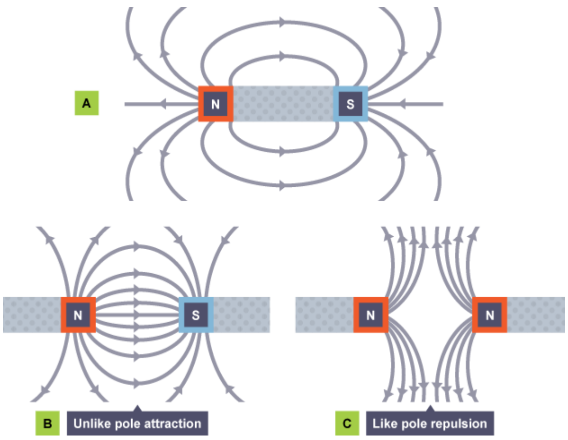
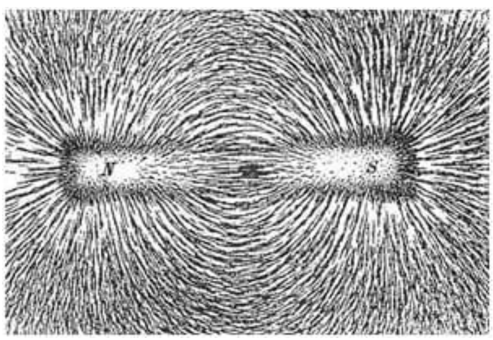
Magnetic Field

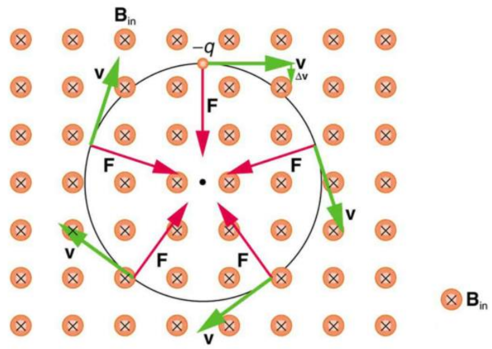
A. DESCRIPTION

- Magnetic field is a region of influence in which a magnetic pole or electric current experiences a magnetic force from interaction with the field.
- Magnetic field can be produced by permanents magnet or electric current
- The magnetic field lines,
  - Start at north pole and end at a south pole
  - Are smooth curves which never touch or cross
  - The strength of magnetic field is indicated by the closeness of the lines, the stronger the lines, the stronger the magnetic field. If a magnet placed at which there were more lines passing through it, it'll experience a stronger force than at a spot with less lines passing through





B. FORCE ON A MOVING CHARGED PARTICLE



- Magnetic force can cause a charged particle to move in a circular or spiral path. Since it goes on a circular motion the causes are:
  - Force is perpendicular to the velocity.
  - Speed is constant.
  - Therefore, kinetic energy is constant too.

- Force on free charge

$$F = BQv$$

B= flux density

Q= charge of the particle

V= velocity (it has it be perpendicular to the magnetic field)

- Force on electron

$$F = Bev$$

$e = 1.6\ x\ 10^{\wedge}(-19)$

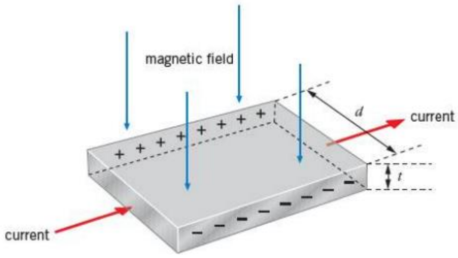
- If it's going in a circle of radius R then the force on the charged particle (electron) is equal to the centripetal force. So we have,

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

And thus we also have,

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

The Hall Effect



- The Hall effect is a mechanism in which magnetic and electric forces on a moving charged particle are balanced
- A small current flows through the probe and a magnetic field is applied so the electrons are pushed sideways by the magnetic force, accumulating on one side hence producing a small voltage; Hall voltage

The greater the flux density, greater the Hall voltage

The Hall Voltage

- An electric field is set up in the probe as there is a difference in voltage between a distance so,

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

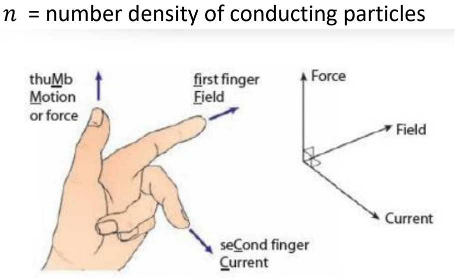
- As a single electron travels with drift velocity v , it experiences a force to the left due to the magnetic field Bqv and a force to the right due to the electric field Eq
- Soon an equilibrium is reached hence forces equated

$$Eq = Bqv$$

- Current is related to mean drift velocity by

$$I = nAvq$$

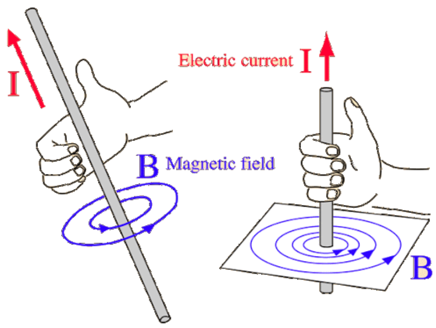
$A = td$ is cross sectional area
n = number density of conducting particles



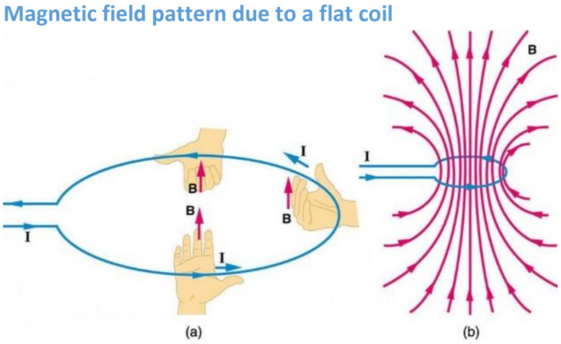
C. MAGNETIC FIELD DUE TO CURRENTS

- the magnetic field caused by the current through wire can be found by using the right-hand rule. Also make sure to point the thumb in the direction of conventional current.

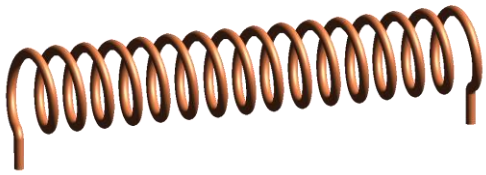
Magnetic field pattern due to long straight wire

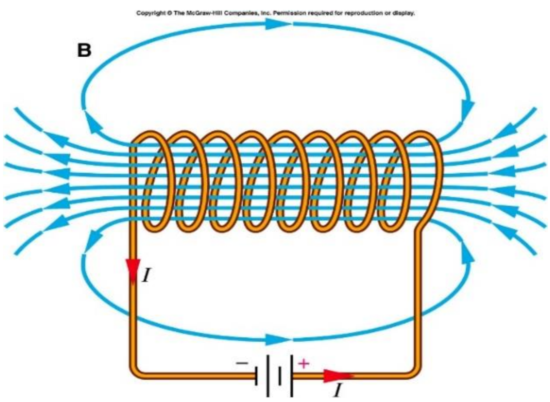


Magnetic field pattern due to a flat coil



- Solenoid may be thought as of being made up of many flat coils. The field is uniform and the strength of B at each end is one-half that at the centre. The magnetic field pattern due to solenoid is illustrates by the picture below.

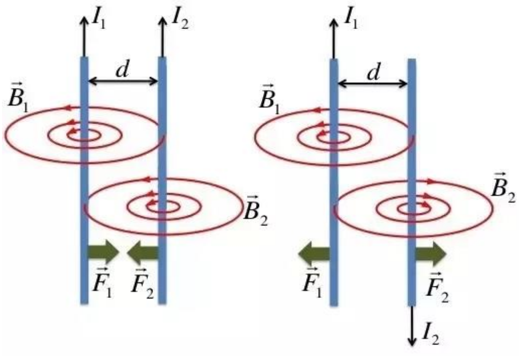


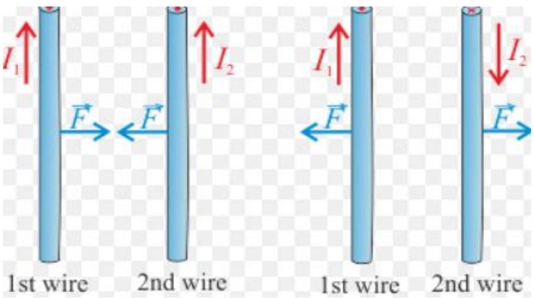


- zConventional current: Idea that electric current is a flow of positive charge from positive to negative, based on early studies of electricity. In reality electric current is the flow of electrons from negative to positive. I would refer to conventional current.

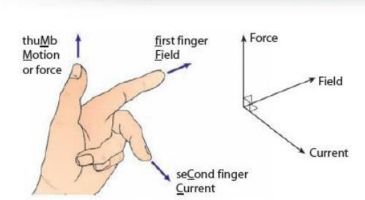
D. MAGNETIC FIELD BETWEEN PARALLEL CONDUCTOR

- If two wire or current carrying conductor is placed parallel side by side, each of the two wires will experience a force.
- Assume the two wire is X and Y, the X will produce $magnetic\ field\ B_1$ that will affect Y, hence there will be a force acting on Y. Similarly, Y will also produce $magnetic\ field\ B_2$ that will be the reason why another force will act on X.





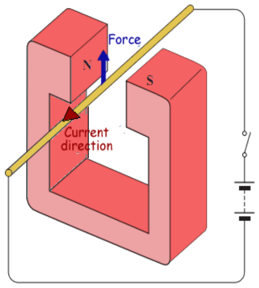
- Use right hand rule on I_2 to gain the direction of B_2
- Let the I_2 pointing up, then the B_2 acting on 1st wire will pointing out the paper (towards you) or $\odot$
- If the I_2 pointing down, then the B_2 acting on the 1st wire will pointing into the paper (away from you) $\otimes$
- Then using the Fleming's left hand rule on the 1st wire, we can gain the direction of force acting on it as shown in the picture



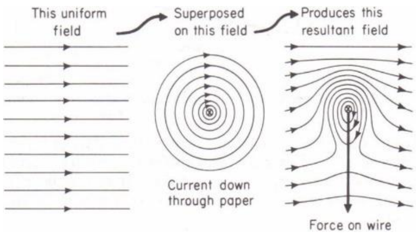
- With the same method, we can gain the direction of force on 2nd
- Finally, we can conclude:
  - If the currents are pointing in the same direction then the wires will
  - If the currents are pointing in opposite direction, the wires will repel

E. FORCE ON A CURRENT-CARRYING CONDUCTOR

The Motor Effect



(Fig. 1)



(Fig. 2)

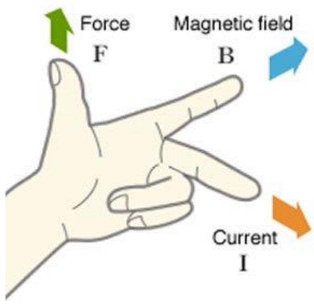
We already learned that the wire produces magnetic field, but what if the wire is placed between the poles of permanent magnet?

Well, the magnetic fields of the current-carrying conductor and the magnet will interact and either the wire will move or the magnets that will move. But in this case, we will assume that the magnet will stay at its position while the wire will be moved by it.

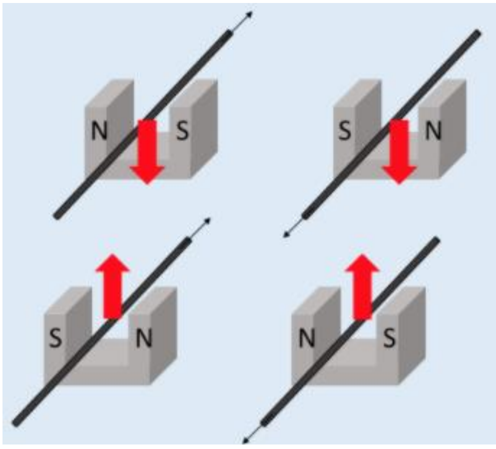
The phenomenon when a current-carrying conductor is at an angle to a magnetic field is called the **Motor Effect**

- The wire is at right angles to **magnetic field**
- The direction of movement of the wire is F
- F can be found by using the Fleming's lefts hand rule shown by (Fig. 3)
- The Magnetic field B is the magnetic field that produce by the permanent magnet and always flow from the north pole to the south pole.
- In some cases when using the rule, magnetic field will be stated by:
  - "into the page" or can also symbolized by cross ⊗ those mean that when using the rule you must point the first finger away from you.
  - "come out the page" or can also symbolized by big dot ⊙ those mean that when using the rule, you must point your first finger towards you.

- The wire shown by the (fig.1) will move up, but if the current is reverse, then the wire will fall. Difference in the direction of force will also observed if the poles are switch (fig.4)



(Fig. 3)



(Fig. 4)

From the experiment, the F be found by formula:

$$F = BIL\sin\theta$$

B = magnetic flux density (T for Tesla or Wbm^{-2} for Weber per square)

θ = angle between wire and magnetic field

From the equation we can gain the definition of

$$B = \frac{F}{IL\sin\theta}$$

Magnetic flux density B is force per current per unit length on a straight wire placed at right angles to uniform magnetic field

Note: One tesla is the uniform magnetic flux density which, acting normally to a long straight wire carrying a current of 1 ampere, causes a force per unit length on the conductor

F. THE USE OF NUCLEAR MAGNETIC RESONANCE IMAGING

- When a magnetic field is applied to the nuclei, they tend to line up along the field. However, this alignment is not perfect and the nuclei rotate about the direction of the magnetic field, due to their spin. The motion can be modelled as the motion of a top spinning about the direction of a gravitational field. This rotation is known as **precession.**
- The spinning about the direction of the magnetic field has a frequency known as the frequency of precession or the **Lamor frequency.**
- The short time between the end of the RF pulse and the re-emitting of the radiation is known as the **relaxation time.**
- The whole process is referred to as **nuclear magnetic resonance.**

G. EXERCISE

- An electron and an α-particle travelling at the same speed both enter the same region of a uniform magnetic field which is at right angles to their direction of motion. State and explain any differences between the two paths in the field.

Solution:

The forces are in opposite direction and the radius on the circular motion produce by the α particle will be bigger compared to electron because the mass of α particle is bigger and mass is proportional with radius

$$Bqv\sin 90° = \frac{mv^2}{r}$$

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

The magnetic flux density B at a distance r from a long straight wire carrying a current I is given by the expression $B = (2.0\times10^{-7})\times I/r$, where r is in metres and I is in amperes.

a Calculate:

i the magnetic flux density at a point distance 4.0 cm from a wire carrying a current of 16 A,

ii the force per unit length on a second wire, also carrying a current of 16 A, which is parallel to, and 4.0 cm from, the first wire.

b Suggest why the force between two wires is demonstrated in the laboratory using aluminium foil rather than copper wires.

- The magnetic flux density B at a distance r from a long straight wire carrying a current I is given by the expression $B = [2.0\times10^{-7}]\times\frac{I}{r}$,
where r is in metres and I is in amperes.
a). Calculate:
i. the magnetic flux density at a point distance 4.0 cm from a wire carrying a current of 16 A,
ii. the force per unit length on a second wire, also carrying a current of 16 A, which is parallel to, and 4.0 cm from, the first wire.
b). Suggest why the force between two wires is demonstrated in the laboratory using aluminium foil rather than copper wires.

Solution:

a).

i. From the given equation,

$$F = 2\times10^{-7}\times\frac{16}{4\times10^{-2}} = 8\times10^{-5}$$

ii. The wires are parallel and magnetic field on the 2nd wire is equal to the magnetic field on the point calculated in A. because the distance is the same.

$$\frac{F}{L} = BI\sin\theta$$

$$F = 8\times10^{-5}\times16\times\sin 90° = 1{,}28\times10^{-3}$$

b). Because density of aluminium is smaller than copper.