B.Sc. Part II

Paper IV

Current electricity

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Current electricity.

Charge Sensitivity of a Ballistic Galvanometer.

The Charge Sensitivity of a ballistic galvanometer is defined as The Throw in m.m. produced on a Scale placed one meter away from The galvanometer mirror when one micro-Coulomb Charge passes through it.

When a charge q passes Through a ballistic Galvanometer. it given an angular impulse to The Coil which is set in oscillation. we know That

$$q = \frac{T}{2\pi} \frac{e}{NBA} \phi_0 ;$$

where T is The time period of oscillation of coil, e The restoring torque per unit twist in The suspension, N The number of turns in The coil, B The magnitude of The magnetic induction of The radial magnetic field, A The area of The coil and ϕ_0 be The angle of Throw of The coil.

suppose The scale is placed at a distance D from The galvanometer mirror. As The coil rotates Through angle ϕ_0. The reflected beam is turned Through $2\phi_0$. Let The spot of light deflects Through a distance d on The Scale.

Then $$2\phi_0 = \frac{d}{D}$$

or $$\phi_0 = \frac{d}{2D}$$

Let d is in m. m. and D = 1 meter = 1000 m.m.

Then $$\phi_0 = \frac{d}{2000}$$

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Then $q = \frac{T}{2\pi} \frac{C}{NBA} \frac{d}{2000}$

Let q is in micro coulomb, Then

$$q \times 10^{-6} = T/2\pi \; C/NBA \; d/2000$$

So That $\frac{d}{q} = (2 \times 10^{-3}) \frac{2\pi}{T} \frac{NBA}{C}$.

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where d/q is The charge Sensitivity of The galvanometer.

Thus Charge Sensitivity.

$$= (2 \times 10^{-3}) \frac{2\pi}{T} \frac{NBA}{C} \quad \text{——} (1)$$

Current sensitivity of a Ballistic Galvanometer :-

The Current Sensitivity of The galvanometer is defined as The deflection in m.m. Produced on a scale Placed one meter away when one micro-ampere Current flows Through it.

We know That if a steady current i Produces a steady deflection ϕ, Then

$$i = \frac{C}{NBA} \phi \quad \frac{d}{q} = (2 \times 10^{-3}) \frac{2\pi}{T} \frac{NBA}{C}.$$

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Let i is ~~TQ~~ in micro-ampere, Then as above

$$i \times 10^{-6} = \frac{C}{NBA} \cdot \frac{d}{2000}$$

So that $\frac{d}{i} = (2\times10^{-3}) \frac{NBA}{C}$

where, d/i is the current sensitivity. Thus

Current sensitivity $= (2\times10^{-3}) \frac{NBA}{C}$ —— (2)

From equ^n (1) and (2), we have

Charge sensitivity $= \frac{2\pi}{T} \times$ current sensitivity

This is the relation between charge sensitivity and current sensitivity

The motion of the coil is damped due to the viscosity of air and the opposing current induced in the coil and the frame of the coil which i rotate in the field of the permanent magnet of the galvanometer. Although we minimise this electromagnetic damping by winding the coil on a non-conducting frame, but the damping due to the viscosity of air is always present. Therefore the coil oscillates with a decreasing amplitude. Hence the observed throw of the coil is smaller than its true value ϕ_0 which would have been if damping were entirely absent. Thus a correction is necessary.

Let ϕ_1, ϕ_2, ϕ_3 --- = be the successive throws observed at the end of the first, second third -- swings of the coil in which ϕ, ϕ_3 -- are ~~one~~ on one side of the rest position of the coil and ϕ_2, ϕ_4 .. --- on the other.

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it is found that $\frac{\phi_1}{\phi_2} = \frac{\phi_2}{\phi_3} = \frac{\phi_3}{\phi_4} = \text{---} \; d$

where is constant which is called the decrement per half vibration and $\log_e d$ is called the logarithmic decrement λ. Therefore

$\log_e d = \lambda$

or $d = e^{\lambda}$

Thus, for half a vibration, the decrement is

$\frac{\phi_1}{\phi_2} = \frac{\phi_2}{\phi_3} = \frac{\phi_3}{\phi_4} = \text{-----} = e^{\lambda}$.

and so for a full vibration, the decrement is

$\frac{\phi_1}{\phi_3} = \frac{\phi_2}{\phi_4} = \frac{\phi_2}{\phi_3} = e^{2\lambda}$ and so on.

Therefore, it is clear that decrement for a quarter of a vibration $e^{\lambda/2}$.

The calculating the true throw ϕ_0 in the absence of damping, the firs throw ϕ is observed after the coil completes a quarter of vibration. Therefore the decrement is

$\frac{\phi_0}{\phi_1} = e^{\lambda/2}$

or $\phi_0 = \phi_1 e^{\lambda/2} = \phi_1 \left(1 + \frac{\lambda}{2} + \text{---}\right)$

as λ is small, terms containing λ^2, λ^3 etc. can be neglected $\therefore \phi_0 = \phi_1 \left(1 + \frac{\lambda}{2}\right)$

substituting this value of ϕ_0 in equ^n 1 we get

$q = \frac{T}{2\pi} \frac{C}{NBA} \phi_1 \left(1 + \frac{\lambda}{2}\right)$

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This is the relation between the charge passed and the first throw observed. The value of λ is found by observing ϕ_1 and ϕ_{11}^*

Thus $$\frac{\phi_1}{\phi_{11}^*} = e^{10\lambda}$$

or $$\lambda = \frac{1}{10}\log_e\frac{\phi_1}{\phi_{11}} = \frac{1}{10}\times 2.3026\times\log_{10}\frac{\phi_1}{\phi_{11}}$$

Use of Moving Coil Ballistic Galvanometer:-

Moving coil ballistic galvanometer is also used for measurement of capacitance of a capacitor, comparison of capacitance of two capacitor and comparison of e.m.f's of two cells

Critical Resistance :-

For the galvanometer to be ballistic or deadbeat depends also on the external resistance of the circuit in which the galvanometer is placed. Smaller the resistance larger will be the induced current & greater the damping with a sufficient small external resistance the motion ceases to be oscillatory, the coil making only one swing and returning slowly to its rest position. The particular resistance for which the motion just ceases to be oscillatory is called the critical external damping resistance or only critical resistance and the galvanometer is then said to be critically damped. With more resistance is under-damped and with less resistance it is over damped.