Field

Magnetic Flux Density, *B*

is defined as the <u>force per unit length per unit current</u> acting on a long straight current-carrying conductor placed perpendicular to a magnetic field.
Known as the magnetic field, It is a vector quantity with SI Unit: Tesla (T)

Long straight current carrying conductor

- The magnetic flux density, B, at a distance, d , from a long straight wire carrying a current, I, is given by

$$\boxed{\begin{gathered} B = \frac{\mu_0 I}{2\pi d} \\ d: perpendilcular\ distance \\ from\ the\ wire \\ \mu_0: 4\pi \times 10^{-7} Hm^{-1} \end{gathered}}$$

Circular coils

- B, at the centre of a flat circular coil of N turns, radius, r, and carrying current, I, is given by

$$\boxed{\begin{gathered} B = \frac{\mu_0 N I}{2r} \\ \Delta V: potential\ difference \\ between\ the\ plates \\ r: radius\ of\ the\ circular\ coil \end{gathered}}$$

Solenoid

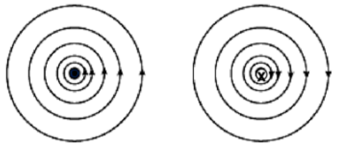
- B, at the centre of a long solenoid with n turns per unit length and carrying current, I, is given by

$$\boxed{B = \mu_0 n I}$$

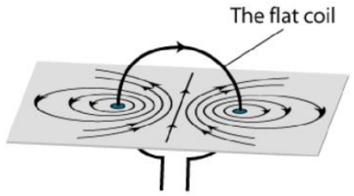
- n is the number of turns per unit length,
- N (capital N) is the total number of turns.

Sketching the magnetic field lines using **Right Hand Grip Rule**

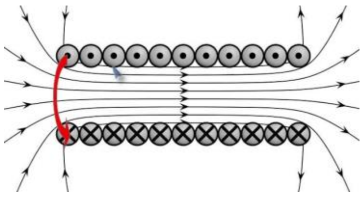
→ Long straight current carrying conductor



→ Circular coils



→ Solenoid



Force

Force on Current Carrying Conductor

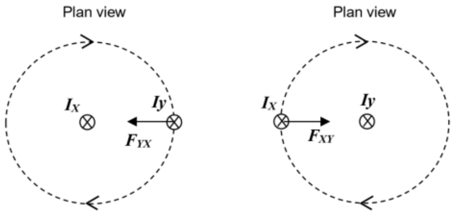
Magnitude of the force *F_B*

$$F_B = BIL\ sin\theta$$

Where L is the length of the conductor carrying current, I, in the magnetic field, *B* and θ is the angle between *B* and *I*.

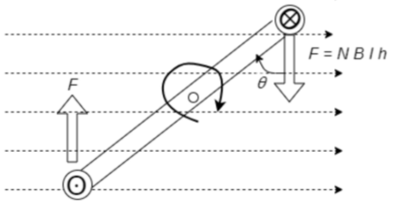
Note that F_B is zero when the current is along the direction of the external B.

<u>Special case: Parallel Currents</u>



- Like currents attract. Unlike currents repel.
- By Newton's 3rd Law, the forces on both currents are equal in magnitude and opposite in direction.

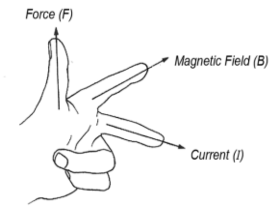
<u>Special case: Torque in DC Motor</u>



$$\boxed{\begin{aligned} Torque = F \times b\ sin\theta &= NBI\ hb\ sin\theta \\ &= NBI\ A\ sin\theta \end{aligned}}$$

Where *N* : no. of turns; *h* : length of wire perpendicular to plane of page; *b* : length of wire in plane of page.

Fleming's Left Hand Rule: allows us to find the direction of F_B.



Fleming's Left Hand Rule: allows us to find the direction of F_B.

The direction of *I* will be given by the direction of flow of positive charge. For negative charges, the direction of *I* will be opposite to direction of *v*,

From FLHR, we conclude that the direction of F_B is always perpendicular to the direction of *v*. Hence the moving charge moves in a uniform circular path where the centripetal force is <u>provided by</u> the magnetic force (tip: make this point clear to the examiner)

Since

$$v = \frac{L}{t}$$

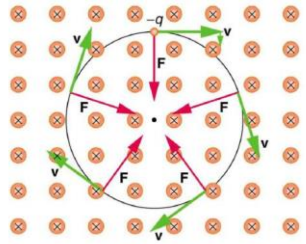
And

$$I = \frac{Q}{t}$$

We can express:

$$F_B = F_C$$
$$BQv = \frac{mv^2}{r}$$
$$r = \frac{mv}{BQ}$$

Force on Moving Charge:



Magnitude of the force *F_B*

$$F_B = BQv\ sin\theta$$

Where *Q* is the charge, moving with velocity *v* in a magnetic field of flux density *B* and θ is the angle between *v* and *B*.

Velocity selector

An *E* and *B* field exist in the same region of space and are directly perpendicular to each other, Consider a positive ion entering the region:

- For *E*-field: $F_E = qE$ and force is in the direction of *E* field.
- For *B*-field: $F_B = BQv$ and force is in the direction is given by **FLHR**
- To pass through undeflected:
- $F_E = F_B\ \rightarrow qE = BQv\ \rightarrow \frac{E}{B} = v$
  if $v > E/B, F_B > F_E$
  → deflect in the direction of F_B
  if $v < E/B, F_E > F_B$
  → deflect in the direction of F_E