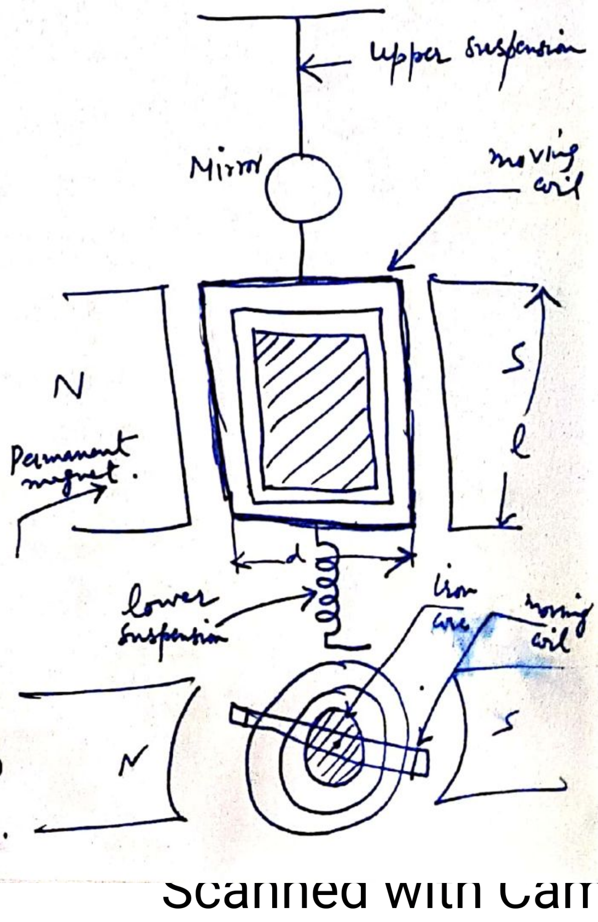
GALVANOMETERS

A galvanometer is an instrument used for detecting presence of small currents and voltages in a circuit or for measuring their magnitudes. Galvanometers find their principal application in bridge and potentiometer measurements where their function is to indicate zero current. Therefore, a galvanometer, in addition to being sensitive, should have a stable zero, a short periodic time and nearly critical damping.

D' Arsonval Galvanometer

used in various methods of resistance measurement and also in D.C. potentiometer work.

Fig 1.



Construction

The various parts are

(1) **Moving coil**: It is the current carrying element. It is either rectangular or circular in shape and consists of a no. of turns of fine wire. The coil is suspended so that it is free to rotate about its vertical axis of symmetry. It is arranged in a uniform, radial, horizontal magnetic field in the airgap b/w polepieces of a permanent magnet + iron core.

The iron core is used to provide a flux path of low reluctance and therefore to produce strong magnetic field for the coil to move in. This increases the deflecting torque and hence the sensitivity of the galvanometer.

(2) Damping : Damping torque is ~~provided~~ produced due to production of eddy currents in the metal former on which the coil is mounted. Damping is also obtained by connecting a low resistance across the galvanometer terminals. Damping torque depends upon the resistance and thus critical damping can be obtained by adjusting the value of resistance.

(3) Suspension : The coil is supported by a flat ribbon suspension which also carries current to the coil. The other current connection is a sensitive galvanometer is a coiled wire. This is called the lower suspension and has a negligible torque effect. Careful levelling is required so that coil hangs straight and centrally w/o rubbing the poles or soft iron cylinder. Taut suspension can be used so that suspension is improved and exact levelling is not required.

(4) Indication : The suspension carries a small mirror upon which a beam of light is cast. This beam of light is reflected on to a scale upon which the deflection is measured. This scale is usually 1 metre away from the instrument, although $\frac{1}{2}$ m can be used for greater compactness.

Torque Equation :

Refer to fig 1; we have,

Let l, d = length of ~~to~~ vertical & horizontal side of coil ; m .
(height) (width).

N = no. of turns in the coil

B = Flux density in the airgap (Wb/m^2).

i = current through moving coil ; A

K = spring constant ; (Nm/rad)

θ_F = Final Steady deflection of coil ; rad ;

Force on each side of coil $F = N B i l \sin\alpha$ (Biot-Savart Law).

where α = angle b/w direction of magnetic field & the conductor ;

for radial field $\alpha = 90^\circ$; $\therefore \sin\alpha = 1$;

Force ~~of~~ on each side of coil = $NBil$

Deflecting torque T_d = force × distance = $NBild$

$T_d = NBAi$ where $A = l \times d$; (area of coil) ; m^2.

Now $N, B, \& A$ are constants . $NBA = G$.

$$\boxed{T_d = G i}$$ where G = Displacement constant = (N-m/A)

Now for spring control $T_c = K\theta_F$; ~~for~~

At balance ; $T_c = T_d$;

$K\theta_F = G i$ or $\boxed{\theta_F = \dfrac{G i}{K}}$

Thus deflection is proportional to current i.

Dynamic Behaviour of Galvanometers :-

We have so far considered the steadystate relationship of deflection w.r.t. current. When we pass current through a galvanometer, it does not reach its steadystate value immediately but there is a time interval or period of transition during which the moving system of the galvanometer deflects from its initial position to the final steady state position. The dynamic behaviour of the galvanometer during this period is examined by the equation of motion. This equation helps us to study most of problems related to speed of response, overshoot & damping.

Intrinsic Constants of a D' Assonval Galvanometer

(i) Displacement constant

Deflecting Torque $\boxed{T_d = G i}$;

where G = Displacement constant (N-m/A);

& is equal to NBA or $NBld$;

(ii) Inertia constant :- The inertia torque produced due to inertia of moving system & which is a retarding torque. It depends upon moment of inertia & angular acceleration.

$$\boxed{T_i = J \cdot \frac{d^2\theta}{dt^2}}$$

where J = Inertia Constant ($N\text{-}m/rad\,sec^{-2}$).
– ($Kg\text{-}m^2$)

θ = Deflection at any time (rad).

(iii) Damping constant

The damping torque is proportional to velocity of moving system. Combining all effects of damping together we express damping torque as:

$$\boxed{T_D = D\frac{d\theta}{dt}}$$

where D = Damping constant. units are N-m/rad sec^{-1}.

This torque is also a retarding torque.

(iv) Control Constant A controlling torque is produced due to elasticity of the system which tries restore the moving system back to its original position.

Controlling torque, $\boxed{T_C = K\theta}$ where K = Control constt = Spring " = Torsion cost.

It is also a retarding torque.

Equation of Motion :-

Thus there are four (04) torques acting on the moving system; Deflecting torque T_D ~~&~~ tries to accelerate the system while ~~&~~ inertia torque T_i, damping torque T_D, and controlling torque T_C, try to retard the system. Therefore for any deflection θ at any instant.

$$\boxed{T_d = T_i + T_D + T_C}$$

or $$J\frac{d^2\theta}{dt^2} + D\frac{d\theta}{dt} + K\theta = T_d \quad \text{—— (1)}$$

This linear second order differential equation is called the equation of motion and represents the motion of galvanometer.

In order to express the deflection θ as a function of time, we have to solve the equation. The solution is comprised of two parts. complementary function & particular integral.

CF: is obtained from auxillary equation -

$$Jm^2 + Dm + K = 0$$

$$m_1 = \frac{-D \pm \sqrt{D^2 - 4ac}}{2J}, \quad m_2 = \frac{-D - \sqrt{D^2 - 4ac}}{2J}$$

Thus $\theta = Ae^{m_1 t} + Be^{m_2 t}$.

PI we pass a steady current i through the galv.

under steady state; $\frac{d^2\theta}{dt^2} = 0$, $\frac{d\theta}{dt} = 0$; & $\theta = \theta_F$;

from eqn (1), we get,

$$K\theta_F = ~~T~~ Td = Gi$$

$$\boxed{\theta_F = \frac{G}{K} i}$$ —— is the PI.

Thus complete solution is $\theta =$ CF + PI

$$\boxed{\theta = Ae^{m_1 t} + Be^{m_2 t} + \theta_F}$$

The part of solution is $Ae^{m_1 t} + Be^{m_2 t}$ represents the transient part which exists for a very short period and may or may not be oscillatory. ~~and the~~ once those transients are dead, whatever is left is θ_F which we call final steady deflection.

The nature of roots m_1 & m_2 determine the transient response. These are describe the behaviour of three possibilities :—

Case 1   if $D^2 < 4KJ$

The roots m_1 & m_2 are imaginary. The motion is oscillatory. The galvanometer oscillates about its final steady position with decreasing amplitude before finally settling at its final steady position. The galvanometer is said to be underdamped.

Case 2   if $D^2 = 4KJ$; In this case both roots are equal and real. The response is non-oscillatory and final steady position is reached in the shortest time and without any overshoots. The galvanometer is said to be critically damped.

Case 3 $D^2 > 4KJ$; The motion is non-oscillatory

Both roots are real. but the galvanometer reaches its final position in a sluggish manner. The galvanometer is overdamped.

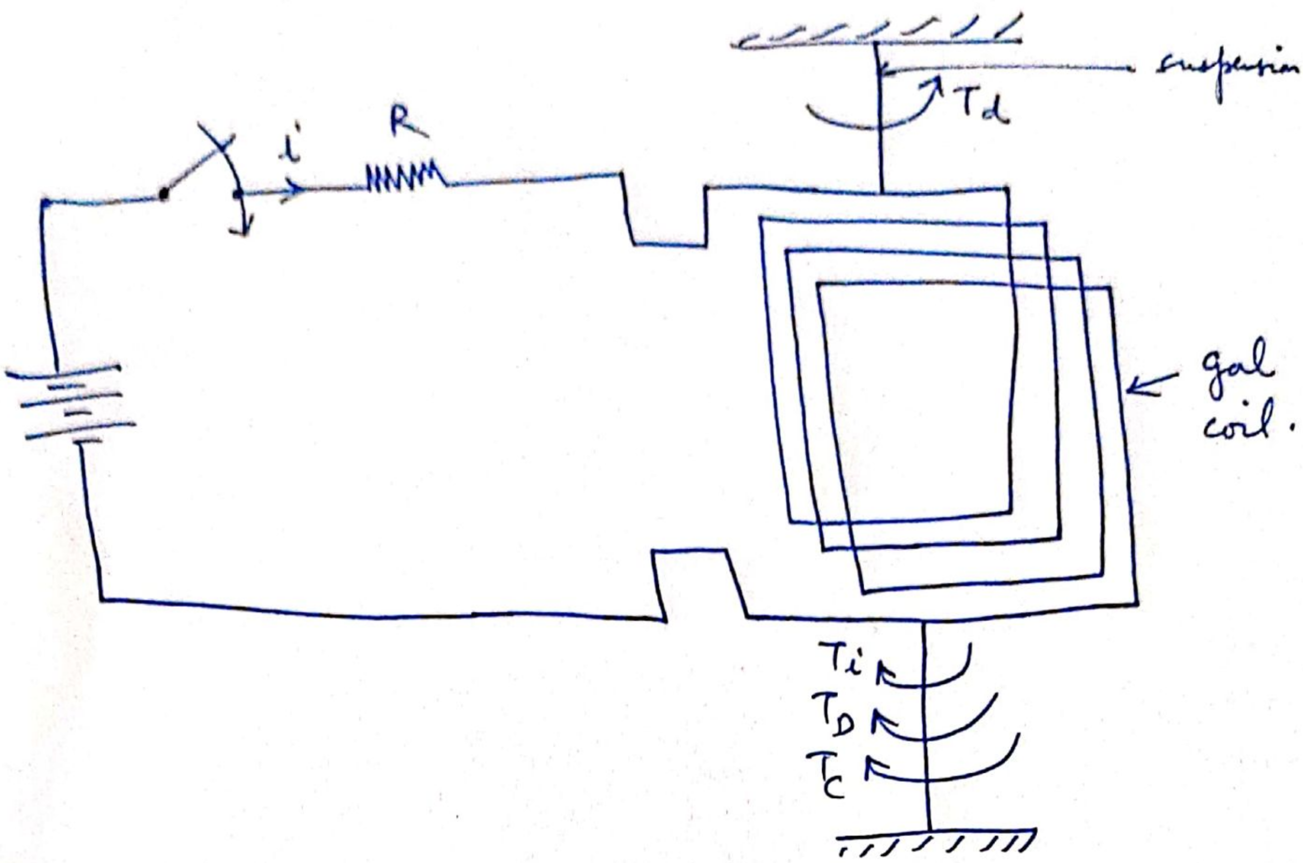


Fig 2.

Torques acting on a Galvanometer.

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