3.05. MOVING COIL GALVANOMETER

The moving coil galvanometer was first devised by Kelvin and later on modified by D' Arsonaval. It is also known as ***American type galvanometer.***

It is a device used to detect small current flowing in an electric circuit. With suitable modifications, a moving coil galvanometer can be used to measure current and potential difference.

Principle. *When a current carrying coil is placed in a magnetic field, it experiences a torque.*

Construction. It consists of a coil ABCD suspended between the poles of a permanent magnet NS as shown in Fig. 3.06. The coil is wound on a non-metallic frame and has a central soft iron core. The coil is suspended from the torsion head with a phosphor bronze wire. The other end of the coil is attached to a hair spring. A small concave mirror M is attached to the suspension wire. The whole arrangement is enclosed in a non-magnetic case to avoid disturbance due to air. The galvanometer can be levelled with the help of levelling screws, so that the coil can rotate freely without touching the iron core or the poles of the magnet.

To connect the galvanometer in the circuit, the binding screws T_1 and T_2 are provided at the back of the case of the galvanometer.

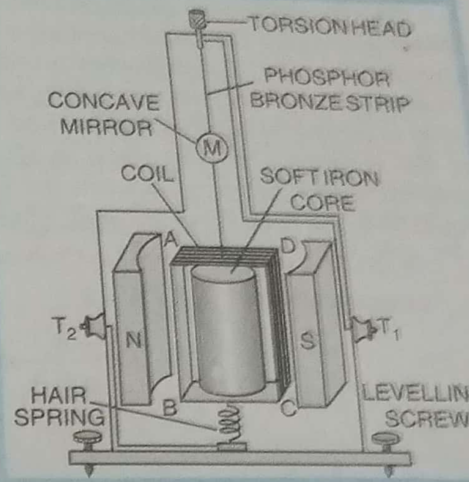

Fig. 3.06

Theory. Suppose that the rectangular coil ABCD having n turns is of length l (= AB or CD) and breadth b (= AD or BC). Let B be the strength of the magnetic field due to the magnet NS. Initially *i.e.* (before passing the current through the galvanometer), the plane of the coil is parallel to the magnetic field. When current is passed through the coil, forces act on the arms of the coil. The forces on arms DA and BC being equal and opposite†, cancel the effect of each other. If current is passed in the direction of ABCD, then

force on arm AB, $F = n\,B\,I\,l$ (normally outwards)

and force on arm CD, $F = n\,B\,I\,l$ (normally inwards)

The two forces are equal, opposite, parallel and act at different points as shown in Fig. 3.07. Hence, the two forces constitute a torque. As the coil rotates under the effect of the torque, the suspension wire gets twisted and a restoring torque is developed in the suspension wire. The coil will rotate, till *the deflecting torque acting on the coil due to flow of current is balanced by the restoring torque developed in the suspension wire due to twisting.* Therefore, in equilibrium,

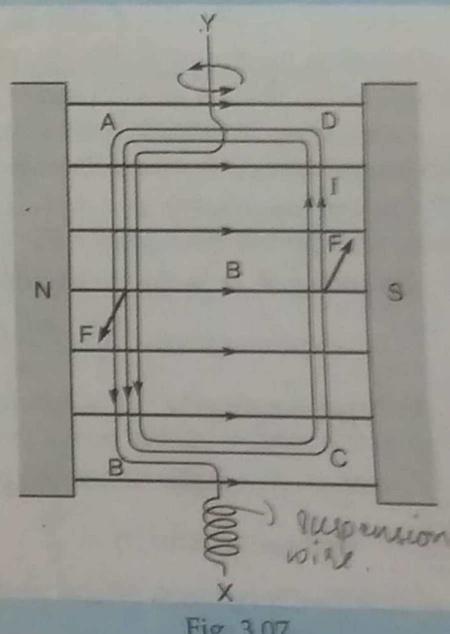

Fig. 3.07

deflecting torque = restoring torque (in magnitude)

*For detailed explanation, refer to S.A.Q. 3.15.

Suppose that the coil comes to rest after rotating through an angle α. In this position, the plane of the coil makes angle α with the direction of the field [Fig. 3.08]. The perpendicular distance between the forces acting on the arms AB and CD is given by

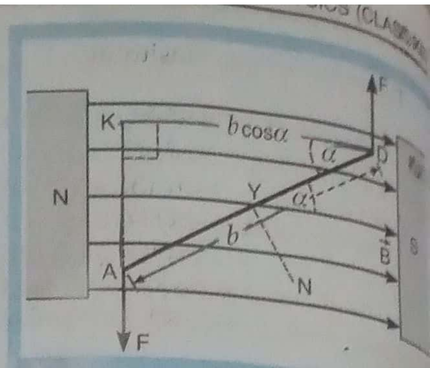

Fig. 3.08

$$DK = AD \cos\alpha = b\cos\alpha$$

Therefore, deflecting torque acting on coil = either force × DK

$$= n\,B\,I\,l \times b\cos\alpha$$

$$= n\,B\,I\,A\cos\alpha, \quad ...(3.14)$$

where $A = l \times b$ is the area of the coil. If k is the restoring torque per unit twist for the material of the suspension wire, then

restoring torque $= k\alpha$

Since in equilibrium, the restoring torque is just equal and opposite to the deflecting torque,

$$n\,B\,I\,A\cos\alpha = k\alpha$$

or
$$I = \frac{k}{n\,B\,A}\cdot\frac{\alpha}{\cos\alpha}$$

Since the factor $\frac{k}{n\,B\,A}$ is constant for the given galvanometer,

$$I \propto \frac{\alpha}{\cos\alpha}$$

As the deflection (α) produced is not directly proportional to the current (I) passing through the galvanometer, a linear scale cannot be used for measuring the current. In order that deflection produced in the coil of the galvanometer may be directly proportional to the current passed, the poles of the magnet are made concave so as to produce ***radial magnetic field***. In such a field, the plane of the coil is parallel to the magnetic lines of force in all positions of the coil [Fig. 3.09] and hence perpendicular distance between the forces on the two arms of the coil is always equal to b, the breadth of the coil. Therefore, in case of radial magnetic field,

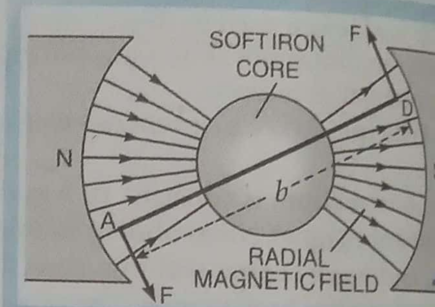

Fig. 3.09

deflecting torque $= n\,B\,I\,l \times b = n\,B\,I\,A$

In equilibrium, $n\,B\,I\,A = k\alpha$

or
$$I = \frac{k}{n\,B\,A}\alpha \quad ...(3.15)$$

or
$$I = G\alpha, \quad ...(3.16)$$

where $G = \frac{k}{n\,B\,A}$ is constant for a galvanometer and is called ***galvanometer constant***.

Hence, $I \propto \alpha$

i.e. deflection produced is directly proportional to the current passed through the galvanometer. Such a galvanometer will have a linear scale.

Sensitivity. *A galvanometer is said to be sensitive, if it gives a large deflection, even when a small current is passed through it or a small voltage is applied across its coil.*

Current sensitivity. *It is defined as the deflection produced in the galvanometer on passing unit current through its coil.*

Therefore, if α is the deflection produced on passing current I, then

$$\text{current sensitivity, } \frac{\alpha}{I} = \frac{n\,B\,A}{k} \quad ...(3.17)$$

Voltage sensitivity. *It is defined as the deflection produced in the galvanometer, when a unit voltage is applied across its coil.*

Therefore, if α is the deflection produced on applying voltage V, then

$$\text{voltage sensitivity} = \frac{\alpha}{V}$$

If R is the resistance of coil and I is the current that passes through coil on applying voltage V, then

$$V = I\,R$$

Therefore, voltage sensitivity, $\frac{\alpha}{V} = \frac{\alpha}{IR} = \frac{nBA}{kR}$ ...(3.18)

3.06. CONDITIONS FOR SENSITIVITY AND ACCURACY OF A MOVING COIL GALVANOMETER

From the expression (3.17) for the current sensitivity, it follows that a galvanometer will be highly sensitive, if

(*i*) *n is large* ; (*ii*) *B is large* ; (*iii*) *A is large* and (*iv*) *k is small.*

However, *n* and A cannot be increased beyond a certain limit, as otherwise the size of the galvanometer and its resistance will become large. Therefore, B is made as large as possible and *k* is made as small as possible. To increase B, a very strong permanent magnet is used. To decrease *k*, the suspension wire is made of phosphor bronze ; as for this material, *k* is very small. The value of *k* further decreases, if the wire is hammered in to a flat strip. In very sensitive galvanometers, quartz fibre is used for suspension of the coil; as for quartz, *k* is still smaller.

Accuracy. The accuracy of a galvanometer implies the extent to which it can measure the current accurately.

It is defined as the reciprocal of the relative error in measuring the current with a galvanometer.

Therefore, accuracy of the galvanometer $= \frac{1}{dI/I}$, ...(3.19)

where dI/I is the relative error in measuring the current. The lesser it is , more will be the accuracy of the galvanometer.

Since I $\propto \alpha$, It follows that an error $d\alpha$ in noting the deflection will cause an error dI in the measurement of current.

$$\therefore \quad \frac{dI}{I} = \frac{d\alpha}{\alpha}$$

Hence, accuracy of the galvanometer $= \frac{1}{dI/I} = \frac{\alpha}{d\alpha}$ ...(3.20)

Thus, a galvanometer will be highly accurate, if it gives a large deflection for a given current.