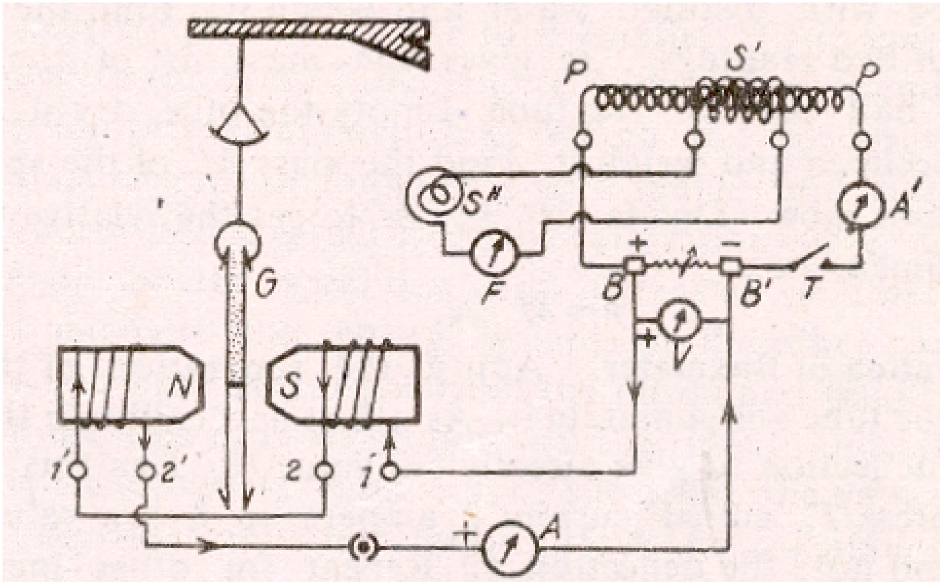
QUINCKE'S METHOD



An Electromagnet (capable of producing field of the order of 10,000 oersteds), Power supply unit including ammeter, Travelling microscope (or cathetometer). Fluxmeter connected with a search coil, a paramagnetic substance ($NiSO_4$ or $MnCl_2 . 4H_2O$) U-tube, funnel water, flask (100 c.c), weighing bottle, physical balance and weight box, etc.

Formula used

: The mass susceptibility of a solution is given by

$$Xm = \frac{K}{p} = \frac{2gh}{H^2}$$

where K = Volume susceptibility of the solution.
p = density of the solution,
h = rise of the liquid in capillary tube placed inside the magnetic field,
g = acceleration due to gravity,
H = magnetic field intensity between pole pieces to be measured by using fluxmeter

Description of the app.

The (experimental) solution of $MnCl_2$ (paramagnetic salt) is taken in a glass U tube (or rubber tube) whose one limb is wide and the other is narrow. The narrow limb of the tube is placed in a magnetic field (i.e. between the polepieces of the electromagnet) while the wider limb is slightly away from it. Thus the wider limb can be assumed to be in a field of negligible intensity. When the current is sent through the coils of the electromagnet, the meniscus of the liquid (of paramagnetic substance like $NiSO_4$ or $MnCl_2$) in the narrow limb rises (or falls in the case of diamagnetic substance like water). This rise of meniscus is measured by means of a travelling microscope.

Principle and Theory : When a solution of a paramagnetic salt (i.e. $MnCl_2$) or ferromagnetic salt ($FeCl_3$) taken in a tube, is placed between the pole of a magnet, there is a rise of the liquid level. A measurement of this rise enables to determine the susceptibility of the solution.

The magnetic field between the wedge-shapedpole pieces varies rapidly along the vertical. The force on a substance of volume V, situated in a non-uniform magnetic field at a place of field strength H_p, is given by

$$F = \frac{1}{2} (K-K_0) \frac{d H_p^2}{dx} V \qquad \text{... (1)}$$

where K is the magnetic susceptibility of the substance and K_0 that of the surrounding medium (which is assumed to be zero for air), So we can write

$$F = \frac{1}{2} K \frac{d H_p^2}{dx} V \qquad \text{... (2)}$$

Let the position of levels of the solution be AB (in the wider limb) and C (in the narrow limb) before the field is applied. On applying the field, let the new levels be A' B' and D respectively. Thus the rise in the level of the solution in the narrow limb is CD (=h, say). Let a' and a be areas of section

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of the wider limb and narrow limb respectively. The level in the wider limb has sunk from AB to A'B', Hence D stands at a height above the general level, greater then h. If the level AB sunks through a distance d, then a volume a'd of solution has passed into the other narrow limb and now lies above the level C. Thus we can write

$$a'd = ah$$

OR $$d = \frac{a\,h}{a'}$$

Since h is the rise in the level of the solution in the narrow beam and d is the fall in the wider limb, the corrected height is h +d. This a' is height of the liquid column supported by the forces arising from the magnetic field. If p be the density of the solution and g the acceleration due to gravity, then the weight of this

l

$$= 1 + \frac{a}{a'}\ hpga \qquad \dots (3)$$

Now, let O be a section where the field is negligible. Let x be the vertical coordinate of O. The force on a liquid element of volume (V = adx), above the point O (using equation 2) is given by

$$dF = \frac{1}{2} K \frac{d\,Hp2}{dx} (adx) \qquad \dots (4)$$

If H be the field intensity at the upper level, then the force on the entire liquid above the point O is therefore

$$F = -\frac{1}{2} Ka \int H \frac{dH_p^{\,2}}{dx} dx = \frac{1}{2} K a H^2$$

It is this force which supports, the weight column obtained in equation (3). Thus, equating (3) and (5)

$$\frac{1}{2} K a h^2 = 1 + \frac{a}{a^1}\ hpga$$

If a<a1, the ratio a/a1 may be neglected. So

$$\frac{1}{2} K a H^2 = hpga$$

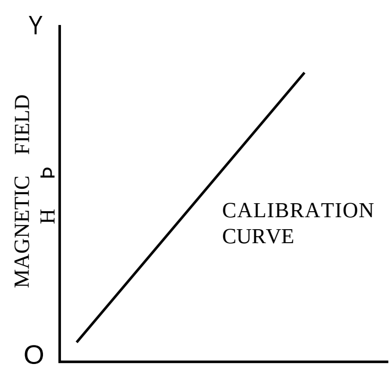
$$= \qquad K = \frac{2pgh}{H^2}\ \text{e.m.u./cm}^3 \ \dots (6)$$

This is the volume susceptibility of the solution. Dividing this volume susceptibility by the density p, gives the mass susceptibility of the solution.

PART (B) Measurement of Susceptibility :

1. Dissolve a known quantity of paramagnetic salt (25 gm of $MnCl_2$ or $NiSO_4$ or Ferrous ammonium sulphate) in the known volume of water (100 c.c.) in the flask and thus prepare a solution of known strength.
2. Clean the U-tube with warm chromic acid and insert its narrow limb vertically between the pole pieces of the electromagnet. Pour the prepared solution in it to such an extent that the level in the capillary reaches (below the centre of the poles of electromagnet NS) at C so that when the field is applied, the menisus reaches in the centre of the poles of magnet NS.
3. Illuminate the menisus with an ordinary lamp and observe it with a travelling microscope (or cathetometer). Focus the position of this meniscus in the travelling microscope and bring the horizontal cross wire of the eyepiece on the meniscus. Note down this reading on its vertical scale.
4. Switch on the power supply and send a suitable current i in the electromagnet to apply a magnetic field on the solution meniscus. The value of this magnetising current i is noted by means of ammeter A.
5. When the magnetic field is applied, the level in the capillary rises. When the rise of the liquid column becomes constant (or ends), note down this new level by travelling microscope. The difference of the initial and final readings gives the rise, h.
6. Change the value of current i through the coils of the electromagnet (to change the value of the magnetising field) and again note the final reading of the meniscus.
7. Also note the density of the solution.
8. Repeat the experiment by taking solutions having different concentrations of paramagnetic salt.

S.No.	Current i (amp)	Fluxmeter Reading: Initial position of pointer $Ø_1$ (div).	Final position of $Ø_2$ (div.)	Deflection $Ø$ (= $Ø_2$ - $Ø_1$)	Magnetic field $H = \frac{Ø \times b}{A \times N}$ (oersted)
1	...	...	...	...	...
2	...	...	...	...	...
3	...	...	...	...	...
4	...	...	...	...	...
5	...	...	...	...	...
6	...	...	...	...	...



OBSERVATIONS :

(a) For calibration of the Fluxmeter :

Number of turns in the search coil,
N = ...

Mean area of the search coil,
A = ... sq.cm.

Number of Maxwell turns corresponding to one division of fluxmeter, b = ...