SelfStudy.in

Dolezalek Quadrant Electrometer :

Construction: It consists of a hollow cylinderical box of brass, 5 cm in diameter & 1 cm in height, cut into four hollow quadrants which are mounted on insulating stands. A light paddle made of thin paper coated with silver or aluminium, in the shape of a double-sector is suspended by a phosphor bronze strip or a quartz fibre from a torsion head. The torsion head can be rotated as well as raised or lowered and then clamped in any position, so that the needle is free to swing in a horizontal plane without touching the quadrants. The deflection of the needle is measured with lamp and scale arrangement reflection being take place from a tiny mirror attached to the suspension fibre. The whole instrument is enclosed in a metal box which is earthed to protect it from stary electric field and disturbance of air draughts. There is a window for the light beam to pass. The whole instrument is based on three levelling screws.

SelfStudy.in

Principle or Theory: When AA and BB are earthed or charged to same potential, the needle rests symmetrically between them but when these are charged to a different potentials the needle deflects from higher to lower potential. The needle comes to rest when the deflecting couple due to P.d becomes equal to the restoring couple due to twist. The deflection 'θ' then becomes proportional to the difference of potential, which can be deduced by the energy evaluation method.

When the needle is deflected through an angle 'θ' then surface $\frac{1}{2}(r)(r\theta) = \frac{1}{2}r^2\theta$ (area of the triangle) is transfered from under the Quadrants AA to BB. Now since the needle has two arms and two faces the total area transfered from AA to BB

$$= 4 \times \frac{1}{2} r^2\theta = 2r^2\theta.$$

Here we will assume that quadrants being edge to edge, the direct capacity between them is negligible in comparison to the capacity between the quadrants & needle.

Due to the transference of area of the needle, the capacity of AN condenser will decrease by an amount $c = \frac{k_0 2r^2\theta}{t}$ farad.

where t = thickness of air space between needle and the quadrant and

the capacity of BN condenser will increase by same amount.

Loss of ~~energy~~ charge by AN condenser = Cap × P.d

$$= \frac{\epsilon_0 2r^2\theta}{t}(V_0 - V_a)$$

Loss of energy of AN condenser = Charge × P.d

$$= \frac{\epsilon_0 2r^2\theta}{t}(V_0 - V_a)^2 \quad \text{---(1)}$$

Gain of electrical energy of BN condenser

$$= \frac{\epsilon_0 2r^2\theta}{t}(V_0 - V_b)^2 \quad \text{---(2)}$$

The net gain of energy $= \frac{2\epsilon_0 r^2\theta}{t}\left[(V_0-V_b)^2 - (V_0-V_a)^2\right]$

$$= \frac{2\epsilon_0 r^2\theta}{t}\left[(V_a - V_b)\left\{2V_0 - (V_a+V_b)\right\}\right]$$

$$\therefore W = \frac{4\epsilon_0 r^2\theta}{t}\left[V_0 - \left(\frac{V_a+V_b}{2}\right)\right](V_a - V_b) \quad \text{---(3)}$$

This excess energy is supplied to the electrometer from the source of supply producing P.d $(V_a - V_b)$. This energy does two things:

① Increases the electrical potential energy of the system and

② performs mechanical work in twisting the suspension fibre when the deflection of the needle takes place.

The P.E of the charge on A-N condenser has been reduced by

$$\frac{1}{2}CV^2 = \frac{1}{2}\frac{\epsilon_0 \cdot 2r^2\theta}{t}(V_0 - V_a)^2 \quad \text{---④}$$

SelfStudy.in

The gain in electrical P.E of the B-M condenser

$$= \frac{1}{2}\epsilon_0 . 2r^2\theta (V_0 - V_b)^2 \quad \text{—— (5)}$$

The net gain in electrical P.E

$$= \frac{2\epsilon_0 r^2 \theta}{t}\left[V_0 - \left(\frac{V_a + V_b}{2}\right)\right](V_a - V_b) \quad \text{—— (6)}$$

The energy available for twisting the fibre is therefore $= \frac{2\epsilon_0 r^2\theta}{t}\left[V_0 - \left(\frac{V_a+V_b}{2}\right)\right](V_a - V_b)$

which produces a deflection θ.

Energy for deflection = couple × θ

$$\text{or} \quad \frac{1}{2}C\theta^2 = \frac{2\epsilon_0 r^2\theta}{t}(V_a - V_b)\left[V_0 - \left(\frac{V_a+V_b}{2}\right)\right]$$

$$\text{or,} \quad \theta = K(V_a - V_b)\left[V_0 - \frac{(V_a+V_b)}{2}\right], \quad K = \frac{4\epsilon_0 r^2}{Ct} = \text{const}$$

There are two ways of using a quadrant electrometer as a potential measurer.

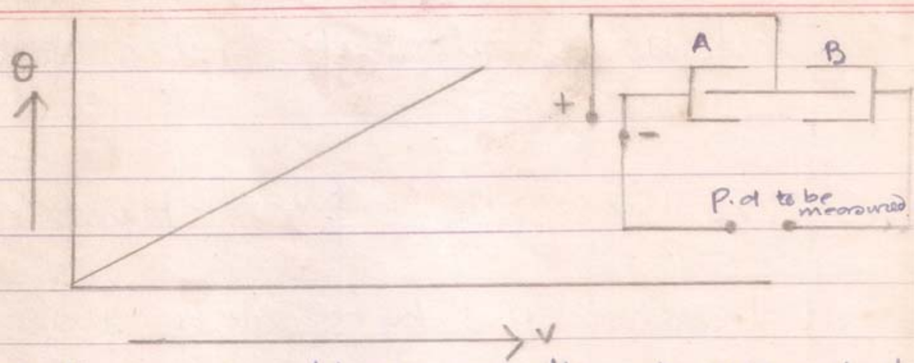
1. Heterostatic use: Here the needle is charged to a very high potential (V_0) as compared to V_a and V_b. Thus $V_0 >> V_a$ & V_b

$$\therefore \theta = K(V_a - V_b)V_0 \quad \text{—— (8)}$$

$$= K'(V_a - V_b) \quad \text{—— (9)} \qquad \text{where } K' = KV_0$$

Hence the deflection in Heterostatic use is directly proportional to p.d.

Graph:

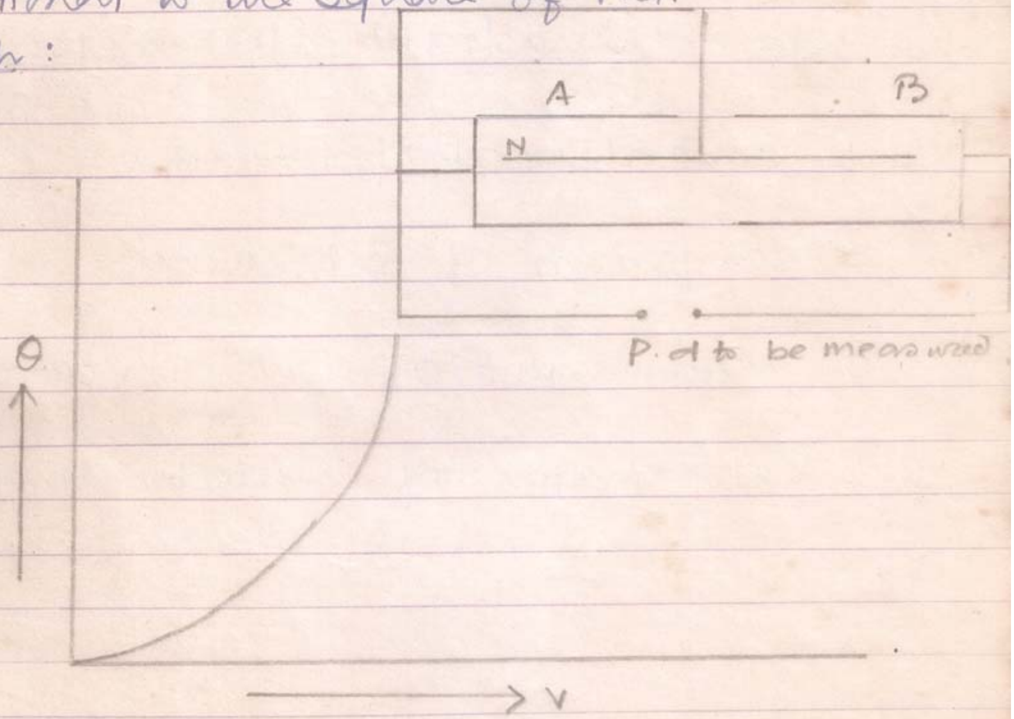


(2). Idiostatic use: Here needle is connected to one pair of Quadrants A A. The unknown potential difference is applied across BB and common contact of AA & N. Thus $V_0 = V_a$.

$$\therefore \theta = \frac{1}{2} K (V_a - V_b)^2 = K'' (V_a - V_b)^2 \quad \text{—(10)}$$

Hence the deflection in idiostatic use is proportional to the square of P.d.

Graph:



Relative merits of Heterostatic use and Idiostatic use :-

We have $\frac{K'}{K''} = 2V_0$. Hence $K' >> K''$ &

therefore the heterostatic use is more accurate than idiostatic use as a small P.d prod a much larger deflection in the former case. Another great advantage of heterostatic use is that deflection is proportional to the P.d. When the instrument is used idiostatically the deflection is proportional to the square of the P.d and independent of the direction and hence the instrument can be used for the measurement of alternating p.d.

Uses of Quadrant Electrometer :-

①. Comparison of potentials.

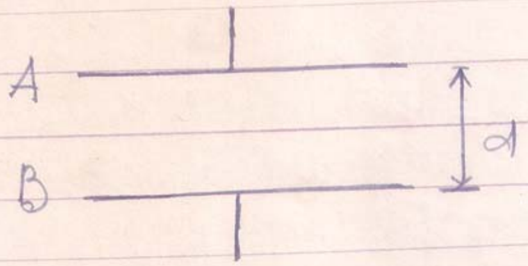
②. Comparison of Capacitance.

③. Measurement of ionisation current.

④. Determination of Dielectric constants.

SelfStudy.in

S.I.C of a gas: By Boltzmann method:



Potential of plat A = V, when the space between A & B is vacuum.

When the gas is introduced, potential of the plate A falls to V'. Because ;

$$V = E \times d = \frac{\sigma}{\epsilon_0} . d$$ where σ = Surface density of charge on the plate.

when the gas is introduced, the surface density of charge on the plate remains same but due to change in permitivity of the medium E changes and hence V changes.

$$V' = E' d = \frac{\sigma}{\epsilon} . d = \frac{\sigma}{\epsilon_0} d . \frac{\epsilon_0}{\epsilon}$$

$$V' = \frac{V}{\epsilon_r}$$