AS/A Levels Physics:

MAGNETIC FIELDS

Lesson 21.04

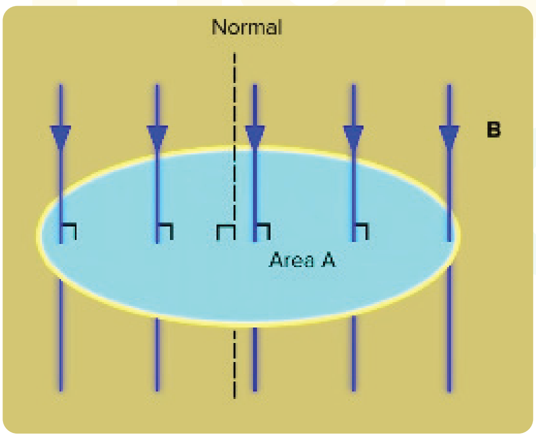
Electromagnetic Induction

Revision Notes

Cambridge will assess your ability to:

- Define magnetic flux as the product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density
- Recall and use $\Phi = BA$
- Understand and use the concept of magnetic flux linkage
- Understand and explain experiments that demonstrate:
  - that a changing magnetic flux can induce an e.m.f. in a circuit
  - that the induced e.m.f. is in such a direction as to oppose the change producing it
  - the factors affecting the magnitude of the induced e.m.f
- Recall and use Faraday's and Lenz's laws of electromagnetic induction

- **Magnetic Flux**
  - It is given as the **product** of the **magnetic flux density** and the cross-sectional **area perpendicular** to the **direction** of the **magnetic flux density.**



Mathematically,

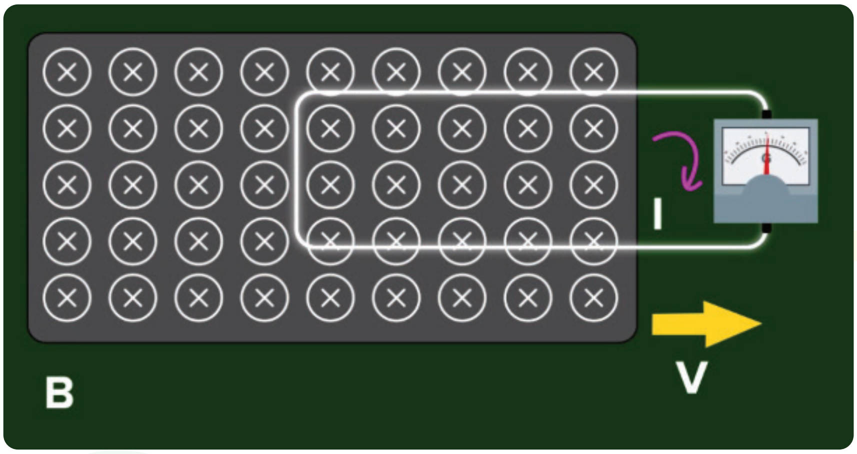
Magnetic flux (Φ) = BA cosθ

- **Magnetic flux** will be **maximum** when **θ = 0°** , i.e., when the **magnetic field** is **parallel** to the **normal area vector.**
- **Magnetic flux** will be **minimum** when **θ = 90°** , i.e., when the **magnetic field** is **perpendicular** to the **normal area vector**.

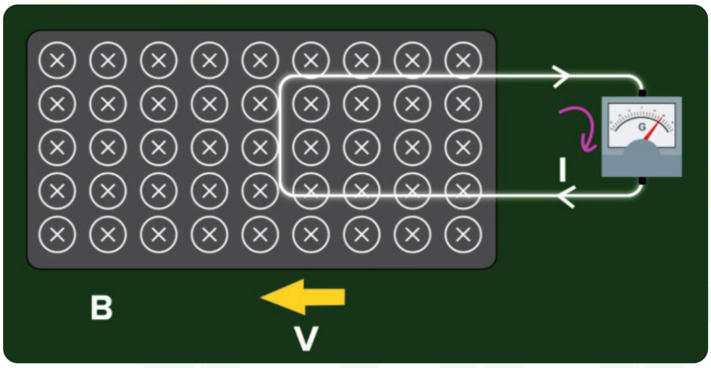
- It is the **measurement** of the **total magnetic field** passing through a given **area**.
- **Magnetic Flux** is measured in **Tm²** or **Weber**.

- Electromagnetic Induction: Whenever the **magnetic flux** through a circuit **changes**, an **emf** and a **current** are induced in it. The **emf** and **current** are called **induced emf** and **induced current**, respectively.

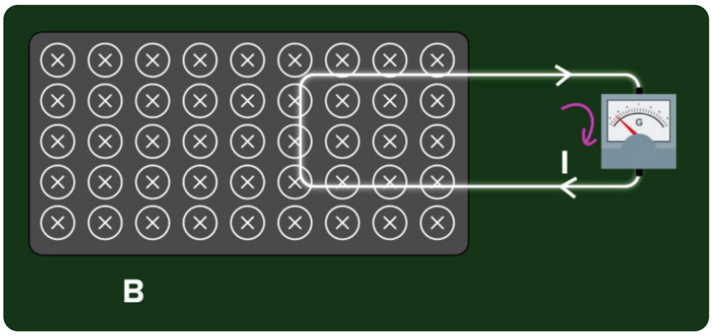
- Faraday's experiment on electromagnetic induction
  - When a **loop of wire** is pulled through a **constant** magnetic field (B), emf is **induced because** the **flux** that is passing through the **area** enclosed by the coil **decreases**.



- When a **magnet (magnetic field)** is pulled through a **stationary loop of wire, emf** is **induced because** the flux that is passing through the **area** enclosed by the **coil decreases**.



- Both the magnet **(magnetic field)** and the **loop** of wire are **stationary**. But the magnitude of the **magnetic field** is **changing**, whereas the **area** remains the same. Since the **strength of** the magnetic field is changing, **magnetic flux changes** as well, resulting in the induction of emf.

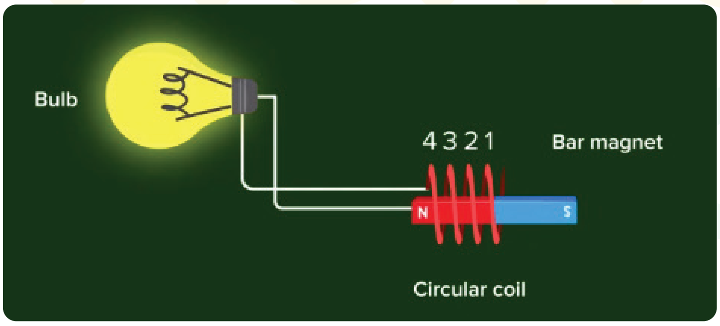


- Magnetic flux Linkage:
  - It is the **product** of **magnetic flux** and the **number of turns.**
    Magnetic flux Linkage = **magnetic flux** × **the number of turns**
  - It incorporates the **number of turns** into the calculation of **electromagnetic induction.**

- Faraday's Law of electromagnetic induction
    - The **magnitude** of the **induced e.m.f.** is **proportional** to the **rate of change of magnetic flux linkage.**

    Mathematically, $\varepsilon \propto \frac{N\Delta(\Phi)}{\Delta t}$

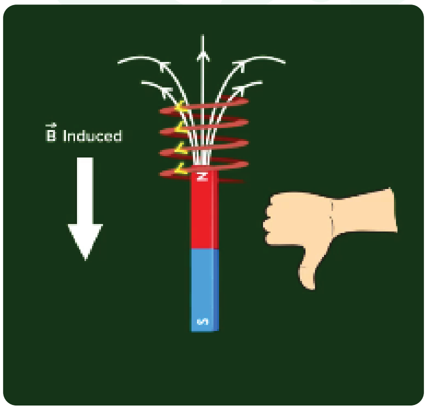
    Induced emf $(\varepsilon) = \frac{N\Delta(\Phi)}{\Delta t}$

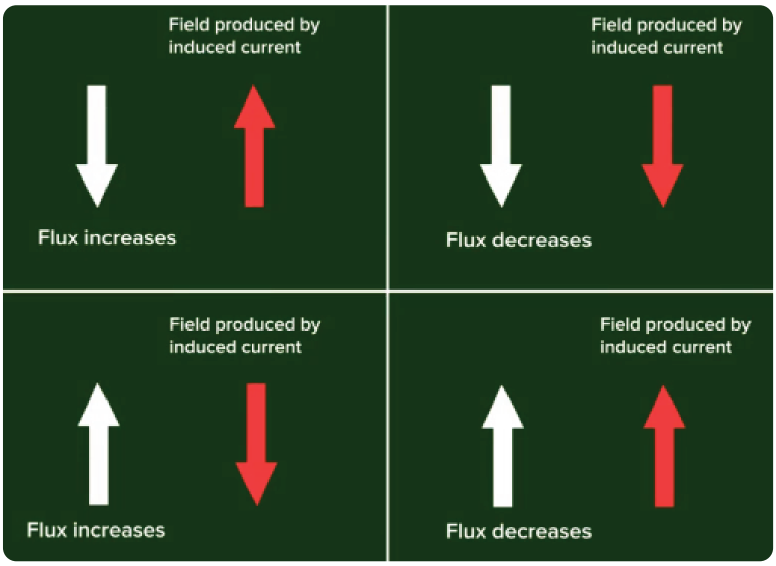
    

    - As seen from the above formula, induced **emf depends** upon the **number of turns** of the wire and the **rate of change of magnetic flux**.

- Lenz's law:
  Any **induced current** or **induced e.m.f.** will be established in a **direction** so as to **produce effects** which **oppose** the **change** that is **producing** it.
  It **gives** the **direction** of an **induced current** and **emf.**
  Induced emf (**ε**) = $-\dfrac{N\Delta(\Phi)}{\Delta t}$

  For example:
  When the bar magnet is gradually moved towards the coil and the **magnetic field** through the coil due to the bar magnet is **increasing and acting upwards,** the current is induced in the **clockwise direction.** The induced current is producing its own magnetic field in such a way as to **counter the effects** of the change in magnetic flux.





Sample examination question on this topic:

1. A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

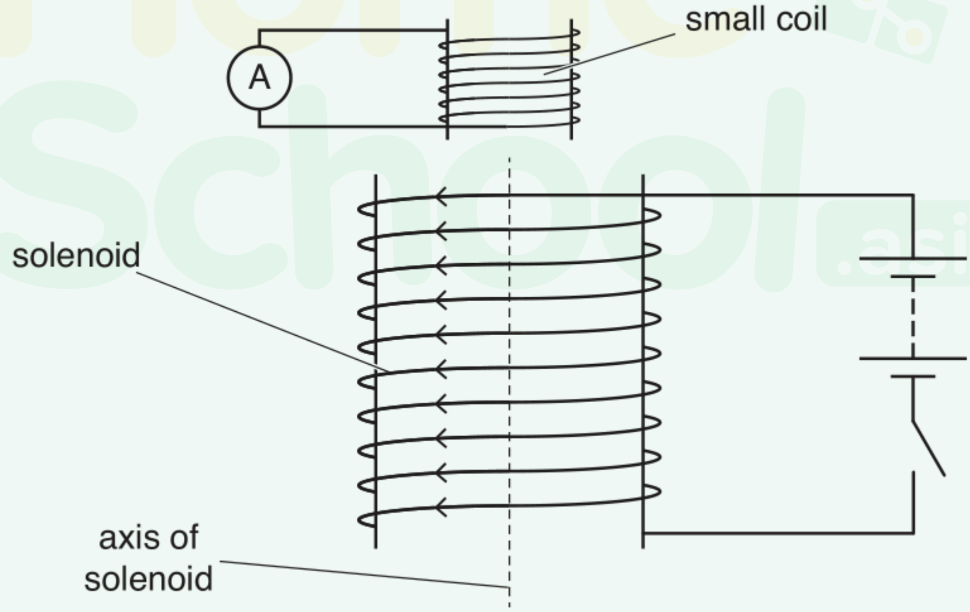


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

a. State Lenz's law.

b. A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1. A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

Answer:

a. The direction of induced e.m.f./current always opposes/ tends to oppose the change causing it.

b. A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.
As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid. Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil.
In Fig. 8.1, mark this direction with an arrow inside the small coil.

When switched on, the magnetic field in the solenoid is increasing, which induces an emf in the small coil. According to Lenz's law, this induced emf creates a field coil in the opposite direction to oppose an increase in the magnetic field due to the solenoid.
So, we need to draw an arrow inside or just above small coil pointing in opposite direction to magnetic of the solenoid.