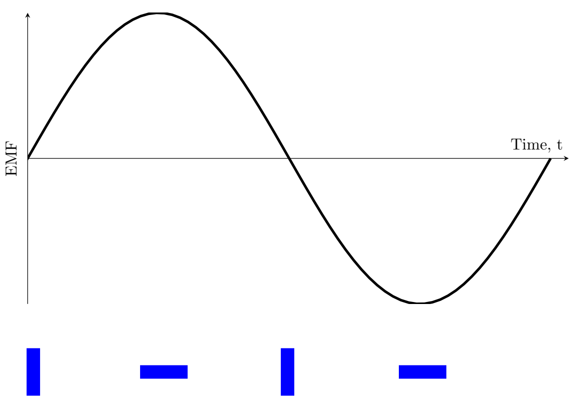
The speed that θ changes depends on angular velocity, ω

$$\theta = \omega t$$

$$N\phi = BAN\cos(\omega t)$$

EMF = Negative Rate of change of flux linkage

$$-\frac{d}{dt}BAN\cos(\omega t) = BAN\omega\sin(\omega t)$$



5.1 Generators

These effects can be used to create generators

Figure 1: AC Generator

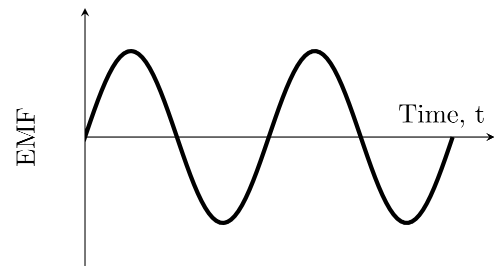


Figure 2: Graph of EMF from an AC generator

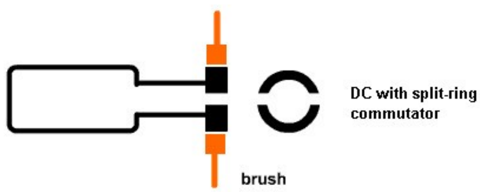


Figure 3: DC Generator

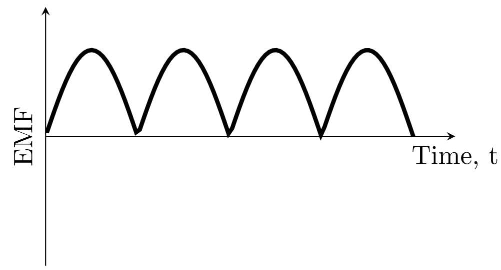
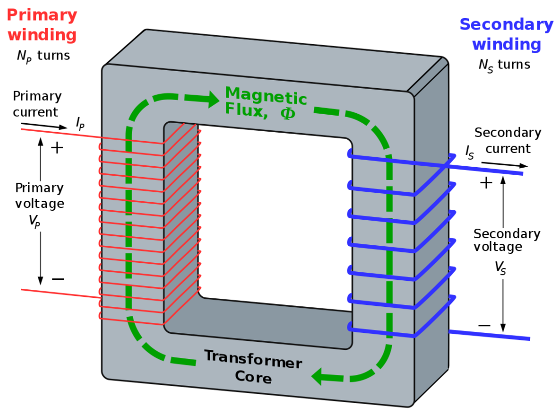


Figure 4: Graph of EMF from a DC generator

6 Transformers

6.1 Structure



6.2 What they are designed to do

Increase or decrease an A.C. voltage
Step up - Increase
Step down - Decrease

6.3 How they work

- Two coils, primary and secondary, connected by a soft iron core
- The primary coil is connected to a source of alternating p.d., creating an alternating magnetic field in the core
- The field passes through the secondary coil, creating an alternating emf in the secondary coil
- A transformer is designed so all the magnetic flux produced by the primary coil passes through the secondary coil

6.4 How energy losses are reduced

1. Low resistance windings to reduce power wasted due to the heating effect of the current
2. A laminated core which consists of layers of iron separated by layers of insulator. Induced currents in the core itself, referred to as **eddy currents**, are reduced in this was so the magnetic flux is as high as possible. Also, the heating effect of the induced currents in the core are reduced
3. A core of **soft iron** which is easily magnetised and demagnetised. This reduces power wasted through repeated magnetisation and demagnetisation of the core

6.5 Equations

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

$$\text{Efficiency} = \frac{I_S V_S}{I_P V_P} \times 100$$

7 The national grid

Transmission of electrical power over long distances is much more efficient at high voltages compared to low voltages.

7.1 Transmit 1MW of power through wires of resistance 500Ω

7.1.1 At 25kV

$$I = \frac{P}{V} = \frac{1 \times 10^6}{25 \times 10^3} = 40A$$

$$\text{Power lost as heat} = I^2R = 40^2 \times 500 = 0.8MW = 20\% \text{ Efficient}$$

7.1.2 At 400kV

$$I = \frac{P}{V} = \frac{1 \times 10^6}{400 \times 10^3} = 2.5A$$

$$\text{Power lost as heat} = I^2R = 2.5^2 \times 500 = 0.003MW = 99.7\% \text{ Efficient}$$