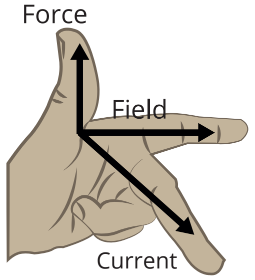
GCE Physics Component 3.9 Magnetic Fields

eduqas

Fleming's Left-Hand rule:

When a **current** flows through a **magnetic field** at an angle, a **force** acts on the wire. The direction of this force is perpendicular to the current and the field, and can be predicted using Fleming's Left-Hand rule.



The size of the force is given by this equation:

$$F = BIl\sin\theta$$

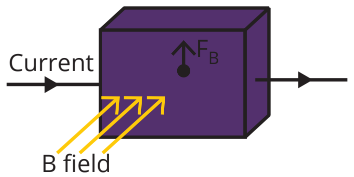
B is the magnetic field strength (or flux density), measured in **Tesla (T), where 1 T = 1 $N\,A^{-1}$ m^{-1}**.

As current is defined as the rate of flow of charge the above equation can be expressed in terms of the force on a single charged particle.

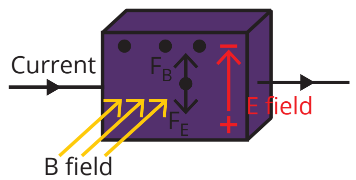
$$\boldsymbol{F = Bqv\sin\theta}$$

In both equations, θ is the angle between the current and the field lines.

Hall Voltage, V_H:



When a current flows at 90° through a magnetic field, there will be a **force on the electrons** flowing through the wire, forcing them to **one surface** of the conductor. This will cause one surface to become **negative** and the other **positive**. This creates an electrical field between the surfaces and cause a **force on the electrons in the opposite direction**.



In the end, the magnetic force and the electrical force will **balance** and **an equilibrium is reached**.

$$qE = Bqv$$

As $E = \frac{V}{d}$ this can be written as $V_H = Bvd$ where V_H is the potential difference between the surfaces, measured with a voltmeter, when this equilibrium is reached.

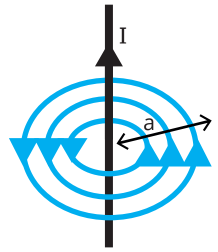
This can be used to measure the strength of B fields as

$$B \propto V_H.$$

Magnetic fields:

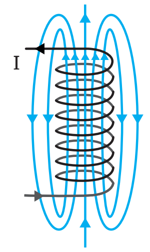
Magnetic fields are created by current carrying wires, the shape of the field can be predicted by the right-hand grip rule.

Long straight wire



Thumb in the direction of the current, fingers in the direction of the field.

Solenoid



Fingers in the direction of the current, thumb in the direction of the field inside the coil.

The strength of each field is given by these equations:

$$B = \frac{\mu_o I}{2\pi a}$$

Where a is the distance from the wire to a point.

$$B = \mu_o nI$$

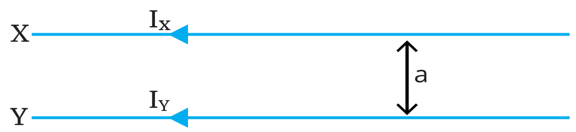
Where n is the number of turns per meter.

$$n = \frac{number\ of\ turns}{length}$$

The strength can be increased by using an iron core inside the solenoid.

Parallel wires:

When a current passes through a wire it creates a magnetic field. If two parallel wires carry a current, they will each be in the others magnetic field, therefore a force will act on the wires.



In this example, consider wire X, it creates a magnetic field with strength, $B = \frac{\mu_o I_X}{2\pi a}$. As wire Y is in this field, the force on wire Y will be $F = BI_Y l$. The direction of the force, given by Fleming's Left-Hand Rule, will be towards wire X.

Newton's 3rd law means that there will also be an equal force on wire X towards wire Y.

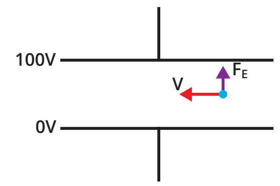
Charged particles in E and B fields:

Any moving charges can be deflected by a magnetic field or an electric field.

Magnetic forces always act perpendicular to the motion. Therefore, the magnetic force acts as a centripetal force and makes the charges move in a circular path.

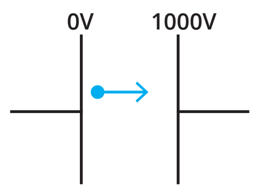
$$Bqv = \frac{mv^2}{r}$$

The **electrical force** between two parallel plates is constant due to the uniform electric field. Therefore, the force acting on the electron here, F_E will cause a vertical acceleration but not change its horizontal velocity.

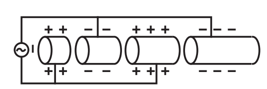
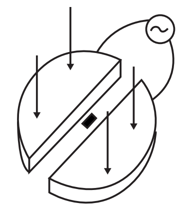
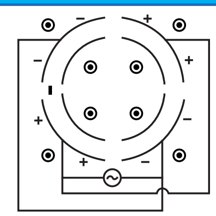


Particle accelerators:

When a charged particle is accelerated by a potential difference it gains kinetic energy. In this example an electron is accelerated by a p.d. of 1000V, the energy it gains = 1000 eV, where 1 eV = 1.6 × 10^{-19} J.



There are 3 types of particle accelerators which use this process. They all use an alternating p.d. to accelerate the particles in the gaps between electrodes.

	Linear	Cyclotron	Synchotron
			
Path	Straight line	Circular but with increasing radius	Circular, constant radius
Magnetic field	None	Constant, to ensure circular motion	Increasing to ensure circular motion with constant r
Alternating p.d.	Constant, increasing length of tube ensures the p.d. changes in time	Constant, increasing path length ensures the p.d. changes in time	Increasing

F = force in B
I = current in A
q = charge in C
n = number of turns per m in m^{-1}
V_H = Hall voltage in V
θ = angle between the current and the field lines in °
B = Magnetic field strength in T
l = length in m
v = speed in m s^{-1}
E = Electrical field strength in N C^{-1}
d = plate separation in m