Electromagnetism

Field

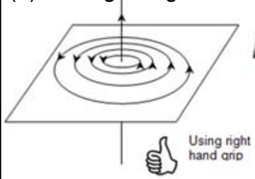
Force

A **magnetic field** is a region of space where a <u>permanent magnet</u> or a <u>moving charge</u> or a <u>current-carrying conductor</u> will experience a magnetic force.

The **magnetic flux density** of a magnetic field is defined as the <u>force per unit current per unit length</u> (of conductor) acting on a straight current-carrying conductor placed at right angles to the magnetic field.

Magnetic field lines (use RHGR)

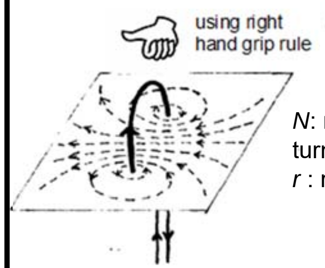
(a) Long straight current-carrying conductor



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

d: distance perpendicular to the current to a point.

(b) Circular flat coils

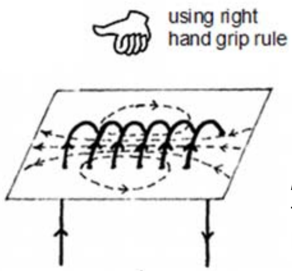


$$B = \frac{\mu_o N I}{2r}$$

N: number of turns in the coil

r : radius of coil

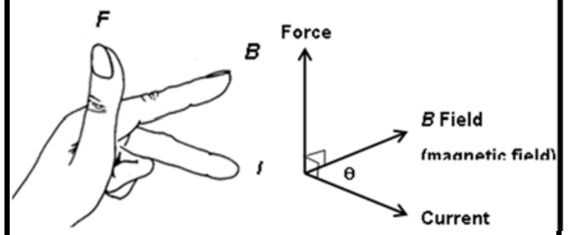
(c) Solenoid



$$B = \mu_o n I$$

n: number of turns per unit length

Force on Current-carrying conductor



Magnitude of the force F_B:

$$F_B = BIL\sin\theta$$

where *L*: length of conductor

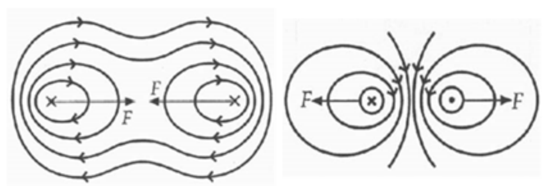
θ : angle between *B* and *I*

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

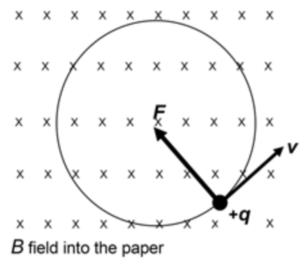
Direction of F_B: Use Fleming's Left Hand Rule

Parallel current-carrying conductors

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



Force on Moving Charge:



Magnitude of the force F_B:

$$F_B = Bqv\sin\theta$$

where *q*: charge v : speed

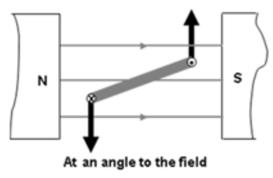
θ : angle between *B* and v

Note F_B is zero when the direction of *v* is along *B* or when *v* = 0.

Direction of F_B : Use FLHR

Direction of *I* in FLHR 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 .

Torque in DC motor



Torque = force × distance perpendicular to the forces between the forces

Velocity selector:

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

For *E*-field: $F_E = qE$ and the force is in direction of the *E*-field.

For *B*-field: $F_E = Bqv$ and direction is given by FLHR.

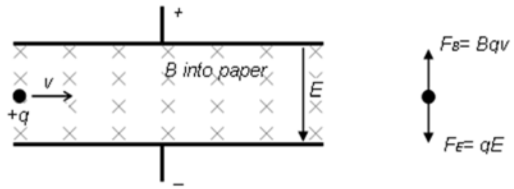
To pass through undeflected:

$F_B = F_E$

$Bqv = qE$

$v = E/B$

- If $v > E/B$, $F_B > F_E$: deflect in direction of F_B.
- If $v < E/B$, $F_B < F_E$: deflect in direction of F_E.



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 <u>centripetal force is provided by the magnetic force</u>.

$$F_B = ma_C$$

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

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