OCR B Physics A Level

Module 6.1: Fields

Notes

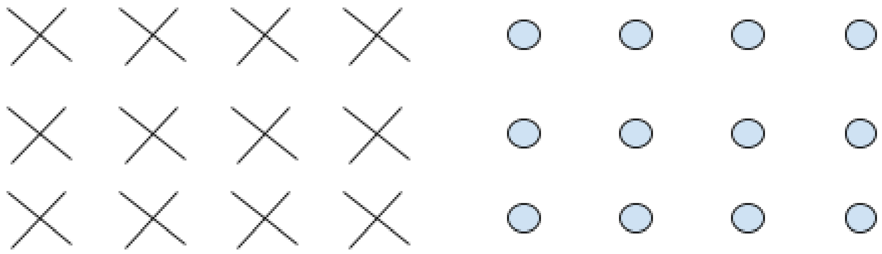
6.1.1 Electromagnetism

Magnetic Fields

Magnetic fields are represented by lines of **magnetic flux**. Flux is measured in **Webers**, Wb. **Magnetic flux density, B,** is the number of lines per unit area, and is a measurement of the strength of a magnetic field. This is measured in **Teslas, T.**

Magnetic field lines

- Always run from the **north to south** poles.
- Never cross, touch or overlap.
- Tend to shorten/straighten (the magnets are moved to achieve this).



away from observer towards observer

Flux density and flux are linked by the following equation:

$$\Phi = BA$$

Φ = flux / Wb | B = flux density / T (or Wbm^{-2}) | A = area / m^2

Flux linkage, NΦ, is the product of the flux and the number of coils.

Electromagnetic Induction

Induction is the production of a p.d. when there is **relative motion between a conductor and a magnetic field**. If the circuit is complete, a current will flow. This is summarised by the laws of **Faraday** and **Lenz**.

Faraday's law states that the emf, ε, induced is directly proportional to the **rate of change of flux linkage**, $\frac{\Delta N\Phi}{\Delta t}$.

Lenz's law states that the emf is induced so as to **oppose the change which caused it.** This means that the current produces a magnetic field in the opposite direction to the magnetic field that the wire is placed in.

These laws come together to form the equation:

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

Magnetic Circuits

Permeance is like conductance - a magnetic system with high permeance conducts flux lines well. Air has a low **permeability**, so gaps between metallic materials reduces the magnetic field considerably.

A high **cross-sectional area** increases the permeance of a magnetic circuit.

Transformers

Transformers use electromagnetic induction to change the voltage and current of an electric supply. A magnetic core is used to convey the magnetic field produced by an alternating current in the primary coil. The alternating current produces a changing magnetic field, inducing an emf and current in the secondary coil.

The transformer equations are:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$$

Eddy currents reduce the efficiency of transformers. Small currents are induced in the magnetic core, running horizontally around it. This dissipates power as **heat**, wasting some of the electrical energy.

The effect of eddy currents can be reduced by **lamination.** This involves placing vertical layers of an insulating material at intervals in the iron core. This prevents currents from flowing through the core.

Rotating a coil in a magnetic field also produces a flux change which induces an emf.

The Motor Effect

When a current carrying wire is placed in a **uniform magnetic field**, it experiences a force (known as a **catapult** force), as the field lines shorten and straighten across the wire.

The magnitude of this force is given by the equation:

$$F = BIL$$

Where F = force / N
B = magnetic flux density / T
I = current / A
L = length / m

The motor effect is what causes motors to turn. The current flows along a rectangular piece of wire, causing an upwards force on one side and a downwards force on the other. Once a motor starts spinning, a **back emf** is generated. This provides resistance against the catapult force and limits the speed of the motor.

6.1.2 Charge and Field

Uniform Fields

An **electric field** is a region in which a charged particle experiences a force.

In a uniform field, the following equations apply:

$$E = \frac{V}{d}$$

Where E = electric field strength
V = potential difference
d = separation of charges

$$E = \frac{F}{q}$$

Where E = electric field strength
F = electric force
q = charge

Equipotentials are always perpendicular to the field lines.

Coulomb's Law

Coulomb's law is used to calculate the electric force on a charge.

$$F = \frac{kQq}{r^2}$$

Where F = electric force / N
k = electric force constant ($= \frac{1}{4\pi\varepsilon_0}$) / Nm^2C^{-2}
Q and q = the two charges
r = the separation of the charges

$$E_{electric} = \frac{kQ}{r^2} = \frac{F}{q}$$

(Where $E_{electric}$ is the **electric field strength**, or the force per unit charge, in N/C).

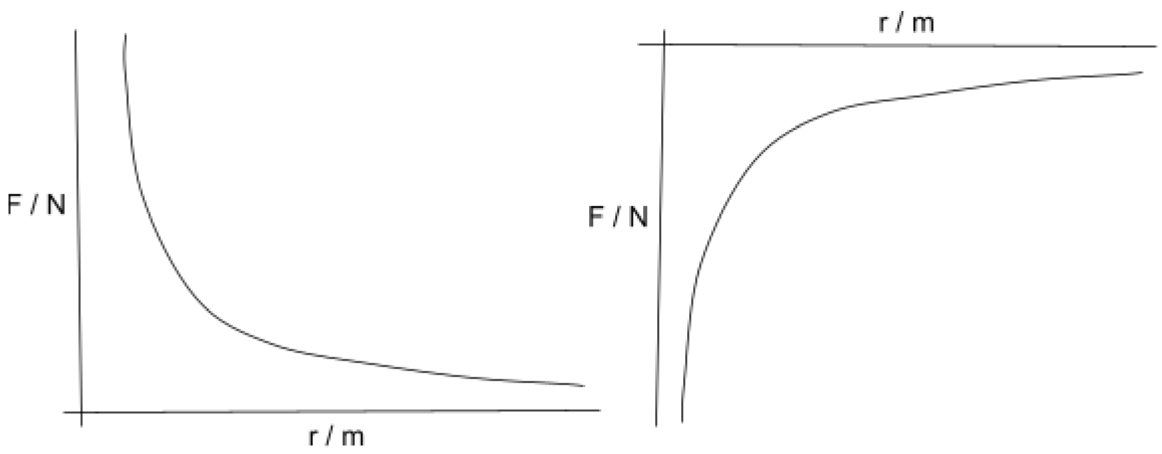
$$E = \frac{kQq}{r}$$

(Where E is the **electric potential energy**, in J).

$$V = \frac{kQ}{r}$$

(Where V is the **electric potential**, or **potential energy per unit charge.** This is the work done to bring a unit positive charge from infinity to a given point).

Unlike gravitational fields, electric fields can be **attractive** or **repulsive**. This means that the graphs can be above or below the x axis.



The relationship between the graphs is the same as for the gravitational field graphs:

- The **gradient** of an energy graph gives the electric force.
- The **area** under a force graph gives the change in electric potential energy.
- The **gradient** of an electric potential graph gives the electric field strength.
- The **area** under an electric field strength graph gives the electric potential.

Electric vs. Gravitational Fields

Electric Fields	**Gravitational Fields**
Field strength: **force per unit charge**	Field strength: **force per unit mass**
Field lines point **towards** a **negative** charge, or away from a positive one	Field lines point **towards** the **mass** (attractive)
Can be attractive or repulsive	Can only be attractive
Follow the **inverse square law**	Follow the **inverse square law**
Objects can be **shielded**	Objects cannot be **shielded**
Field strength depends on **medium**	Field strength is independent of the **medium**
	that the field is in

Milikan's Oil Drop Experiment

Milikan's oil drop experiment was used to identify the **charge on an electron**, *e*.

Tiny oil droplets were ionised between two charged plates. The p.d. was then adjusted until the weight of the drop was balanced by the electric force on it. By equating *mg* with *qE*, a value for q could be obtained.

All of the values for q were multiples of 1.6×10^{-19}C. This showed that charge was **quantised** and this value was deduced to be the charge on an electron.

Charges in Magnetic Fields

A current carrying wire experiences a force in a magnetic field; the same is true for a moving charge.

$$F = qvB$$

Where F = force / N
Q = charge / C
v = velocity / m/s
B = magnetic field strength / T

Charged particles in a magnetic field are deflected in a **circular path**. The **radius** of this path depends on the particle's momentum, and therefore mass and velocity.

$$r = \frac{mv}{qB}$$

Where r = radius / m
m = mass / kg
v = velocity / m/s
q = charge / C
B = magnetic field strength / T