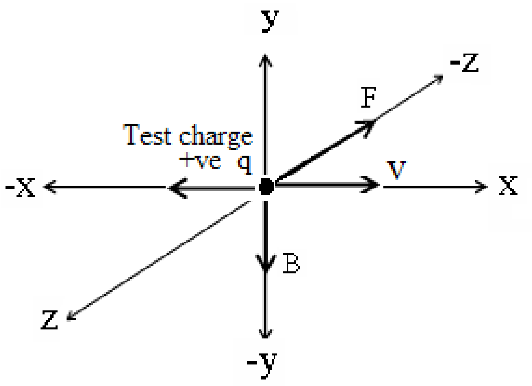
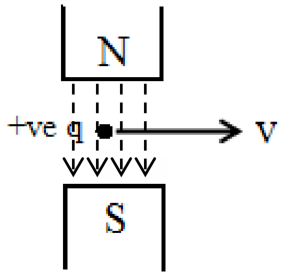
<u>Effect of magnetic field on electric charge</u>

a- There is no effect of constant stationary magnetic field on a +ve test charge in such a field.

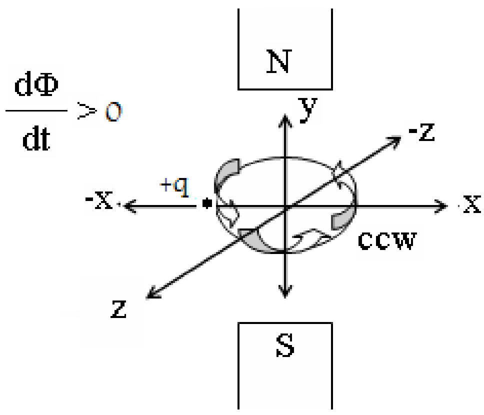
b- If there is a moving *+ve* test charge in a certain velocity (*v*) in a constant stationary magnetic field, such a field will exerts a force as shown in the figure besides.
This force will be normal to the plane containing the vectors *V* and *B* Due to the *Right-Hand-Rule* (R.H.R) such that " you have to turn the fingers of your right hand from V to B in the direction of the smallest angle between them, the thumb will assignee the direction of the force"





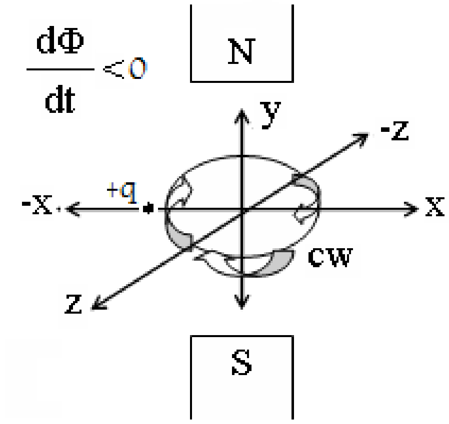
c- If there is a charge *(+ve* test charge) effected by a stationary variable magnetic field, this charge will move due to Lenz's law which states that " The direction of the induced current will be such as to oppose the cause producing it"

The figure besides declares the idea.
In that fig (a) shows an increasing magnetic field so the charge will move anti clockwise in the (z-x) plane in order to generate a flux against the main field because it is increasing and the induced flux will reduce the increase (the cause)



a

Fig (b) shows the same direction of the magnetic field in (a) but it decreasing ($d\Phi$/dt) < 0 .this will cause the +*ve* test charge to move clockwise in the (z-x) plane to increase the applied field and reduce it's reduction (the cause).

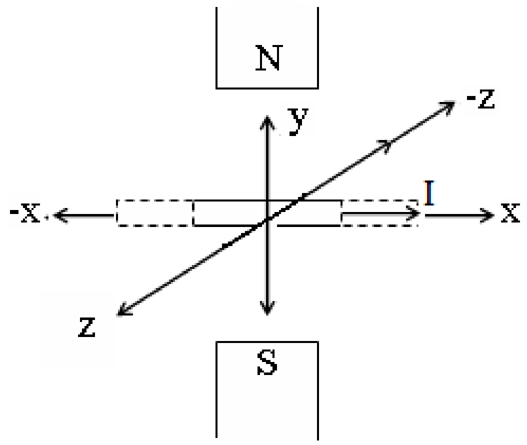


b

<u>Motor Principle</u>

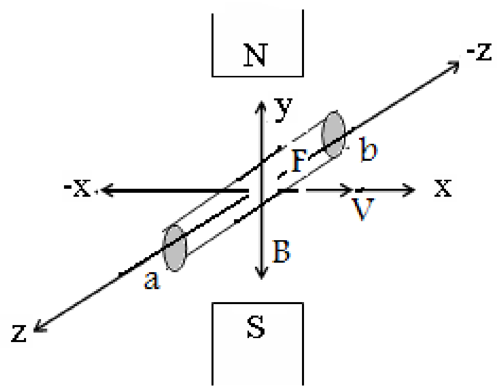
In the figure shown suppose that there is a current carrying conductor In a constant magnetic field. As the current composed of a huge quantity of +ve charges moving in the +*ve* (x) direction hence and due to R.H.R. the magnetic field will exerts a force in the –*ve* (z) direction. Hence, if the conductor is free it will move in the direction of the force shown in figure.

So , if we insert a current in such a conductor subjected to a constant magnetic field , a movement will achieved giving the principle of electric motor , which is a transducer changes electric energy to mechanical.



Principle of Generator

Suppose that a conductor (a b) shown in figure moved by certain mechanical mean in the (x-z) plane by a velocity *V* as shown . Then each *+ve* charge inside this conductor will be effected by the magnetic field by a force in the (-z) direction which will leads in a movement of the *+ve* charges to terminal ***b*** while terminal ***a*** will be of (-) polarity, hence , generating an electromotive force in this part of a conductor and it will be an electric s source. Hence the mechanical power transferred to an electric power.



The Magnitude of Force

In previous lesson we deal with the direction of force only, but here we will consider the magnitude of force.

$\overline{F} \alpha q$,

$\overline{F} \alpha \overline{V}$,

$\overline{F} \alpha \overline{B}$,

$\& \overline{F} \alpha \sin\theta$ where θ is the smallest angle between $\overline{V} \& \overline{B}$

Note: $\overline{F}, \overline{V}, \& \overline{B}$ are vector quantities, while *q* is a scalar one

since if any of θ, q, $\overline{V}$, or $\overline{B}$ zero, *F* will be zero then

$$\overline{F} \, \alpha \, q \overline{V} \, \overline{B} \sin\theta$$
$$or \quad \overline{F} = q \overline{V} \, \overline{B} \sin\theta$$

By introducing the cross product principle can write

$$\overline{F} = q \overline{V} \times \overline{B} \quad (N) \quad where\, \overline{V} \times \overline{B} = |V||B| \sin\theta \qquad . \ . \ .... (1.1)$$

The Electromotive Force

In the figure shown suppose that the segment of length *L* (meters) from the conductor is subjected to a magnetic field *B* (*T*) in (-y) direction. since it moves in the (+x) direction in the (x-z) plane parallel to the z-axis. A force *F* (*Newton*) will creates all the *+ve* charges to move a distance *L* in the direction of force *F* so the force will do a *work = FL,* hence using eqn. (1.1)

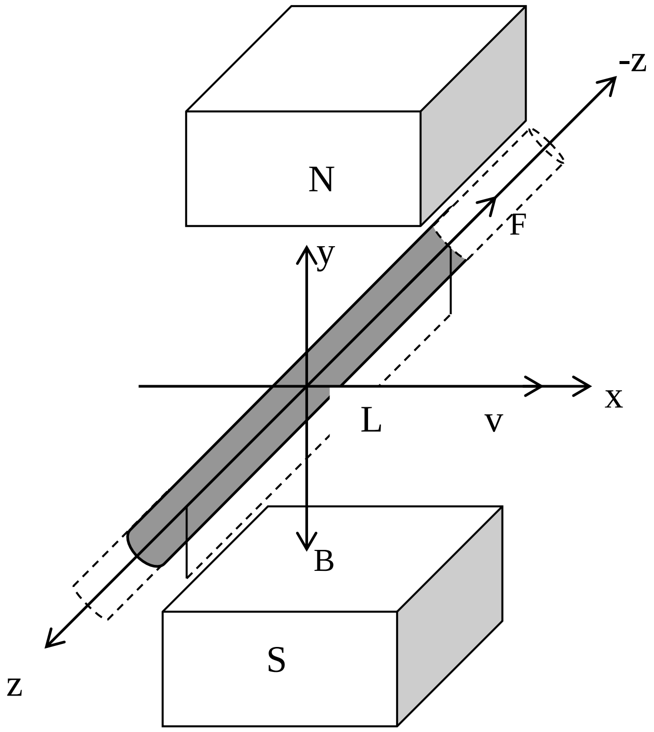
w = qVBL (Joul), since $\theta = 90^\circ$ *&* *sin* $\theta = 1$

Then each charge will have a potential energy (so it has the ability to do work). Then, the potential energy per unit change is

$$\frac{w}{q} = V\,B\,L \quad (Volt)$$

The term "Potential energy per unit change" is abbreviated to one word "Potential" or "Electric Potential". The quantity (*VBL*) is also know as "Electromotive Force" and abbreviated as "*e.m.f.*" (E).

$E = VBL$ ……… (1.2)



Force on a current carrying conductor

Suppose there is a conductor carrying a current density J inside a magnetic field B as shown in figure, J will represents the direction of the drift velocity of the $+ve$ carriers V_1 while the $-ve$ carriers velocity V_2 will be in the reverse direction. For both types of carriers F_1 & F_2 will be in the (-z) direction. Let n_1 and n_2 represents the numbers of positive and negative change carriers per unit volume,

A is the cross – sectional area of the conductor, and L is the length of the conductor influenced by the field. Then, the number of carriers in the portion is the n_1AL and n_2AL and total force F on all carriers (and hence the total force on the wire) has magnitude.

$$F = (n_1AL)(q_1v_1B) + (n_2AL)q_2v_2B = (n_1q_1v_1 + n_2q_2v_2)ALB$$

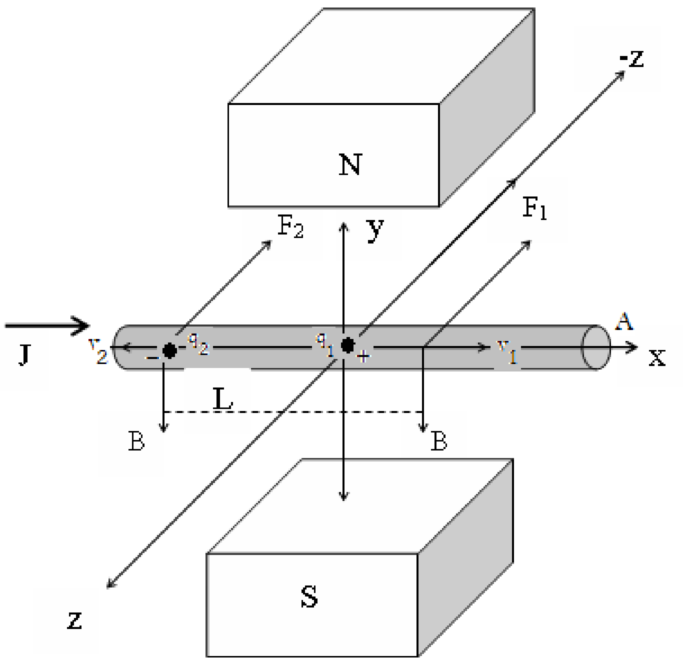
$$= JALB$$

$$F = ILB \qquad \ldots\ldots\ldots\ldots(1.3)$$

In vector form

$$\bar{F} = I L \times \bar{B} \qquad \ldots\ldots\ldots\ldots (1.4)$$

The vector L in the direction of current density $\bar{J}$



<u>Faraday's low</u>

The direction of the force determined by Lenz's law, while the determination of the force magnitude in this case is considers as follow:

For the coil shown if it is subjected to a varying magnetic field the charges will rotates counter clockwise (if the field is downwards and increasing). Due to a force on these charges they will try to accumulate at point (a) while point b will be of *–ve* polarity. Then these chargers accept potential energy due to their position (i.e. an ability to do work). This energy comes from the work done by the induced force in the coil, so the potential energy in this case is called "Induced emf". This *emf* determined by faraday who notice that "The magnitude of the induced emf in a coil due to the effect of a variable magnetic field on its turns is numerically equal to the product of number of turns of the coil and the rate of change of the linkage flux on it" that is

$$E = -N\frac{d\Phi}{dt} \qquad \text{……….} \ (1.5)$$

The *–ve* sign in this law represent the polarity of the induced emf across the terminated of a coil supplied by a.c. current.