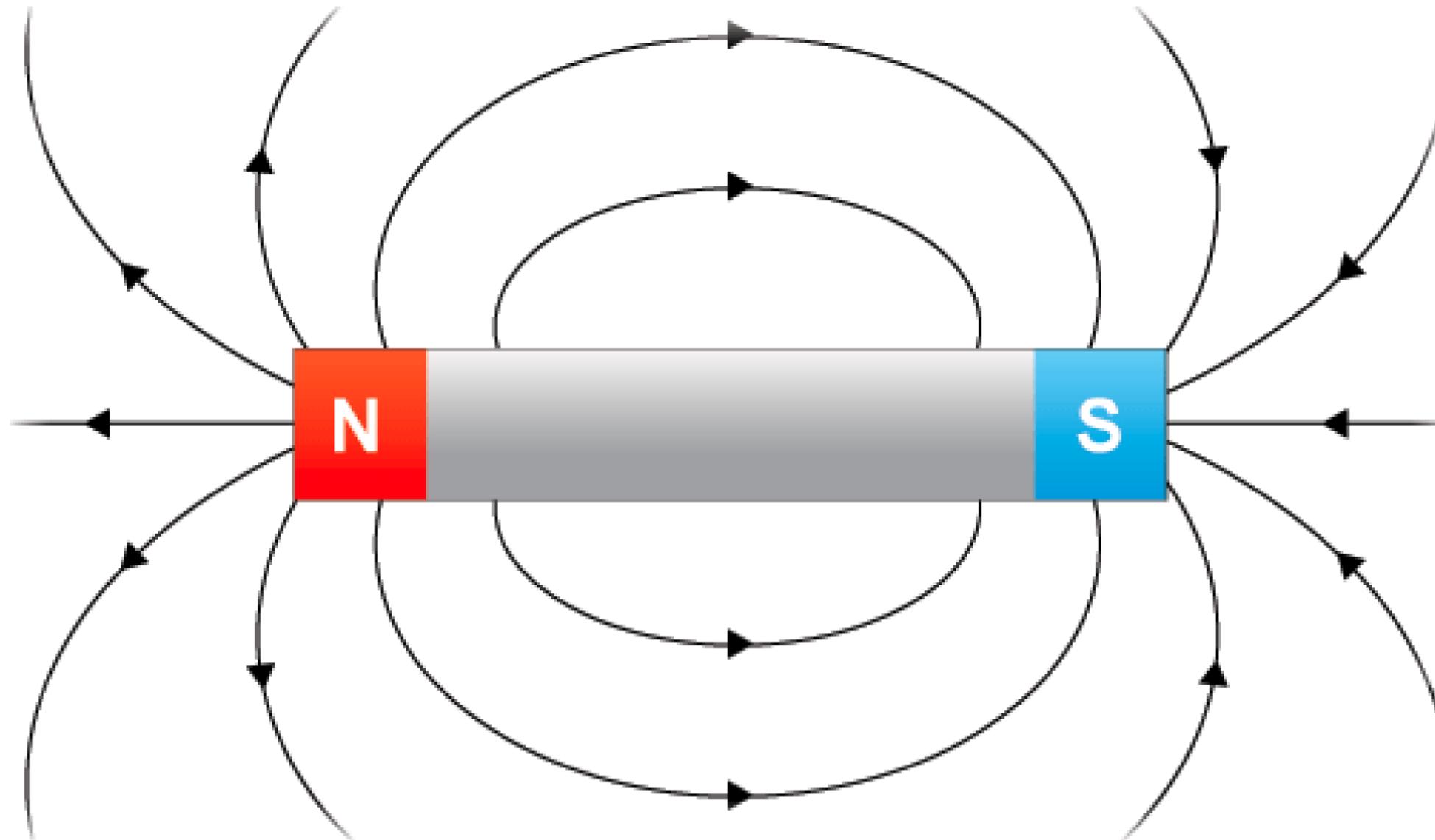


# 9702 C20 Magnetic fields

## (Part 2)



# Magnetic Flux

**magnetic flux = product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density**

$$\Phi = BA \cos(\theta)$$

Where:

- $\Phi$  = magnetic flux (Wb)
- $B$  = magnetic flux density (T)
- $A$  = cross-sectional area (m<sup>2</sup>)

**magnetic flux linkage = product of the magnetic flux and the number of turns**

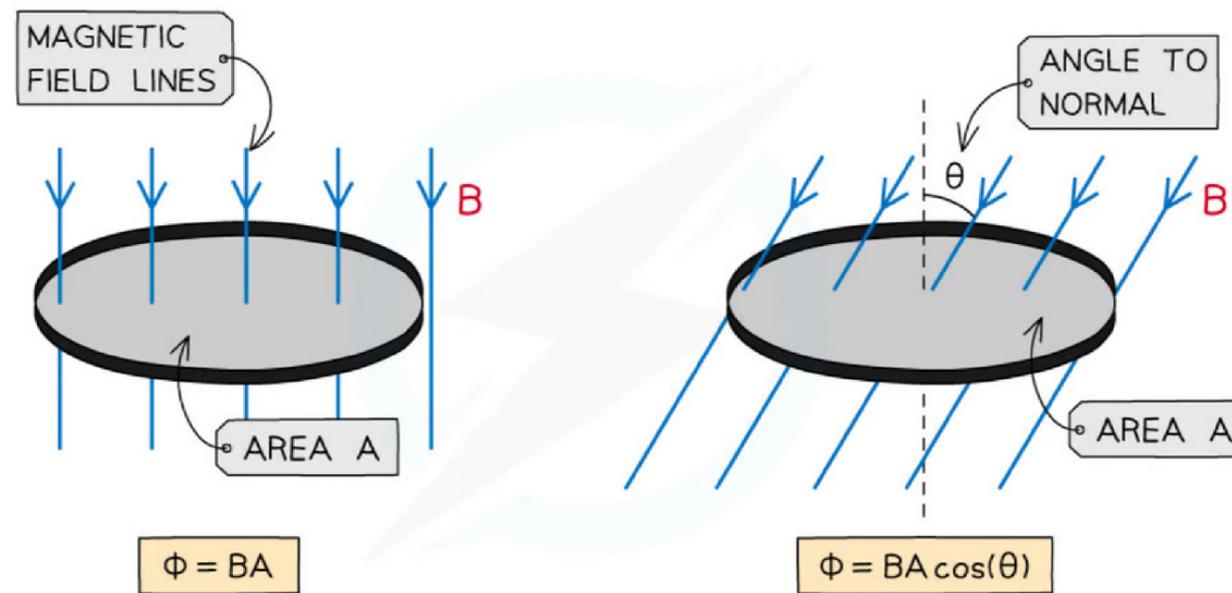
$$\Phi N = BAN \cos(\theta)$$

Where:

- $\Phi$  = magnetic flux (Wb)
- $N$  = number of turns of the coil
- $B$  = magnetic flux density (T)
- $A$  = cross-sectional area (m<sup>2</sup>)

The flux linkage  $\Phi N$  has the units of **Weber turns (Wb turns)**

$\theta$  = angle between magnetic field lines and the line perpendicular to the plane of the area (often called the normal line) (degrees)



*The magnetic flux decreases as the angle between the field lines and plane decrease*

**maximum** when B-field lines are **perpendicular** to the plane ( $\theta=0^\circ$ )  
**minimum** when B-field lines are **parallel** to the plane ( $\theta=90^\circ$ )

# Principles of Electromagnetic Induction

Electromagnetic induction occurs when **e.m.f is induced when a conductor moves through a B-field** when the conductor cuts through B-field lines OR direction of B-field through a coil changes:

**Change in  $\phi$  --> which causes work to be done. This work is then transformed into electrical energy**

therefore if attached to a complete circuit, a current will be induced

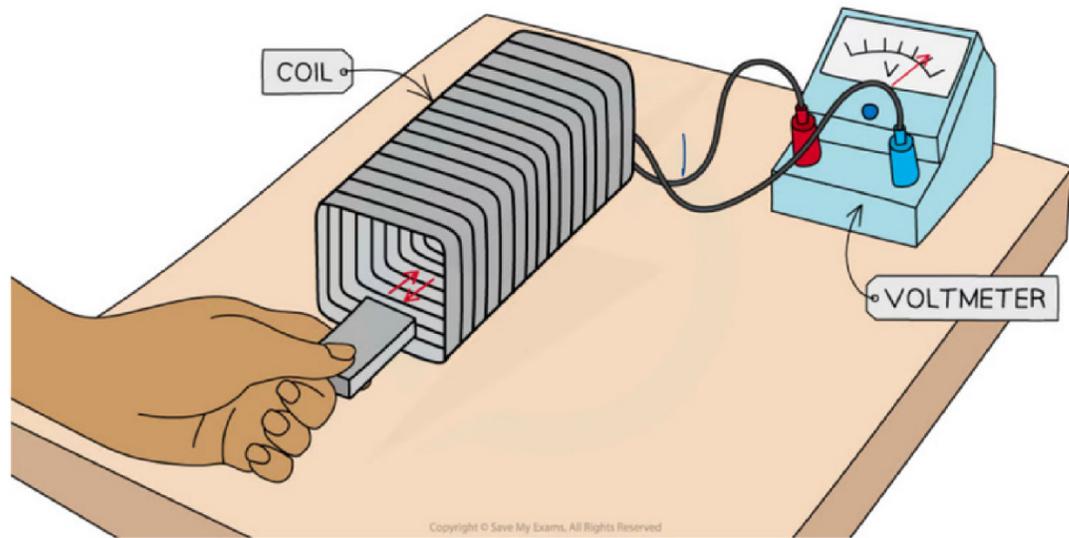
Electromagnetic Induction is used in:

1. Electrical generators convert mechanical energy to electrical energy
2. Transformers which are used in electrical power transmission

Electromagnetic induction can be shown by these 2 experiments

1. Moving a magnet through a coil
2. Moving a wire through a B-field

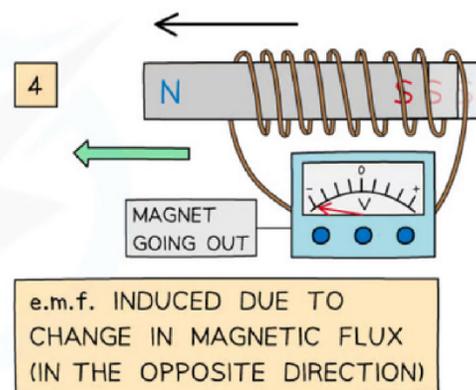
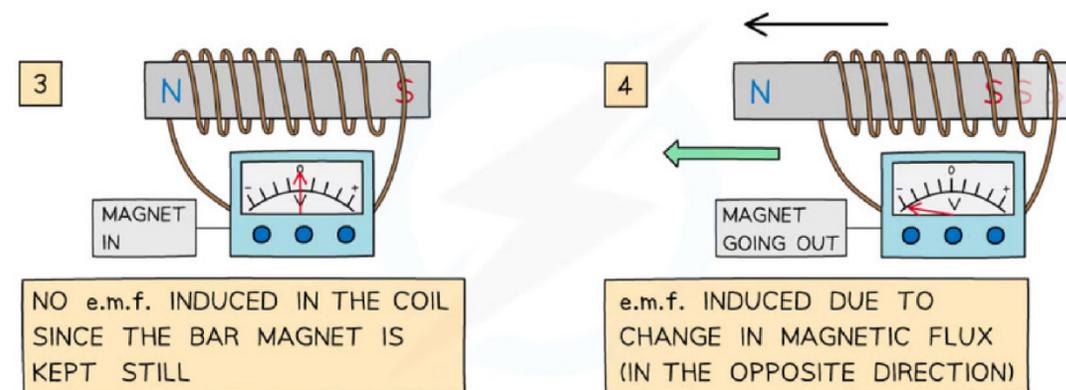
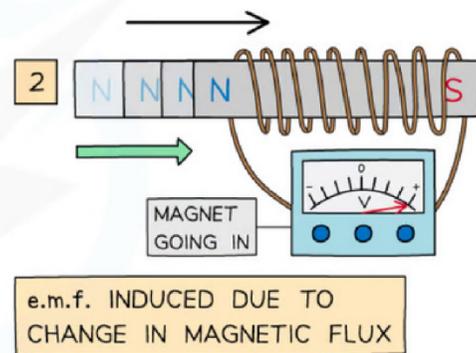
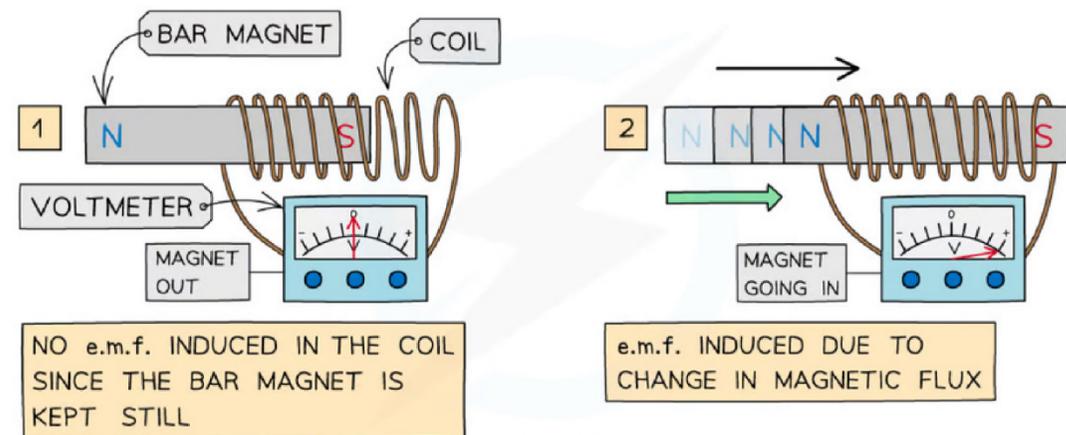
# Experiment 1: Moving a magnet through a coil



when the bar magnet is not moving, voltmeter shows zero reading  
-->because the rate of change of flux = 0 so no e.m.f is induced

when the bar magnet begins to move inside the coil, there is a reading on voltmeter

-->because B-field lines cut through the coil generating a change in magnetic flux, inducing e.m.f within the coil

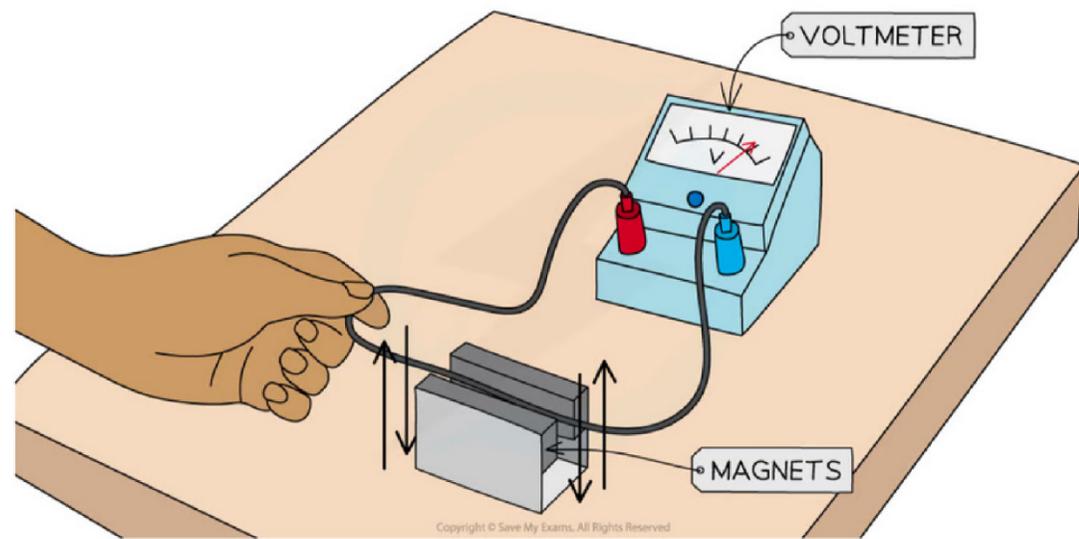


when the bar magnet is taken back out of the coil, an e.m.f is induced in the opposite direction

Direction of the current changes as the magnet changes direction. Voltmeter read in opposite sign

The direction of the electric current, and e.m.f induced in the conductor is such that it opposes the change that produces it (Lenz's Law)

# Experiment 2: Moving a wire through a magnetic field



when the wire is not moving, voltmeter shows zero reading.  
-->because the rate of change of flux = 0 so no e.m.f is induced

when the wire begins to move inside the coil, there is a reading on  
voltmeter

-->because B-field lines cut through the coil generating a change in magnetic flux, inducing e.m.f within the coil

when the wire is taken back out of the magnet, an e.m.f is induced  
in the opposite direction

Direction of the current changes as the wire changes direction.  
Voltmeter read in opposite sign

The direction of the electric current, and e.m.f induced in the conductor is such that it opposes the change that produces it (Lenz's Law)

# Faraday's and Lenz's Laws

Faraday's law = the magnitude of the induced e.m.f is directly proportional to the rate of change in magnetic flux linkage


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

Where:

- $\varepsilon$  = induced e.m.f (V)
- $N$  = number of turns of coil
- $\Delta\phi$  = change in magnetic flux (Wb)
- $\Delta t$  = time interval (s)

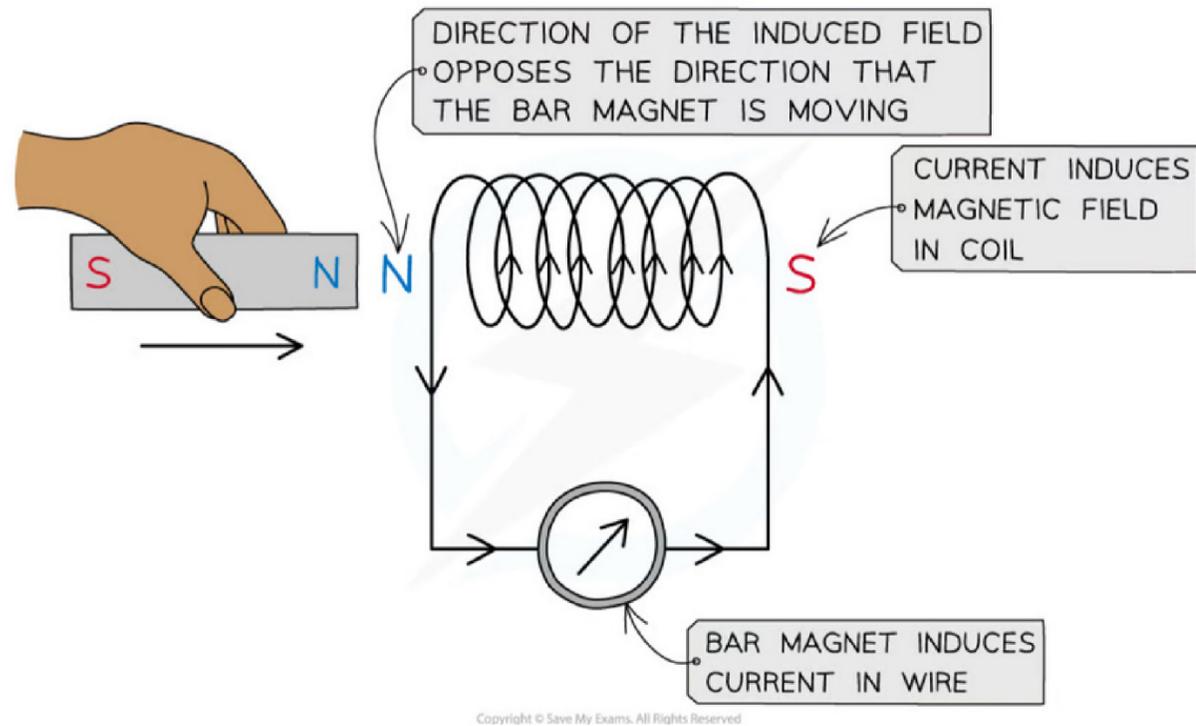
Lenz's law = the direction of current due to emf induced by a changing magnetic flux is always such that it opposes the change that induced it.


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

coil's B-field acts in the **opposite direction** to B-field of the bar magnet

if a d.c power supply is replaced with a.c supply, the e.m.f induced will also be alternating with same frequency as the supply

# Experiment Evidence for Lenz's Law



a known pole (either N or S) of the bar magnet is pushed into the coil, which induces a B-field in the coil

using right hand grip rule, curled fingers = direction of finger, thumb = direction of induced B-field

the direction of the current is observed on the ammeter --> reversing the magnet direction would give an opposite deflection on the meter

**the induced field (in the coil) repels the bar magnet due to Lenz's law: the direction of the induced field in the coil pushes against the change creating (the bar magnet)**