DEPARTMENT OF PHYSICS

LAB MANUVAL

LIST OF THE EXPERIMENTS:

1. .Compound Pendulum -Determination of 'g' and 'k'.
2. Young's modulus –non-uniform bending -Pin and microscope

3. Rigidity modulus -Torsional Pendulum -without masses.

4. Young's modulus cantilever- depression- dynamic method-Mirror, Scale and Telescope

5. Young's modulus –non-uniform bending -Optic lever

6. Young's modulus - Koenig's method - non- uniform bending.
   Young's modulus -Koenig's method - uniform bending.

7. Rigidity modulus -Static torsion -Mirror, scale and telescope

8. Coefficient of viscosity of liquid-Graduated burette -

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10. Thermal conductivity of a poor conductor -Lee's disc method

11. Sonometer -Frequency of Tuning fork.
12. . Sonometer- Frequency of AC mains - Steel and Brass wires

13. Focal length -R and μ of a convex lens [focal length i) u-v and ii) conjugate foci

14. Spectrometer -Solid prism- Refractive indexof material of a prism

15. Spectrometer -i-d curve-μ of a Prism

16. Spectrometer i- i' Curve.

17. Spectrometer-Dispersive power of a prism.
18. Spectrometer-Dispersive power of a grating

19. Spectrometer -Solid prism- Refractive indexof material of a prism.
20. Spectrometer -Grating -N and λ -Normal incidence method.

21. Spectrometer -Grating -N and λ -Minimum deviation method

22. Newton's rings -Refractive index of material a convex lines

23. . Air wedge - Thickness of a thin wire.

24. Deflection magnetometer and vibration magnetometer-Determination of m and B_HTanC position.

25. Field along the axis of circular coil -Deflection magnetometer -M and B_H- Null Deflection Method.
26. Field along the axis of circular coil –Vibration magnetometer -Determination of B_H.

27. Potentiometer - Resistance and specific resistance of a wire.

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29. Potentiometer –Calibration of high range Voltmeter

30. Potentiometer - Conversion of galvanometer into Ammeter.

31. Potentiometer – EMF of a thermo couple.

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35. Logic gates-AND, OR (using diodes) and NOT (using transistor).

14. Compound Pendulum (Method I)

AIM. To determine the periods of oscillation of the compound pendulum about various points of suspension on both sides of the centre of gravity, to draw a suitable graph and use it to determine the radius of gyration about the centre of gravity of the bar and the value of acceleration due to gravity at the place. Also to find the moment of inertia of the bar about its centre of gravity.

Apparatus. Compound pendulum, knife-edge, stop watch and a berranger balance.

Description. A compound pendulum consists of a uniform rectangular metal bar *AB* made of iron or brass. A number of circular holes are bored all along the bar from one end to the other at regular intervals.

The bar can be made to oscillate about a knife-edge passing through any of these holes.

Procedure. The bar is first suspended by the knife-edge passing through the topmost hole on one side of the C.G. of the bar. The bar is set to oscillations without wobbling. After omitting the first few oscillations, the time taken for a known number of oscillations and hence the period *T* sec. for one oscillation is determined. The distance (*d*) between the knife-edge and the end *A* is measured. Suspending the bar at different holes from *A*, the period of oscillation in each case is found, noting the distance (*d*) of the knife-edge from the end *A*. When the centre of the bar is crossed, the bar is inverted to the other side of C.G and periods of oscillation are determined in each case suspending the bar through the different holes. But the distance of the knife-edge is noted from the end *A* only.

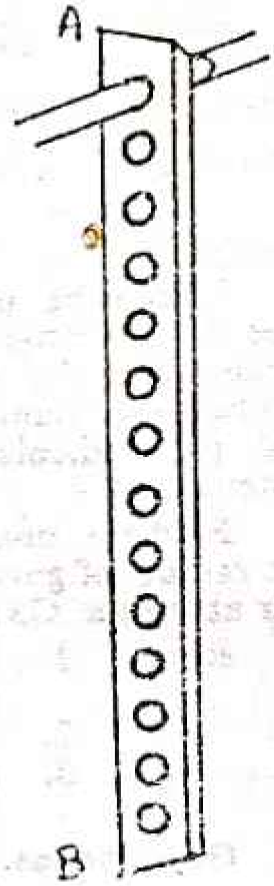


Fig. 14·1

A graph is drawn taking the distance of the knife-edge from the end *A* along *X*-axis and the corresponding period of oscillation along *Y*-axis. There will be two symmetrical curves on either side of the C.G. as shown in fig. 14·2.

For any period *T*, draw a horizontal line which will cut the curve at four points *A, B, C, D*. Then the length of equivalent simple pendulum is given by

$$l = \frac{AC + BD}{2}$$

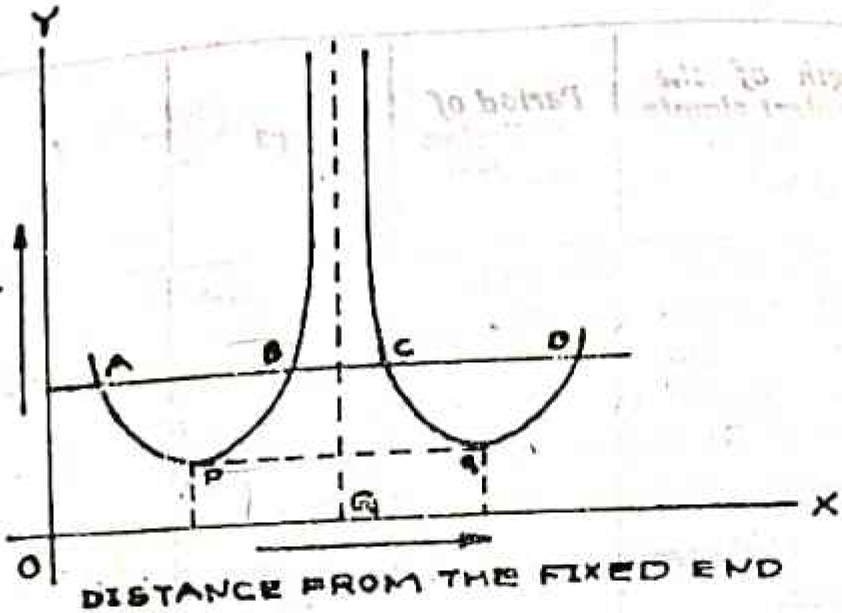


Fig. 14·2

Calculate $\frac{l}{T^2}$. Choosing different periods, the length of the equivalent simple pendulum is found from the graph and $\frac{l}{T^2}$ calculated. Acceleration due to gravity is given by the formula

$$g = 4\pi^2 \left(\frac{l}{T^2}\right).$$

Locate the positions of the minimum period of the two curves. The line parallel to the X-axis joining these two positions gives the value $2K$ in the scale of X-axis, where K is the radius of gyration of the bar pendulum about an axis passing through its centre of gravity and perpendicular to its length. Thus, $PQ=2K$. From this K is obtained.

Find the mass (M kg.) of the bar by a berranger balance. If K is the radius of gyration about the C.G. the moment of inertia of the bar about its C.G. is given by $I=MK^2$ kg-m².

Result. 1. Mean acceleration due to gravity at the place $=\ldots$m/sec²
2. Radius of gyration $=\ldots$m
3. Moment of inertia of the bar about its C.G. $=\ldots$kg-m²

Observations. Mass of the bar by a berranger balance $=M=\ldots$kg.

S. No.	*Distance of the knife-edge from the fixed end A (m)*	*Time for 20 oscillations*			*Period of oscillation T*
		Trial I	*Trial II*	*Mean*	

S.No.	*Length of the equivalent simple pendulum (l m.)*	*Period of oscillation (T) secs.*	T^2	$\frac{l}{T^2}$	$g=4\pi^2\left(\frac{l}{T^2}\right)$
				Mean	

Length PQ in the scale of X-axis $=2K=\ldots$m.

Radius of gyration $=K=\ldots$m.

Moment of inertia of the bar about its C.G. $=I=MK^2$

$=\ldots$kg-m^2

(2)

Mechanics and Properties of Matter

1. Non-Uniform Bending—Pin and Microscope

AIM. To verify the relation between the load and the depression produced at the centre of a beam subjected to non-uniform bending by measuring depression using vernier microscope, to draw a graph connecting them and hence to determine the Young's modulus of the material of the beam. Also to find the mass of the given body.

Apparatus. A long uniform beam usually a metre scale, pin, vernier microscope, two knife-edge supports, weight hanger with slotted weights, vernier calipers, screw gauge and the given body.

Procedure. The given beam is placed on the two knife-edge supports so that the distance of the beam between the knife edges is about 0·7 metre. A weight hanger is kept suspended at the centre of the beam and a pin fixed vertically on the frame of the hanger. A vernier microscope is adjusted in front of this arrangement so that the tip of the needle is seen in the field of view of the microscope. To start with the beam is brought into elastic mood by loading and unloading it several times.

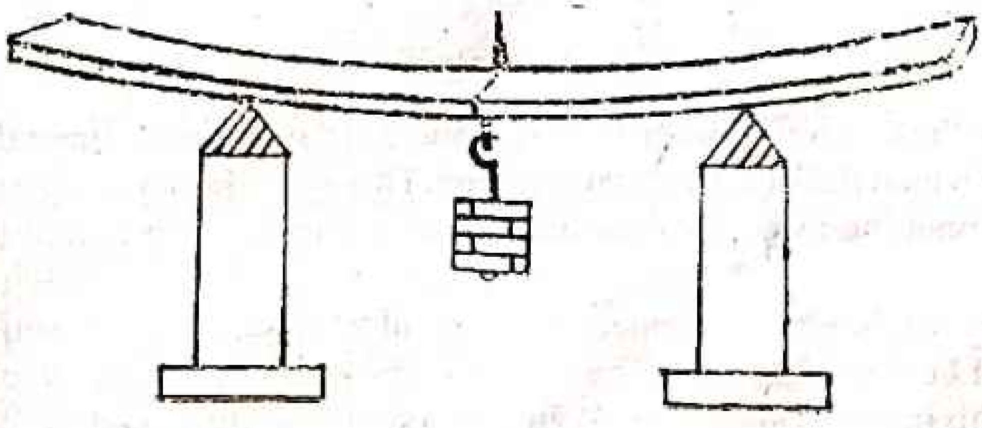


Fig. 1.

Taking the weight hanger as the dead load, the microscope is adjusted until the tip of the pin just touches the horizontal cross-wire. The reading of the microscope in the vertical scale is noted. Then add weights to the hanger in steps of 0·05 kg, each time noting the reading of the vertical scale after ensuring that the tip of the pin just touches the horizontal cross-wire in each case. The experiment is performed by unloading the weights in steps of .05 kg, and the readings in each case are measured as in the loading part. The mean of these two readings for each load is obtained. Measure the distance (l metre) between the knife-edges. The breadth (b metre) and the thickness (d metre) of the beam are found by vernier calipers and screw gauge respectively.

The depression produced at the centre of the beam subjected to non-uniform bending is given by

$$s = \frac{Mgl^3}{48\, q\, AK^2}.$$

For a rectangular bar of breadth b and thickness d,

$$AK^2 = \frac{bd^3}{12}$$

$$\therefore s = \frac{Mgl^3}{48\, q \times \frac{bd^3}{12}}$$

i.e.

$$q = \frac{Mg\, l^3}{4sbd^3}$$

where q = Young's modulus of the material of the beam in N m^{-2}

l = the length of the beam in metre between the two knife-edges

s = depression in metre produced for M kg load

b = breadth of the beam in metre

d = thickness of the beam in metre

g = 9.8 m/sec^2.

It is found from the above formula that other things remaining constant,

$$M \propto s$$

i.e.

$$\frac{M}{s} = \text{a constant.}$$

To verify the relation between mass (M) and depression (s), subtract the mean reading of each load from the dead load reading. This gives the depressions s metre for the corresponding load (M). Calculate $M\, s$ in each case. This is found to be a constant.

A graph may be drawn connecting M kg along X-axis and s metre along Y-axis. It will be a straight line. The slope of this graph gives s/M value. Then substituting this in the formula for q, Young's modulus is determined. Also, taking the mean value of M/s from the experimental readings, Young's modulus is found by the same formula.

To find the mass of the given body, remove all the weights in the hanger leaving the weight hanger alone. Add the given body to the weight hanger. The microscope is adjusted till the tip of the pin just touches the horizontal cross-wire. The reading of the vertical scale is noted. The difference between this reading and the dead load reading gives the depression for the given body. From the M-s graph already drawn, the load corresponding to this depression gives the mass of the given body.

Result. 1. Young's modulus of the material of the material beam by calculation = ...Nm^{-2}

2. Young's modulus of the material of the beam by graph = ...Nm^{-2}

3. The mass of the given body from the graph = ...kg.

Observations. Distance between the two knife-edges = l = ... m.

Load in kg	*Microscope readings in metre*			*Depression for M kg (S metre)*	*M/s*
	Increasing load	*Decreasing load*	*Mean*		
				Mean -	

Reading of the microscope with weight-hanger and the given body = ...m.

Depression of the given body $= s_1 =$ ...m.

Mean value of $\frac{M}{s} = \ldots$

Breadth of the scale by vernier calipers:

L.C. = 0.01 cm.; zero error = ...; zero correction = ...

S.No.	*M.S.R. (cm)*	*V.S.R.*	*Observed reading = M.S.R. + (V.S.R. × L.C.) cm.*	*Corrected reading = (Observed reading + zero correction) cm.*

Thickness of the scale by screw gauge :

L.C.=0·01 m.m.; zero error=... zero correction=...

No.	P.S.R. mm.	H.S.R.	Corrected H.S.R.	P.S.R.+(Corrected H.S.R. × L.C) mm.	Mean mm.

Breadth of the scale =b=...m.

Thickness of the scale =d=...m.

Acceleration due to gravity=g=9 8 m/sec²

$$q=\frac{gl^3}{4bd^3}\times\frac{M}{s}$$

$$=\ldots \text{N m}^{-2}$$

The slope of the M-s graph=K

$$=\frac{g\,l^3}{4bd^3}\times\frac{1}{K}$$

$$=\ldots \text{N m}^{-2}$$

Load corresponding to the depression s_1 metre for the given body =...kg.

10. Rigidity Modulus by Torsion Pendulum (Without Symmetrical Masses)

AIM. To verify the relation between the length and the period of oscillation of a torsion pendulum, to draw a suitable graph connecting them and hence to determine the rigidity modulus of the material of the wire.

Apparatus. A circular metal disc, suspension wire, metre scale, a berranger balance, stop-watch, vernier calipers and screw gauge.

Procedure. The given metal disc fixed to the experimental wire is suspended from a fixed screw chuck. The length of the suspension wire between the point of suspension and the metal disc is the length of the torsion pendulum.

Initially the length of the pendulum is adjusted to be l (say, 0·5 m). Torsional oscillations are set up by giving a small twist to the disc. The time taken for a known number of oscillations and hence the period (T) for one oscillation is found. The length of the pendulum is increased in steps of 0·1 metre and periods of oscillation are found for each length. Measure the radius of the wire (a) by screw gauge. The dimensions of the metal disc are determined by vernier calipers and its mass by a berranger balance.

Fig. 10.

Theory. The period of oscillation of a torsion pendulum is given by

$$T=2\pi\sqrt{\left(\frac{I}{C}\right)}$$

But $$C=\frac{\pi na^4}{2l}$$

$\therefore$ $$T=2\pi\sqrt{\left(\frac{I}{\frac{\pi na^4}{2l}}\right)}$$

or $$T^2=4\pi^2\left(\frac{I}{\pi na^4}\right)\times 2l$$

i.e., $$n=\frac{8\pi Il}{T^2a^4}$$

where n=rigidity modulus of the material of the wire (in N m^{-2})

I=moment of inertia (in kg m^2) of the disc about the axis of rotation.

l=length of the torsion pendulum (in m)

T=period of oscillation (in seconds)

a=radius of the wire (in m)

It is seen from the above formula that other quantities remaining constant

$$l \propto T^2$$

or

$$\frac{l}{T^2}=a \text{ constant.}$$

So, to verify the relation between the length and the period of oscillation, the ratio $\left(\frac{l}{T^2}\right)$ is found for each length and it is found to be almost a constant.

To find the moment of inertia of the disc about its C.G., we use the following formulae. If M kg. is the mass of the disc, then

(*a*) for a circular disc of R radius,

$$I=\frac{MR^2}{2} \text{ kg m}^2$$

(*b*) for a rectangular disc of length L and breadth B

$$I=\frac{M\,(L^2+B^2)}{12} \text{ kg m}^2$$

(*c*) for a cylindrical rod of radius R and length L

$$I=M\left(\frac{R^2}{4}+\frac{L^2}{12}\right)=\text{kg m}^2$$

A graph is drawn taking l along X-axis and T^2 along Y-axis. It will be a straight line. The slope of the curve gives the value $\frac{T^2}{l}$. Substituting this in the formula

$$n=\left(\frac{8\pi I}{a^4}\right)\cdot\left(\frac{l}{T^2}\right),$$

rigidity modulus of the wire can be determined. Also taking the mean value of $\left(\frac{l}{T^2}\right)$ from the experimental readings, n can be determined using the above formula.

Result. 1. Rigidity modulus of the wire by calculation =...N m^{-2}

2. Rigidity modulus of the wire by graph =...N m^{-2}

Observation.

S. No.	Length of the pendulum (l m)	Time for ten oscillations (seconds)	Period of oscillations T (s)	Time for twenty oscillations (s)	Period of oscillations (s)	Mean period T (s)	$\frac{l}{T^2}$
						Mean	

Mass of the disc by a berranger balance $= M = ...$kg

Radius of the disc by vernier calipers :

L.C=0 01 cm; zero error=... zero correction=...

S. No.	M.S.R. (cm)	V.S R.	Observed reading =M.S.R.+(V.S.R.× L.C.) (cm)	Corrected reading =observed reading +zero correction (cm)

Mean diameter of the disc $= 2R = ...$cm,

$= ...$m

Radius of the disc $= R = ...$m.

Moment of inertia of the circular disc $= I = \frac{MR^2}{2} = ...$kg m^2

Radius of the wire by screw gauge

S. No.	P.S.R. mm	H.S.R.	Corrected H.S.R.	(P.S.R. + (Corrected H.S.R. × L.C.) (mm)	Mean diameter 2a (mm)
				Mean	

Mean diameter of the wire $=2a=\ldots$ mm

$=\ldots$ m

Radius of the wire $=a=\ldots$ m

Mean value of $\left(\frac{l}{T^2}\right)=\ldots$

Rigidity modulus $n=\left(\frac{8\pi I}{a^4}\right)\cdot\left(\frac{l}{T^2}\right)$

$=\ldots \text{N m}^{-2}$

The slope of l-T^2 graph, $=K$

$n=\left(\frac{8\pi I}{a^4}\right)\cdot\left(\frac{1}{K}\right)$

$=\ldots \text{N m}^{-2}$

2. Non-Uniform Bending—Scale and Telescope

AIM. To verify the relation between the load and the depression produced at the centre of a beam subjected to non-uniform bending by measuring the depression with a single optic lever, scale and telescope arrangement, to draw a graph connecting them and hence to determine the Young's modulus of the material of the beam. Also to find the mass of the given body.

Apparatus. A long uniform beam (a metre scale), a single optic lever, scale and telescope, two knife-edge supports, weight hanger with slotted weights, vernier calipers, screw gauge and the given body.

Procedure. The given beam is arranged on the two knife-edge supports as described in Experiment 1. The front leg of the single optic lever is made to rest at the centre of the beam, the other two legs resting on a separate platform. A scale and telescope are arranged in front of this arrangement such that the reading of the scale as reflected by the mirror is seen clearly when viewed through the eyepiece of the telescope. With the dead load (weight hanger alone), the reading of the scale along the horizontal cross-wire is noted. Add weights to the hanger in steps of 0.05 kg. and the corresponding readings of the scale are found. Similarly, the readings of the scale for these loads when unloaded are also noted. The mean of the readings for the ascending and descending orders for each load is obtained. The breadth (b metre) and thickness (d metre) of the beam are found by vernier calipers and screw gauge respectively. The legs of the optic lever are pressed on a piece of paper. The impressions of the three legs form the vertices of a triangle. The perpendicular distance (p metre) between the front leg and the two hind legs is measured.

As seen earlier, the depression (s metre) at the centre of a rectangular beam subjected to non-uniform bending is given by

$$s=\frac{Mgl^3}{48q\,\frac{bd^3}{12}}$$

or

$$q=\frac{Mgl^3}{4sbd^3}$$

where the symbols have the usual meaning (refer to Experiment 1). If p metre is the perpendicular distance of the front leg of the optic lever from the line joining the two hind legs, x metre the actual shift in the scale reading for M kg and D metre the distance between the mirror and the scale,

$$s=\frac{px}{2D}$$

$$q=\frac{Mgl^3}{4\left(\frac{px}{2D}\right)bd^3}$$

i.e.,

$$q=\frac{Mgl^3\cdot D}{2pxbd^3}$$

The relation between M and x as seen from the above formula is

$$M \propto x$$

or

$$\frac{M}{x} = \text{a constant.}$$

The mean of the scale readings for each load is subtracted from the dead load reading and this gives x metre depression for the respective loads. In each case M/x is calculated and it is found to be almost a constant.

A graph is drawn between M kg along X-axis and x-metre along Y-axis. It will be a straight line. The slope of this graph gives the value x/M. Then, substituting the slope in the formula

$$q = \frac{gl^3D}{2pbd^3}\left(\frac{M}{x}\right)$$

the Young's modulus is determined.

Also taking the mean value of M/x from the experimental readings, q is found using the above formula.

To find the mass of the given body use only the weight hanger which was already taken as the dead load. The given body whose weight is to be found is added to the weight hanger and the reading of the scale is noted. The difference between this reading and dead loading reading gives the depression x_1 metre for the given body. With the help of the load-depression graph, the mass of the given body corresponding to x_1 metre is easily found.

Result. 1. Young's modulus of the material of the beam by calculation $= \ldots \text{N m}^{-2}$

2. Young's modulus of the material of the beam by graph $= \ldots \text{N m}^{-2}$

3. The mass of the given body from graph $= \ldots$ kg

Observations. Distance between the two knife/edges $= l = \ldots$m

Distance between the mirror and the scale $= D = \ldots$m

Perpendicular distance between the front leg and the two hind legs of the optic lever $= p = \ldots$m

No.	*Load kg.*	*Scale Readings in metre*			*Depression for M kg. (X metre)*	$\frac{M}{X}$
		Increasing load	*Decreasing load*	*Mean*		
					Mean	

Reading of the scale for the weight hanger + the given body = ...m

The depression for the given body = ...x_1 = m

Mean value of M/x = ...

Breadth of the scale = b = ...m

(Tabular column for vernier calipers to be drawn)

Thickness of the scale = d = ...m

(Tabular column for screw gauge to be drawn)

Acceleration due to gravity = g = 9·8m/sec²

$$q = \frac{gl^3 D}{2pbd^3} \left(\frac{M}{x}\right)$$

$$= \ldots \text{N m}^{-2}$$

The slope of the (M-x) graph = K =

$$q = \frac{gl^3 D}{2pbd^3} \times \frac{1}{K}$$

Load from the graph corresponding to x_1 metre = ...kg

6. Young's Modulus by Cantilever (Deflection method)

AIM. To measure the deflection of the loaded free end of a cantilever by scale and telescope arrangement, to draw load-shift graph and hence to determine the Young's modulus of the material of the cantilever. Also to find the mass of the given body.

Apparatus. The given beam (scale), a *G*-clamp, weight-hanger with weights, mirror strip, scale and telescope, vernier calipers, screw gauge and the given body.

Procedure. The given beam is horizontally clamped rigidly at its one end using a *G*-clamp. The other end of the beam carries a weight hanger kept suspended from the groove on the beam. Measure the distance (l) of the beam between the clamped end and the position where the hanger is suspended. A mirror strip is fixed on the frame of the hanger. A scale and telescope are arranged in front of this system and adjusted such that the scale readings are seen clearly when viewed through the telescope.

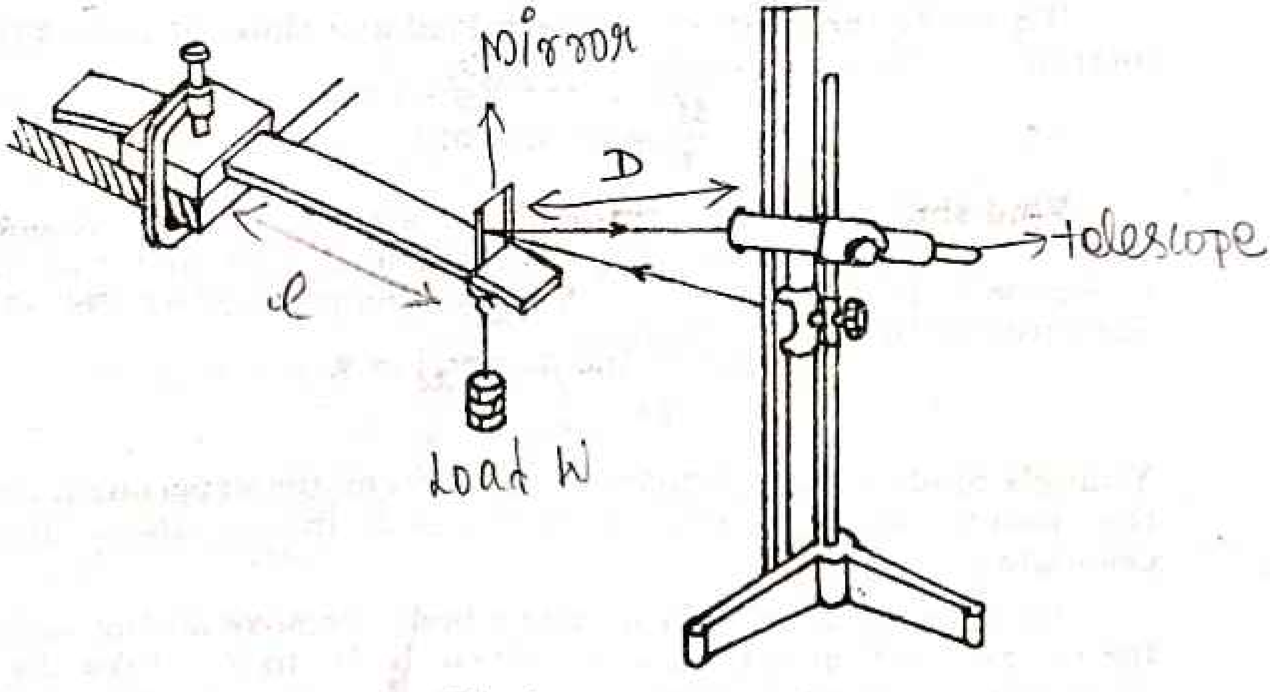


Fig. 6.

Taking the weight hanger as the dead load, the reading of the scale in the telescope coinciding with the horizontal cross-wire is noted. Add weights to the hanger in steps of 0 05 kg and note each time the reading along the horizontal cross-wire. The experiment is performed as described above by unloading weights in steps of 0 05 kg and noting the readings in each case. Find the mean of the two readings for each load. The difference between the mean reading of each load and that of the dead load gives the shift for the respective loads. The deflection produced at the free end of a cantilever is given by

$$\theta = \frac{s}{2D}$$

where s is the shift in the scale reading in metre for M kg. and D is the distance between the mirror and the scale in metre. But,

$$\theta = \frac{Mgl^2}{2q\,AK^2}$$

where the symbols have the usual meaning.

For a rectangular bar,

$$AK^2 = \frac{bd^3}{12}$$

$$= \frac{Mgl^2}{2q \cdot \frac{bd^3}{12}} = \frac{6Mgl^2}{qbd^3}$$

Hence, $$\frac{s}{2D} = \frac{6Mgl^2}{qbd^3}$$

or, $$q = \frac{12Mgl^2D}{sbd^3}.$$

Measure the breadth b metre and the thickness d metre of the beam by vernier calipers and screw gauge respectively.

To verify the relation between load and shift, it is seen that other quantities remaining constant, $M \propto s$.

i.e., $$\frac{M}{s} = \text{a constant.}$$

Find shift s for each load and calculate M/s. It is found to be a constant. A graph is drawn with M along X-axis and s along Y-axis. It will be a straight line. The slope of this graph gives the value s/M. Substituting this in the formula,

$$q = \frac{12gl^2D}{bd^3} \cdot \frac{M}{s}$$

Young's modulus is calculated. Also from the experimental readings, the mean value of M/s is substituted in the above formula to calculate q.

To find the mass of the given body, remove all the weights from the hanger and attach only the given body to it. Take the reading along the horizontal cross-wire. The difference between this reading and the dead load reading gives the shift s_1 for the given body. From the load-shift graph already drawn, the mass of the body corresponding to this shift is found.

Result. 1. Young's modulus of the cantilever by calculation $= \ldots \text{Nm}^{-2}$

2. Young's modulus of the cantilever by graph $= \ldots \text{Nm}^{-2}$

3. Mass of the given body from the graph $= \ldots$kg.

Observations. Distance of the scale between the clamped end and the position where the weight hanger is suspended $= l = \ldots$m.

Breadth of the scale $= b = \ldots$m.

Thickness of the scale $= d = \ldots$m.

(Tabular columns for vernier calipers and screw gauge to be drawn).

Distance between the mirror and the scale $= D \ldots$m.

S. No.	*Load (kg)*	*Reading of the microscope (metre)*			*Shift for M kg. (metre) (s)*	$\frac{M}{s}$
		Increasing load	*Decreasing load*	*Mean*		
					Mean	

Mean value of $M/s =$

Acceleration due to gravity $= g = 9{\cdot}8$ m/sec^2.

$$q = \frac{12gl^2D}{bd^3} \cdot \left(\frac{M}{s}\right)$$
$$= \ldots \text{Nm}^{-2}$$

The slope of the load-shift graph $= \ldots K$.

$$q = \frac{12gl^2D}{bd^3} \cdot \left(\frac{1}{K}\right)$$
$$= \ldots \text{Nm}^{-2}$$

Shift in the scale reading for the given body $= s_1 = \ldots$m.

Mass corresponding to this shift from the graph $= \ldots$kg.

8. Young's Modulus by Koenig's Method

AIM. To verify the relation between the load and the angle through which a beam is bent when loaded at the centre by a method due to Koenig, to draw a load-depression graph and hence to determine the Young's modulus of the material of the beam. Also to find the mass of the given body.

Apparatus. The given uniform beam (metre scale), one weight-hanger with slotted weights, two plane mirrors, scale and telescope, vernier calipers, screw gauge and the given body.

Procedure. The given uniform beam is supported symmetrically on two knife edges so that the distance between them is about 0·6 metre. Two mirrors M_1 and M_2 are fixed on either side of the knife edges such that they are almost normal to the beam. A scale is placed behind one of the mirrors. A telescope is arranged behind the other mirror and adjusted till the scale readings are seen clearly after reflection through the two mirrors.

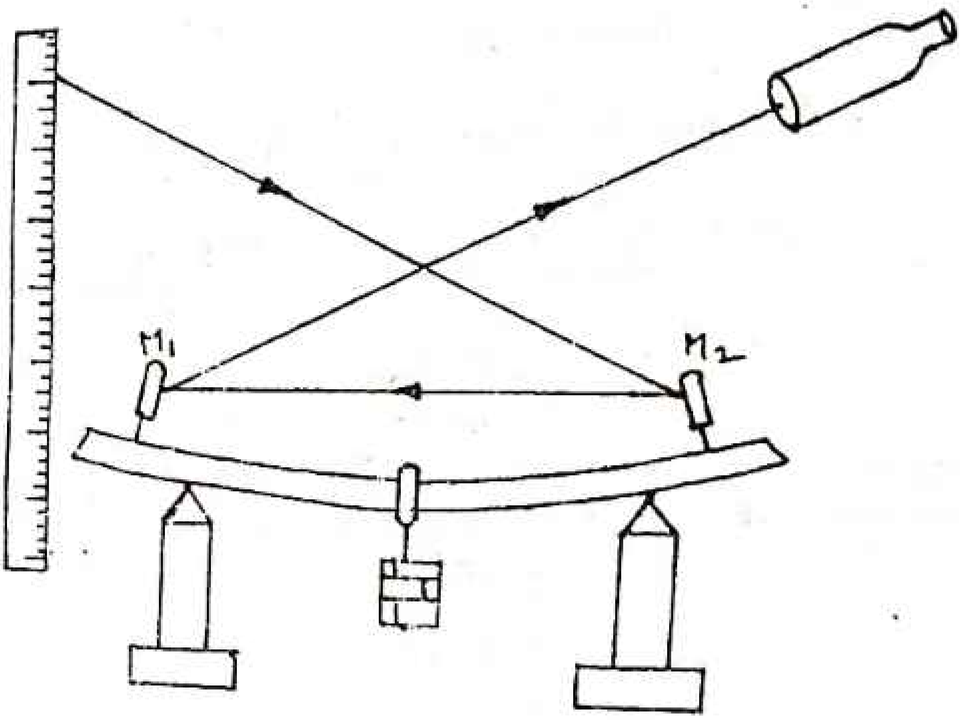


Fig. 8.

With the dead load in the hanger, the reading on the scale as reflected by the two mirrors is found corresponding to the horizontal cross-wire. Weights are added to the hanger in steps of 0·05 kg. and readings on the scale are taken while loading and unloading. The mean of the readings for each load is obtained. The difference between this mean reading and the dead load reading gives the shift 'x' for the respective load. The shift is calculated for different loads.

The depression at the centre of the beam is given by,

$$s=\frac{Mgl^3}{4qbd^3} \quad ...(1)$$

where the symbols have usual meaning (refer Experiment 1).

If x is the shift in the scale reading for the load 'M'

$$x = a\,(2\theta) + D\,(4\theta)$$

where θ is the angle through which the mirrors are tilted, 'a' is the distance between the two mirrors, and 'D' the distance between the scale and the farthest mirror.

So,
$$\theta = \frac{x}{2\,(a+2D)}$$

From eqn. (1),
$$\frac{ds}{dl} = \frac{3Mgl^2}{4qbd^3} = \tan\theta = \theta \text{ (approximately)}$$

$$\frac{3Mgl^2}{4qbd^3} = \frac{x}{2\,(a+2D)}$$

or
$$q = \frac{3Mgl^2\,(a+2D)}{2xbd^3}$$

To verify the relation between load and angle of tilt of the mirrors, the ratio (M/x) is calculated for different loads. It is found to be almost a constant.

A graph may be drawn with 'M' along X-axis and 'x' along Y-axis. This will be a straight line. The slope of the graph gives the value x/M. Substituting this in the formula,

$$q = \frac{3gl^2\,(a+2D)}{2bd^3}\cdot\left(\frac{M}{x}\right),$$

Young's modulus can be calculated. Also taking the mean value of M/x from the experimental readings, q can be determined.

To find the mass of the given body, remove all the weights from the hanger and attach only the given body to it. The reading of the scale is noted. The difference between this and the dead load reading gives the shift x_1 for the given body. From the M-x graph already drawn, the mass of the body corresponding to x_1 can be found. The breadth and the thickness of the scale are determined by vernier calipers and screw gauge respectively.

Result. 1. Young's modulus of the material of the scale by calculation $= \ldots \text{N m}^{-2}$

2. Young's modulus of the material of the scale by graph $= \ldots \text{N m}^{-2}$

3. The mass of the given body from the graph $= \ldots$kg.

Observations. Distance between the two knife-edges $= l = \ldots$m.

Distance between the two mirrors $= a = \ldots$m.

Distance between the scale and the farthest mirror $= D = \ldots$m.

No.	Load (kg)	Scale readings in metre			Shift for M kg. (x m.)	$\frac{M}{x}$
		Increasing load	Decreasing load	Mean		
					Mean	

Reading of the scale for the dead load with the given body = ...

Shift in the scale reading = x_1=...m.

Mean value of $\frac{M}{x}$ = ...

Acceleration due to gravity = $g = 9.8\ \text{m/sec}^2$

Breadth of the scale = b = ...m

(Tabular column for vernier calipers to be drawn)

Thickness of the scale = d = ...m

(Tabular column for screw gauge to be drawn)

Young's modulus = $q = \frac{3gl^2\,(a+2D)}{2bd^3}\left(\frac{M}{x}\right)$

$= ...\text{Nm}^{-2}$

The slope of M-x graph $= K = ...\text{m}$

$q = \frac{3gl^2\,(a+2D)}{2bd^3}\cdot\left(\frac{1}{K}\right)$

$= ...\text{Nm}^{-2}$

The mass corresponding to x_1 from the graph = ...kg.

8 (b) Uniform Bending

AIM. To verify the relation between the load and the elevation produced at the centre of a beam subjected to uniform bending by Koenig's method, to draw the load-elevation graph and hence to determine the Young's modulus of the material of the beam. Also, to find the mass of two equal bodies.

APPARATUS. The given beam (metre scale), two weight hangers with slotted weights, two plane mirrors, scale and telescope, vernier caliper, screw gauge, two equal bodies.

PROCEDURE. The given beam (metre scale) is supported symmetrically on two knife edges such that the distance between them is about 0.7 metre. Two weight hangers are suspended, one each on either side of the knife edges

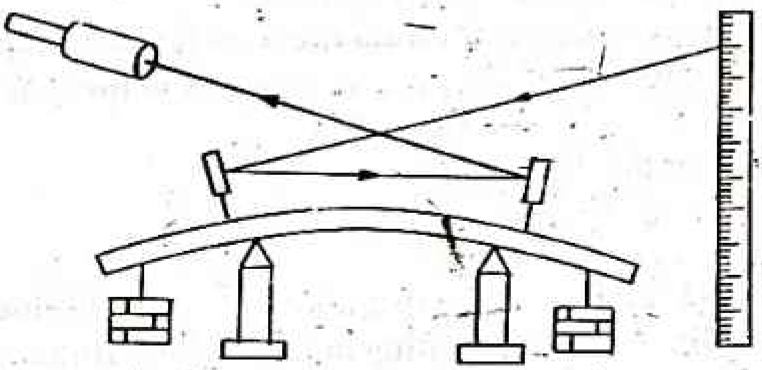


Fig. 8 (*b*).

so that their distances from the nearer knife edges are equal. Two plane mirrors are fixed near the two knife edges so that they are almost normal to the beam. A scale is placed behind one of the mirrors. A telescope is arranged behind the other mirror and adjusted till the scale readings are seen clearly through the mirrors.

With the weight hangers as the dead load, the reading on the scale as reflected by the two mirrors is found corresponding to the horizontal cross wire. Thereafter, equal weights are added to the hangers in steps of 0.05 kg, and the scale readings are taken while loading and unloading. For each load, the mean of the readings is found. The difference between the mean reading of a particular load and the dead load gives the elevation for that particular load.

The elevation(s) produced at the centre of a beam subjected to uniform bending by Koenig's method is given by,

$$s = \frac{12\, Mgal\,(p + 2D)}{bd^3\, q}$$

7where s = the shifting the scale reading in metre for the load M kg.

g = acceleration due to gravity in m/sec^2

a = the distance in metre between any one of the knife edges and the adjacent weight hanger.

D = the distance between the scale and the farthest mirror.

p = the distance between the mirrors in metre.

l = the distance between the two knife edges in metre.

b = breadth of the scale in metre.

d = thickness of the scale in metre.

q = Young's modulus of the beam in Nm^{-2}

It may be seen from the above formula that the other quantities remaining constant,

$$M \alpha s \text{ (or) } \frac{M}{s} = \text{a constant.}$$

So, to verify the relation between load and elevation, the ratio M/s is calculated in each case and it will be found to be a constant.

A graph is drawn connecting M along the X-axis and s along the Y-axis. It will be a straight line. The slope of the graph gives the value (s/M). Substituting this in the formula,

$$q = \frac{12\, gal\ (p + 2D)}{bd^3} \times \frac{M}{s}$$

the Young's modulus is determined. Also taking the mean value of (M/s) from the experimental readings and substituting in the above formula, q can be found.

To find the mass of two equal loads, these two loads are attached to the weight hangers alone after removing all the slotted weights. The scale reading is noted and the difference between this reading and the dead load reading gives the elevation for these two equal loads. With the help of the load-elevation graph, the mass of the two equal loads corresponding to this elevation can be found.

RESULT :

1. Young's modulus of the material of the beam by calculation = Nm^{-2}
2. Young's modulus of the material of the beam by graph = Nm^{-2}
3. The mass of two equal loads from the graph = Kg

OBSERVATIONS :

1. Distance between the two knife edges $= l =$ m
2. Distance between any one of the weight hangers and the adjacent knife edges $= a =$ m

3. Distance between the two mirrors $= p =$ m
4. Distance between the scale and the farthest mirror $= D =$ m.

No.	Load (kg)	Scale reading in metre			Shift for M kg (s m)	$\frac{M}{s}$
		Increasing Load	Decreasing Load	Mean		

Mean

Scale reading with two equal loads attached to the hangers = m

Shift in the scale reading $= s_1 =$ m

Mean value of $\frac{M}{s}$ =

Acceleration due to gravity $= g =$ 9.8 m/sec^2

Breadth of the beam $= b =$ m

(Tabular column for Vernier calipers to be drawn)

Thickness of the beam $= d =$ m

(Tabular column for screw gauge to be drawn)

Young's modulus $= q = \dfrac{12\,gal \times (p + 2D)}{bd^3} \times \dfrac{M}{s}$

= Nm^{-2}

The slope of M-s graph = k =

$$g = \frac{12\,gal \times (p + 2D)}{bd^3} \times \frac{1}{K}$$

= Nm^{-2}

The mass corresponding to s_1 from the graph = kg

9. Rigidity Modulus by Static Torsion (Scale and Telescope)

AIM. To verify the relation between load and angle of twist produced in a rod by the static torsion method, to draw a load-twist graph and hence to determine the rigidity modulus of the material of the rod. Also to find the mass of the given body.

Apparatus. Searle's static torsion apparatus, slotted weights, scale and telescope, screw gauge, the given body.

Description. The apparatus consists of the experimental rod which is held horizontal by introducing one end of the rod into a chuck. The other end is attached to another chuck. This chuck is fixed to the centre of a circular wheel provided with a groove along the circumference of the wheel. A thread attached to the fixed nail on

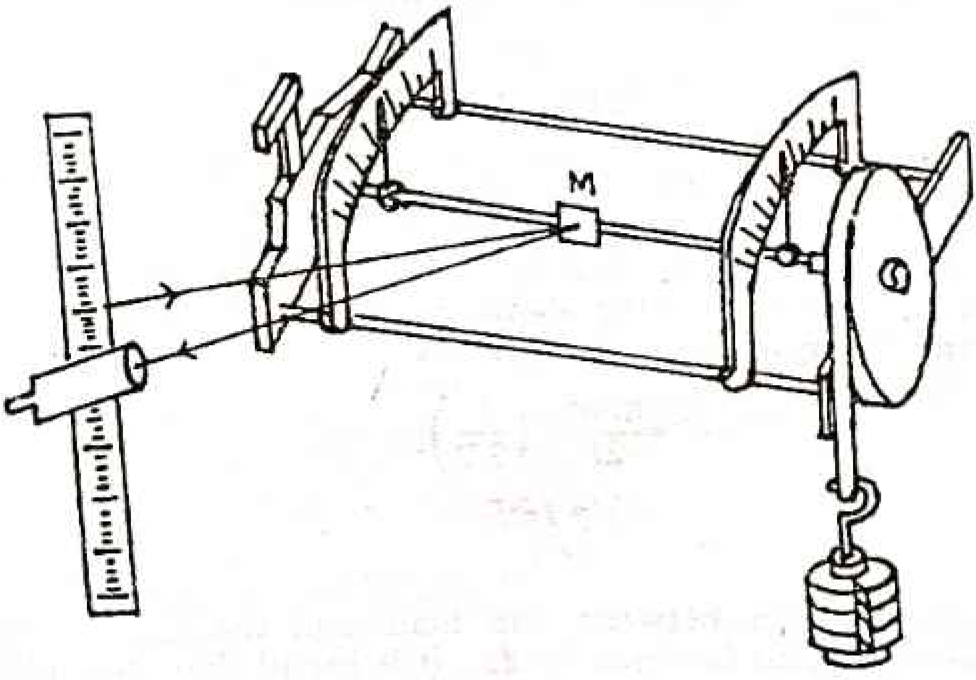


Fig. 9.

the rim of the wheel can be wound over the rim either in the clockwise or anticlockwise direction. The other end of the thread carries a weight hanger. A small plane mirror strip can be fixed to the rod vertically at any distance from its fixed end (the end not carrying the wheel). A scale and telescope arrangement is kept at a distance of one metre from the mirror.

Procedure. The plane mirror is fixed vertically to the experimental rod at a distance l metre from the fixed end. The thread is wound over the rim in the clockwise direction. The other end of the thread carries the weight hanger which is taken as the dead load. A scale and telescope arrangement is placed in front of the mirror and adjusted such that the readings of the scale as reflected by the mirror strip is seen clearly. With the dead load, the reading on the scale corresponding to the horizontal cross-wire is noted. Adding weights to the hanger in steps of 0·5 kg, readings are noted both while loading and unloading the weight hanger. For each load, the mean of the readings is obtained. The difference between the dead-load reading and the mean reading of each load gives the shift for respective loads. The experiment is repeated winding the thread in the anticlockwise direction. The radius 'a' of the rod is measured by screw gauge.

Theory. The angle of twist (θ) produced in the rod is given by

$$C=\frac{\pi n a^4 \theta}{2l}\cdot$$

Where C=moment of the couple
n=rigidity modulus (in N m^{-2})
a=radius of the rod (in m)
l=distance between the fixed end and the mirror strip of the rod (in m)

If s metre is the shift in the scale reading for M kg and D the distance between the scale and the mirror strip (in metre)

$$\theta=\frac{s}{2D}$$

$$C=\frac{\pi n a^4}{2l}\cdot\left(\frac{s}{2D}\right)$$

Also,

$$C=Mg.R$$

where R is the radius of the wheel (in metre) and g the acceleration due to gravity (in m sec^{-2})

$$\therefore \quad Mg\ R=\frac{\pi n a^4}{2l}\cdot\left(\frac{s}{2D}\right)$$

or,

$$n=\frac{4Mg\ lRD}{\pi a^4\ s}$$

To verify the relation between the load and the angle of twist, the ratio (M/s) is calculated for each load. It is found that the ratio is a constant.

A graph is drawn taking load along X-axis and shift along Y-axis. It will be a straight line. The slope of this graph gives the value s/M. Substituting this in the formula,

$$n=\frac{4gl\ RD}{\pi a^4}\cdot\left(\frac{M}{s}\right)$$

the rigidity modulus can be determined. Also taking the mean of M/s value from the experiment readings, n can be determined using the above formula.

To find the mass of the given body, all the weights from the hanger are removed and only the given body is attached to it. The reading on the scale is now found and subtracted from the dead-load reading.

This gives the shift '*s*' metre for the given body. From the load-shift graph already drawn, the mass of the body corresponding to the shift '*s*' can be found.

Result. 1. Rigidity modulus of the material of the rod by calculation $= \ldots N\ m^{-2}$

2. Rigidity modulus of the material of the rod by graph $= \ldots N\ m^{-2}$

3. Mass of the given body from the graph $= \ldots kg.$

Observation. Distance between the fixed end and the mirror strip $= l = \ldots m$

Distance between the mirror and the scale $= D = \ldots m$

S. No.	Load (Kg)	Scale reading for clockwise moment in metre			Shift for (M kg) s (m)	Scale reading anti-clockwise moment in m.			Shift for (M kg) s (m)	Mean s (m)	M/s
		Increasing load	Decreasing load	Mean		Increasing load	Decreasing load	Mean			
										Mean	

Mean vaule of M/s $=$

Acceleration due to gravity $= g = \ldots 9{\cdot}8\ m/sec^2$

Radius of the rod $= a = \ldots m$

(Tabular column for screw gauge to be drawn)

Radius of the wheel $= R = \ldots m$

$$n = \frac{4g\ lRD}{\pi a^4}\left(\frac{M}{s}\right) = \ldots Nm^{-2}$$

Slope of the load-shift graph $= \ldots K$

$$n = \frac{4g}{\pi a^4} lRD \left(\frac{1}{K}\right) = \ldots \text{N m}^{-2}$$

Shift in the scale reading for the anti-clockwise moment for the weight hanger and the given body $= s_1 = \ldots$ m

Shift in the scale reading for the clockwise moment $= s_2 \ldots =$ m

Mean shift $= s' = \frac{s_1 + s_2}{2} = \ldots$ m

Mass of the body corresponding to the shift 's' $= \ldots$kg.

22. Viscosity of a Liquid by Burette

AIM. To verify the relation between the pressure-head and the volume of liquid flowing per second through a capillary tube, to draw a suitable graph connecting them and hence to determine the coefficient of viscosity of the given liquid.

Apparatus. The given liquid, burette (ungraduated), a small rubber tubing, a pinch cock, a capillary tube, watch glass, physical balance with weight box, mercury, a stop watch, an iron stand, a beaker, and a metre scale.

Procedure. An ungraduated burette is held vertically on a retort stand. A capillary tube of suitable bore is attached to the lower end of the burette by a short rubber tubing which is provided with a pinch cock. Marks A, B, C ..etc., are made on a paper which is pasted parallel to the length of the burette.

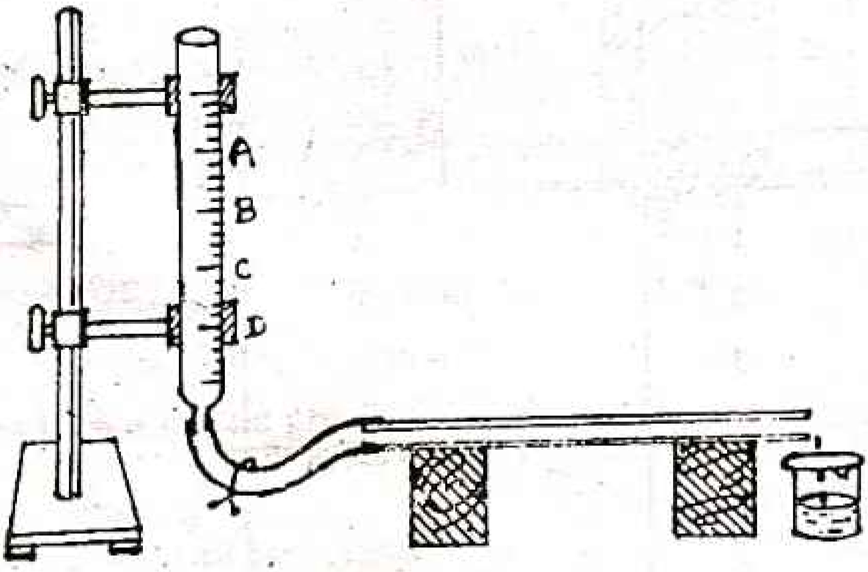


Fig 22.

Fill the burette with the given liquid whose coefficient of viscosity is to be determined. The capillary tube is made horizontal and the liquid is allowed to flow freely through it. When the liquid comes to the level A, start the stop watch. Find the time t secs for the liquid to flow up to the level B collecting simultaneously the liquid in a weighed beaker. A pinch cock is used to stop the flow of liquid. The mass of the beaker with liquid is found again and from this, the mass of liquid collected for the flow from A to B is obtained. Let it be m kg. The heights h_1 and h_2 of A and B from the axis of the capillary tube are measured by a scale. The driving height is given by

$$h = \frac{h_1 + h_2}{2}$$

With the pinch cock open, the experiment is repeated for the flow of liquid from the mark B to C, C to D, etc., till we reach the bottom of the burette. The density ρ of the liquid is found by Hare's apparatus. Measure the length (l) of the capillary tube.

To find the radius of the capillary tube by mercury pellet, a small dry watch glass is weighed. A suitable length (l_1) of mercury thread is drawn into the capillary tube by sucking air from the tube using a short rubber tube. The mercury is transferred to the weighed watch glass and the weight of the watch glass is found again. The difference between the two weights gives the mass (m_1 kg) of the mercury thread. Assuming the density of mercury to be $13{\cdot}6\times10^3$ kg m^{-3}, radius (r m) of the capillary tube is given by

$$\pi r^2 l_1 \times 13{\cdot}6\times10^3 = m_1$$

or
$$r=\left(\frac{m_1}{\pi l_1\times 13{\cdot}6\times10^3}\right)^{1/2}$$

To verify the relation between the pressure-head and volume of liquid flowing per second, we have

$$\frac{v}{t}=\frac{\pi p r^4}{8\eta l} \qquad \ldots(1)$$

But
$$V=\frac{m}{\rho} \text{ and } P=h\rho g$$

$$\frac{m}{\rho t}=\frac{\pi h\rho g r^4}{8\eta l} \qquad \ldots(2)$$

where, h=driving height in metre

m=mass of the liquid collected in kg. in time t secs.

ρ=density of liquid in kg m^{-3}.

r=radius of the capillary tube in metre.

η=coefficient of viscosity of liquid in N S m^{-2}.

l=length of the capillary tube in metre.

g=acceleration due to gravity in m/sec^2.

In the above formula, other quantities remaining constant, we have

$$\frac{m}{t} \propto h$$

or
$$\frac{ht}{m}=\text{a constant.}$$

So, for each driving height, calculate $\left(\frac{ht}{m}\right)$ and it is found to be constant.

A graph may be drawn connecting h along X-axis and (m/t) along Y-axis. It will be a straight line the slope of which gives the value (m/ht).

From (2), we have

$$\eta=\left(\frac{\pi\rho^2 g r^4}{8l}\right)\cdot\left(\frac{ht}{m}\right)$$

Substituting the slope of the graph in the above formula, the coefficient of viscosity is determined. Also taking the mean value of (ht/m) from the experimental readings, η can be found.

Result. 1. Coefficient of viscosity of the liquid by calculation $= \ldots \text{N s m}^{-2}$

2. Coefficient of viscosity of the liquid by graph $= \ldots \text{N s m}^{-2}$

Observations. Length of the capillary tube $= l = \ldots \text{m}$

Length of the mercury thread taken in the capillary tube $= l_1 = \ldots \text{m}$

Density of mercury $= d = 13{\cdot}6 \times 10^3 \text{ kg m}^{-3}$

Acceleration due to gravity $= g = 9{\cdot}8 \text{ m/sec}^2$

Load		*Turning point*		*Resting point*	*R.P. nearer to Z.R.P.*	*Correct weight*
L	*R*	*L*	*R*			
O	*O*			*ZRP=*		
Empty watch glass						W_1
Watch glass+ mercury						W_2
Empty Beaker						
Beaker+ liquid for the flow *A* to *B*						

(Tabular column for liquid flow from *B* to *C*, *C* to *D*, etc., to be extended).

Mass of mercury $= W_2 - W_1 = m_1 = \ldots \text{kg}$

Radius of the capillary tube $= r = \left(\frac{m_1}{\pi l_1 d}\right)^{1/2} = \ldots \text{m}$

Mean specific gravity of the liquid $= \ldots$

Density of the liquid $= \rho =$ specific gravity $\times 10^3 \text{ kg m}^{-3}$

(Tabular column for Hares' apparatus to be drawn as usual)

S. No.	Burette level	Time of flow (t secs)	h_1 m	h_2 m	$h=\frac{h_1+h_2}{2}$ m	Mass of liquid (m kg)	$\frac{ht}{m}$
	A to B B to C C to D						
						Mean	

Mean value of $\frac{ht}{m}$ =

Coefficient of viscosity $=\eta=\left(\frac{\pi\rho^2 g r^4}{8l}\right)\cdot\left(\frac{ht}{m}\right)$

$=\ldots \text{N s m}^{-2}$

The slope of the $\left(h-\frac{m}{t}\right)$ graph $=k=$

$$\eta=\left(\frac{\pi\rho^2 g r^4}{8l}\right)\times\left(\frac{1}{k}\right)$$

$=\ldots \text{N s m}^{-2}$

Note. If a graduated burette is given, the volume of liquid flowing can be directly read from the burette. From this, the mass of liquid collected is easily obtained, knowing the density of the liquid. This avoids taking readings with the physical balance each time.

36. Specific Heat Capacity By Cooling (Newton's Law of Cooling)

AIM. To verify Newton's law of cooling by drawing cooling curves for water and liquid and hence to determine the specific heat capacity of the liquid.

Apparatus. A calorimeter (spherical), one-holed rubber cork, a sensitive thermometer, water, liquid, heater, physical balance, weight box and stop watch.

Procedure. The given spherical calorimeter is weighed first. Hot water, at about 90°C is poured into the calorimeter to fill it completely. The calorimeter is closed with the one-holed rubber cork through which a thrmometer passes. Take time-temperature observations for every one degree fall starting the stop watch at 80°C. After taking a considerable number of readings, say, upto 50°C, the weight of the calorimeter with water is found. Water is then poured out and instead, the calorimeter is filled completely with the hot liquid at 90°C. Again

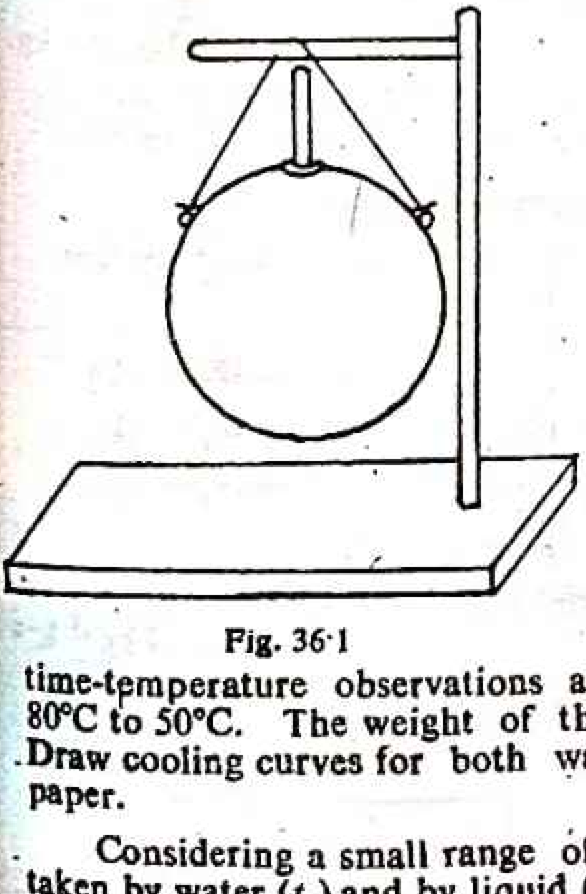


Fig. 36·1

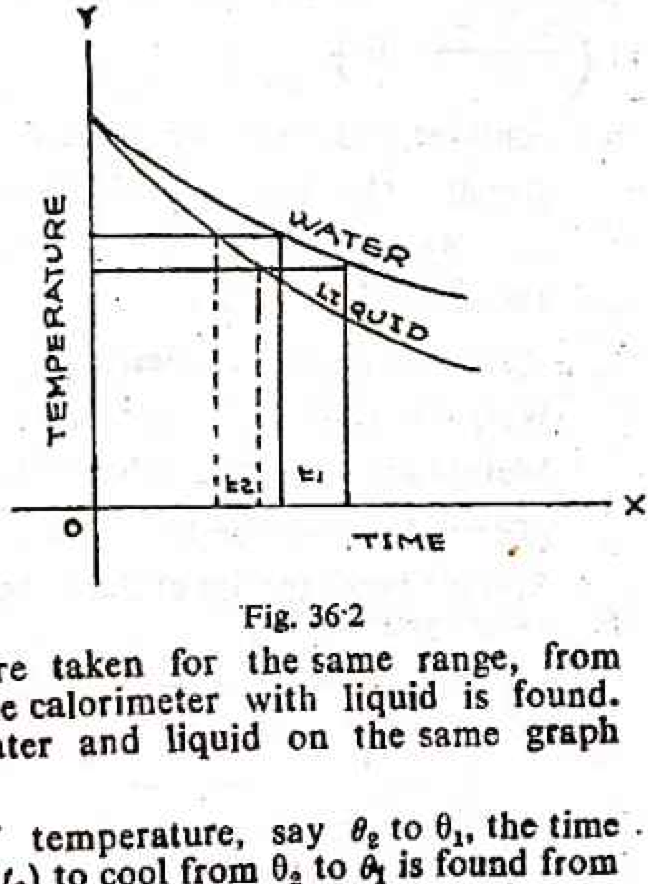


Fig. 36·2

time-temperature observations are taken for the same range, from 80°C to 50°C. The weight of the calorimeter with liquid is found. Draw cooling curves for both water and liquid on the same graph paper.

Considering a small range of temperature, say θ_2 to θ_1, the time taken by water (t_1) and by liquid (t_2) to cool from θ_2 to θ_1 is found from the graph. If W_1, W_2 and W_3 are the weights of empty calorimeter, calorimeter with water and calorimeter with liquid, respectively, then from Newton's law of cooling,

$$\frac{W_1 s + (W_2 - W_1)\, 4180}{t_1} = \frac{W_1 s + (W_3 - W_1)\, x}{t_2}$$

where s is the specific heat capacity of the material of the calorimeter and x is the specific heat capacity of the liquid.

$$\text{or} \quad x = \frac{[W_1 s + (W_2 - W_1)\, 4180]\, t_2}{(W_3 - W_1)\, t_1} - \frac{W_1 s}{W_3 - W_1}$$

$= \ldots$ J kg^{-1}k^{-1}

Choosing different temperature ranges, specific heat capacity of the liquid at different temperature ranges is found.

To verify Newton's law of cooling, we have for water or liquid,

$$\frac{\theta_2 - \theta_1}{t} \propto \frac{\theta_1 + \theta_2}{2} - \theta$$

where θ is the temperature of the surroundings (room temperature).

$$\text{Hence,} \quad \frac{\theta_2 - \theta_1}{t\left(\frac{\theta_1 + \theta_2}{2} - \theta\right)} = \text{a constant.}$$

Choosing different temperature ranges for water and liquid, the cooling times are found from the respective curves and

$\dfrac{\theta_2 - \theta_1}{t\left(\frac{\theta_1 + \theta_2}{2} - \theta\right)}$ is calculated. It is found that $\dfrac{\theta_2 - \theta_1}{t\left(\frac{\theta_1 + \theta_2}{2} - \theta\right)}$

is a constant, thus verifying the law of cooling.

Result. (1) Newton's law of cooling is verified.

(2) Specific heat capacity of the liquid $= \ldots$ J kg^{-1}k^{-1}

Observations.

Weight of empty calorimeter $= W_1 = \ldots$ kg

Weight of calorimeter filled with water $= W_2 = \ldots$ kg

Weight of calorimeter filled with liquid $= W_3 = \ldots$ kg.

(Tabular column for W_1, W_2, etc., to be drawn)

Specific heat capacity of the material of the calorimeter $= s = \ldots$ J kg^{-1} k^{-1}

Water	
Temperature	*Time*

Liquid	
Temperature	*Time*

Verification of Newton's law of cooling :

Room temperature $= \theta$°C

S. No.	Water			$\frac{\theta_2-\theta_1}{t\left(\frac{\theta_1+\theta_2}{2}-\theta\right)}$	Liquid			$\frac{\theta_2-\theta_1}{t\left(\frac{\theta_1+\theta_2}{2}-\theta\right)}$
	θ_1	θ_2	Time of Cooling t		θ_1	θ_2	Time of Cooling t	

Specific heat capacity of the liquid :

To find x at 75°C we have,

Time taken by water to cool from 75·5°C to 74·5°C from the graph $= t_1 = \ldots$secs.

Time taken by the liquid to cool from 75·5°C to 74·5°C from the graph $= t_2 = \ldots$secs.

$$x = \frac{[W_1 s + (W_2 - W_1)\,4180]\,t_2}{(W_3 - W_1)\,t_1} - \frac{W_1 s}{W_3 - W_1}$$

$$= \ldots \text{J kg}^{-1}\text{ k}^{-1}.$$

S. No.	Temperature range		Time of cooling (secs)		Specific heat capacity (x) (J kg^{-1} k^{-1})
	θ_1°C	θ_2°C	Water t_1	Liquid t_2	
1	75·5	74·5			$x_{75} =$
2	70·5	69·5			$x_{70} =$
3	65·5	64·5			$x_{65} =$
4	60·5	59·5			$x_{60} =$
5	55·5	54·5			$x_{55} =$

39. Thermal Conductivity of a Bad Conductor—Lee's Disc

AIM. To determine the thermal conductivity of a cardboard by Lee's disc apparatus. Also to calculate the emissivity of the lower disc at its steady temperature.

Apparatus. Lee's disc apparatus, a card board of the same size as the disc, steam generator, two thermometers of 100°C range, stop-watch, vernier calipers, screw gauge, a berranger balance.

Description. The Lee's disc apparatus consists of a highly polished brass disc B. It is suspended by three strings from a circular ring R which is fixed to an iron stand. A circular cardboard whose diameter is the same as that of the disc is placed on the disc and over it is placed a steam chamber S, also circular in shape having the same diameter as that of the disc. Holes are provided in B and S to facilitate the insertion of thermometers T_1 and T_2.

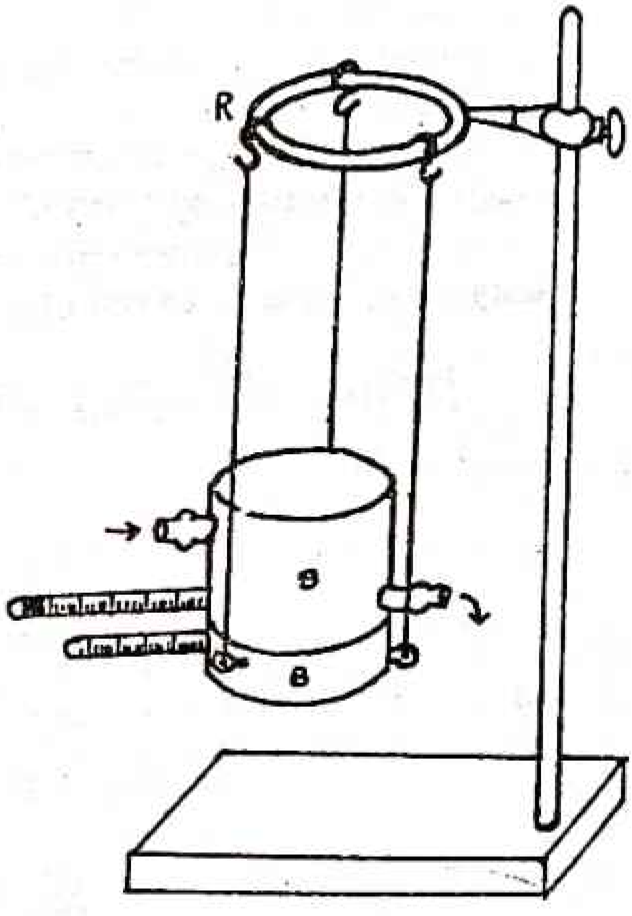


Fig 39·1

Procedure. The diameter ($2r$) and thickness (l) of the lower disc are found by vernier calipers and screwgauge respectively. Let the mass of the disc as found by the berranger balance be M kg. The thickness (d) of the card board disc is measured by screw gauge. The arrangement is set up as shown in the diagram. Steam is allowed to pass through the chamber. The temperatures indicated by the two thermometers will start rising. After about half-an-hour, a steady state is reached when the temperature of the lower disc no longer rises. At this stage, find the temperature T_2 °C of the lower disc. Let the temperature of steam as indicated by the thermometer in the upper chamber be T_1 °C.

Now, the cardboard is removed by gently lifting the upper chamber. The lower disc is allowed to be heated directly by keeping it in contact with the steam chamber. When the temperature of the lower disc attains a value of about 10° more than its steady state temperature, the chamber is removed and the lower disc is allowed to cool down on its own accord. The time—temperature observations are taken every thirty seconds until the temperature falls to at least 5° below the steady state temperature. A graph is drawn taking time

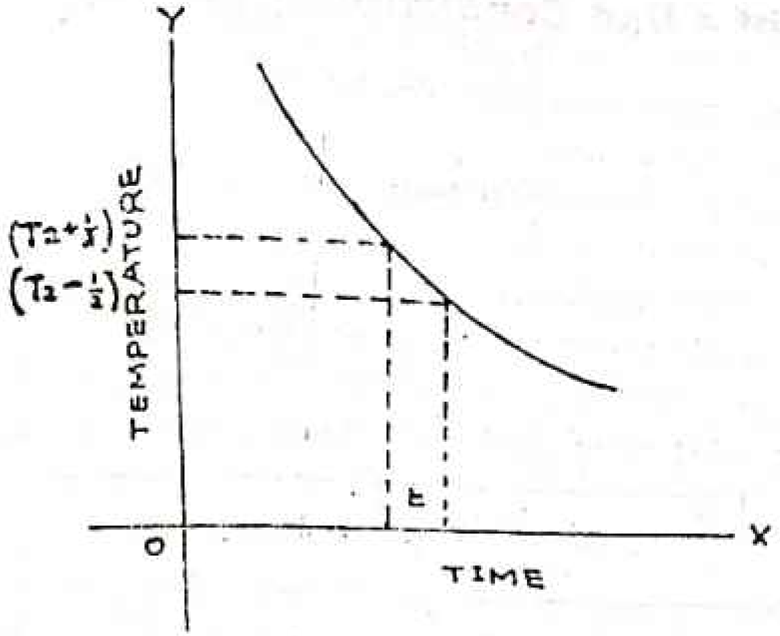


Fig. 39·2

along X-axis and temperature along Y-axis. From the graph, the time taken (t sec) to cool from $(T_2+\frac{1}{2})$°C to $(T_2-\frac{1}{2})$°C is found.

Theory. If s is specific heat capacity of the disc, then rate of loss of heat from the surfaces of the lower disc$=\frac{MS}{t}$ Joule/sec.

In the steady state, only the curved surface and the lower surface of the lower disc are exposed. So,

rate of loss of heat in the steady state $=\frac{Ms\,(r+2l)}{t\,(2r+2l)}$ Joul/sec.

This is the same as the quantity (Q) heat conducted the cardboard.

But,
$$Q=\frac{KA\,(T_1-T_2)}{d} \text{ joule/sec}$$
$$=\frac{K\times\pi r^2\times(T_1-T_2)}{d}$$

Hence,
$$\frac{K\times\pi r^2\times(T_1-T_2)}{d}=\frac{Ms\,(r+2l)}{t\,(2r+2l)}$$

or
$$K=\frac{Msd\,(r+2l)}{\pi r^2 t\,(T_1-T_2)\,(2r+2l)}\ Wm^{-1}\,k^{-1}$$

Emissivity of the lower disc at its steady temperature T_2 °C is given by,

$$E_{T_2}=\frac{Ms}{t\,(T_2-T)\,2\pi r^2+2\pi rl}\,W\,m^{-2}\,k^{-1}$$

where t is the time taken by the lower disc to cool from $(T_2+\frac{1}{2})$°C to $(T_2-\frac{1}{2})$°C and T°C is the room temperature.

Result. (1) Coefficient thermal conductivity of the cardboard $=W\,m^{-1}\,k^{-1}$

(2) Emissivity of the lower disc at its steady temperature $=W\,m^{-2}\,k^{-1}$

Observations.

Mass of the lower disc by a berranger balance $=M=$...kg.

Specific heat capacity of the material of the disc $=S=$...J kg^{-1}

Radius of the lower disc $=r=$...m

(Tabular column for vernier calipers to be drawn)

Thickness of the lower disc $=l=$...m

Thickness of the cardboard $=d=$...m

(Tabular column for screw gauge to be drawn)

Temperature of the upper chamber $=T_1$°C=...

Steady temperature of the lower disc $=T_2$°C=...

Time	*Temperature*

Time taken by the lower disc to cool from $(T_2+\frac{1}{2})$°C to $(T_2-\frac{1}{2})$°C from the graph $=t=$...secs.

Coefficient of Thermal conductivity $=\dfrac{Msd\,(r+2l)}{\pi r^2 t(T_1-T_2)\,(2r+2l)}$

$=$...W m^{-1} k^{-1}

Room temperature $=T$°C=

Emissivity of the lower disc at its steady temperature T_2°C

$$=\frac{Ms}{(T_2-T)\,(2\pi r^2+2\pi rl)t}\quad W\ \mathrm{m}^{-2}\ \mathrm{k}^{-1}$$

Sound

41. Sonometer—Frequency of a Fork

AIM. To verify the relation between the tension and the length of the vibrating segment of a sonometer wire and hence to determine the frequency of the given tuning fork. Also to find the mass of the given body.

Apparatus. Sonometer, the given tuning fork, weight hanger and standard weights.

Description. The sonometer consists of a string stretched on a hollow wooden box. One end of the string is fixed to a nail projecting from one end of the sonometer box, while the other end passes over a pulley and carries a

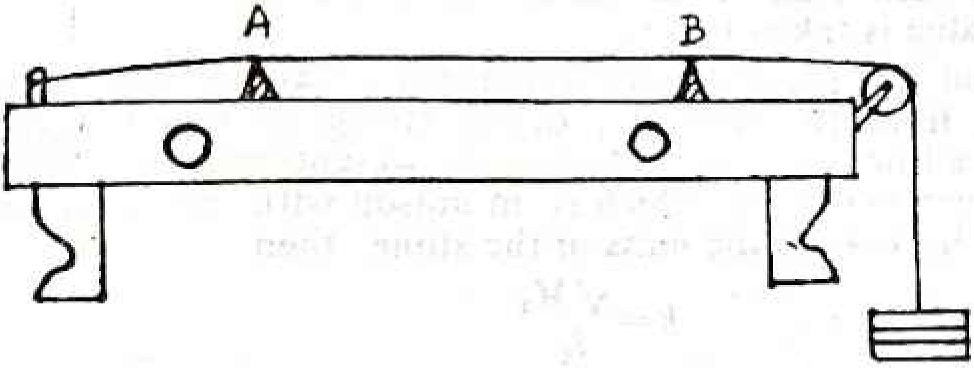


Fig. 41

weight hanger. By placing different weights on the hanger, the tension to which the string is subjected can be varied. There are, two bridges *A* and *B* over which the given wire is stretched. By adjusting the positions of *A* and *B*, the length of the vibrating segment can be altered.

Procedure. The given tuning fork is excited and placed with its stem on the sonometer box. A suitable mass is placed on the hanger. Let *M* kg. be the total mass suspended from the free end of the string. The length of the vibrating segment is adjusted until the note emitted by the wire when plucked at its centre produces beats with that emitted by the fork. Now the length of the vibrating segment is altered slightly so that the number of beats produced per second becomes zero. In this case, the frequency of vibrations of the wire when vibrating in one segment is the same as the frequency of the fork. At this stage, a paper rider placed at the centre of the wire flutters violently and is thrown off. The length of the vibrating segment is measured. The experiment is repeated for different loads.

A known length (L) of the specimen string is taken and its mass M_1 is found by physical balance. Then, the linear density of the string is given by

$$m=\frac{M_1}{L} \text{ kg/m.}$$

The frequency of the tuning fork is given by

$$n=\frac{1}{2l}\sqrt{\frac{Mg}{m}} \text{ Hertz}$$

where g is the acceleration due to gravity (9·8 m/sec²). For a given tuning fork and for a given wire,

$$\frac{\sqrt{M}}{l}=\text{a constant}$$

i.e. $$\sqrt{M} \propto l$$

So, for each load M carried by the string, $\sqrt{M}/l$ is calculated and its mean value is taken to be k.

To find the mass of the given body, say, a heavy stone, it is suspended from the free end of the string of the sonometer after removing all the weights including the weight hanger. The length of vibrating segment (l_1 m) which is in unison with the same tuning fork is found. If M_2 kg is the mass of the stone, then

$$k=\frac{\sqrt{M_2}}{l_1}$$

or $$M_2=k^2 l_1^2 \text{ kg}$$

where k is the mean value obtained already using standard weights.

A graph may be drawn between $\sqrt{M}$ and l. From this graph the mass of the stone M_2 kg is found corresponding to the length l_1 m.

Result. The frequency of the fork $=n=$...Hertz

The mass of the given body (by calculation) =...kg.

(by graph) =...kg..

Observations.

S. No.	Load carried by the string M kg	Length of the vibrating segment (in a single segment) (m)			$\frac{\sqrt{M}}{l}$
		Trial 1	Trial 2	Mean l	
				Mean	

Vibrating length when the given boby (heavy stone) is carried by the string $= l_1 = \ldots$m

Mean value of $\frac{\sqrt{M}}{l} = k = \ldots$

Length of the specimen string $= L = \ldots$m

Mass of the Specimen String :

Load (kg) on pans		*Turning Points*		*Resting point*	*R.P. nearer to Z.R.P.*	*Correct weight (kg)*
L	*R*	*L*	*R*			
0	*0*			*Z.R.P.*		
String						$M_1 = \ldots$kg.

Mass per unit length $= m = \frac{M_1}{L} = \ldots$kg/m

Frequency of the fork $= n = \frac{l}{2} \times \frac{\sqrt{M}}{l} \times \sqrt{\frac{g}{m}}$ Hertz

$= \frac{l}{2} \times k \times \sqrt{\frac{g}{m}}$ Hertz

Mass of the given body (by calculation) $= M_2 = k^2 \times l_1^2 = \ldots$kg

Mass of the given body (by gragh) $= M_2 = \ldots$kg

45. Sonometer—Frequency of A. C. Mains (Using electromagnet and steel wire)

AIM. To determine the frequency of A. C. Mains using a sonometer.

Apparatus. Sonometer, weight hanger with slotted weights and electromagnet.

Procedure. A steel wire is mounted on a sonometer under suitable tensions. An electromagnet is fixed near the centre of the two movable bridges of the wire. The given A.C., whose frequency is to be determined, is applied to the electromagnet. A paper rider is placed

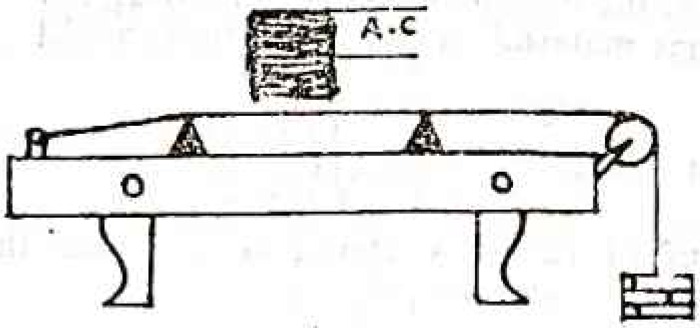


Fig. 45.

between the bridges and the movable bridge is adjusted until the paper rider flutters violently and falls down. The length 'l' of the vibrating segment which has the same frequency 'n' as the *A. C.* is noted. A tuning fork of known frequency 'n_0' is excited and placed on the sonometer box and the length of the vibrating segment 'l_0' which has the same frequency as the tuning fork is noted.

We have

$$nl = n_0 l_0$$

Therefore, $$n = \frac{n_0 l_0}{l}.$$

The frequency of the A. C. supply is given by

$$f = \frac{n}{2} \text{ Hertz},$$

as during both the positive peak and the negative peak of the *A. C.* the wire is pulled by the electromagnet, resulting in the wire vibrating twice, for each cycle of the *A. C.*

The experiment is performed for different loads.

Result. The frequency of A. C. Mains=...Hertz

Observation. Frequency of the tuning fork $n_0 = ...$

Load in kg	Vibrating length for		$n = \frac{n_0 l_0}{l}$
	A. C. mains l metre	Tuning fork l_0 metre	
		Mean	

46. Sonometer—Frequency of A.C. Mains (Using bar magnet and brass wires)

AIM. To determine the frequency of A.C. Mains with a sonometer using bar magnet and brass wire.

Apparatus. Sonometer, brass wire, stepdown transformer and horse-shoe magnet.

Procedure. A brass wire is used as the sonometer wire and it is subjected to a suitable tension by adding a load to the weight hanger. A horse-shoe magnet is placed in the middle in such a way that the

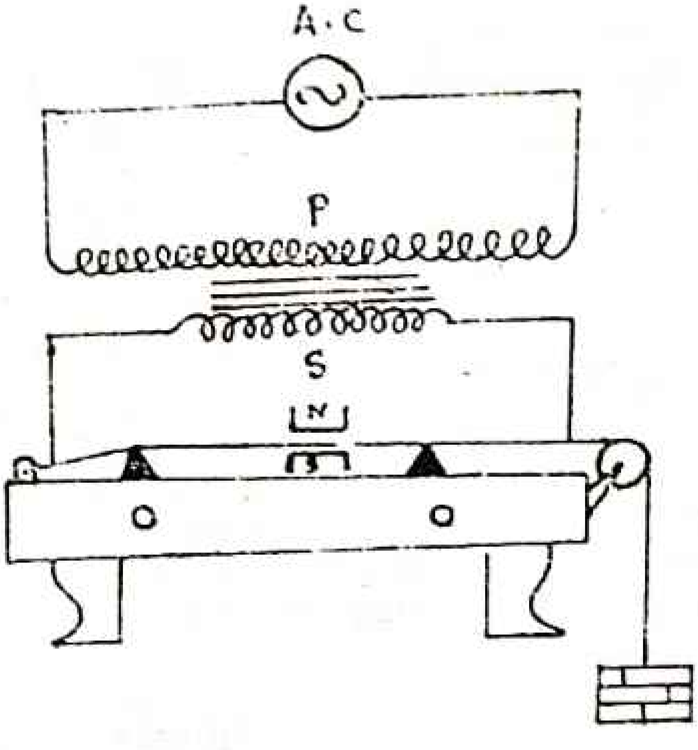


Fig. 46

brass wire passes between the pole pieces of the magnet. The magnetic field should be in a horizontal plane and at right angles to the length of the wire.

The A.C. Mains is connected to the primary of a step-down transformer, the secondary of which is connected to the two ends of the sonometer wire. A paper rider is placed between the movable bridges. The distance between the bridges is adjusted until the paper rider flutters violently and falls down. In this position, the length of the vibrating segment is in unison with the frequency of A.C. Mains. The distance 'l' between the two bridges is measured. The experiment is repeated for different loads.

The linear density of the wire can be determined using the formula $m = \pi r^2 \rho$, where ρ is the density of the wire (can be taken from the tables) and r is the radius of the wire which can be determined using a screw gauge.

The frequency of A.C. Mains is given by

$$n=\frac{1}{2}\sqrt{\left(\frac{M}{l^2}\right)\left(\frac{g}{m}\right)}\text{ Hertz.}$$

Result. Frequency of the A.C. Mains =...Hz

Observation.

S. No.	Load M kg.	Length of the vibrating segment l metres	l^2	$\frac{M}{l^2}$
			Mean M/l^2	

Radius of the wire $=r=$...m

(Screw gauge tabular column to be drawn)

Density of the material of the wire $=\rho=$...kg m^{-3}

Linear density of the wire $=m=...\pi r^2 \rho$ kg m^{-1}

Frequency of the A.C. Mains $=\frac{1}{2}\sqrt{\left(\frac{M}{l^2}\right)\left(\frac{g}{m}\right)}=$...Hz

53. Focal Length of a Convex Lens

AIM. To determine the focal length of a convex lens.

Apparatus. Convex lens, lens holder, lamp housing, screen etc.

Procedure. (1) **Distant object method.** The given convex lens is mounted on a lens holder and placed in front of a distant object. A screen is placed on the other side of the lens and adjusted, so that a clear, well-defined, inverted and real image of the object is caught on the screen. The distance between the lens and the centre of the screen gives the approximate focal length of the given convex lens.

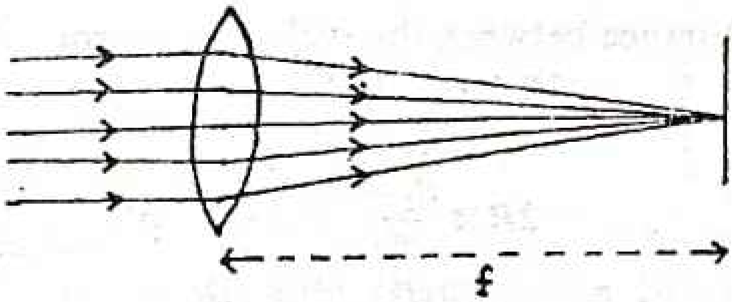


Fig. 53·1.

(2) **Plane mirror method.** The given convex lens is mounted on a lens holder and placed in front of an illuminated wire-gauze of a lamp housing, which serves as the object. A plane mirror strip is placed vertically behind the convex lens, so that its reflecting side faces the object. The position of the lens is adjusted so that a clear, and well-defined image having the same size as the object is formed side-by-side with it.

The distance between the lens and the object gives the focal length of the lens.

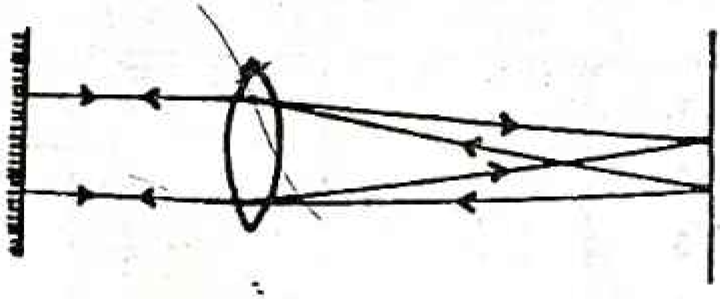


Fig. 53·2

(3) **U-V method.** The lens mounted on a holder is placed in front of the illuminated object at a convenient distance 'u' which is greater than f but less than $2f$, (f, being known by distant object method, or plane mirror method). The screen is placed on the other side of the lens and adjusted so that a clear and enlarged image is caught on it. The distance 'v' between the lens and the screen is measured. The experiment is repeated for different values of 'u', for enlarged images.

The lens is now placed at a distance greater than $2f$ and the screen is adjusted for a clear and diminished image. The value of u and v are measured. The experiment is repeated for different diminished images.

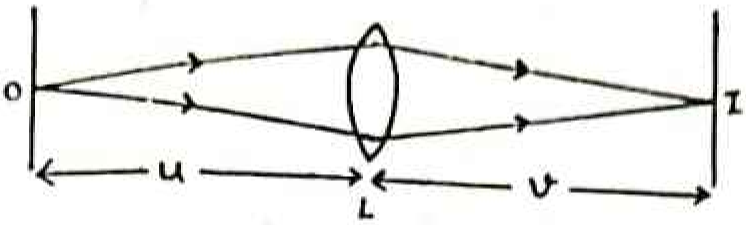


Fig. 53·3

The focal length of the lens is obtained using the relation

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

$$f=\frac{uv}{u+v}$$

The readings are tabulated.

Graphs. (*a*) **u-v graph.** A graph can be drawn by taking u-along the X-axis and v along the Y-axis choosing the same scale on both the axes with origin 'O' representing zero values for both. The shape of the graph will be a rectangular hyperbola. The bisector of XOY will meet the curve at P. From P, lines PA and PB are drawn parallel to the X and Y-axes. OA and OB are measured. Since the values of u and v are equal at P, $OA=OB=2f$ from which f is calculated.

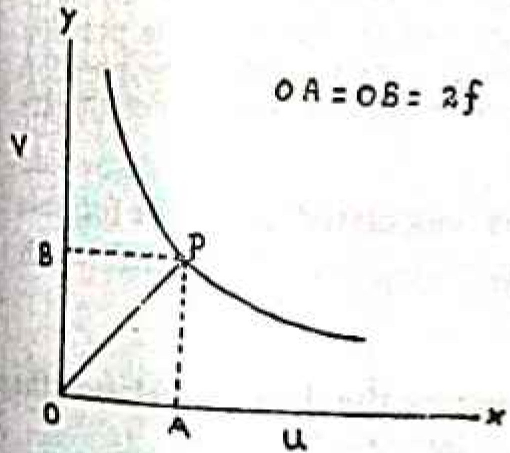


Fig. 53·4

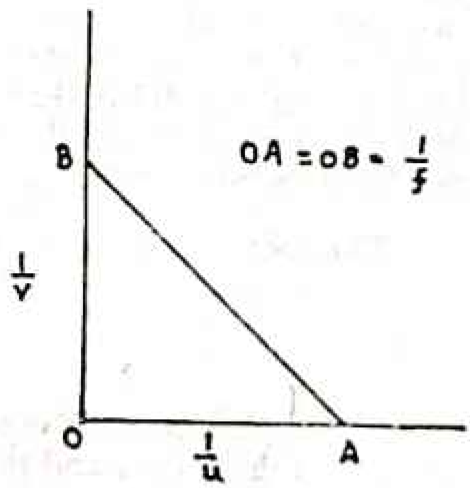


Fig. 53·5

(*b*) $\frac{1}{u}-\frac{1}{v}$ **gragh.** A graph can be drawn with $1/u$ along the X-axis and $1/v$ along the Y-axis with (0, 0) origin. The graph will be a straight line, making equal intercepts on both the axes. The intercept of the line along the X or Y axis gives $1/f$, from which f is calculated.

(*c*) **u−(u+v) graph/u−(uv) graph.** A graph can be drawn with u along the X-axis and $(u+v)$ or (uv) along the Y-axis. The shape of the graph will be as shown in Fig. 53·6. The value along the X-axis corresponding to the minimum value of $(u+v)$ or (uv) gives $2f$, from which f is calculated.

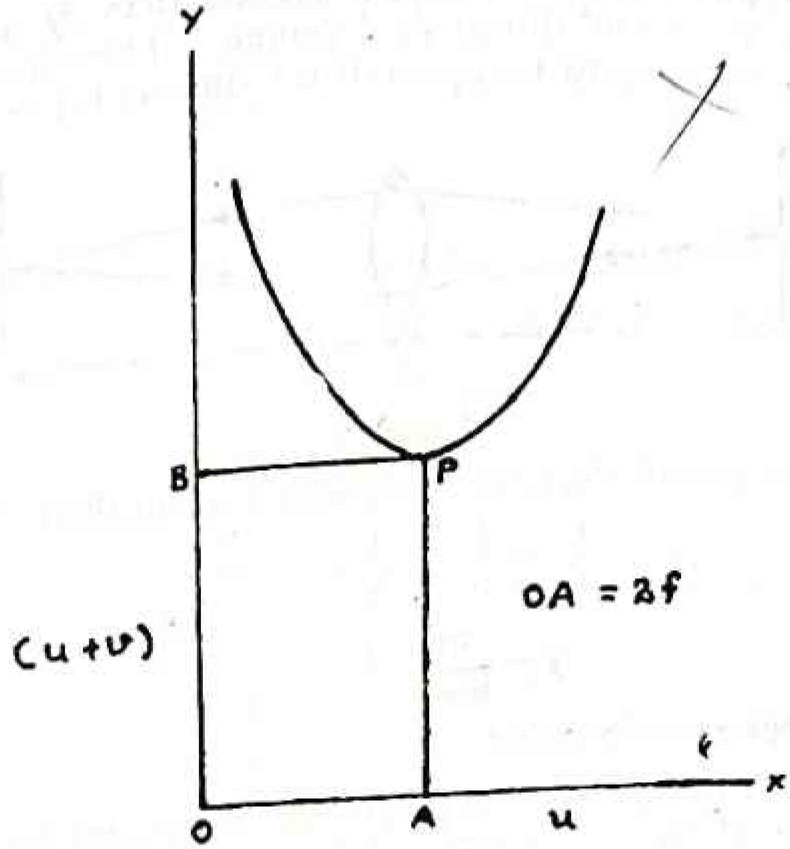


Fig. 53·6

4. **Conjugate foci method.** (*displacement method*). The distance '*a*' between the illuminated object and the screen is adjusted to be greater then 4*f*. The lens, mounted on a lens holder is interposed between them and moved from the object towards the screen until a clear, inverted, well defined and enlarged image is seen on the screen. The position of the lens is noted. It is then moved to its conjugate position until a clear and diminished image is formed on the screen. The position of the lens is again noted. The distance '*b*' between the two conjugate positions is measured.

The focal length of the convex lens is calculated using the formula

$$f = \frac{a^2 - b^2}{4a}$$

The experiment is repeated by changing the distance between the object and the screen and the readings are tabulated.

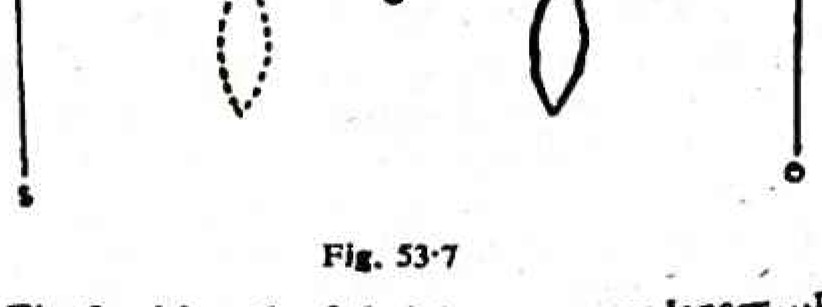


Fig. 53·7

Result. The focal length of the given convex lens = ...m

Note:

Focal length of a long-focus convex lens. For determining the focal length of a long-focus convex lens, a short-focus convex lens is used. At first the focal length 'f' of the short-focus convex lens is determined by u—v method. It is then kept in contact with the long-focus convex lens and the focal length 'F' of the combination is determined.

The focal length 'f_2' of the long-focus convex lens is determined using the formula

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\therefore \quad f_2 = \frac{F f_1}{f_1 - F}$$

Tabular Column

(u — v method)

S.No.	*Nature of image*	*u* *metre*	*v* *metre*	$f = \frac{uv}{(u+v)}$
1	Enlarged			
2	"			
3	"			
4	Diminished			
5	"			
6	"			

Conjugate foci method

S.No.	*Distance between object and screen 'a' metre*	*Distance between conjugate positions 'b' metre*	$f = \frac{a^2 - b^2}{4a}$ *metre*

58. Spectrometer—Refractive Index of A Glass Prism (Minimum Deviation)

AIM. To determine the refractive index of the material of a glass prism using a spectrometer.

Apparatus. Spectrometer, glass prism, spirit level, sodium vapour lamp, etc.

Description of the Spectrometer. The spectrometer consists of (*i*) a collimator, (*ii*) a telescope and (*iii*) a prism table.

The collimator consists of two hollow metal tubes, one sliding over the other. A convex lens is fixed to one end of one tube and a slit of adjustable width at the farther end of the other tube. The distance between the slit and the convex lens can be adjusted by a rack and pinion arrangement. The collimator is fixed to a rigid stand.

The telescope consists of two coaxial metal tubes sliding one over another, one having an objective at one end and another having an eyepiece at the farther end. Two cross-wires are fixed near the eye-piece. The distance between the objective and the eyepiece can be adjusted by a rack and pinion arrangement. The telescope is capable of rotation about a vertical axis and can be fixed at any position by a screw. Slight adjustments can be made with the help of a tangential screw.

The prism-table consists of two circular discs connected by three levelling screws. The table is fixed at the centre of the instrument and it can be raised or lowered and can be fixed at any position by a long screw.

A circular scale, graduated in degrees and half of a degree is attached to the telescope. A circular disc provided with two vernier scales moves over the circular main scale.

Procedure. (*a*) **Initial adjustments of the spectrometer.** Before using the spectrometer for any optical experiment certain initial adjustments have to be made :

(1) The eyepiece is adjusted until the cross-wires are clearly seen, when viewed through the telescope.

(2) The telescope is directed towards a distant object and the distance between the objective and the eyepiece is adjusted until a clear, well defined, inverted and diminished image of the object is seen through it. Now the telescope is capabe of receiving parallel rays.

(3) The telescope is rotated and fixed in line with the collimator. The width of the slit is made narrow. The slit is illuminated by a source of light. On looking through the telescope, the slit is moved forward and backward with the help of the rack and pinion screw until a clear

image of the slit is seen through the telescope. Now the rays of light emerging out from the collimator will be rendered parallel.

(4) The base of the spectrometer is adjusted to be horizontal with the help of levelling screws and spirit level.

(5) The prism table is now adjusted to be horizontal. For this, a spirit-level is placed on the prism table, parallel to the line joining any two levelling screws. One of the screws is adjusted until the air bubble inside the spirit level is at centre. It is then placed in a perpendicular direction and the third screw is adjusted, so that the air bubble is at the centre of the spirit level. Now the prism table will be horizontal.

(*b*) **Angle of the prism.** The slit is illuminated by yellow light from sodium vapour lamp.

The given equilateral prism is placed on the prism table, such that light emerging from the collimator is incident on both the refracting surfaces of the prism.

The telescope is released and rotated to catch the image of the slit as reflected by one refracting face of the prism. The telescope is fixed and the tangential screw is adjusted until the vertical cross-wire coincides with the fixed edge of the image of the slit. The main scale and vernier scale readings are taken for both the verniers. The telescope is again rotated to catch the image reflected by the other face of the prism As before, the readings are taken. The difference between the two readings gives $2A$, where A is the angle the prism.

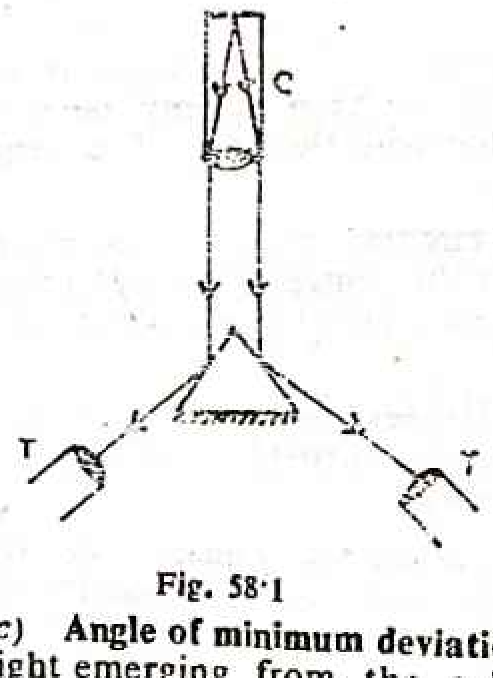


Fig. 58·1

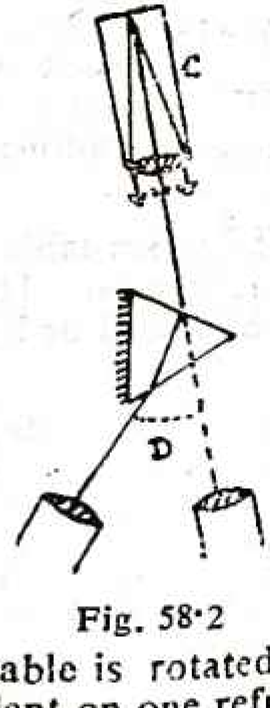


Fig. 58·2

(*c*) **Angle of minimum deviation.** The prism table is rotated such that light emerging from the collimator is incident on one refracting face of the prism, gets refracted and emerges out from the other refracting face. The refracted image is seen through the telescope. Looking through the telescope the prism table is rotated such that the image travels towards the position of the direct ray and at one particular position retraces its path. This position is the position of minimum deviation and the telescope is fixed in this position and as before the readings are taken. The prism is removed, and the telescope is rotated to catch the direct image and as before the readings are taken. The difference between the two readings gives '*D*', the angle of minimum deviation.

The readings are entered in a tabular column.

The refractive index of the material of the glass prism is calculated using the formula

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Result. The refractive index of the material of the glass prism = ...

Angle of the prism (A)

Reflected image				*2A*		*A*		*Average A*
Face I		*Face II*						
V_A	V_B	V_A	V_B	V_A	V_B	V_A	V_B	

Angle of minimum deviation (D)

Direct Reading		*minimum deviation position*		*Angle of minimum deviation D*		*Average D*
V_A	V_B	V_A	V_B	V_A	V_B	

60. Spectrometer—(i-d Curve)

AIM. To find the angle of deviation (*d*) for different angles of incidence (*i*), when a ray of light passes through a glass prism and hence to calculate the refractive index of the material of the glass prism by drawing the *i–a* curve.

Apparatus. Spectrometer, glass prism, spirit level, sodium light, etc.

Procedure. The initial adjustments of the spectrometer are made. The telescope is kept in front of the collimator and the direct reading is taken. In this experiment care is taken to see that the vernier disc is kept fixed once and for all so that the direct reading does not change.

The prism is mounted on the prism table, so that light falling on one refracting face, emerges out through the other face as shown in the diagram. To keep the prism for an angle of incidence '*i*', the telescope is rotated through an angle $\theta = 180 - 2i$, from the direct reading position. For example, for an angle of incideace of 40°, the telescope should be rotated through an angle 100° [$= 180 - (2 \times 40)$] from the direct reading position and fixed in that position. The prism table is rotated so that the image of the slit as reflected by one face of the prism coincides with the vertical cross wire of the telescope. The prism table is fixed. The telescope is then released and rotated to catch the refracted image from the other face of the prism. As before, the scale reading is taken, after making the vertical cross wire of the telescope coincide with the image of the slit. The difference between this reading and the direct reading gives the angle of deviation (*d*) for the particuiar angle of incidence.

The angle of incidence is increased to 45°. by rotating the telescope by an angle 90° from the direct reading and the experiment is performed as before, to find the angle of deviation.

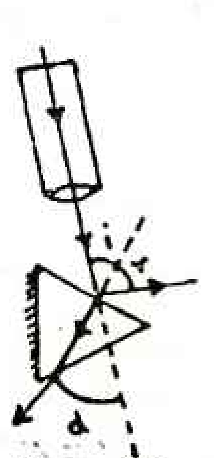


Fig. 60·1.

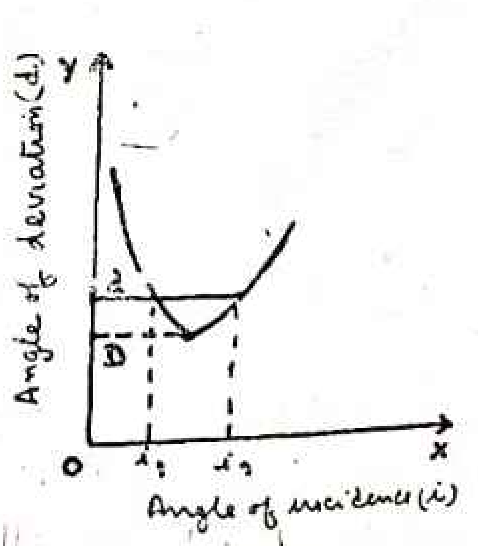


Fig. 60·2.

The experiment is repeated for different angles of incidence and the readings are tabulated. A graph is drawn taking the angle of incidence along the X-axis and the angle of deviation along the Y-axis. From the graph the angle of minimum deviation (D) is noted.

A line is drawn parallel to the X-axis for a particular angle of deviation (d). The angles of incidence i_1 and i_2, corresponding to the points, where this line meets the graph, are found.

Then, $A+d=i_1+i_2$ where A is the angle of the prism.

Therefore $A=i_1+i_2-d$.

The refractive index of the material of prism is given by

$$\mu=\frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Result. The refractive index of the material of the prism=...

Observations :

Direct Reading		Angle of incidence i	Angle of rotation of the telescope from direct reading		Reading for refracted image		Angle of deviation		Mean Deviation 'd'
VA	VB		VA	VB	VA	VB	VA	VB	

61. Spectrometer (i – i′ curve)

AIM. To determine the angles of emergence for different angles of incidence, to draw the $i-i'$ curve and hence to calculate the refractive index of the material of the prism.

Apparatus. Spectrometer, glass prism, spirit level, sodium light etc.

Procedure. The initial adjustments of the spectrometer are made. The telescope is kept in front of the collimator and the direct reading is taken. (It is convenient to adjust the vernier, so that the direct reading is 0° in one vernier and 180° in another. After this adjustment, the vernier disc is kept fixed once and for all, so that the direct reading does not change).

The prism is mounted on the prism table in such a way that light from the collimator falling on one refracting face emerges out through the other refracting face. To keep the prism for an angle of incidence i, the telescope is rotated through an angle $\theta = 180 - 2i$, from direct reading position. For example, for an angle of incidence of 40°, the telescope is rotated through an angle 100° $\{= 180 - (2 \times 40)\}$ from the direct reading position and fixed in that position. The prism table is released and rotated, until the image of the slit as reflected by one face of the prism is made to coincide with the vertical cross wire of the telescope. The prism table is fixed in this position. Now the angle of incidence is 40°. The telescope is then released and rotated to catch the refracted image from the other face of the prism. The telescope is fixed in that position where the image coincides with the vertical cross wire. The prism table is again released and rotated, so that while looking through the telescope, the refracted image moves towards the minimum deviation position and then returns back. Rotation of the prism table is continued in the same direction until the image returns and coincides with the vertical cross wire. Now, the angle of incidence, on the other face, is i'. To determine this, the telescope is released and rotated to catch the reflected image from the telescope. The reading is taken. The difference between this reading and the direct reading gives θ.

But $\quad \theta = 180° - 2i'$

$\therefore \quad i' = 90° - \theta/2$

The experiment is repeated for different values of i, and the readings are tabulated.

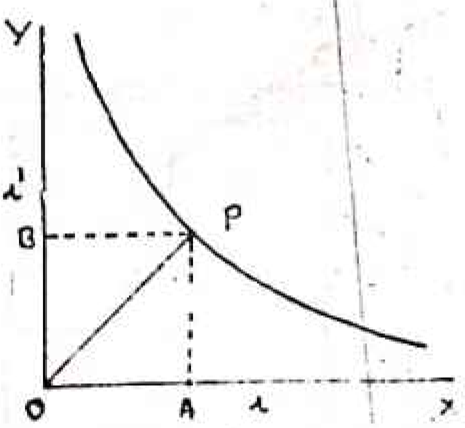


Fig. 61·1.

A graph is drawn with i along the X-axis and i' along the Y-axis with (0, 0) as origin. The nature of the graph is a rectangular hyperbola. The bisector of angle XOY will meet the curve at P. From P lines PA and PB are drawn perpendicular to X and Y axes. It will be seen that $OA=OB=i$, the angle of incidence corresponding to the position of minimum deviation 'D'.

Hence $$D=2i-A,$$

where A is the angle of the prism, determined as explained before.

$$\therefore \quad i=\left(\frac{A+D}{2}\right)$$

The refractive index of the material of the prism is given by

$$\mu=\frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}=\frac{\sin i}{\sin\left(\frac{A}{2}\right)}$$

Result. The refractive index of the material of the glass prism=...

Observations :

Direct reading		*Reading for the reflected image*		θ		$i'=(90-\theta/2)$		*Mean* i'
VA	*VB*	*VA*	*VB*	*VA*	*VB*	*VA*	*VB*	

Note. *Verification of Stoke's law.*

If 'i' and 'r' be the angles of incidence and refraction at the first face and r' and i' the angles of incidence and emergence at the second face of the prism then from Stoke's law,

$$\tan\frac{r-r'}{2}=\frac{\tan\left(\frac{A}{2}\right)\tan\left(\frac{i-i'}{2}\right)}{\tan\left(\frac{i+i'}{2}\right)}$$

from which $r-r'$ is calculated

Since $r+r'=A$, r and r' can be determined.

Then $$\mu=\frac{\sin i}{\sin r}=\frac{\sin i'}{\sin r'},$$ thus verifying Stoke's law.

The readings are entered in a tabular column.

i	i'	$\tan\frac{r-r'}{2}$	r	r'	$\frac{\sin i}{\sin r}$	$\frac{\sin i'}{\sin r'}$	Mean μ

62. Spectrometer-Prism : Cauchy's Constants and Dispersive Power

AIM. To determine Cauchy's constants.

Apparatus. Spectrometer, prism, mercury light etc.

Procedure. The initial adjusments of the spectrometer are made. The slit is illuminated by mercury light. The prism is mounted on the prism table and the telescope is rotated to catch the mercury spectrum obtained by refraction through the prism. The prism is adjusted for minimum deviation position for any colour of light (say green colour). The telescope is adjusted so that the vertical cross wire coincides with the position of minimum deviation for that particular colour of light. The reading is taken. The prism is adjusted for minimum deviation position for the other lines in the spectrum and the corresponding readings are taken. The prism is removed and the direct reading is taken. From the knowledge of the direct reading, the angle of minimum deviation (D) for each colour of light is calculated.

The angle 'A' of the prism is determined, by taking readings for the rays reflected from the two refracting faces of the prism, for a particular colour of light.

The refractive index of the prism for any particular colour is determined using the formula

$$\mu = \frac{\sin \frac{(A+D)}{2}}{\sin \frac{A}{2}}$$

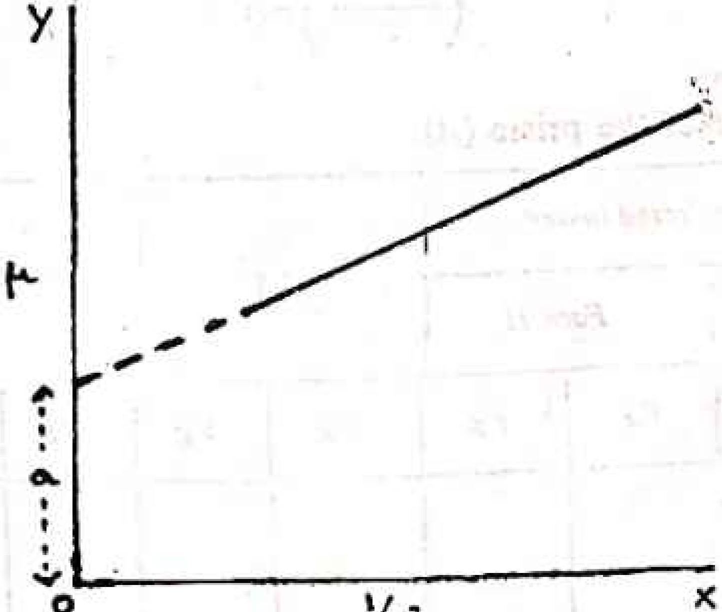


Fig. 62·1

The wavelengths (λ) of the different colours of mercury spectrum can be determined using a grating or can be taken from the Tables.

According to Cauchy's formula, the refractive index is given by

$$\mu=a+\frac{b}{\lambda^2}$$

where 'a' and 'b' are called cauchy's constants.

A graph is drawn with $\frac{1}{\lambda^2}$ along the X-axis and μ along the Y-axis. The graph is a straight line. The slope of the straight line gives 'b' and the intercept along the Y-axis gives 'a'.

Result. The value of Cauchy's constant 'a' =...

The value of Cauchy's constant 'b' =...

Notes 1. Cauchy's constants can also be determined by knowing the refractive indices μ_1 and μ_2 corresponding to any two colours of wavelengths λ_1 and λ_2. We have,

$$\mu_1=a+\frac{b}{\lambda_1^2} \quad ...(1)$$

$$\mu_2=a+\frac{b}{\lambda_2^2} \quad ...(2)$$

$$b_b=\frac{\mu_1-\mu_2}{\left(\frac{1}{\lambda_1^2}-\frac{1}{\lambda_2^2}\right)}$$

$$a=\mu_1-\frac{b}{\lambda_1^2}.$$

2. The dispersive power of the prism in the wavelength region between λ_1 and λ_2 is

$$\frac{\mu_1-\mu_2}{\left(\frac{\mu_1+\mu_2}{2}\right)-1}$$

Tabulation :

(*i*) Angle of the prism (A).

Readings for reflected image				*2A*		*A*		*Mean A*
Face I		*Face II*						
V_A	V_B	V_A	V_B	V_A	V_B	V_A	V_B	

(ii) Angle of minimum deviation (D) and refractive index (μ) for Mercury Spectrum.

Colour of light	Position of minimum deviation		Direct reading		Angle of min. deviation		Mean D	$\mu = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}}$
	V_A	V_B	V_A	V_B	V_A	V_B		
Red								
Yellow I								
Yellow II								
Green								
Blue green								
Blue								
Violet								

(iii) Wavelength of light. Mercury spectrum. Grating.

Order	colour	Diffracted image				2θ		θ		Mean θ	λ
		Left		right							
		V_A	V_B	V_A	V_B	V_A	V_B	V_A	V_B		

63. Spectrometer. Narrow angled Prism

AIM. To determine (*i*) the angle of the prism, (*ii*) the angle of deviation corresponding to normal incidence, and (*iii*) the angle of incidence corresponding to normal emergence and hence to calculate the refractive index of the prism.

Apparatus. Spectrometer, sodium light, narrow angled prism, etc.

Procedure. (*i*) *Determination of the angle of the prism.* The initial adjustments of the spectrometer are made. The slit is illuminated by monochromatic light (yellow light from sodium light), and the telescope is rotated to catch the direct ray. The direct reading when the vertical cross wire coincides with the image of the slit is taken. (Usually the vernier disc is adjusted, so that the direct reading is 0—180). The telescope is now rotated through 90°, and fixed, so that it is at right angles to the collimator. The given small angled prism is mounted centrally on the prism table and the prism table is

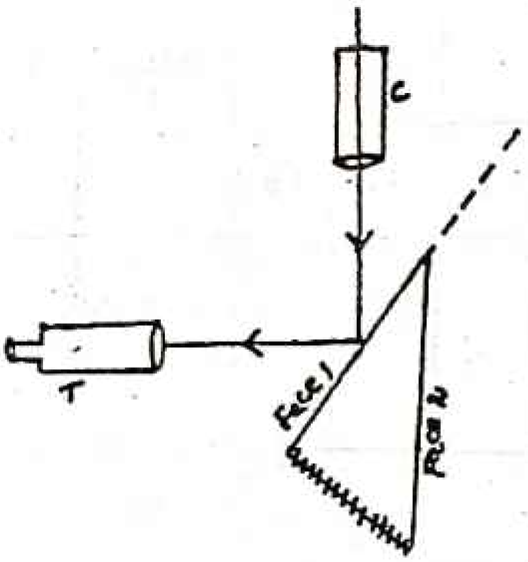


Fig. 63·1.

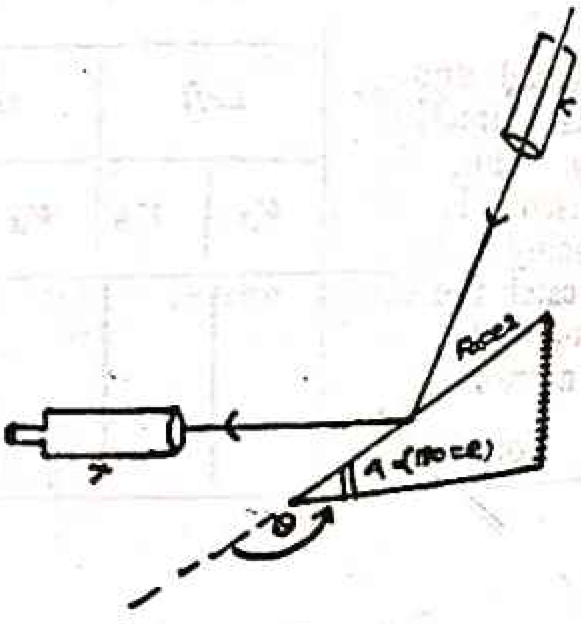


Fig. 63·2.

rotated, so that the image of the slit as reflected by one refracting face of the prism is seen through the telescope. The prism table is adjusted, so that the image coincides with the vertical cross-wire. The reading is taken. (This reading will be 90—270, if the direct reading is 0—180.) The vernier screw is loosened and the vernier table is rotated until the reflected light from the other face of the prism coincides with the vertical cross-wire. The vernier table is fixed and the reading is taken. The difference between the two readings gives θ, which is the supplement of the angle of the prism. The angle of the prism is, therefore, given by $A=(180-\theta)$.

(*ii*) *Angle of deviation corresponding to normal incidence.* The direct reading is taken (usually adjusted for (0°—180°). The telescope is rotated through 90° and fixed, so that it is at right angles to the collimator. The prism is mounted on the prism table and the prism table is rotated, so that the image of the slit as reflected by one face coincides with the vertical cross-wire. Now that face of the prism will be inclined at an angle 45° to the incident ray. The vernier screw is

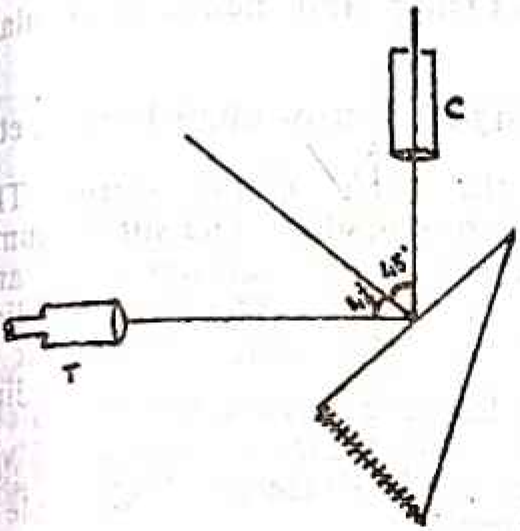


Fig. 63·3.

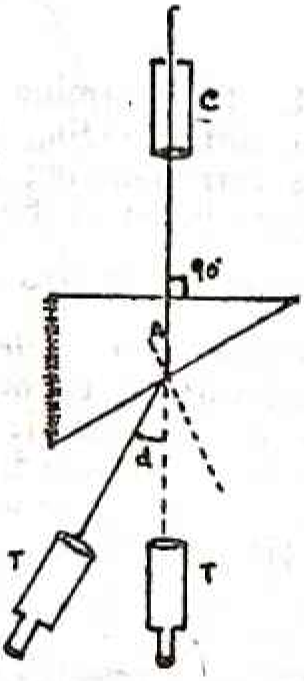


Fig. 63·4.

released and the vernier table is rotated by an angle 45° in the appropriate direction, so that the face of the prism is normal to the incident ray. Thus the prism is adjusted for normal incidence. Now the telescope is released and rotated to catch the refracted image. The reading is taken. The prism is removed and the telescope is rotated to catch the direct image. The direct reading is taken. The difference between the two readings gives the angle of deviation '*d*' corresponding to normal incidence.

For refraction at the second face,

$$\mu=\frac{\sin r}{\sin i}.$$

But $i=A$ and $r=A+d$ (from the fig.)

$$\therefore \quad \mu=\frac{\sin (A+d)}{\sin A}.$$

The readings are tabulated.

(*iii*) *Angle of incidence corresponding to normal emergence.* As before, the prism is adjusted for normal incidence for the first face. The telescope is released and rotated to catch the refracted image and fixed. The prism table is released and rotated, so that the refracted image moves towards the minimum deviation position and returns back. The rotation is continued in the same direction until the image returns and coincides with the vertical cross-wire. The prism table is then fixed. The telescope is released to catch the reflected image from the first face. The reading is taken.

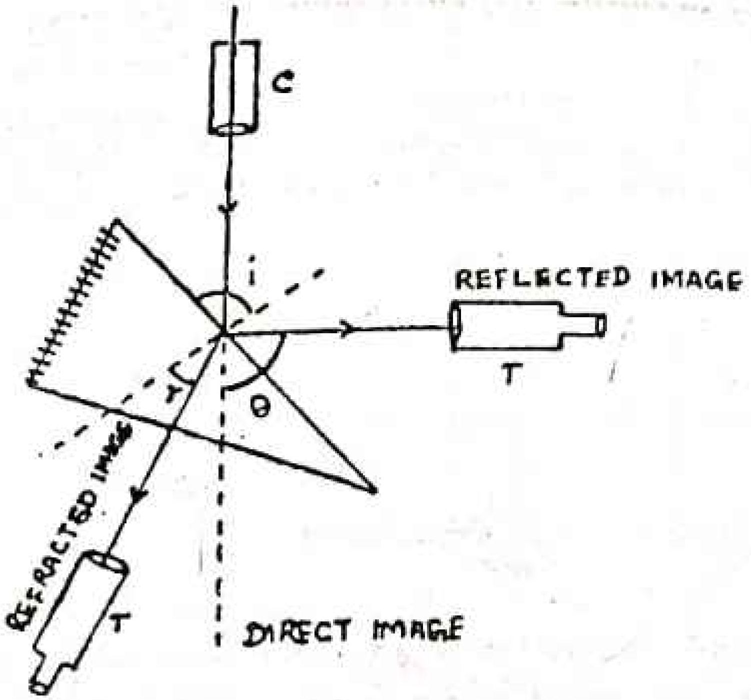


Fig. 63·5.

The prism is removed and the telescope is rotated to catch the direct image. The reading is taken. The difference between the two readings gives θ. The angle of incidence corresponding to normal emergence is calculated using the formula

$$i = 90 - \frac{\theta}{2}.$$

For refraction at the first face,

$$\mu = \frac{\sin i}{\sin r}$$

$$= \frac{\sin i}{\sin A}.$$

Result. The mean refractive index of the material of the narrow angled prism = ...

Observations :

(*i*) *Angle of the prism* (*A*) Direct reading 0°—180°.

Reading corresponding to reflected image				*Difference* (θ)		*Mean* θ	$A = 180° - \theta$
Face I		*Face II*					
VA	*VB*	*VA*	*VB*	*VA*	*VB*		

(ii) *Angle of deviation* (*d*) *corresponding to normal incidence.*

Reading for Refracted image		Reading for Direct image		Difference		Mean d
VA	VB	VA	VB	VA	VB	

$$\mu = \frac{\sin (A+d)}{\sin A}.$$

(iii) *Angle of incidence corresponding to normal emergence.*

Reading for Reflected image		Reading for Direct image		Difference		Mean	$i = 90 - \frac{\theta}{2}$
VA	VB	VA	VB	VA	VB	θ	

$$\mu = \frac{\sin i}{\sin A}$$

65. Spectrometer—Diffraction Grating—Normal Incidence

AIM. To determine the wavelengths of the constituent colours of a composite light, using a plane transmission grating.

Apparatus. Plane transmission grating, Mercury vapour lamp, spectrometer, etc.

Procedure. (*a*) *Adjustment of the grating for normal incidence*: The initial adjustments of the spectrometer are made. The plane transmission grating is mounted on the grating table. The telescope is released and placed in front of the collimator. The direct reading is taken, after making the vertical cross-wire to coincide with the fixed edge of the image of the slit which is illuminated by a monochromatic source of light. The telescope is then rotated through an angle of 90° and fixed. The grating table is rotated until on seeing through the telescope the reflected image of the slit coincides with the vertical cross-wire. This is possible only when light emerging from the collimator is incident at an angle of 45° to the normal to the grating. The vernier table is now released and rotated by an angle 45° in one appropriate direction. Now light coming out from the collimator will be incident normally on the grating.

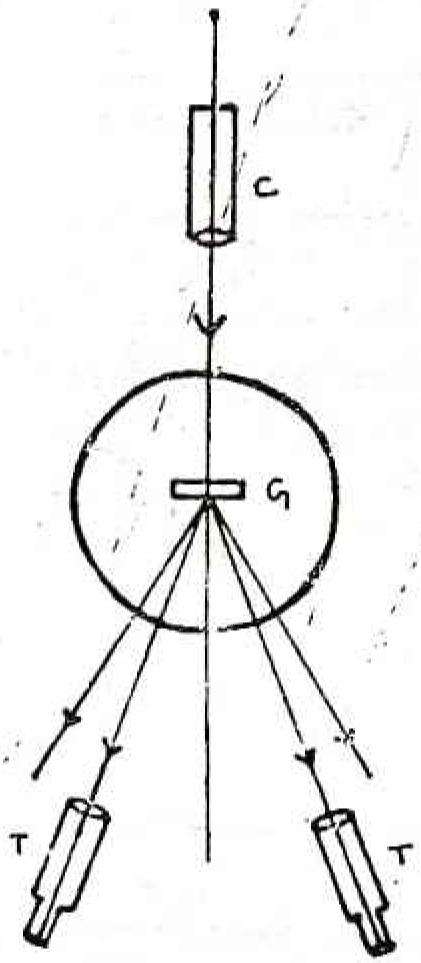


Fig. 65·1

(*b*) *Standardisation of the grating*, (*i.e.*, finding the number of lines on unit length of the grating) : The slit is illuminated by sodium light of wavelength $\lambda = 5893$Å. The telescope is released to catch the first order diffracted image on the left side of the direct image. The reading is taken. It is then turned to the right side to catch the first order diffracted image and the reading is again taken. The difference between the two readings gives 2θ for the first order, where θ is the angle of diffraction. The experiment is repeated for the second order image and the readings are tabulated. The n mber of lines on unit length of the grating (m) is determined using the formula

$$\sin\theta = mn\lambda$$

where n is the order of the image and λ is the wavelength of light used.

Therefor , $m = \sin\theta / n\lambda$.

(c) *Determination of wavelengths of different colours of the mercury spectrum* : The slit is now illuminated by white light from mercury vapour lamp. The central direct image will be an undispersed image. But on the either side of the direct image, we will get dispersed diffracted images of the slit in the different regions, constituent colour corresponding to the different orders. The angles of diffraction for different colours are determined as in the standardisation part for the first and second orders and the readings are tabulated.

The wavelength of a particular colour of light is determined using the formula $\sin\theta = mn\lambda$ where θ is the angle of diffraction for that colour of light.

Therefore $\lambda = \sin\theta / mn$.

Result. The wavelengths of spectral lines are determined.

Note. *Dispersive power of the grating.* The change of angle of diffraction with wavelength is called dispersive power of the grating.

According to the theory of grating,

$$\sin\theta = mn\lambda$$

Differentiating

$$\cos\theta \, d\theta = mn d\lambda$$

$$\therefore \quad \frac{d\theta}{d\lambda} = \frac{mn}{\cos\theta}$$

$\frac{d\theta}{d\lambda}$ is called the dispersive power of the grating. This can also be calculated for any two lines for the mercury spectrum using the formula $\frac{d\theta}{d\lambda} = \frac{\theta_2 - \theta_1}{\lambda_2 - \lambda_1}$.

Observations :

(1) Standardisation of the grating (sodium vapour lamp)

Order of image (n)	*Diffracted image*				2θ		θ		Mean θ	$m = \frac{\sin\theta}{n\lambda}$
	left		*right*							
	V_A	V_B	V_A	V_B	(V_A)	(V_B)	(V_A)	(V_B)		
1.										
2.										

(2) Determination of wavelength of different colours (mercury light)

Order of image	Colour of light	Diffracted image				2θ		θ		$\lambda = \frac{\sin\theta}{mn}$
		Left		Right						
		V_A	V_B	V_A	V_B	V_A	V_B	V_A	V_B	
1.	Violet I									
	Violet II									
	Blue									
	Blue green									
	Green									
	Yellow I									
	Yellow II									
	Red									
2.	Violet I									
	Violet II									
	Blue									
	Blue green									
	Green									
	Yellow I									
	Yellow II									
	Red									

66. Spectrometer—Grating, Minimum Deviation

AIM. To determine the wavelengths of the different colours of mercury spectrum using a grating adjusted for minimun deviation position.

Apparatus. Grating, mercury light, spectrometer, etc.

Procedure. The initial adjustments of the spectrometer are made. The slit is illuminated by mercury light. The grating is mounted on the grating table. The telescope is rotated to catch the first order spectrum on one side of the direct image. The grating table is released and rotated so that one spectral line (say, violet) moves towards the minimun deviation position and retraces its path. The grating is set at the minimum deviation position. The telescope is adjusted so that the vertical cross-wire coincides with the position of minimum deviation for that given colour. The reading is taken. Readings are taken, when the vertical cross-wire coincides with minimum deviation position for other colours in the spectrum. The telescope is released and rotated towards the other side of the direct image and the readings are taken corresponding to minimum deviation positions for different colours. The difference between two readings for a particular colour on both sides of the direct image gives 2θ where θ is the angle of minimum deviation for that colour of light.

For minimum deviation,

$$2 \sin \frac{\theta}{2} = mn\lambda$$

$$\therefore \qquad \lambda = \frac{2 \sin \theta/2}{mn}$$

λ is calculated for other colours of mercury spectrum using the above formula. The experiment is repeated for the second order spectrum also and the readings are tabulated.

Result. The wavelengths of the spectral lines of the mercury spectrum are determined.

Observations :

Order of the image	Colour of light	Reading corresponding to diffracted image at minimum deviation — Left		Right		2θ		θ		Mean θ	$\lambda = \frac{2 \sin \theta/2}{mn}$
		V_A	V_B	V_A	V_B	V_A	V_B	V_A	V_B		
1	Violet I										
	Violet II										
	Blue										
	Blue green										
	Yellow I										
	Yellow II										
	Red										
2											

70. Newton's Rings

AIM. To determine the wavelength of a monochromatic light by forming Newton's rings.

Apparatus. Newton's rings apparatus, a long focus convex lens; sodium vapour lamp, condensing lens, microscope, etc.

Procedure. Light from sodium vapour lamp is rendered parallel by a condensing lens *L*. The parallel beam is incident on a plane glass plate, inclined at an angle 45° to the horizontal and gets reflected. The reflected light is incident normally on the convex lens-glass plate system. The interference pattern is viewed through a microscope. The microscope is moved up and down until alternate bright and dark circular rings are observed. These rings are called Newton's rings. In this system, the central ring will be a dark ring. For want of proper curvature in the convex lens, the central ring and a few rings at the centre will not be well defined. Hence that dark ring which appears as a perfect circle is taken as the n^{th} ring. To find the diameter of the n^{th} dark ring, the vertical cross-wire of the microscope is made tangential to the left and right sides of the ring and readings are taken. The difference between the two readings gives the diameter of the n^{th} ring from which its radius can be calculated. Similarly, the diameter for the other rings can be found. But this process involves the movement of the microscope in opposite directions which will result in an error in the reading known as the 'back lash' error. Further, since the rings get closer as we go away from the central ring system, it may be difficult to find the diameter for each ring. Both these difficulties are overcome by the following procedure :

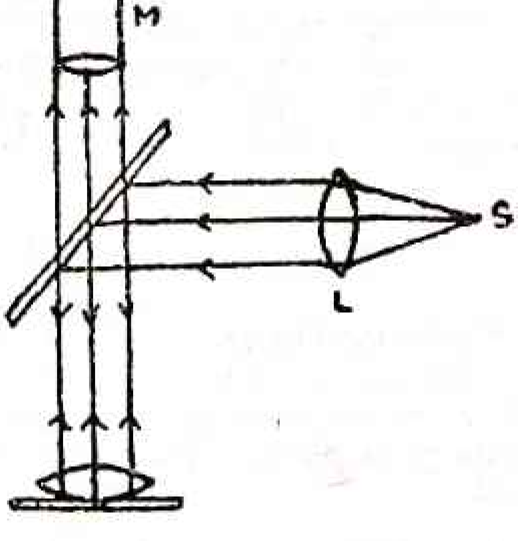


Fig. 70·1

The microscope is moved until the vertical cross-wire is tangential to the $(n+27)^{th}$ ring on the left side and the scale reading is taken. Readings are taken when the vertical cross-wire is tangential to the $(n+24)^{th}$, $(n+21)^{st}$...n^{th} rings on the left side. The microscope is moved in the same direction to the right side of the ring system and readings are taken when the vertical cross wire is tangential to the n^{th}, $(n+3)^{rd}$...$(n+27)^{th}$ rings on the right side. From the above readings the diameter and hence the radii (ρ) of the n^{th}, $(n+3)^{rd}$...$(n+27)^{th}$ rings are calculated.

The readings are entered in a tabular column. It will be seen that the values in the last column will be a constant. Let 'S' be the average of the last column.

$$S=\rho^2_{n+15}-\rho_n^2=15\,R\lambda$$

where R is the radius of the curvature of the surface convex lens in contact with the glass plate (known).

Therefore, $\lambda=S/15\,R$ metre.

Result. The wavelength of sodium vapour light =nm

Notes. (1) The radius of curvature of the convex lens is calculated using the formula $R=S/15\lambda$ metres, where λ is the wavelength of light in metre (given).

(2) To find the refractive index of the material of the lens, the radii of curvature R_1 and R_2 of the lens are first determined using the above method.

The focal length f of the lens is determined by auto-collimation method using the following procedure :

The telescope is adjusted for parallel rays. A bright scale is mounted in front of the telescope. The given convex lens is fixed in front of the objective of the telescope and the distance between the scale and the telescope is adjusted until the scale image is clearly seen through the eyepiece. The distance between the scale and the lens gives the focal length of the lens. The refractive index of the material of the lens is calculated using the formula

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

(3) To determine the refractive index of a liquid, the given liquid (say, water) is introduced between the plane glass plate and the convex lens, so that a plane concave shaped liquid film is formed between the lens and the glass plate. The experiment is repeated as above and S' is calculated.

The refractive index of the given liquid is given by

$$\mu=\frac{S}{S'}$$

Order of rings	Microscope reading		Diameter (2ρ)	ρ	ρ^2	$S=\rho^2_{n+15}-\rho^2_n$
	Left	Right				
n						
$n+3$						
$n+6$						
$n+9$						
$n+12$						
$n+15$						
$n+18$						
$n+21$						
$n+24$						
$n+27$						
					Meen	

Radius of curvature of the surface of the convex lens in contact with the glass plate $=R=\ldots$m

$$\lambda=\frac{S}{15R}=\ldots\text{m}$$

71. Air Wedge

AIM. To determine the thickness of a thin wire by forming interference fringes due to an air wedge.

Apparatus. Two optically plane glass plates, given wire, sodium light, microscope, etc.

Procedure. Tow optically plane glass plates are placed one over the other and tied at one end. The given wire is introduced near the other end, so that an air wedge is formed between the plates. The distance 'l' between the wire and the tied end is measured using the microscope.

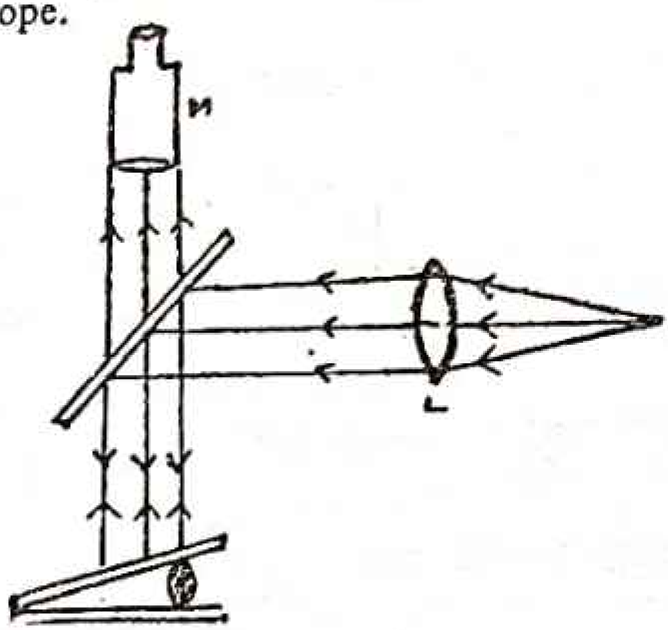


Fig. 71·1.

Fig. 71·2.

Light from a sodium vapour lamp is rendered parallel by a condensing lens L. The parallel beam is incident on a plane glass plate inclined at an angle 45° to the horizontal and gets reflected. The reflected light is incident normally on the optically plane glass plates forming the air wedge and again gets reflected. The reflected light is viewed through the eye-piece of a microscope. The microscope is moved up and down and adjusted for clear interference fringes of alternate brightness and darkness. The microscope is fixed so that the vertical cross-wire coincides with the fixed edge of a dark band (say, the n^{th} band) and the reading is taken. The microscope is moved across the fringes and readings are taken when the vertical cross-wire coincides with the fixed edges of $(n+2)$, $(n+4)$ .... dark bands. The readings are tabulated. From the observations the width 'β' of a band is calculated.

If 'λ' is the wavelength of light illuminating the system, then the angle of the wedge is given by $\theta = \frac{\lambda}{2\beta}$.

But $\theta=\frac{t}{l}$ where 't' is the thickness of the given thin wire

$$\therefore \quad \frac{t}{l}=\frac{\lambda}{2\beta}$$

$$\therefore \quad t=\frac{\lambda l}{2\beta}.$$

Result. The thickness of the thin wire $=\ldots$m

Note. The thickness of insulation of a connecting wire can be determined using the above method. At first the thickness 't_1' of the wire with insulation is determined. The wire is taken out and the insulation is removed carefully and again placed between the plates. The thickness t_2 without insulation is determined as before. The thickness of insulation is given by

$$t=\frac{t_1-t_2}{2}.$$

Observations :

Determination of Band width (β).

Order of the fringe	*Microscope reading*			*Order of the fringe*	*Microscope reading*			*Width for 50 fringes cm*	*Band width β cm.*
	MSR cm	*VSR*	*CR cm*		*MSR cm*	*VSR*	*CR cm*		
n				$n+10$					
$n+2$				$n+12$					
$n+4$				$n+14$					
$n+6$				$n+16$					
$n+8$				$n+18$					

Average ...... $\times 10^{-2}$ metres

Wavelength of the monochromatic light $\lambda=\ldots$m

Distance between the wire and the tied end of the system $l=\ldots$m

$$t=\frac{\lambda l}{2\beta}=\ldots\text{m}.$$

76. Determination of m and B_H—Tan C Position

AIM. To determine the pole strength (m) and the value of the horizontal component B_H of the earth's magnetic induction at the place using a deflection magnetometer in the Tan C position and a box type vibration magnetometer.

Apparatus. Given magnet, a deflection magnetometer, box type vibration magnetometer, a physical balance and a vernier calipers.

Procedure. The deflection magnetometer is adjusted to be in Tan A position. The given magnet is kept vertically on one arm of the deflection magnetometer at a suitable distance. The distance d between the centre of the magnet and the centre of the compass box is measured. Let one of the poles of the magnet, say, north pole be facing downwards. The deflections corresponding to the 2 ends of the pointer are noted. The magnet is reversed pole for pole and two more deflections are noted. The magnet is transferred to the other arm and kept in a similar manner at the same distance d. Four more deflections are noted as described and the mean deflection θ is obtained. If L is the length of the magnet

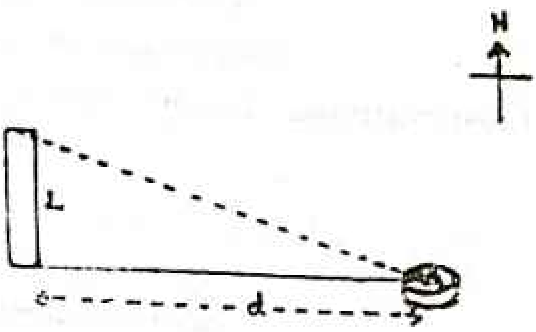


Fig. 75.

$$\frac{\mu_0}{4\pi}\left[\frac{m}{d^2}-\frac{md}{(d^2+L^2)^{3/2}}\right]=B_H \tan\theta$$

$$\frac{m}{B_H}=\frac{4\pi}{\mu_0}\cdot\frac{d^2\cdot(d^2+L^2)^{3/2}\cdot\tan\theta}{[(d^2+L^2)^{3/2}-d^3]}$$

Here $\mu_0=4\pi\times^{-7}$ henry/meter

is the permeability of free space. Choosing different distances the experiment is repeated and m/B_H calculated. Its mean value is then obtained. Let it be X.

The given magnet is placed on the stirrup of the vibration magnetometer and its period is determined by finding the time taken for a definite number of oscillations. If I is the moment of inertia of the bar magaet, then

$$T=2\pi\sqrt{\left(\frac{I}{MB_H}\right)}=2\pi\sqrt{\left(\frac{I}{mB_H\times L}\right)}$$

$$mB_H=\frac{4\pi^2\cdot I}{T^2\cdot L}$$

To determine the moment of inertia (I), we have

$$I=\frac{\text{Mass of the magnet}\times(L^2+B^2)}{12}$$

where L and B are the length and breadth of the magnet measured by vernier calipers. The mass of the magnet is determined by physical balance.

Let the value of mB_H be Y. Then

Pole strength of the magnet

$$= m = \sqrt{\left(mB_H \times \frac{m}{B_H}\right)} = \sqrt{(Y \times X)} = \text{...amp} - \text{m}$$

Horizontal component of the earth's magnetic induction

$$= B_H = \sqrt{\left(\frac{mB_H}{m/B_H}\right)} = \sqrt{\left(\frac{Y}{X}\right)} = \text{... Tesla}$$

Results. 1. Pole strength of the given magnet = ... amp – m

2. Horizontal componen of the magnetic induction of the earth's field = ... Tesla

Observations. Length of the magnet = L = ... m

S.No.	*Distance between centre of the magnet and centre of the compass box d metres*	*Deflection* *1 2 3 4 5 6 7 8 Mean*	$\frac{m}{B_H}$ (θ)
		Mean	

Mass of the magnet = ...kg

Length of the magnet = L = ...m

Breadth of the magnet = B = ...m

(Separate tabular columns for balance and vernier calipers may be drawn.)

$$\text{Moment of inertia} = I = \frac{\text{mass of magnet} \times (L^2 + B^2)}{12}$$

$$= \text{... kg-m}^2$$

Period of Oscillation:

S.No.	*Number of Oscillations (secs)*	*Time taken*	*Period T (secs)*	*Mean*

Mean period of oscillation $= T = \ldots$ secs

$$mB_H = \frac{4\pi^2 \times I}{T^2 \times L} = Y = \ldots$$

Mean value of $\frac{m}{B_H} = X = \ldots$

$$m = \sqrt{\left(mB_H \times \frac{m}{B_H}\right)} = \sqrt{(YX)} = \ldots \text{amp. m}$$

$$B_H = \sqrt{\left(\frac{mB_H}{m/B_H}\right)} = \sqrt{\left(\frac{Y}{X}\right)} = \ldots \text{Tesla}$$

75. Determination of M and B_H

AIM. To determine the magnetic moment (M) of the given bar magnet and the horizontal component of the earth's magnetic induction (B_H) using deflection magnetometer and the box-type vibration magnetometer.

Apparatus. Given bar magnet, a deflection magnetometer, a box-type vibration magnetometer, a physical balance and a vernier calipers.

Description. *Deflection Magnetometer.* The deflection magnetometer consists of a compass box provided with a short magnet pivoted at the centre of a circular scale with a long aluminium pointer fixed at right angles to it. This is enclosed in a brass box with a glass cover. The circular scale is graduated from 0° to 90° in all the four

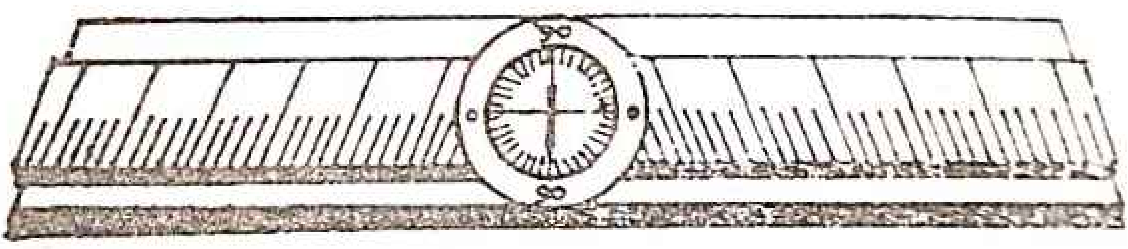


Fig. 74·1.

quadrants, so that 0-0 readings form a diameter. At the centre of the compass box, there is a plane mirror to facilitate taking readings without parallax. There are two arms on either side of the compass box with scales fixed to them in such a way that the zero readings of the scales coincide with the centre of the compass box.

Vibration Magnetometer. A box-type vibration magnetometer consists of a rectangular wooden box with sliding glass doors. Its base is covered with a mirror having a straight line drawn parallel to its length. There is a narrow slit on the top of the case with its length parallel to the line drawn in the mirror. On the top is fixed a glass tube with a brass cap. An unspun silk thread is attached to the brass cap. The other end of the thread carries a light stirrup on which the given magnet can be placed. When the magnet placed on the stirrup is allowed to come to rest, it settles itself in the magnetic meridian. The box is then rotated to a position where the axis of the magnet is parallel to the line drawn in the mirror fixed to the base.

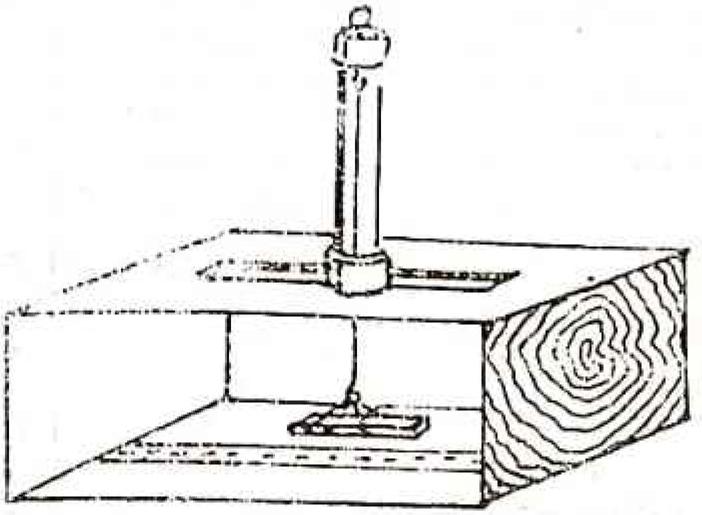


Fig. 74·2.

Procedure. (*a*) *To determine the ratio* (M/B_H) *using the deflection magnetometer.* The deflection magnetometer is first adjusted to be in the Tan *A* position. The given bar magnet is placed at a suitable distance on the eastern arm so that the centre of the compass box lies on the axial line of the bar magnet. The distance *d* between the centre of the magnet and the centre of the compass box is measured.

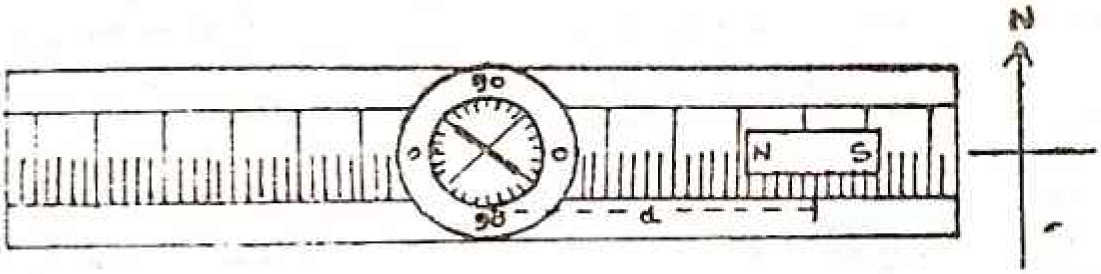


Fig. 74·3.

The deflections of the aluminium pointer corresponding to its ends are observed without parallax. The magnet is reversed in the same place pole for pole and two more deflections are observed. Now the magnet is transferred to the western arm. Keeping it at the same distance *d*, in a similar manner, four more deflections are observed as before. The mean of the eight deflections is taken to be θ. If $2l$ is the length of the magnet, then for Tan *A* position.

$$\frac{\mu_0}{4\pi} \cdot \frac{2Md}{(d^2-l^2)^2} = B_H \tan \theta$$

$$\therefore \quad \frac{M}{B_H} = \frac{2\pi}{\mu_0} \cdot \frac{(d^2-l^2)^2}{d} \cdot \tan \theta$$

The experiment is repeated for various other distances and in each case M/B_H is calculated. The distance chosen should be such that the deflections lie between 30° and 60°.

Here, $\mu_0 = 4\pi \times 10^{-7}$ henry/meter, is the permeability of free space.

Now, the deflection magnetometer is adjusted to be in the Tan *B* position.

The given magnet is placed at a distance d on the northern arm such that the equatorial line of the bar magnet passes through the centre of the compass box. Deflections are noted corresponding to both ends of the pointer. The magnet is reversed pole for pole and kept at the same distance. Two more deflections are noted. The procedure is repeated transferring the magnet to the southern arm and four more deflections are noted. Let the mean of the eight deflections be θ. Then for Tan B,

$$\frac{\mu_0}{4\pi}\cdot\frac{M}{(d^2+l^2)^{3/2}}=B_H \tan\theta$$

or,
$$\frac{M}{B_H}=\frac{4\pi}{\mu_0}(d^2+l^2)^{3/2}.\tan\theta$$

Choosing different distances and ensuring that the deflections are between 30° and 60°, the experiment is repeated and M/B_H calculated in each case. The mean value of M/B_H determined by Tan A and Tan B methods is found. Let it be X.

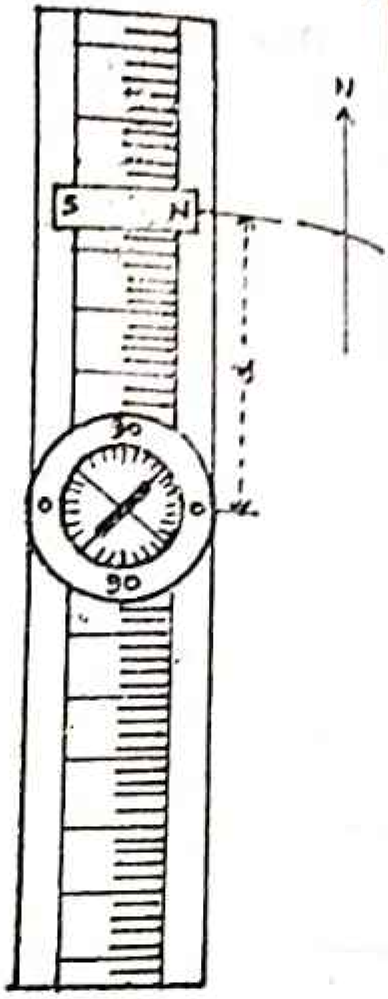


Fig. 74·4.

Now the vibration magnetometer is set along the magnetic meridian. The bar magnet is placed on the stirrup and is made to oscillate by the use of another magnet. The period of oscillation T is calculated by knowing the time taken for a definite number of oscillations. If I is the moment of inertia of the magnet,

$$MB_H=\frac{4\pi^2\times I}{T^2}$$

To calculate the moment of inertia I of the magnet, the mass of the magnet (W) is determined by physical balance and its length L and breadth B by vernier calipers. Then for the rectangular magnet,

$$I=W\left(\frac{L^2+B^2}{12}\right)\text{ kg-m}^2$$

substituting I and T, the value of MB_H is calculated. Let it be Y.

Then, magnetic moment $=M=\sqrt{\frac{M}{B_H}\times MB_H}=\sqrt{XY}=\ldots$ amp-m²

Horizontal component of the earth's field $=B_H=\sqrt{\frac{HB_H}{H/B_H}}=\sqrt{\frac{Y}{X}}=\ldots$ Tesla

Results. 1. Magnetic moment of the given magnet $=\ldots$ amp-m²

2. Horizontal component of the earth's magnetic induction at the place $=\ldots$ Tesla

Observations. Length of the magnet $= 2l = \ldots m$

For Tan A position :

S. No.	Distance between the centre of the magnet and the centre of the compass box d metres	Deflections in degrees									$\frac{M}{B_H}$
		1	2	3	4	5	6	7	8	Mean (θ)	
										Mean	

For Tan B position :

S. No.	Distance between the centre of the magnet and the centre of the compass box d metres	Deflections in degrees									$\frac{M}{B_H}$
		1	2	3	4	5	6	7	8	Mean (θ)	
										Mean	

To find MB_H :

Mass of the magnet $= W = \ldots$ kg.
Length of the magnet $= L = \ldots m$
Breadth of the magnet $= B = \ldots m$

(Separate tabular colums for balance and vernier calipers may be drawn.)

The moment of inertia of the magnet is given by

$$I = \frac{W(L^2 + B^2)}{12} = \ldots \text{ kg-m}^2$$

Period of oscillation :

S. No.	Number of oscillations	Time taken	Period T	Mean

Mean period of oscillation $= T = \ldots$secs.

$$MB_H = \frac{4\pi^2 I}{T^2} = Y = \ldots$$

Mean value of M/B_H in Tan A position$=\ldots$

Mean value of M/B_H in Tan B position$=\ldots$

$\therefore$ Mean $M/B_H = X$

$M = \sqrt{YX} = \ldots$amp-m²

$B_H = \sqrt{Y/X} = \ldots$Tesla.

Electro-Magnetism and Electricity

78. Field Along the Axis of a Coil—Deflection Magnetometer

AIM. To determine the magnetic moment of a bar magnet and the value of the horizontal component of the earth's magnetic induction at the place using field along the axis of coil apparatus with a deflection magnetometer.

Apparatus. Field along the axis of a coil apparatus, magnetometer, compass box, a 6-volt battery, a rheostat, a commutator, an ammeter and a plug key.

Procedure. Remove magnetic materials, if any, from the vicinity of the apparatus. The initial adjustments are made by setting the plane of the coil in the magnetic meridian and the wooden bench along the magnetic east-west. A compass box placed with its centre coinciding with the axis of the coil is adjusted to read zero-zero.

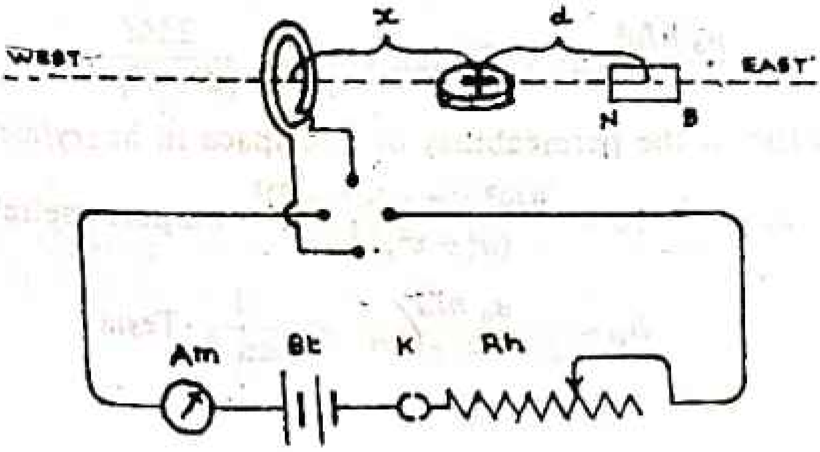


Fig. 78·1.

A circuit is made connecting the circular coil in series with an ammeter, a six-volt battery, a key, a rheostat and a commutator. The rheostat and ammeter should be kept sufficiently away from the circular coil. The compass box is placed along the axis, with its centre at a distance 'x' metre from the centre of the coil on one side, say, east. The rheostat is adjusted to pass a suitable current I amps through the coil such that the deflection is between 30° and 60°. The deflections as read by the ends of the pointer are noted. The given bar magnet is kept on the eastern side of the compass box on the bench with its axis along the axis of the coil. The position of the magnet is adjusted until the deflection in the magnetometer compass box becomes zero. Measure the distance d between the centre of the magnet and centre of the magnetometer compass box. The current in the coil is reversed and the deflections without the magnet in vicinity are noted. The magnet is reversed end to end and its distance corresponding to zero deflection is again found. The experiment is repeated by keeping the magnetometer compass box on the other side of the coil. The mean deflection θ and the mean distance d are obtained. Likewise keeping the magnetometer at various other distances from the centre of the coil, the experiment is repeated. The radius 'a' of the coil is found by measuring the external and internal diameter of the coil and calculating the mean diameter. If n is the number of turns of the coil used in the experiment, field produced along the axis at a distance x from the centre of the coil is given by

$$F_B = \frac{\mu_0 \, nIa^2}{2\,(a^2+x^2)^{3/2}} \text{ Tesla.}$$

If θ is the mean deflection in the magnetometer,

$$F_B = \frac{\mu_0 \, nIa^2}{2\,(a^2+x^2)^{3/2}} = B_H \tan\theta$$

where B_H is the horizontal component of the earth's field in Tesla.

If this field is nullified by a bar magnet of magnetic moment M amp. metre² of length '$2l$' metres kept with its centre at a distance 'd' metre from the centre of the magnetometer with its axis along the axis of the coil.

$$F_B = \frac{\mu_0 \, nIa^2}{2\,(a^2+x^2)^{3/2}} = B_H \tan\theta = \frac{\mu_0}{4\pi}\,\frac{2Md}{(d^2-l^2)^2}$$

where $\mu_0 = 4\pi \times 10^{-7}$ is the permeability of free space in henry/metre

$$\therefore \quad M = \frac{nIa^2 \times \pi \times (d^2-l^2)^2}{(u^2+x^2)^{3/2} \times d} \text{ ampere-metre}^2$$

$$B_B = \frac{\mu_0 \, nIa^2}{2\,(a^2+x^2)^{3/2}} \times \frac{1}{\tan\theta} \text{ Tesla}$$

Result :

1. Horizontal componenr of the earth's magnetic induction at the given place =...Tesla
2. Magnetic moment of the magnet =...ampere-metre²

Observations :

Length of the magnet $= 2l = \ldots m$

Semi-length of the magnet $= l = \ldots m$

Number of turns in the coil $= n = \ldots m$

External diameter of the coil $= d_1 = \ldots m$

Internal diameter of the coil $= d_2 = \ldots m$

Mean diameter $\dfrac{d_1+d_2}{2} = \ldots m$

Radius of the coil $= a = \ldots m$

To find horizontal component of the earth's magnetic induction :

S No.	Distance x metre	Current I amp.	Magnetometer to east deflections				Magnetometer to west deflections				Mean θ	tan θ	B_H
			1	2	3	4	5	6	7	8			
												Mean	

To find magnetic moment :

S. No.	Distance x metre	Current I amp	Magnetometer to east distance of the magnet (m)		Magnetometer to west distance of the magnet (m)		Mean d metre	M
			1	2	3	4		
							Mean	

*Note. The radius (a) of the coil can also be determined by measuring its circumference ($2\pi a$) with a thread.

80. Field Along the Axis of a Coil—Vibration Magnetometer

AIM. To determine the value of horizontal component of earth's magnetic induction (B_H) at the place by using the field along the axis of a coil apparatus and a vibration magnetometer.

Apparatus. The field along the axis of a coil apparatus, a vibration magnetometer of Searle's type, six-volt battery, commutator, rheostat, ammeter and a plug key.

Procedure. A circuit is made connecting the circular coil in series with a six-volt battery, a rheostat a plug key and a commutator.

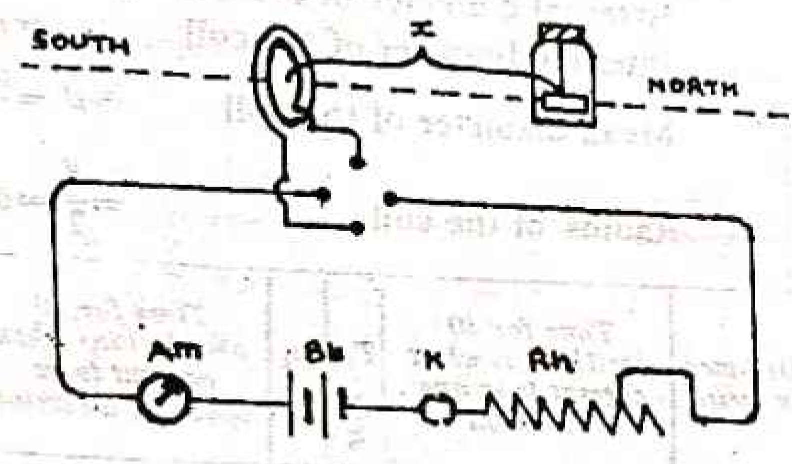


Fig. 80.

The coil is set with its plane perpendicular to the magnetic-meridian. The vibration magnetometer is arranged along the axis of the coil in such a way that the centre of the circular coil is in the same level as the centre of the suspended needle of the magnetometer. The distance 'x' between the centre of the needle and the centre of circular coil is measured. The circuit is closed and a suitable current I amp is passed through circular coil by adjusting the rheostat. The needle of the vibration magnetometer is set to oscillations and the period of oscillation and hence the frequency n_1 for the combined field produced by the coil and the earth is found. The current is reversed and the frequency n_2 is determined. The experiment is repeated for various currents in the coil keeping the distance x constant. It is advisable to keep the distance x as small as possible with a current of one ampere or more so that F_B is always greater than B_H. If n_1 is greater than n_2, n_1 corresponds to (F_B+B_H) and n_2 corresponds to (F_B-B_H) always. We have,

$$F_B+B_H \propto n_1^2$$

$$F_B-B_H \propto n_2^2$$

Here n_1 is assumed to be greater than n_2. Then,

$$\frac{F_B+B_H}{F_B-B_H}=\frac{n_1^2}{n_2^2}$$

or,
$$\frac{F_B}{B_H}=\frac{n_1^2+n_2^2}{n_1^2-n_2^2}$$

$$\therefore \qquad B_H=\frac{n_1^2-n_2^2}{n_1^2+n_2^2}\times F_B$$

But
$$F_B=\frac{\mu_0 n I a^2}{2(a^2+x^2)^{3/2}}$$

where $\mu_0=4\pi\times10^{-7}$ henry/metre is the permeability of free space.

$$\therefore \qquad B_H=\frac{n_1^2-n_2^2}{n_1^2+n_2^2}\cdot\frac{\mu_0 n I a^2}{2(a^2+x^2)^{3/2}}$$

Result. The mean value of the horizontal component of the earth's magnetic induction $=B_H=$...Tesla

Observations. Number of turns in the coil $=n=$...

External diameter of the coil $=d_1=$...m

Internal diameter of the coil $=d_2=$...m

Mean diameter of the coil $=d=\frac{d_1+d_2}{2}=$...m

Radius of the coil $=\frac{d}{2}=a$...m

S. No.	Current I amp	Distance x metre	Time for 10 oscillations when current is in one direction	T_1 secs.	n_1	Time for 10 oscillations when current is in opposite direction	T_2 secs.	n_2	B_H
								Mean	

87. Resistance and Specific Resistance—Potentiometer

AIM. To find the resistance of the given coil using a potentiometer and hence determine its specific resistance.

Apparatus. The given coil, potentiometer, lead accumulators, two plug keys, rheostat, resistance box (0 – 10 ohms), *DPDT* switch (Pohl's commutator), table galvanometer and a high resistance.

Procedure. The primary of the potentiometer is made by connecting the ends *A* and *B* in series with one accumulator and plug key. Care is taken to see that the end *A* is connected to the positive of the accumulator. The secondary is made by connecting the resistance box *R* in series with the given coil (whose resistance *X* is to be determined), plug key, rheostat and a battery of accumulators. The central top terminal of the *DPDT* switch is connected to end *A* which ensures that all the three terminals in the top of the *DPDT* switch are positive. The central bottom terminal is connected to the jockey through a galvanometer, and high resistance.

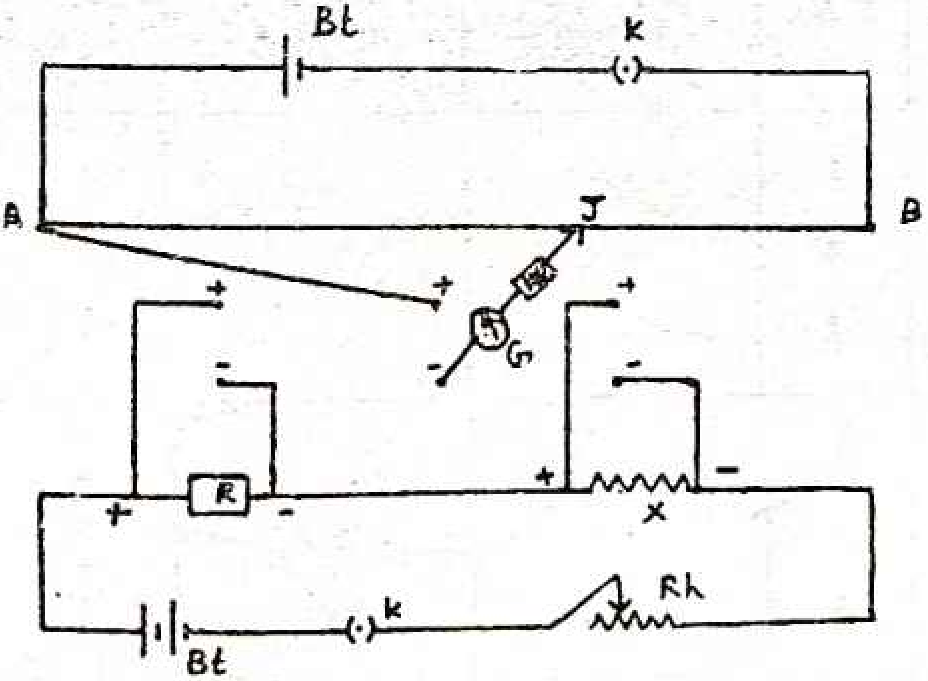


Fig. 87.

The resistance *R* is connected to the left pair of terminals of the *DPDT* switch and the unknown resistance *X* to the right pair of terminals, ensuring proper polarity.

Include a suitable resistance in *R*. The *DPDT* switch is thrown to one side so as to include the resistance *R*. The p.d. across *R* is balanced against the potentiometer wire and the balancing length l_1

metre is found. The *DPDT* switch is thrown to the other side to include X and the balancing length l_2 metre is found as before. Then

$$\frac{R}{X}=\frac{l_1}{l_2}$$

or

$$X=R\times\left(\frac{l_2}{l_1}\right) \text{ ohm}$$

Keeping R the same, the experiment is repeated by adjusting the rheostat to different positions. The experiment may also be repeated for different values of R. The given coil is unwound and its length L metre is determined by stretching it on a scale. Its mean radius r metre is found using a screw gauge.

$$\text{Specific resistance}=\frac{\pi r^2 \cdot X}{L}\times 10^6 \text{ microhm-metre,}$$

Result. 1. Resistance of the given coil =...ohm

2. The specific resistance of the coil =...microhm-metre.

Observations : 1. To find X

R in ohms	*S. No.*	*Balancing length when R is included (l_1 metre)*	*Balancing length when X is included (l_2 metre)*	$X=R\times\frac{l_2}{l_1}$ *ohm*	*Mean X ohm*
	1				
	2				
	3				
	1				
	2				
	3				
	1				
	2				
	3				
				Average	

2. To find the radius of the coil :

L.C.=0·01 mm.

Zero error...=Zero correction=...

S. No.	P.S.R. (mm)	H.S.R.	Corrected H.S.R.	P.S.R.+(Corrected H.S.R.×L.C.) (mm)	Mean diameter d mm

Mean diameter $=d=\ldots$mm

Radius of the coil $=r=d/2=\ldots$mm

$=\ldots$m

Length of the coil $=L=\ldots$m

Mean resistance of the coil $=X=\ldots$ohm

Specific resistance$=\dfrac{\pi r^2\times X}{L}\times 10^6$ microhm-metre= ...

89. Carey-Foster's Bridge— Resistance and Specific Resistance

AIM. To find the resistance of the given coil using Carey-Foster's bridge and hence calculate the specific resistance of the material of the coil.

Apparatus. The given coil, Carey-Foster's bridge, a fractional resistance box, a two-dial resistance box (0.1–1 ohm, 1–10 ohms), two standard resistances of equal value, Lechlanche cell, plug key, table galvanometer, high resistance and a pencil jockey.

Description. The Carey-Foster's bridge consists of a uniform wire *AB* of length one metre. It is stretched along a wooden board and soldered at its ends to two L-shaped copper strips fixed at the ends of the board. In between these strips are fixed three copper strips so that there are four gaps formed between the strips. A scale fixed parallel to the wire enables us to measure balancing lengths accurately.

Procedure. Two resistances *P* and *Q* of equal value are included in the two inner gaps. A resistance box *R* is included in the left extreme gap and the coil whose resistance (*X*) is to be found in the right extreme gap. Between *M* and *N* are connected a Lechlanche cell and a plug key. A table galvanometer through a high resistance is connected between *O* and *J*. The arrangement is a modified form

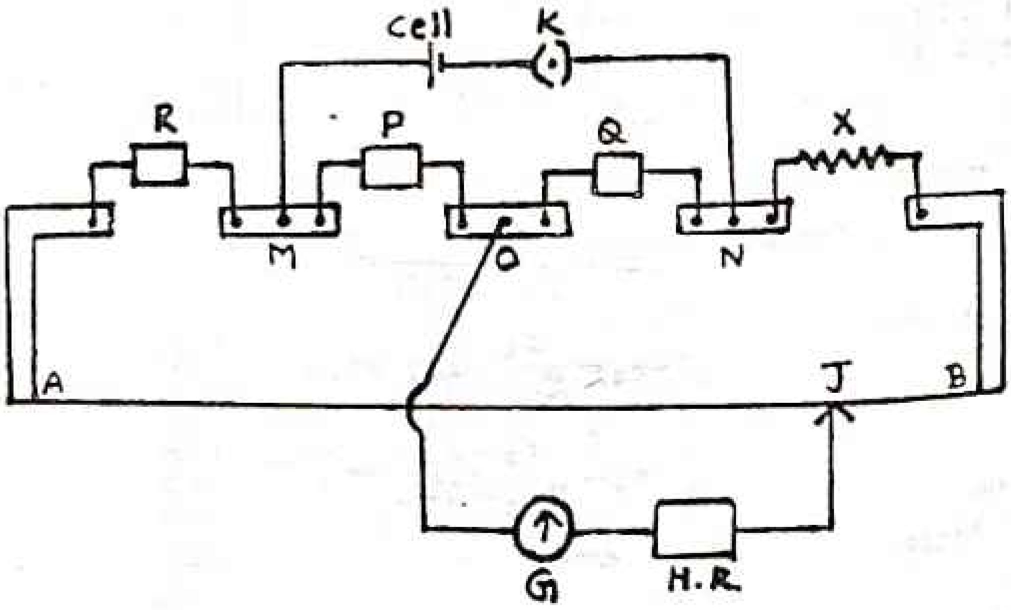


Fig. 89.

of Wheatstone's bridge with the resistances *P* and *Q* forming the two arms, the resistance box *R* and the portion *AJ* of the bridge wire the third arm and the unknown resistance *X* and the portion *BJ* of the wire the fourth arm.

(*a*) *To find the resistance per metre length of the bridge wire* :

In the left gap of the bridge is connected a fractional resistance box R_1 (0·1–0·9 ohm) and in the right gap a copper strip. Include a resistance say 0·1 ohm in R_1. Find the balancing length l_1' metre on the bridge wire. Interchange R_1 and the copper strip and then find the balancing length l_2' metre. If ρ is the resistance per metre length of the bridge wire,

$$\rho=\frac{R_1}{l_1'\sim l_2'} \text{ ohm/metre}$$

The experiment is repeated for different values for R_1 (say, 0·2 ohm and 0·3 ohm) and the mean ρ obtained.

(*b*) *To find the resistance of the coil* :

To find the resistance, the given coil is connected to the right extreme gap and the two-dial resistance box R (0, 1–0·9, 1–10) to the extreme left gap. Pressing the jockey near the middle of the wire the value of R for which the galvanometer deflection is very nearly zero is determined. Choosing six different values of R around this value, the exact balancing length l_1 metre for each resistance is found when R is in the left extreme gap and X in the right extreme gap. Then R and X are interchanged and the balancing lengths l_2 metre for all the values of R are found. The unknown resistance is calculated using the formula,

$$X=R-(l_2-l_1)\times\rho$$

It may be noted that for some values of R, (l_2-l_1) is positive and for some others negative. The sign must be maintained throughout the calculation of X.

To determine the specific resistance, the given coil is unwound and its length L metre is measured by a scale and its radius r metre using a screw gauge. Then,

$$\text{Specific Resistance}=\frac{\pi r^2 X}{L}\times 10^6 \text{ microhm-metre}$$

Result. (1) Resistance of the coil =...ohm

(2) Specific resistance of the material of the coil =...microhm-metre

Observations.

(*a*) *To find the resistance per metre length* :

S. No.	R_1 *in ohm*	*Balancing length when R_1 is in the left-gap and copper strip in the right gap (l_1' metre)*	*Balancing length when R_1 and copper strip are interchanged (l_2' metre)*	$\rho=\frac{R_1}{l_1'\sim l_2'}$ *ohm/m*
1	0·1			
2	0·2			
3	0·3			
			Mean	

(b) *To find the resistance of the coil :*

S. No.	R in ohm	Balancing length when R is in the left gap and X in the right gap l_1 metre	Balancing length when R and X are interchanged l_2 metre	$X = R - (l_2 - l_1)\rho$ ohm
			Mean	

(c) *To find the radius of the coil :*

L. C. of the screw gauge =0·01 mm

Zero error =...

Zero correction =...

S. No.	P. S. R. in mm.	H. S. R.	Corrected H. S. R.	P. S. R.+(Corrected H. S. R.×L.C.) (mm)	Mean diameter mm

Mean diameter $=d=\ldots$ mm

Radius of the coil $=r=\frac{d}{2}=\ldots$ mm

$=\ldots$ m

(d) *Specific resistance of the coil :*

Length of the coil $=L=\ldots$ m

Mean resistance of the coil $=X=\ldots$ ohm

Specific resistance $=\frac{\pi r^2 \times X}{L}\times 10^6$ microhm-metre

$=\ldots$

92. Calibration of High Range Voltmeter—Potentiometer

AIM. To calibrate the given high range voltmeter using a potentiometer.

Apparatus. The given high range voltmeter, potentiometer, a battery of lead accumulators, a Daniell cell, two plug keys, a rheostat, two resistance boxes, a table galvanometer and a high resistance.

Procedure. (*a*) **To determine the potential fall across 1 metre length of the potentiometer wire**

The experiment is done as described in the first part of Experiment 91.

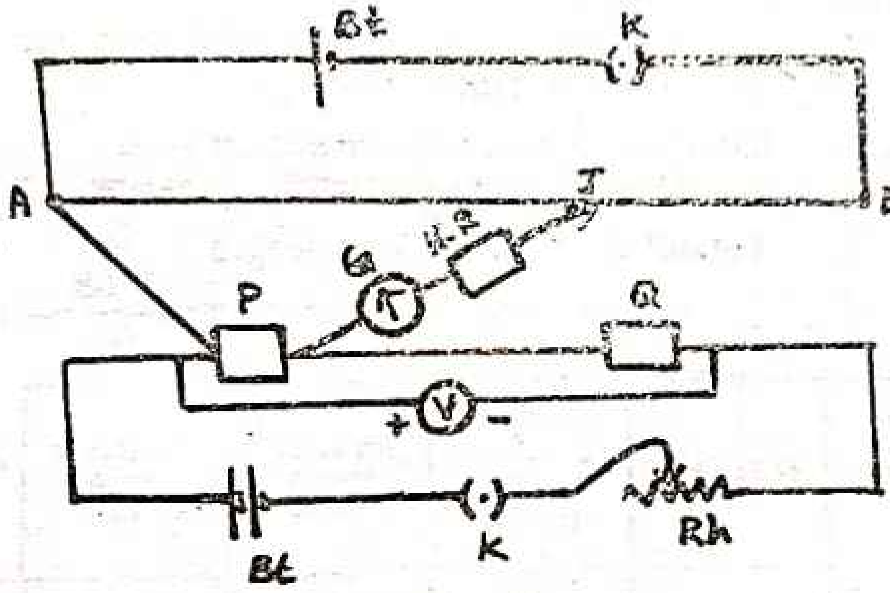


Fig. 92.

(*b*) **To calibrate the given high range voltmeter**

The primary circuit is left undisturbed during this part. A secondary circuit is made by connecting two resistance boxes P and Q in series with a battery of accumulators, a plug key and a rheostat. The voltmeter to be calibrated is connected between the positive terminal of P and the negative terminal of Q so that the reading in the voltmeter corresponds to the potential difference across $(P+Q)$. The positive terminal of P is connected to the end A of the potentiometer and its negative to the jockey through a galvanometer and high resistance. Choosing any convenient values of P and Q say, $P=1$ ohm and $Q=9$ ohm, the rheostat is adjusted to have a desired reading in the voltmeter, say, V volts. The potential difference across P is balanced by a length l metre of the potentiometer wire.

Theory. Let V' be the potential difference across $(P+Q)$

Current in $P=\frac{V'}{(P+Q)}$ and so

P.d. across $P=\frac{V'P}{(P+Q)}$.

Since this p.d. is balanced against the length l metre,

P.d. across $P=\frac{1\cdot 08}{l_0}\times l$

Hence $\frac{V'P}{P+Q}=\frac{1\cdot 08}{l_0}\times l$

or $$V'=\frac{1\cdot 08}{l_0}\cdot l\left(\frac{P+Q}{P}\right).$$

The correction to be applied to the observed reading is $(V'-V)$.

The experiment is repeated for different voltmeter readings, either keeping the resistances P and Q the same or varying them each time suitably, if necessary. A calibration graph is drawn between the observed readings and correction.

Result. The given high range voltmeter is calibrated for different reading on it, and the calibration graph drawn.

Observations. Balancing length when e.m.f. of Daniell cell is balanced $=l_0=\ldots$m

Potential drop per metre length of the potentiometur wire $=\frac{1\cdot 08}{l_0}=\ldots$volt/m.

S.No.	*P in ohm*	*Q in ohm*	*Observed volmeter reading (volt)*	*Balancing length l metre*	*Calculated value V' volt*	*Correction (V'−V)*

95. Calibration of High Range Ammeter—Potentiometer

AIM. To calibrate a high range ammeter using potentiometer.

Apparatus. The given high range ammeter, potentiometer, a battery of accumulators, Daniell cell, two plug keys, a dial type resistance box (0–10 ohm), a rheostat, a table galvanometer and a high resistance.

Procedure. (*a*) *To determine potential fall across 1 metre length of the potentiometer wire.*

The potential fall across one metre length of the potentiometer wire is determined by the method described in Experiment 91.

(*b*) *To calibrate the given high range ammeter :*

The primary of the potentiometer is left undisturbed. A secondary circuit is made by connecting the resistance box R in series with the given ammeter, plug key, rheostat and the battery of accumulators.

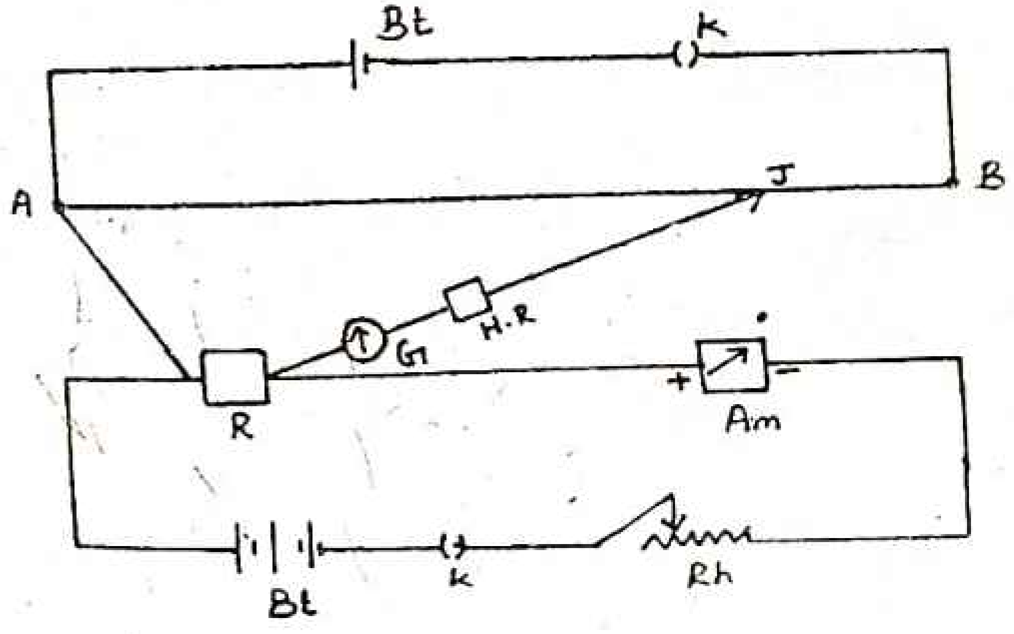


Fig. 95.

Connect the positive terminal of R to end A and its negative terminal to the jockey through a galvanometer and high resistance. Include a suitable resistance in R and adjust the rheostat to have a reading C in the ammeter. Find the balancing length l metre. The current in R and hence through the ammeter is given by

$$C' = \frac{1 \cdot 08}{l_0} \times \frac{l}{R} \text{ amp.}$$

The correction $C'-C$ is calculated. The experiment is repeated for different readings in the ammeter by measuring the corresponding balancing lengths. The calibration graph is drawn.

Result. The given high range ammeter is calibrated and the calibration graph drawn.

Observations.

Balancing length when e.m.f. of Daniell Cell is balanced $= l_0 = \ldots$ m

Observed reading in the ammeter C amp	*S. No.*	*R in ohm*	*Balancing length l metre*	*Calculated current C' amp.*	*Correction C'−C amp.*

97. E.M.F. of a Thermocouple—Potentiometer (Method I)

AIM. (*a*) To find the resistance of the potentiometer wire,

(*b*) to calibrate the potentiometer for a fall of potential of 1 milli volt per metre assuming the e.m.f. of the Daniell cell and hence

(*c*) to determine the e.m.f. of thermocouple for various temperature differences between the two junctions.

Apparatus. A ten-metre potentiometer, two resistance boxes R_1 and R_2 (0-5000 ohm), one resistance box R (0-10 ohm), a lead accumulator, a Daniell cell, a table galvanometer, suspended coil galvanometer or any other equivalent sensitive galvanometer, a high resistance, and a thermocouple.

Procedure. (*a*) *To determine the resistance of the potentiometer :*

The primary circuit of the potentiometer is made by connecting the ends A and B in series with a lead accumulator, key and a resistance box R (0-10 ohm) taking care to see that the end A is connected to the positive of the lead accumulator through R. Let a resistance of 1 ohm be included in R. The e.m.f. of the Daniell cell is balanced against the potential drop across 1 ohm resistance and that across the

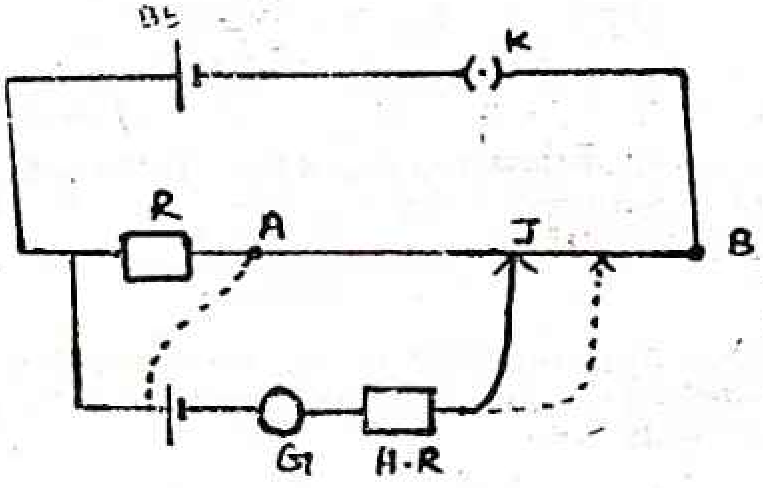


Fig. 97·1.

potentiometer wire. The balancing length l_1 is obtained by the use of a secondary circuit consisting of table galvanometer, high resistance and the Daniell cell connected in series between the positive end of R and the jockey. Care is taken to see that the positive terminal of the Daniell cell is connected to the positive end of R.

After l_1 is found, the positive of the cell is connected to the end A and now the e.m.f. of the cell is balanced against the potentiometer wire alone. Balancing length l_2 is found. It follows then that the resistance of the length $(l_1 \sim l_2)$ metre of the potentiometer wire is

Final corrected temperature$=t_2$ °C$=$Maximum observed temperature$+$Radiation correction$=$...

Mass of the empty watch glass $=m_1=$...kg.

1 ohm. Hence, for the entire potentiometer of length 10 metre, the resistance is given by,

$$P = \frac{R}{(l_1 \sim l_2)} \times 10 \text{ ohm.}$$

The experiment is repeated for different values of R.

(*b*) *To calibrate the potentiometer :*

To calibrate the potentiometer for a fall of potential of 1 millivolt per metre,

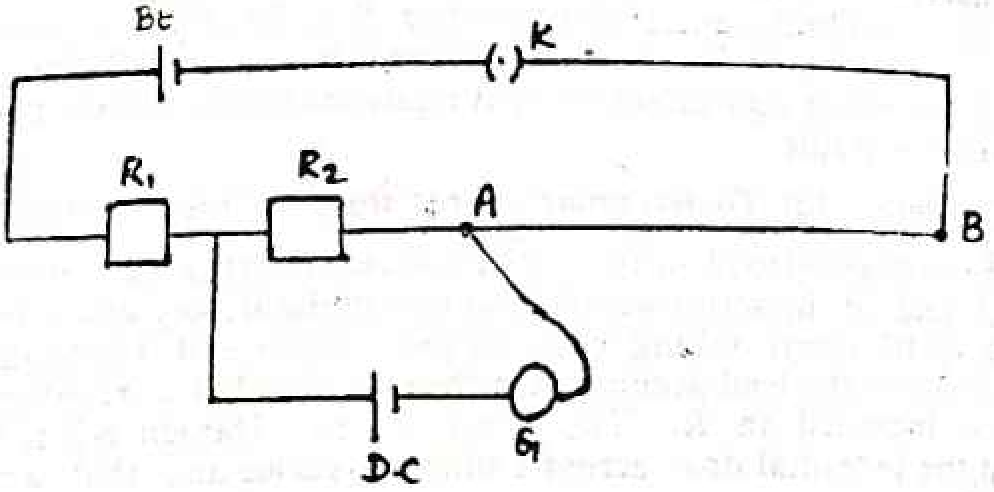


Fig. 97·2.

the required fall of potential across full length of the potentiometer $= 10$ milli volts

Consider the circuit shown in Fig. 97·2. If the p.d. across P ohm (between A and B) is 10 milli volts, then the current in AB is given by,

$$C = \frac{10 \times 10^{-3}}{P} \text{ amp.}$$

If a resistance R_2 is included in the resistance box R_2 so that there is zero deflection in the galvanometer, then the potential drop across R_2 is 1·08 volts.

Hence, current in $R_2 = \frac{1.08}{R_2}$ amp. Since R_2 and AB are connected in series.

$$\frac{1 \cdot 08}{R_2} = \frac{10 \times 10^{-3}}{P}$$

or

$$R_2 = 108 \times P.$$

Thus, if the p.d. across $R_2 = 108$ P ohm balances the e.m.f. of the Daniell cell, the potential fall across the potentiometer is 10 millivolt.

Now a circuit is made connecting the potentiometer in series with two resistance boxes R_1 and R_2 (each of range 0 to 5000 ohms) and key. The calculated value of $108 \times P$ is included in R_2, omitting the fractional part, if any. The Daniell cell, the table galvanometer and the high resistance are connected across the resistance box R_2 as shown in Fig. 97·2. A suitable resistance is included in R_1 for zero deflection in the galvanometers. Now with resistances R_1 and R_2 included as above, the fall of potential across the potentiometer wire is 10 millivolts.

(c) *To determine the e.m.f. of thermocouple :*

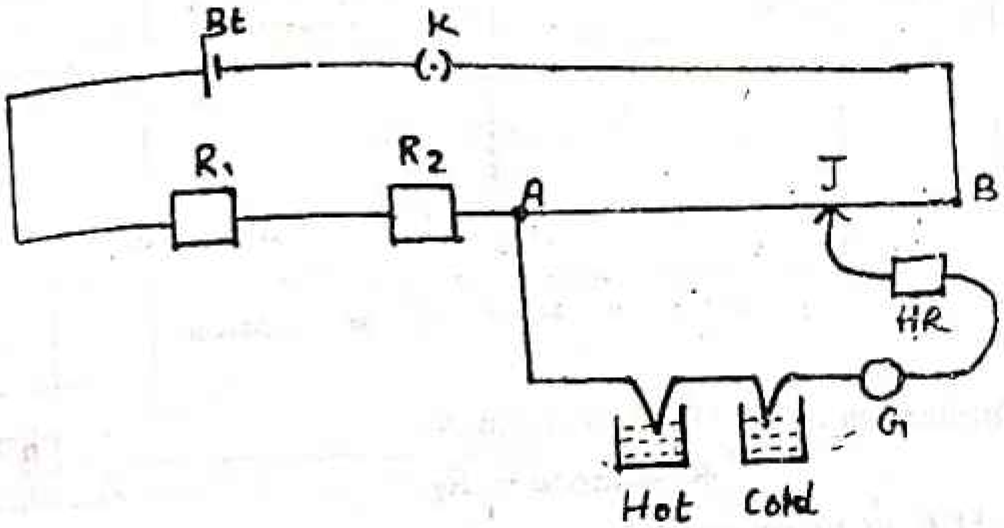


Fig. 97·3.

The primary of the potentiometer of the previous part with R_1 R_2 having been included for 10 millivolt calibration, is left undisturbed. For the secondary, the given thermocouple is connected between *A* and the jockey through a sensitive galvanometer (suspended type) and a high resistance. A difference of temperature is maintained between the junctions. The circuit is closed and the jockey is pressed first near *A* and then near *B*. If the deflections in the galvanometer are in opposite directions, the e.m.f. of the thermocouple opposes the p.d. on the wire and the connections are made. Otherwise, the terminals of the junctions of the thermocouple must be interchanged. After ensuring the correctness of the circuit, the exact balancing length (l_3) is found for a particular temperature difference.

$$\text{The e.m.f. of thermocouple} = \frac{10 \times l_3}{10} = l_3 \text{ millivolt}$$

where l_3 is in metre. Usually one of the junctions is maintained at the temperature of melting ice and the other at the temperature of a water bath which can be maintained at different temperatures.

A graph can be drawn connecting the temperature of the hot junction on the *X*-axis and the corresponding e.m f. of the thermocouple on the *Y*-axis. The graph is found to be a straight line.

Result. E.M.F. of thermocouple for various temperature differences is determined.

Observations. *Resistance of the potentiometer :*

S.No.	R in ohm	Balancing length when postiive of Danie'l cell is connected to positive of R (l_1 in metre)	Balancing length when positive of D. cell is connected to end A (l_2 in metres)	Resistance of the potentiometer $P=\frac{P}{l_1 \sim l_2}\times 10$ ohm
			Mean	

Calibartion part : Resistance in R_1 =...ohms.

Resistance in R_2 =...ohms.

E.M.F. of thermocouple :

Temperature of the cold junction $=t_1°C=...$

S.No.	Temperature of the hot junction (t_2°C)	Balancing length l_3 in metre	E.M.F. of thermocouple millivolt (l_3)

124. Regulated Power Supply Using Zener Diode

AIM. To construct a regulated power supply using a zener diode to provide a predetermined D.C. voltage of 8 V and study its regulation characteristics.

Apparatus and Components. A 12-0-12 transformer, IN 400. diodes, 1000 μF 24 V capacitor, zener diode (8·1 *Z*) resistance box, multimeter etc.

Procedure. The connections are made as shown in the diagram, by effectively soldering on a bread-board arrangement. In a regulated power supply, we design the circuit to get a predetermined D.C. volt-

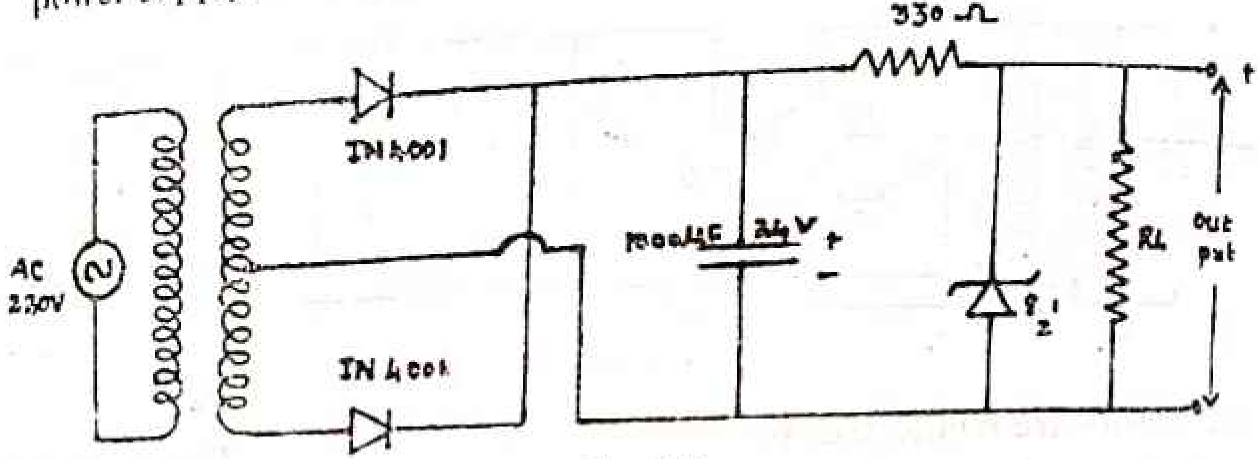


Fig. 124.

age, which is 8 V in the case of the present experiment. Here independent of the current drawn and independent of the line A.C. voltage, the output voltage is a constant. The circuit consists of a transformer, two rectifier diodes (IN 4001) connected across the secondary of the transformer. The *N* regions of the 2 diodes are short-circuited. Across the common *N* junction and t e centre tap of the secondary the rectifier circuit is connected. The resistance 330Ω ensures that the zener dicde operates in the break-down region. The A C. voltage to be regulated is connected across the primary of the transformer. The A.C input is switched on and using a multimeter the D.C. output voltage is measured, when no load resistance (R_L) is connected across the output terminals. With a resistance box (R_L) connected across the output terminals, the output voltage is measured for R_L 200 ohm, 400 ohm, 600 ohm, 800 ohm and 1000 ohm. Care should be taken to see that R_L never becomes zero. The percentage regulation is obtained from the formula

$$\%\ \text{regulation} = \frac{\text{Voltage without } R_L - \text{voltage with } R_L}{\text{voltage without } R_L}$$

Result. A zener-regulated power supply is constructed and its regulation characteristics are studied.

Tabular Column

AC input voltage =...volts

DC voltage across the output terminals when no load resistance is connected = V_0 volts = ...

S. No.	R_L ohm	Voltage across the output terminals V volts	% regulation = $\frac{V_0 - V}{V_0}$
1	200		
2	400		
3	600		
4	800		
5	1000		

129. Hartley Oscillator (Solid State)

AIM. To construct a Hartley oscillator in the *AF* range and determine the frequency of oscillations for different values of capacitance.

Apparatus and Components. Transistor power supply, *AC* 128 Transistor, Audio frequency oscillator, speaker, inductance coil, capacitance box, etc.

Procedure. The connections are made as in Fig. 129 by effective soldering on a bread-board arrangement. The power supply is switched

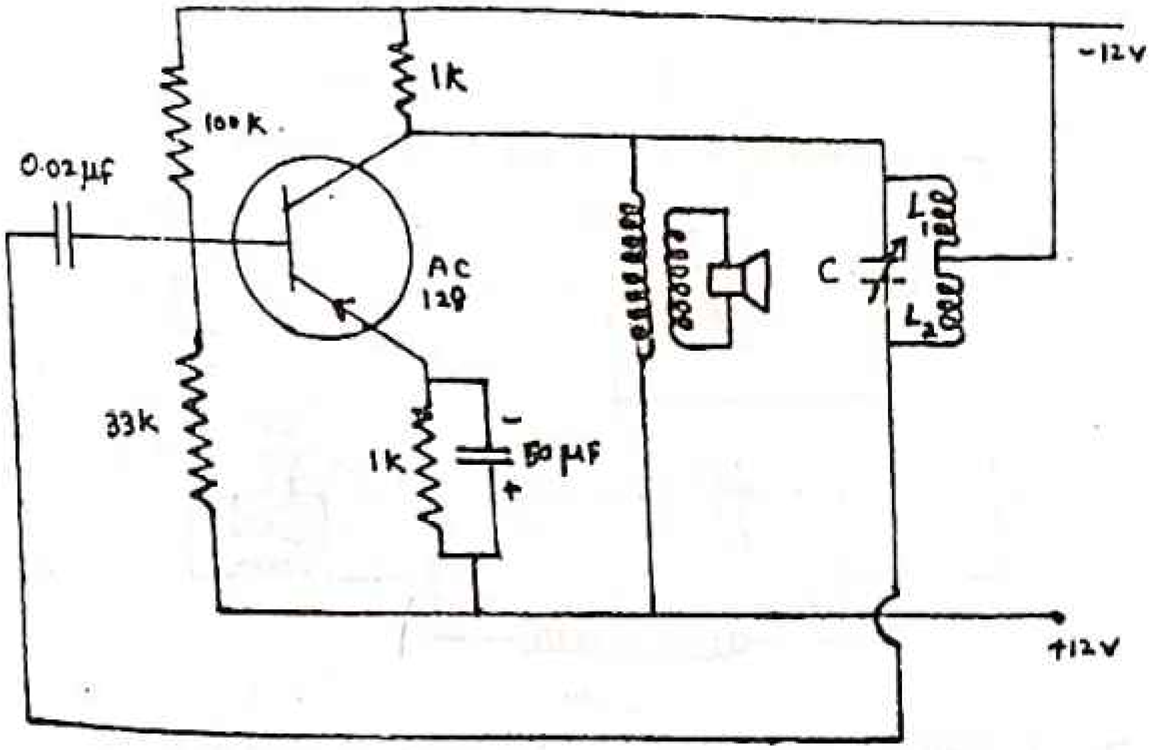


Fig. 129.

on with a capacitance of 0·5 μ*F* introduced in the constructed oscillator and frequency is found by (*i*) beats method and (*ii*) CRO as explained in the previous experiment. The experiment is repeated for different values of *C*.

Result. The Hartley oscillator is constructed and its frequencies for different values of *C* are found.

Tabular Column :

S. No.	*C* μ*F*	*Frequency (Hz)*		*Mean frequency Hz*
		By beats	*By CRO*	
1	0·1			
2	0·2			
3	0·3			
4	0·4			
5	0·5			
6	0·6			

131. Colpitt's Oscillator (Solid State)

AIM. To Construct a Colpitt's oscillator using a transistor and to find its frequency for different values of capacitances.

Apparatus and components. Transistor power supply, BC 107 npn transistor, inductance coil, 2 condenser boxes, base board, Audio frequency oscillator, speaker, etc.

Procedure. The connections are made as in Fig. 131 by effective soldering on a bread-board arrangement. The power supply is switched on with a capacitance of 0·5 μF in each of the condenser boxes. The

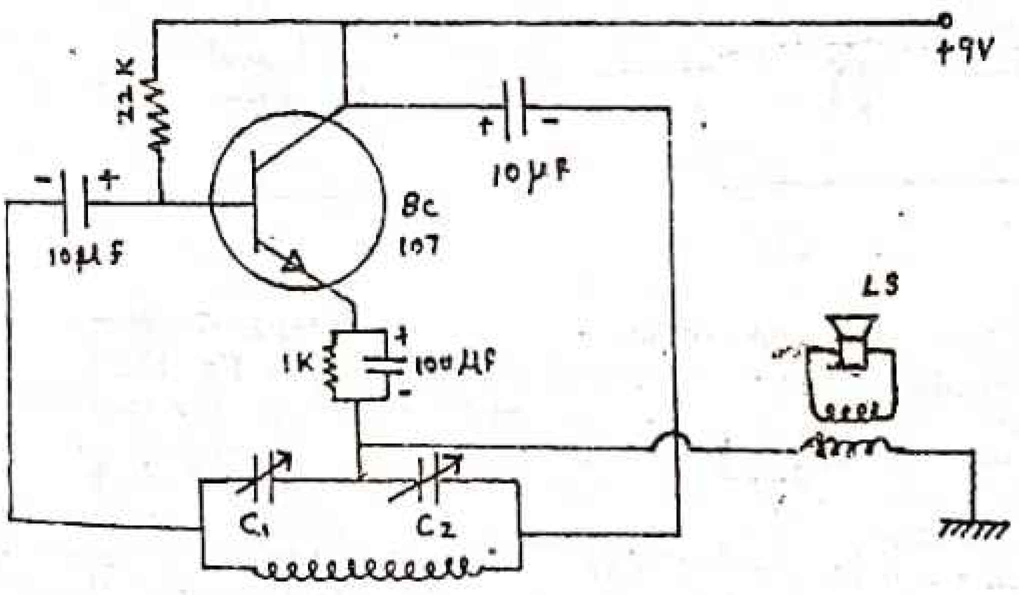


Fig. 131.

frequency of the oscillations produced in the oscillator is determined by (*i*) beats method and (*ii*) CRO, as explained earlier. The experiment is repeated for different values of C_1 and C_2.

Result. The Colpitt's oscillator is constructed and its frequencies for different values of C_1 and C_2 are found.

Tabular column :

S. No.	C_1 μF	C_2 μF	*Frequency*		*Mean frequency*
			by beats	*by CRO*	
1	0·1	0·1			
2	0·2	0·2			
3	0·3	0·3			
4	0·4	0·4			
5	0·5	0·5			
6	0·6	0·6			

136. Logic Gates Using Diodes and Transistors

AIM. To construct the basic logic gates using diodes and transistors and prepare the truth table for each logic gate.

Apparatus and Components. 5 V power supply, two SM 1 diodes, resistors of value 510 ohm, 22 *K*, 56 ohm, 1*K*, etc., two SG 221 transistors, 0–6 voltmeter etc.

Procedure. (*a*) **AND Gate**

The connections are made as in Fig. 136·1. A voltmeter is connected across the output terminals. For 1 level, the point is connected

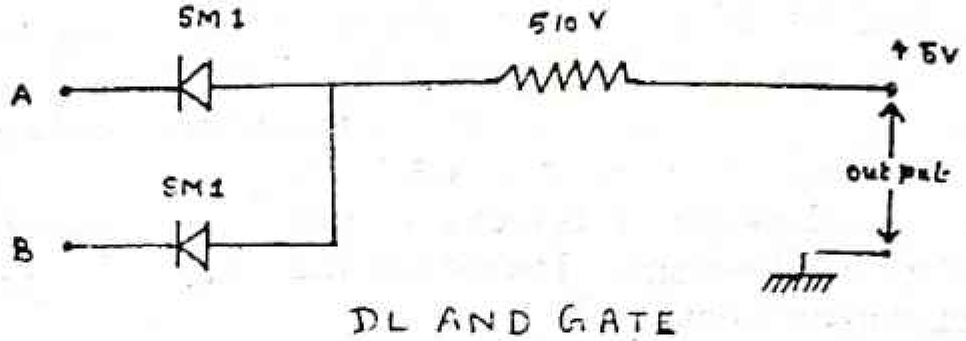


Fig. 136·1.

to the +5 volt supply and for 0 level, the point is connected to the earth. Both the points *A* and *B* are kept at the 0 level and the output is measured. The experiment is repeated keeping *A* and *B* at 0 level and 1 level, 1 level and 0 level and 1 level and 1 level respectively and in each case the output is measured. A truth table is prepared as under:

A	*B*	*Output*
0	0	0 (low level)
1	0	0 (low level)
0	1	0 (low level)
1	1	1 (high level)

It is found that the output is high only when *A* and *B* are at 1 level.

(*b*) **OR Gate :**

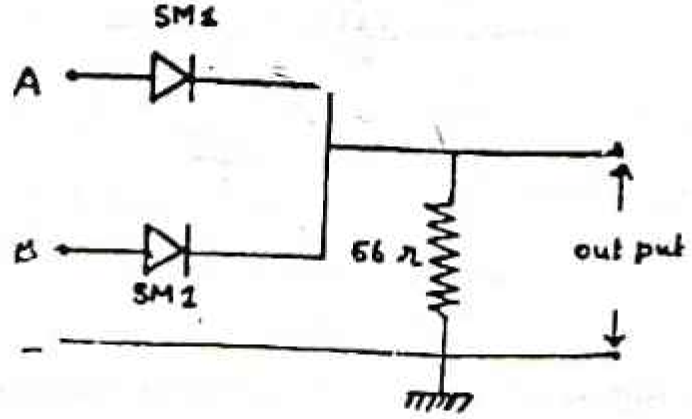


Fig. 136·2.

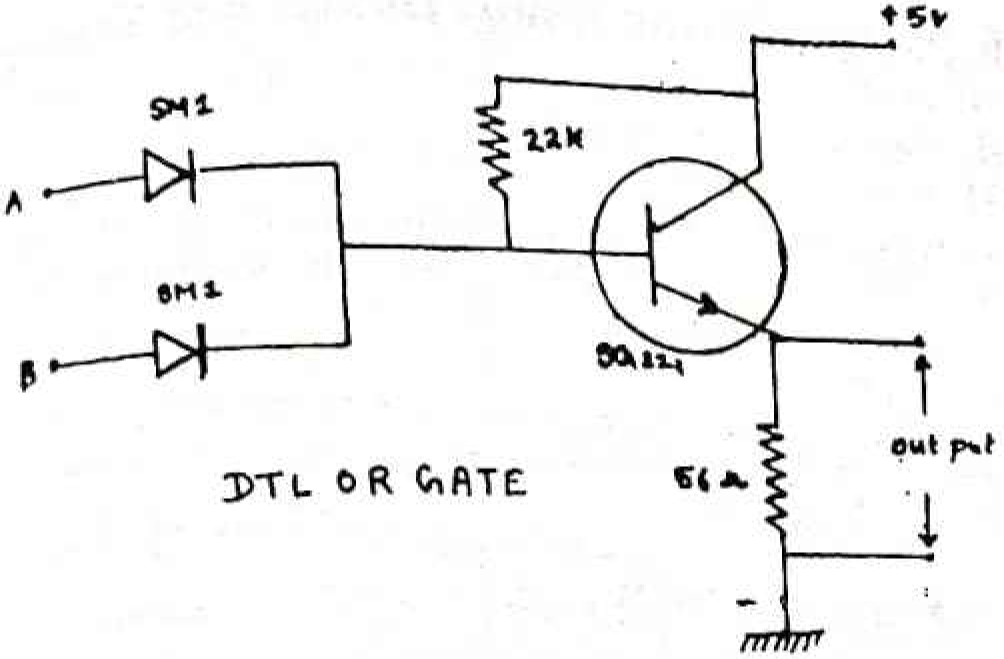


Fig. 136·3.

The connections are made as in Fig. 136·2. A voltmeter is connected across the output terminals. The output is measured for various input combinations as in the previous case. The truth table is prepared and it will be as follows :

A	*B*	*Output*
0	0	0
1	0	1
0	1	1
1	1	1

It is found that the output is high whether *A* or *B* is at 1 level. The experiment is repeated using 2 diodes and a transistor. The

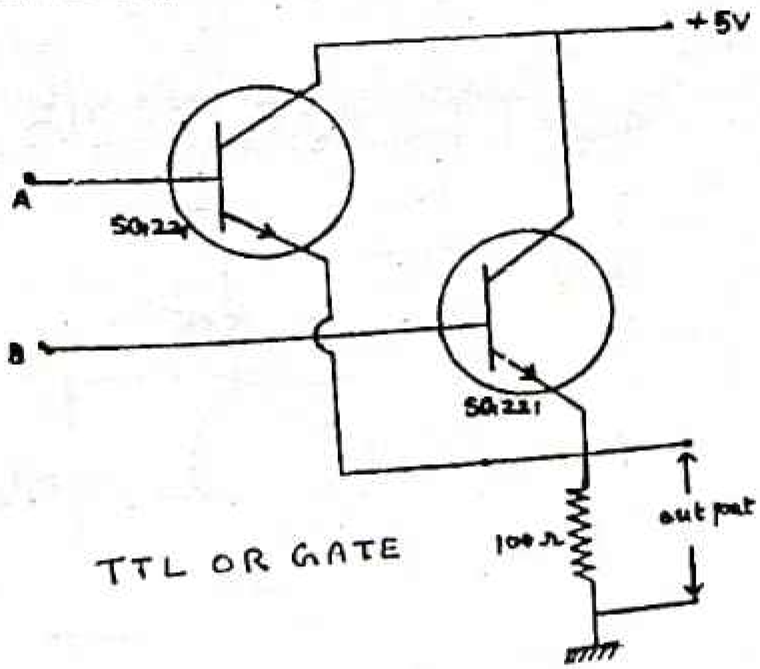


Fig. 136·4.

former is known as diode logic (DL) and the latter as diode-transistor logic (DIL) OR Gate. We can also form a transistor, transistor logic (TIL) OR Gate as in Fig. 136·4.

(c) NOT GATE

The connections are made as in Fig. 136·5. A voltmeter is connected across the output terminals. The output is measured when *A* is

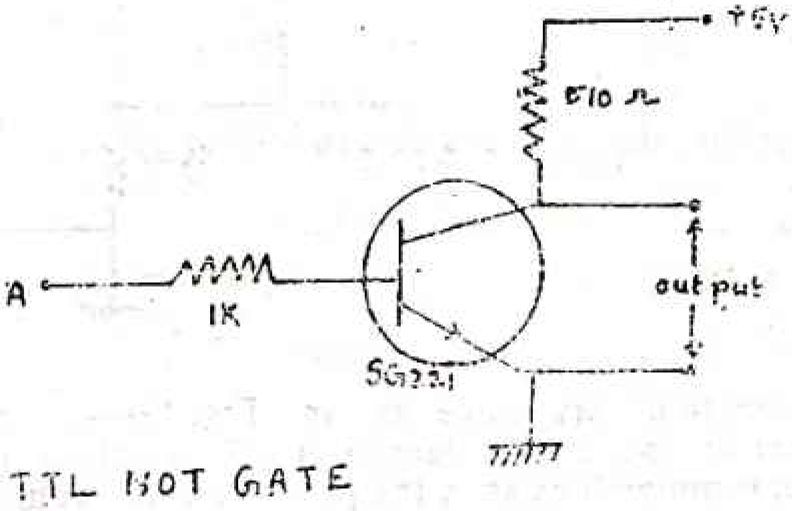


Fig. 136·5.

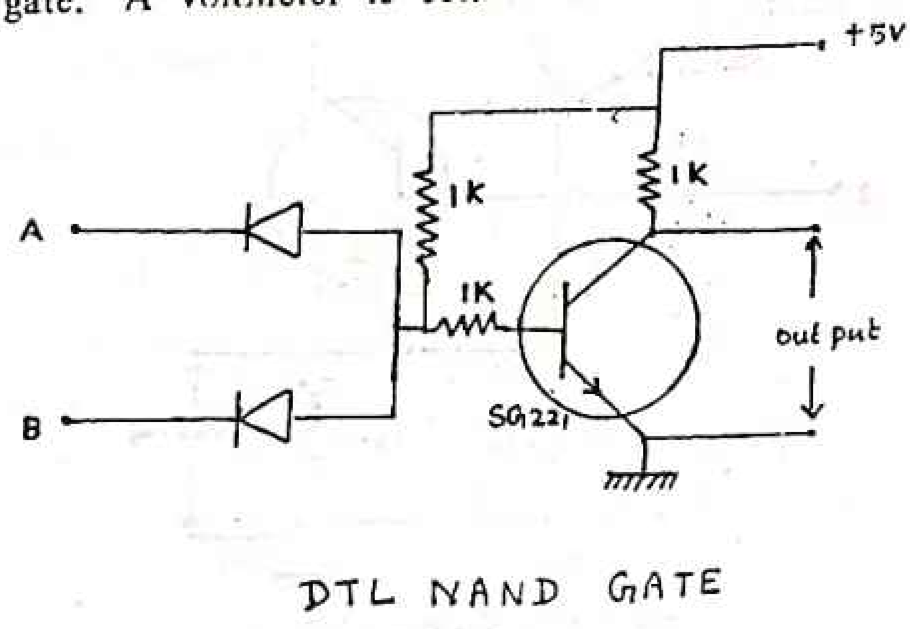
at 0 and 1 level and the truth table is prepared which will be as follows :

A	*Output*
1	0
0	1

Since, when the input is at 1 level, the output is at 0 level and when the input is at 0 level, the output is at 1 level, this logic gate is known as the INVERTER.

(d) NAND GATE

The connections are made as in Fig. 136·6 which forms a DTL NAND gate. A voltmeter is connected across the output terminals.



The output is measured for various input combinations. The truth table is prepared which is as follows :

A	*B*	*Output*
0	0	1
0	1	1
1	0	1
1	1	0

It is found that the output is at zero level only when *A* and *B* are at 1 level. The NAND gate can also be constructed with 2 transistors as in Fig. 136·7 to form a TTL NAND gate.

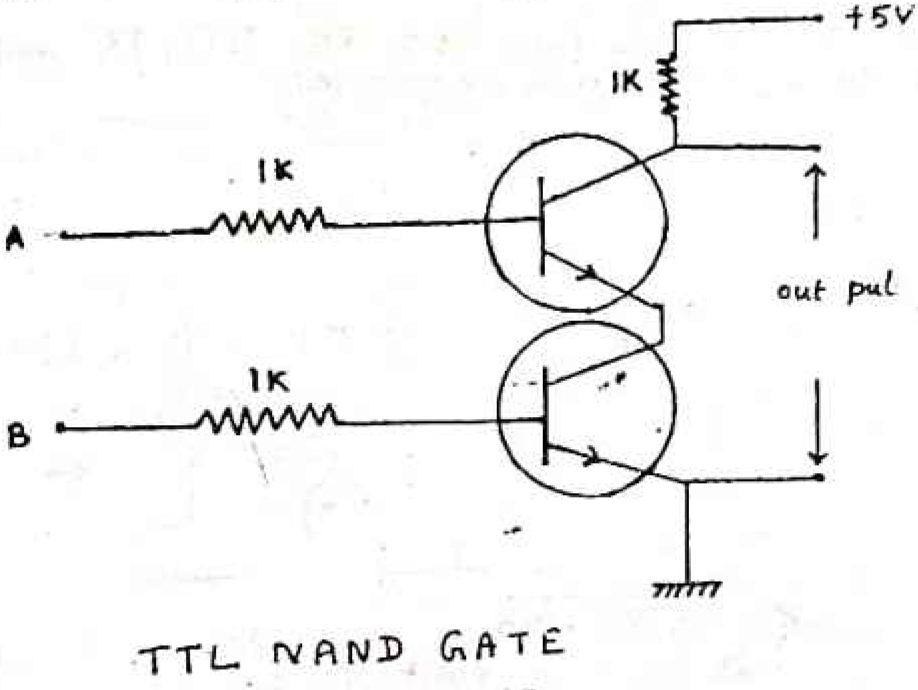


Fig. 136·7.

(*e*) **NOR GATE**

The connections are made as in Fig. 136·8, which forms a Transistor Logic (TL) NOR gate. A voltmeter is connected across the output

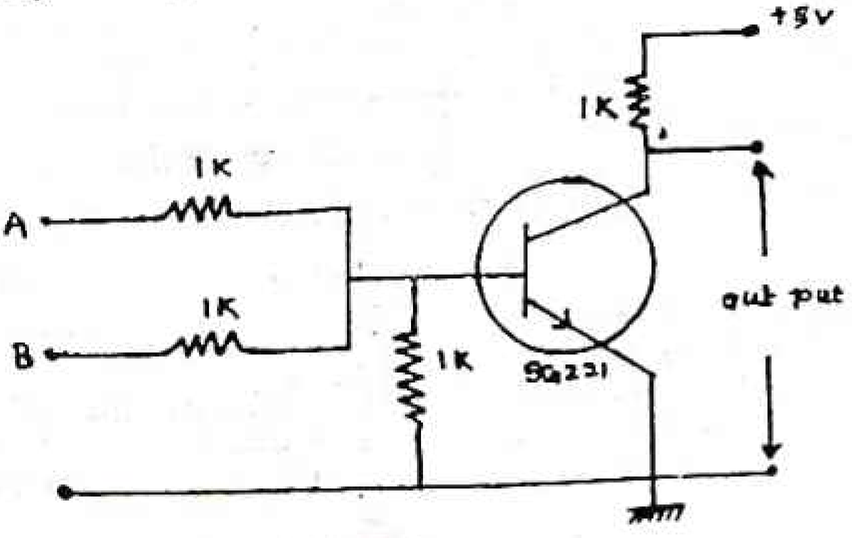


Fig. 136·8. TL NOR GATE.

terminals. The output is measured for the various input combinations. The truth table is prepared, which is as follows :

A	*B*	*Output*
0	0	1
0	1	0
1	0	0
1	1	0

It is found that the output is at 1 level only when *A* and *B* both are at 0 level.

Result. All the logic gates using DL, DTL, TL and TTL are constructed and their logic levels are recorded.

DEPARTMENT OF PHYSICS

M.SC., PHYSICS LABORATORY MANUAL

CONTENT

ADVANCED GENERAL EXPERIMENTS

1. Determination of plancḱs constant and work function of metals using photoelectric effect.
2. To determine the viscosity of water by Meyers oscillating disk method.
3. Laser –Transmission grating ,Determination of wavelength.
4. Determination of Numerical Aperture of optical fibres.
5. Hydrogen spectrum and determination of Rydberg constant.
6. The Michelson Interferometer.
7. Energy band gap by Four probe method.
8. Measurement of susceptibility of a Liquid or a solution by Quinckés method.
9. Magnetic susceptibility using a Gouy balance.
10. Forbidden energy band gap.

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DETERMINATION OF PLANCKS CONSTANT AND WORK FUNCTION OF METALS USING PHOTOELECTRIC EFFECT

OBJECTIVE *(i) To determine Planck's constant 'h' from the stopping voltages measured at different frequencies (wavelengths) of light.*
(ii) To determine the work function "Φ" of a metal.

INTRODUCTION -

One of the most important experiments from the early 20th century was the photoelectric-effect experiment. In this experiment, shining light upon a metal surface may cause electrons to be emitted from the metal. In 1905, Albert Einstein working in a Swiss patent office published a paper in which he explained the photoelectric effect. He argued that light was not a wave - it is particulate - and it travels in little energy bundles (or packets) called photons. The energy of one of these photons is 'hf' where 'h' is the fundamental constant of nature as proposed by Max Planck to explain blackbody radiation, and 'f' is the frequency of the photon. This novel interpretation of light turned out to be very significant and secured a Nobel Prize for Albert Einstein. Robert Millikan, co-founder of the California Institute of Technology and fellow Nobel Prize Winner, performed the careful experimental verification of Einstein's predictions.

THEORY -

An electron in a metal can be modelled as a particle in an average potential well due to the net attraction and repulsion of protons and electrons. The minimum depth that an electron is located in the potential well is called the work function of the metal, 'Φ'. In other words, it is a measure of the amount of work that must be done on the electrons (located in the well) to make it free from the metal. Since different metal atoms have different number of protons, it is reasonable to assume that the work function (Φ) depends on the metal. This is also supported by the fact that different metals have different values for electrical properties that should depend on the electron binding including conductivity. The electron in the potential well of a metal is shown below in. It is analogous to a marble trapped in a water-well. The shallower the well (i.e. the lower the work function "Φ"), less is the energy required to cause the emission of the electron. If we shine a light with sufficient energy, then an electron is emitted.

When a photon with frequency 'f' strikes the surface of a metal, it imparts all of its energy to a conduction electron near the surface of the metal. If the energy of the *photon (hf) is greater than the work function (Φ), the electron may be ejected from the metal. If the energy is less than the work function, the electron will simply acquire some kinetic energy hat will dissipate almost immediately in subsequent collisions with other particles in the metal. By conservation of energy, the maximum kinetic energy with which the electron could be emitted from the metal surface T_{max}, is related to the energy of the absorbed photon 'hf', and the work function 'Φ', by the relation,*

$$T_{max} = (1/2)mv^2_{max} = hf - e\Phi \qquad ...(1)$$

Now consider the case of electrons being emitted by a photocathode in a vacuum tube, as illustrated. In this case, all emitted electrons are slowed down as they approach the anode, and some of their kinetic energy is converted into potential energy. There are three possibilities that could happen.

i) *First, if the potential is small then the potential energy at the anode is less than the kinetic energy of the electrons and there is a current through the tube.*

ii) *The second is if the potential is large enough the potential energy at the anode is larger than the kinetic energy and the electrons are driven back to the cathode. In this case, there is no current.*

iii) *The third case is if the voltage just stops the electrons (with maximum kinetic energy Tmax) from reaching the anode. The voltage required to do this is called the "stopping potential" (V0). A typical I-V characteristic for a given frequency of light is also depicted in.*

Thus Eq. 1 can be rewritten as,

$$eV_0 = hf - e\Phi \qquad ...(2)$$

$$V_0 = hf/e - \Phi \qquad ...(3)$$

It is worth noting here that, since the anode and cathode surfaces are different, an additional contact potential "A" comes into the picture which simply gets added to the work function "Φ". Eq. (3) can be written in terms of wavelength as

$V_0 = (hc/e)\,(1/\lambda) - (\Phi + A)$ ...(4)

Standard value of h *is known to be 6.626 x 10^{34} J-s.*

EXPERIMENTAL SET UP -

The present experimental set-up comprises of a tungsten-halogen light source with five different colour filters, a Cesium-type vacuum phototube, a built-in power supply and a current multiplier. The base of the phototube is built into a dark room and in front of it a receptor (pipe) is installed to mount filters.

PROCEDURE -

i) Plug in and switch on the apparatus using the red button at the bottom right corner of the set up.

ii) Before the lamp is switched on, put the toggle switch in current mode and check that the dark current is zero.

iii) Turn on the lamp source (it may take 5-10 mins. to warm up). Set the light intensity near to maximum. Note that the intensity should be such that the value of current should not exceed the display range. In case it happens, you need to reduce the intensity. You should not change intensity while taking data.

iv) Insert one of the five specified filters into the drawtube of the receptor.

v) Set the voltage direction switch to "+ve" polarity. Adjust the voltage knob at minimum and current knob at "X 0.1" position which means the resolution is up to one decimal point. Vary the voltage and record the current till the value of current becomes relatively constant. Use the display mode switch to record the values of voltage and the corresponding current each time.

vi) Now, set the voltage direction switch to "-ve" polarity. Adjust the voltage knob at minimum and current knob at "X 0.001" (we need higher resolution since current will be less here). Vary the voltage and record the current till the value of current becomes 0. Use the display mode switch to record the values of voltage and the corresponding current each time.

vii) The above steps 5 and 6 provides data to plot the I-V characteristics of the phototube for the wavelength (or frequency) selected by the filter.

viii) Repeat the steps 5-7 for all the filters provided.

ix) Fill up the observation tables and draw necessary plots. Determine the values of Planck's constant and work function of the metal used in the phototube.

OBSERVATIONS:

Specification of Filters:

Colour	Blue	Green	Yellow	Orange	Red
Wavalength (nm)	460	500	540	570	635

Table 1: For I-V characteristics

Voltage (+ ve polarity)					
Current (A)					

Voltage (- ve polarity)					
Current (A)					

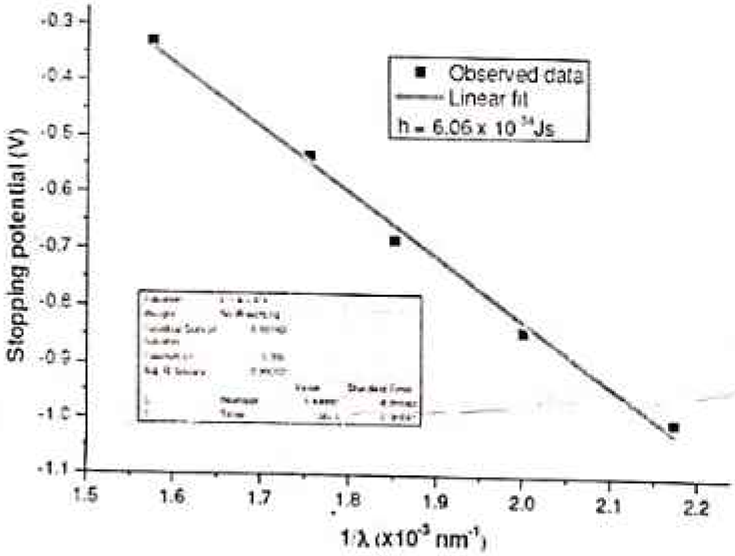
Table 2: Data for stopping potential ˜ wavelength

Stopping Potential (V)					
Wavelength (nm)					

GRAPH -

i) *Plot I˜ V characteristics for different wavelengths.*

ii) *Plot Stopping potential ˜ (1/wavelength) and calculate slope and intercept using Eq.4. A sample graph is shown below.*



CALCULATION AND ESTIMATION OF ERROR - *Determine h and f and estimate error.*

PRECAUTIONS -

i) *Rotate all the knobs very slowly.*

ii) *Handle the filters with utmost care and avoid touching their surfaces.*

14.

To determine the viscosity of water by Meyer's oscillating disk method

Experiment 14(V)

Theory

If a disk undergoes torsional oscillations about its symmetry axis in a fluid medium, it does not push aside any additional fluid while executing this motion. The fluid in contact with the disk then remains at rest with respect to it, while the fluid far away is at rest with respect to the enclosure/container. so a transverse velocity gradient is set up in the fluid, and this in turn causes a viscous force to act and damp out the oscillations. Oscar Meyer suggested measuring the decay of these oscillations to find the viscosity of a liquid.
The equation to a harmonic oscillator undergoing torsional os-

cillations is.

$$I\frac{d^2\theta}{dt^2} + K\frac{d\theta}{dt} + \tau\theta = 0. \tag{14.1}$$

Here I is the moment of inertia of the oscillator, K is the damping coefficient, τ is the restoring torque per unit twist and θ is the oscillations (twist) angle. The solution of this equation is given by,

$$\theta(t) = \theta_0 e^{-\frac{2\lambda t}{T}} sin(\frac{2\pi t}{T} + \phi), \lambda = \frac{KT}{4}, T = 2\pi I\left(\frac{1}{\tau - \frac{K^2}{4}}\right)^{\frac{1}{2}} \tag{14.2}$$

where θ_0 and ϕ are constants of integration. The variation of this function with time is shown in the Fig 14.1. The quantity λ, known as the logarithmic decrement, is the logarithm of the ratio of any two successive amplitudes on opposite sides of the equilibrium position. Thus,

$$e^{\lambda} = \frac{B_1C_1}{B_2C_2} = \frac{B_2C_2}{B_3C_3} = \frac{B_1C_1 + B_2C_2}{B_2C_2 + B_3C_3} = \frac{B_1C_1 + B_2C_2... + B_nC_n}{B_2C_2 + B_3C_3... + B_{n+1}C_{n+1}} \tag{14.3}$$

Here B_j is the amplitude at the i^{th} turning point of the disk, as shown in Fig.1. Thus by measuring the amplitudes on either side of the equilibrium position, we can find out the damping coefficient using Eq.(14.3).

In the case of a disk oscillating inside a liquid, the damping is due to two causes: damping due to the viscous forces of the liquid, and damping due to the friction of the wire suspension at the support. Meyer suggested that the instrument be first used to find the logarithmic decrement λ_0 in air, where the viscous damping is negligible, followed by a measurement of the logarithmic decrement λ in the liquid. As the frictional damping at the support is the same in both cases., this (unknown quantity) can be eliminated by taking the difference $\lambda - \lambda_0$. Using this, he was able to find a formula for the viscosity of the liquid as,

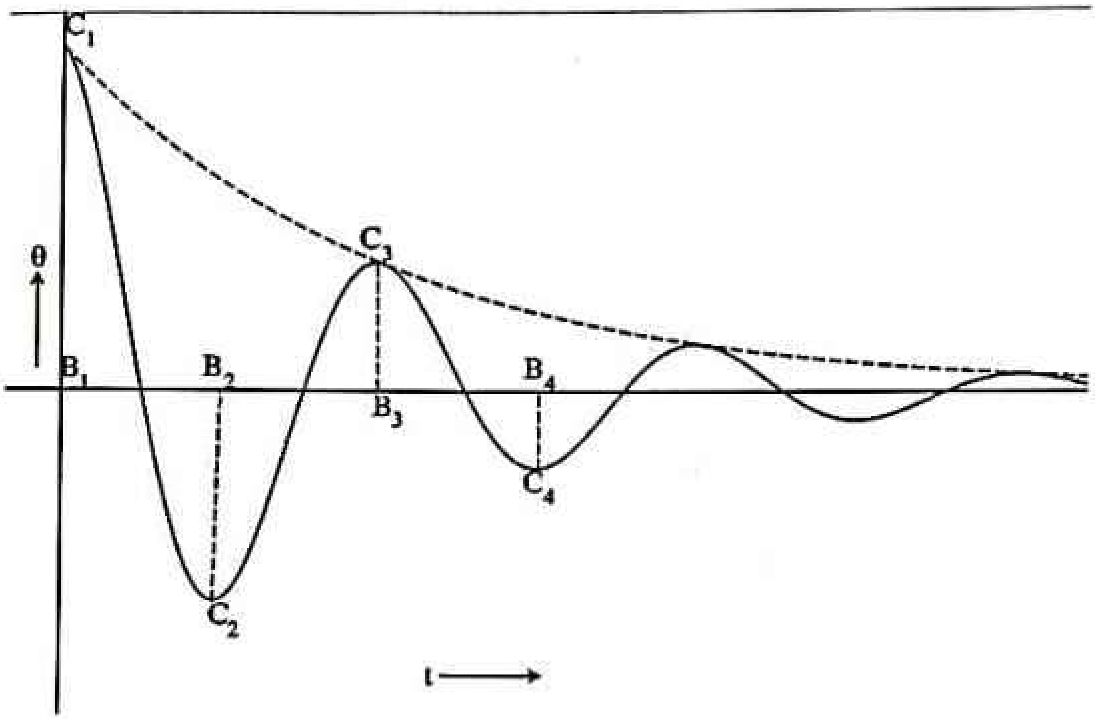


Figure 14.1: Damped Oscillations

$$\eta = \frac{16I^2}{\pi\rho T(r^4 + 2r^3 d)^2}\left[\left[\frac{\lambda - \lambda_0}{\pi}\right] + \left[\frac{\lambda - \lambda_0}{\pi}\right]^2\right]^2 \qquad (14.4)$$

Here,
I - moment of inertia of the torsional pendulum about the suspension axis.
T - time period for one complete oscillation.
r - radius of the disk.
d - thickness of the disk.

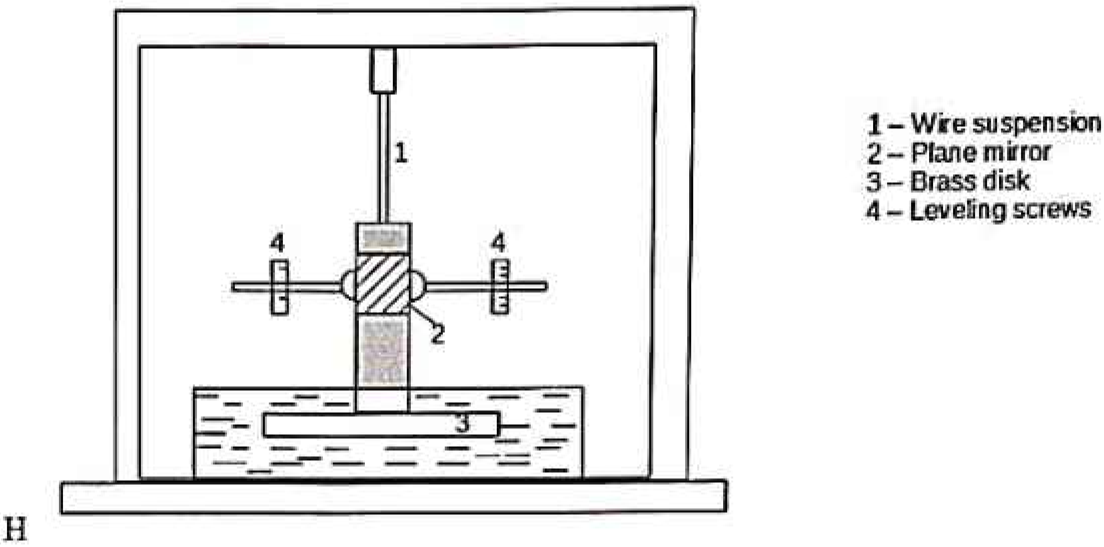


Figure 14.2: Meyer's Apparatus

ρ - density of the liquid.
λ - logarithmic decrement in the liquid.
ρ_0 - logarithmic decrement in air.

The quantities mentioned above can all be measured directly, except the moment of intertia of the disk which is a complex object. To find the moment of inertia, the time period (T) of the disk in air is found and then a ring with a known moment of inertia I_r is placed on the disk with its center on the suspension axis. The time period of the disk and the ring together in air(T') is again found, when the moment of inertia of the ring-loaded disk is $I + I_t$. Then, we have

$$I_r = ma^2 \qquad \therefore \quad I = ma^2 \frac{T^2}{(T')^2 - T^2} \qquad (14.5)$$

$$T = 2\pi \left(\frac{I}{\tau - \frac{\kappa^2}{4}} \right)^{\frac{1}{2}} = \left(\frac{I}{\tau} \right)^{\frac{1}{2}} \quad \textit{and} \quad T' = \left(\frac{I + I_r}{\tau} \right)^{\frac{1}{2}} \tag{14.6}$$

here, m is the mass, a is the average radius of the ring, i.e., $a = (d_1+d_2)/4$ where d_1 and d_2 are the inner and outer diameters of the ring, respectively. Using equations (4) and.(6) we can find the viscosity of water.

PROCEDURE

1. The apparatus consists of a flat disk attached to a short rod passing through its center which is suspended (with the disk remaining horizontal) by means of a phosphor bronze wire. The central rod has a perpendicular screw with two movable masses on opposite sides for leveling the disk. A small concave mirror with a radius of curvature of about one meter is also mounted on this rod (see Fig.2).

A lamp and scale arrangement is provided which is to be adjusted till a beam from the lamp after reflection from the concave mirror forms a well defined circular patch of light on the scale. The image of the cross wires on the lamp should be clearly visible on the screen. The positions of the scale and the disk are adjusted till the equilibrium position of the spot of light is close to the center of the scale.

2. Taking care to avoid all transverse oscillations (such as lateral swing or wobble), the disk is rotated slightly to give a small torque and left free to undergo torsional oscillations. By measuring the time of 25 oscillations, the time period of the pendulum

T is found. Repeat this step once more and take the mean value of T.

3. The given metallic ring is placed flat on the disk, so that it's center is as close as possible to the axis of suspension. The time period of the pendulum T' is now found by the procedure described above. The mass of the ring, and the outer and inner diameters (d_1 and d_2) of the ring are measured. Make observation tables for these measurements. (The ring may not be exactly circular: therefore measure the diameter along different directions and take the average value). Using these two measurements and Eq.(6) the moment of inertia I of the pendulum can be calculated. The ring can now be removed and is not required in the rest of the experiment.

4. To measure the logarithmic decrement, the disk is again set into torsional oscillation. When the amplitude has fallen to approximately the full scale reading, start the readings by noting down the reading on the scale at one extreme position, B_1C_1. The very next reading at the outer turning point B_2C_2 is then recorded (see Fig.1).

5. After 20 complete oscillations, again record the maximum amplitudes on both sides $B_{41}C_{41}$ & $B_{42}C_{42}$. The logarithmic decrement in air can now be found by using these readings and Eq.(3) for 20 oscillations (i.e., for n=20) as,

$$\lambda_0 = \frac{1}{40} \ln \left(\frac{B_1C_1 + B_2C_2}{B_{41}C_{41} + B_{42}C_{42}} \right) \tag{14.7}$$

In general, if n is the number of oscillations, then the logarithmic decrement is the given by

$$\lambda_0 = \frac{1}{2n} \ln\left(\frac{B_1C_1 + B_2C_2}{B_{2n+1}C_{2n+1} + B_{2n+2}C_{2n+2}}\right) \tag{14.8}$$

Repeat the procedure for 30 and 40 oscillations to calculate λ_0. Take the mean value of λ_0 to obtain the logarithmic decrement.

6. A clean glass dish is now placed so as to contain the disk, and water is poured into it so as to cover the disk but not submerge the mirror (see Fig.2). The equilibrium position of the light spot is now adjusted (if necessary) so that it again lies at the center of the scale. The same procedure (as that to find the logarithmic decrement in air) is now repeated to find the logarithmic decrement λ in water. Since the oscillations in this case are very much damped, the experiment has to be performed for smaller number of oscillations.

Tabulate the observation for air and water as shown in Table 1 and Table 2.

7. Using the data measured above, and the dimensions of the disk equation (4) is used to find the viscosity of water. The temperature of the water used must be measured and quoted along with the result.

Observations:

Least count of vernier caliper used =
Least count of stop watch =
Least count of balance used =

Radius of the disk, r =
Thickness of the disk, d =
Outer diameter of the ring, d_1 =
Inner diameter of the ring, d_2 =
Average radius of the ring, a =
Mass of the ring, m =
Temperature of water =
Time required for 25 oscillations in air =
Time period in air, T =
Time required for 25 oscillations in air with ring =
Time period in air with ring, T' =

Table 14.1: Readings for finding logarithmic decrement in Air

Trial number	Serial no. of oscillation		Maximum Amplitude Left(B_iC_i) Right(B_{i+})C_{i+1})	λ_0 {using Eq.(8)}
1	Start n = 20	(i= 1) (i = 41)		
2	Start n = 30	(i= 1) (i = 61)		
3	Start n = 40	(i= 1) (i = 31)		

Calculate the maximum probable error $d\eta$ and write down the precautions and sources of error.

Result:

The viscosity of water was found to be ________ poise, at a temperature of ________degrees centigrade.

Table 14.2: Readings for logarithmic decrement in Water

Trial number	Serial No. of oscillation		Maximum Amplitude Left (B_iC_i) Right ($B_{i+1}C_{i+1}$)	λ {using Eq.(8)}
1	Start	(i= 1)		
	n = 5	(i = 11)		
2	Start	(i= 1)		
	n = 10	(i = 21)		
3	Start	(i= 1)		
	n = 15	(i = 31)		

ADJUSTMENT OF ULTRASONIC INTERFEROMETER

For initial adjustment two knobs 'ADJ' and 'GAIN 'are provided on high frequency generator for Initial Adjustment

"ADJ" is to adjust the position of the needle on the ammeter
GAIN" is used to increase the sensitivity of the instruments for greater deflection. If desired.

The ammeter is used to notice the number of maximum defection while micrometer is moved up and down in liquid.

PROCEDURE

1. Unscrew the knurled cap of and cell and lift it away from double walled construction of the cell. In the middle portion of it pour experimental liquid and screw the knurled cap. Wipe out excess liquid overflowing from the cell
2. Insert the cell in the base socket and clamp it with the help of a screw provided on its side.
3. Connect the high frequency generator with cell by co - axial cable provided with the instruments.
4. Move the micrometer slowly in either clockwise or anticlockwise direction till the anode current on the ammeter on the high frequency generator shows a maximum or minimum.
5. Note the reading of micrometer corresponding to the maximum or minimum (whichever is sharper) in micro - ammeter.
6. Take about 50 readings of consecutive maximum or minimum and tabulate them as shown below.
7. take average of all the difference ($\lambda/2$)
8. Once the wavelength is known the velocity in the liquid can be calculated with the help of the relation $v = \lambda \times f$

S.No.	Micrometer Reading (Maximum Deflection)	Difference between two maxima ($\lambda/2$)
1	R1	
2	R2	R2-R1
3	R3	R3-R2
26	And so on	R26-R25

PRECAUTIONS:

- ✓ Do not switch ON the generator without filling the experimental liquid in the cell.
- ✓ **Do not tilt the cell after filling the liquid to avoid flow of liquid towards micrometer which may rust/jam the threads of micrometer head.**
- ✓ Remove experimental liquid out of cell after use .keep it cleaned and dried.
- ✓ Keep micrometer open at 25mm after use.
- ✓ Avoid sudden rise or fall in temperature of circulated liquid to prevent thermal shock to the quartz crystal.
- ✓ While cleaning the cell care should be taken not to spoil or scratch the gold plating on the quartz crystal.
- ✓ Allow generator 15 seconds warming up time before the observation

- CLEAN THE CELL WITH ACETONE AFTER EVERY EXPERIMENT AND KEEP THE CELL DRY.
- ALWAYS KEEP THE CELL INVERTED OR COVERED TO PREVENT DAMAGE TO THE QUARTZ CRYSTAL

TECHNICAL SPECIFICATIONS

HIGH FREQUENCY GENERATOR

Measuring frequency	2MHz

MEASURING CELL

Max.displacement of the reflector	20mm
Required Quantity of liquid	12 c.c
Least Count of micrometer	0.01 mm

SHIELDED CABLE

Length of connecting cable between the generator and the cell. Is 50 cm approximately.

TROUBLE SHOOTING

If deflection in the Ammeter is nil or insufficient for any particular liquid. Try to increase the same with the help of GAIN knob. If problem still persist. Please follow following tuning instruction for the high frequency generator:

1. Turn trimmer A on the back side of the generator till maximum deflection is achieved in Ammeter. Then turn trimmer B for minimum deflection.
2. Repeat the process by again turning trimmer A for maximum followed by turning trimmer B for minimum.
3. This can be done for a number of times till they are properly tuned.

WARRANTY

One year against manufacturing defeat.

Damage to crystal or micrometer not covered by warranty

Instrument has to be sent to our works for any service.

Repair work will not be carried out at the customers premises

SAMPLE CALCULATION

Sample: Water

Frequency = 2MHz

Average $\lambda/2$ = 0.740mm

λ = 1.48mm

Ultrasonic velocity in Sample, $v = f \times \lambda = 1 \times 10^6 \times 1.48 \times 10^{-3} =$ 1480m/sec

Density of liquid ρ = 996.458 kg/m

Compressibility $\beta_{ad} = 1/\rho v^2$

$= 1/(\ 996.458 \times (1480)^2) = 4.58 \times 10^{-10}$ N/m2

Above calculation are for 2 MHz ultrasonic interferometer. Check the frequency of interferometer from specification and calculate velocity

Experiment may be tried for other liquids.

Compressibility and ultrasonic velocity is temperature dependent. Suitable water bath may be attached to vary the temperature for ultrasonic velocity and calculation of compressibility at different Temperatures.

Note: Extra peaks in between minima and maxima may occurs due to a number of reasons, but they don't effect the value of /2

LASER – TRANSIMISSION GRATING

DETERMINATION OF WAVELENGTH

AIM : To Determine the wavelength of laser using transmission grating

Apparatus : Laser Source , grating , screen and fixture to mount and measure the distance between the grating and screen.

Formula : $\lambda = (d/m) \times \sin\theta$

$$= (d/m) \times (X_m{}^2 / (X_m{}^2 + D^2)^{1/2})$$

d = grating element (2500 Lines / inch or approx 100 lines per mm)

θ = Angle of Diffration

m = Order of spectrum

X_m = distance from the m th order from zero order

D = Distance between the grating and screen

Insert the 150-0-150 scale into the U clamp (Fig 1 & 2)

Place the U type fixture into the clip provided on the wooden bench at the '0' side of the scale. Fig 3

Place the Laser Source in the on the Wooden Bench near the 50cm mark on the scale

Switch on the Laser

Adjust the 150-0-150 scale such that the laser beam falls on the 0 mark of the scale. (Fig 4)

This centre location is the 0^{th} order position.

Insert the grating into the grating holder.

Place the grating holder on the wooden bench between the laser source and the screen.

Place the grating such that the laser beam passes through the centre of the grating. Fig (5)

The diffraction Pattern will be visible on the screen.

Note the distance between the grating and the screen using the scale provided on the wooden bench. This is 'D'

The diffraction pattern will show spots on either side of the 0^{th} order. Note the distance between the 1^{st} order from the 0^{th} order . note the distance on both the sides. This is ' Xm' .

We are noting the distance between the 0^{th} and 1^{st} order hence m = 1

The results may be calculated from the formula provided above.

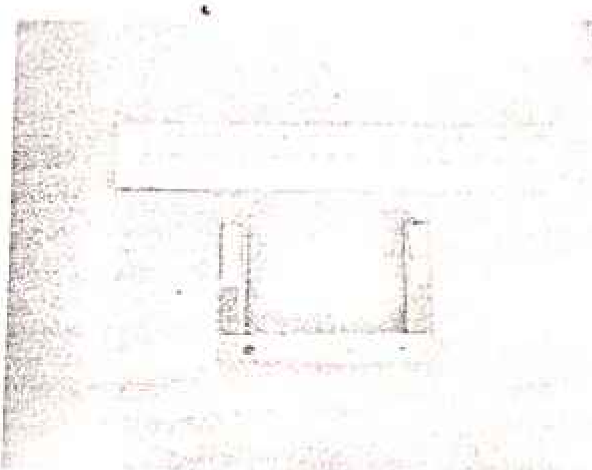


Fig 1

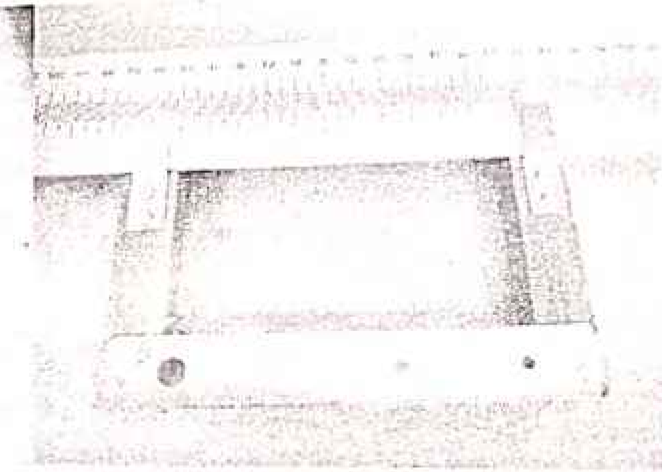


Fig 2

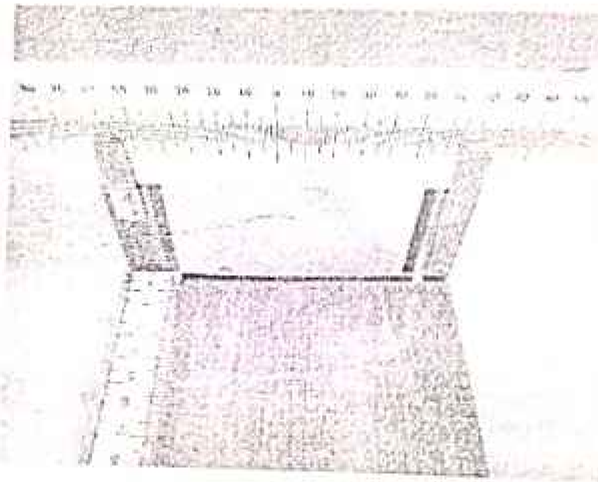


Fig 3

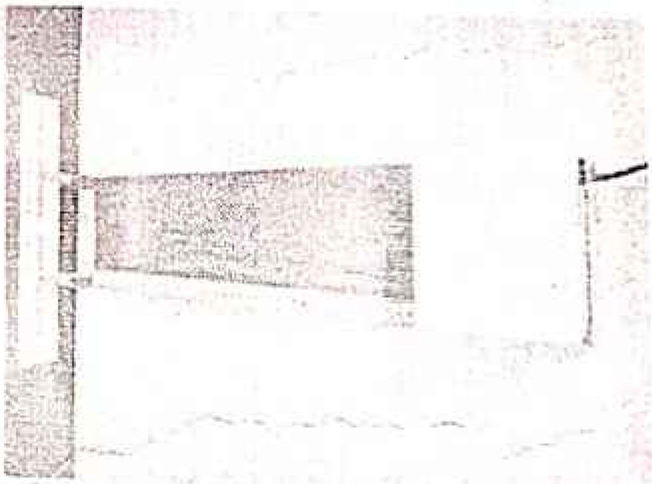


Fig 4

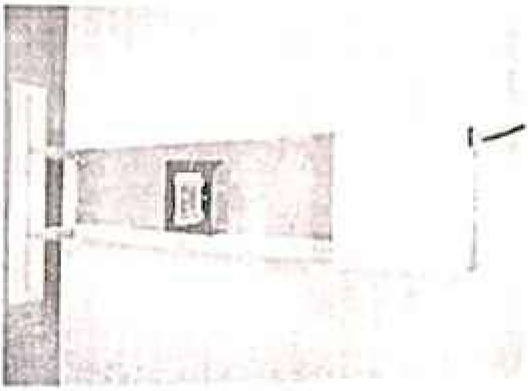
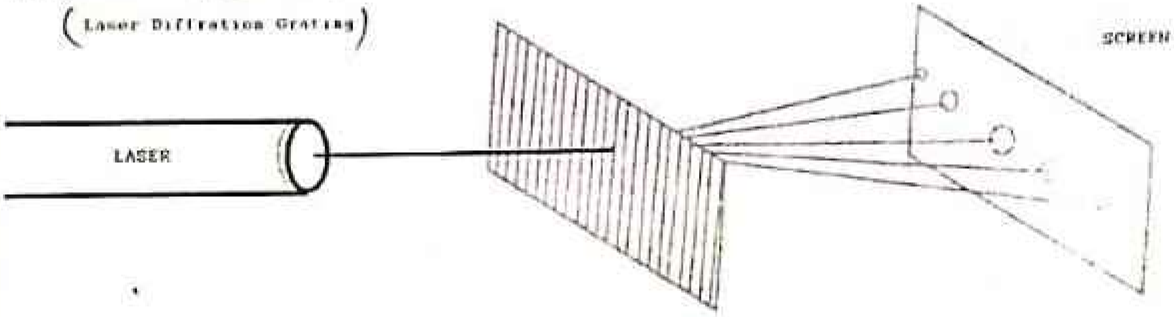
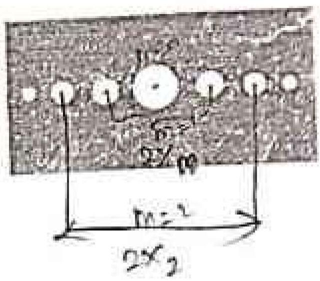


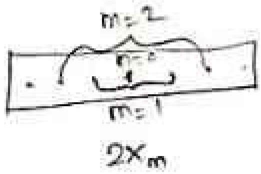
Fig 5

(i) Find the wavelength:

(Laser Diffration Grating)







Determination of size of particle :-

PARTICLE SIZE DETERMIANTION USING LASER

The frequency of the laser has been determined using the above experiment.

Remove the scale and the U clamp.

Place the Circular scale as shown in fig 6.

Remove the grating and place the slide provided.

This experiment is to be performed only in a dark room.

Circular fringes will be visible on the screen.

If the fringes are not clear change the area on which the laser beam is incident on the slide. This could be due to variation in the coating of the particles on the slide.

Adjust the distance between the grating and the screen so that the fringes are clear and correspond to the markings provided in the scale.

The formula

$$D=1.22\ \lambda\ \ n\ (d/r_n)$$

D is the size of the particles.

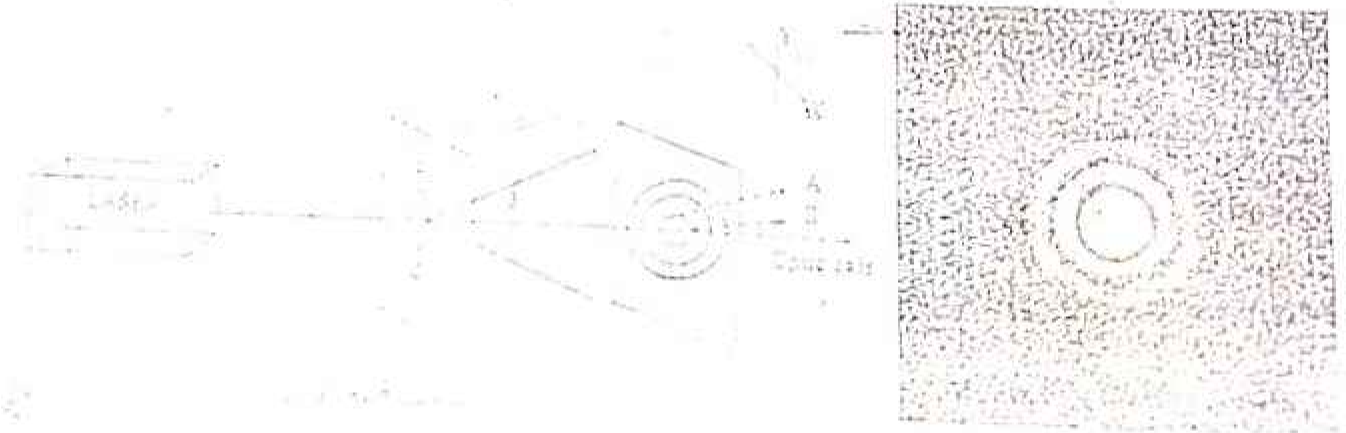
λ is the wave length of Laser

d is the distance between the particle (Slide) and the screen.

r is the radius of the circle (image formed)

n is the order of diffraction

(ii) Determination of Particle Size (S):



CALCULATIONS

Frequency	670*10^(-9)	670nM
D	size of Particle	
r	Radius of order of diffraction	
n	Order of diffraction	

d distance between screen & slide	n Order	daimeter of order in metres	radius of order in metres	nd/r	particle size D in meters	D in microns	
0.11	1	0.02	0.01	11	0.00000899	8.9914	microns
0.11	2	0.04	0.02	11	0.00000899	8.9914	microns
0.16	1	0.03	0.015	10.66667	0.00000872	8.71893333	microns
0.16	2	0.06	0.03	10.66667	0.00000872	8.71893333	microns
0.22	1	0.04	0.02	11	0.00000899	8.9914	microns
0.22	2	0.08	0.04	11	0.00000899	8.9914	microns

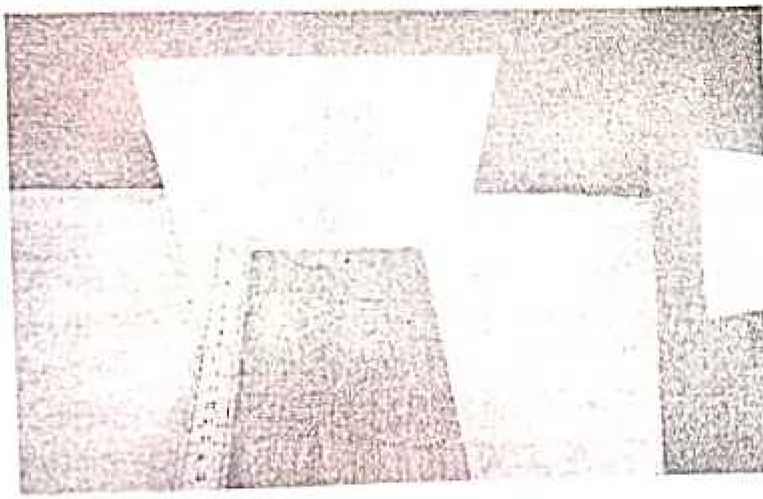


Fig 6

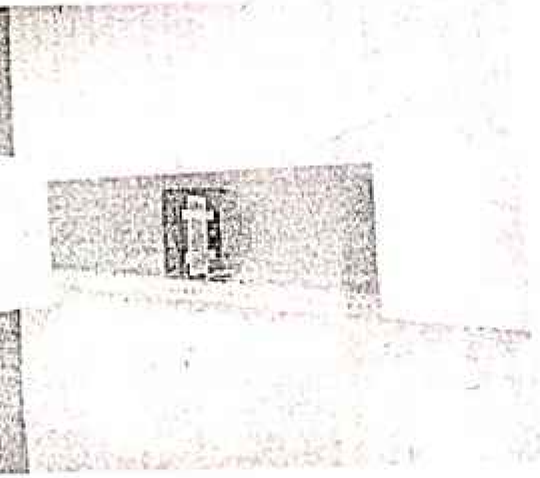


Fig 7

CAUTION

- Never stare into the laser beam or the reflected beam.
- *Even if no output is visible please do not stare into the hole from which the beam is radiated.*
- Laser beam should be seen only by projecting it on a screen.
- *Staring into the beam or reflected beam directly will result in permanent damage to your eye sight.*
- **Always connect the Power Chord to the Mains and switch on laser .**
- The laser should be switched off whenever it is not required.

EXPERIMENT 1

DETERMINATION OF NUMERICAL APERTURE OF OPTICAL FIBRES

1.1AIM OF THE EXPERIMENT

The aim of the experiments is to determine the numerical aperture of the PMMA fibre cables included in

1.2BASIC DEFINITION

Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the maximum ray angle.

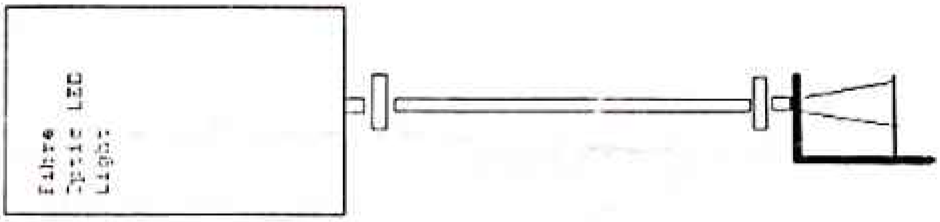
$$NA = ni.Sin\theta_{max}$$

ni for Air = 1

Hence **$NA = Sin\theta_{max}$**

1.3PROCEDURE WITH BLOCK SCHEMATIC

The schematic diagram of the numerical aperture measurement system is shown below and is self-explanatory.



The step-by-step procedure is given here:

Step 1: connect one end of the 1-meter FO cable to FO LED and the other end to the NA jig as shown.

Step 2: plug the AC main. Light should appear at the end of the fibre on the NA jig.

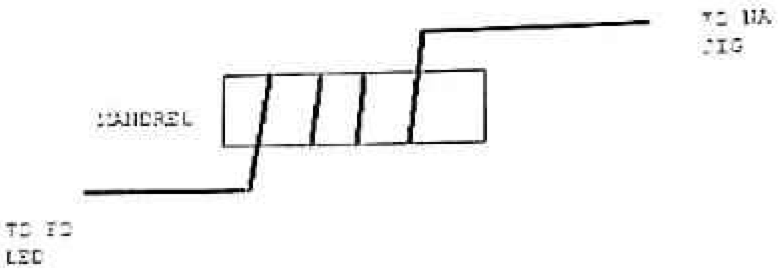
Step 3: hold the white screen with the 4 concentric circles (10,15,20,and 25mm diameter) vertically at a suitable distance to make the red spot from the emitting Fibre coincide with 10 mm circle. Note that the circumference of the spot (outermost) must coincide with the circle. A dark room will facilitate good contrast record L, the distance of the screen from the fibre end and note the diameter (W) of the spot .you may measure the diameter of the circle accurately with a suitable scale.

Step 4: compute NA from the formula

$$NA = W / (4L^2 + W^2)^{1/2}$$

tabulate the reading and repeat the experiment for 15mm, 20mm,and and25mm diameter too.

Step 5: In case the fibre is under filled, the intensity within the spot may not be evenly distributed. To ensure even distribution of light in the fibre, first



Remove twist on the fibre and then wind 5 turns of the fibre on to the mandrel as shown. Use an adhesive tape to hold the winding in position. Now view the spot. The intensity will be more evenly distributed within the core.

TABLE OF READING,

S.No	L	W	NA	θ(Degrees)
1				
2				
3				

DETERMINATION OF ACCEPTANCE ANGLE OF OPTICAL FIBRES

Acceptance Angle is a value derived form θ (NA)

ACCEPTANCE ANGLE = 2 θ

EXPERIMENT 2: LOSSES IN OPTICAL FIBRES

2.1 AIM OF THE EXPERIMENT

The aim of the experiment is to study various types of losses that occur in optical fibre and measure the loss in dB of two optical fibre patch cords,

2.2 BASIC DEFINITIONS

Attenuation in an optical fibre is a result of a number of effects. This aspect is well covered in the books referred to. We will confine our study to attenuation in fibre due to macro bending and estimate the losses in two patchcords. Preferably we will use patch cord of two different lengths.

The loss as a function of the length of the fibre is measurable only when we use a 5-meter cable too in the experiment.

The optical power at a distance in an optical fibre is given by

$$P_L = P_o\, 10^{(-\alpha L/10)}$$

where P_o is the launched power and α is the attenuation coefficient value for the fibre under consideration here is 0.3 dB per meter at a wavelength of 660nm.

Loss in fibre is expressed in decibels is given by -10 log (P_o/P_f) whereupon is the launched power and P_f is power at the far end of the fibre.

Losses in fibre occur at fibre-fibre joints or splices due to axial displacement, angular displacement, separation (air gap), mismatch of cores diameters, mismatch of numerical apertures, improper cleaving and polishing at the end. The loss equation for a simple fibre optic link is given as:

$P_{in} - P_{out} = L_{j1} + L_{FIB1} + L_{j2} + L_{FIB2} + L_{j3}$,

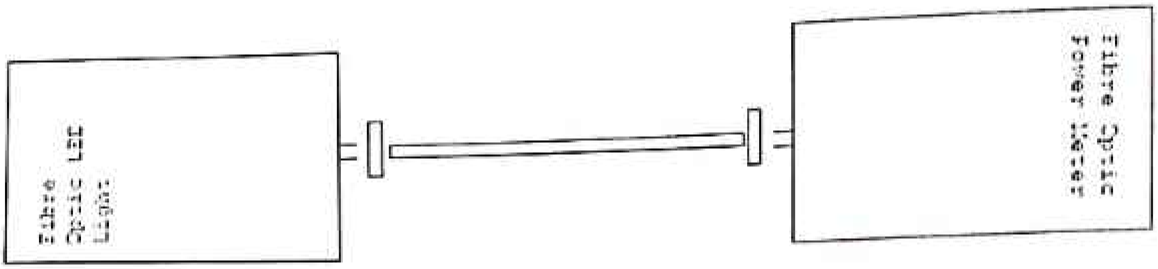
Where

L_{j1} is the loss at LED-connector junction
L_{FIB1} is the loss in cable 1
L_{j2} is the insertion loss at a splice or in line adaptor
L_{FIB2} is the loss in cable 2
L_{J3} is the loss at the connector detector junction

$P_L = P_o\, 10^{(-\alpha_L/10)}$
$\alpha_L = 0.3$ dB / me
$\lambda = 660$nm
$-10 \log\left(\frac{P_o}{P_f}\right)$
P_f - far e

2.3 Procedure with block schematic

The schematic diagram of the optical fibre loss measurement system is shown below and is self explanatory,



The step by step procedure is given here:

Step1: connect one end of the 1-metre FO cable to FO LED and the other end to the FO Power Meter

Step2: plug the AC mains. Connect the optical fibre patch cord securely, as shown after relieving all twists and strains on the fibre. Note the value on the power meter note this as Po1

Step3: wind one turn of the fibre on the mandrel, as shown in experiment 1 and note the new reading of the powermeterPo2. Now the loss due to bending and strain on the plastic fibre is Po1-Po2 dB.

Step4: next remove the mandrel and relieve the cable of all twist and strains note the reading Po1 for the 1-meter cable.

Repeat the measurement with the 5 meter cable and note the reading Po2.

Use the in line SMA adaptor and connect the cables in series as shown. Note the measurement Po3

Po3-Po1 gives loss in the second cable plus the loss due to inline adaptor.
Po3-Po2 gives loss in the first cable plus the loss due to in the in-line adaptor.
Assuming a loss of 1.0dB in the in-line adaptor, we obtain the loss in each cable.

2.4.TABLE OF READING

S.No.	Po1	Po2	Po3	Loss in cable1	Loss in cable 2	Loss / metre

EXPERIMENT 3:LOSS DUE TO AIRGAPS IN FIBRES WITH IN-LINE ADAPTORS

3.1 AIM OF THE EXPERIMENT

The aim of the experiment is to study losses at fibre junction with in-line SMA-SMA adaptor by creating known air-gaps.

3.2 BASIC DEFINITIONS

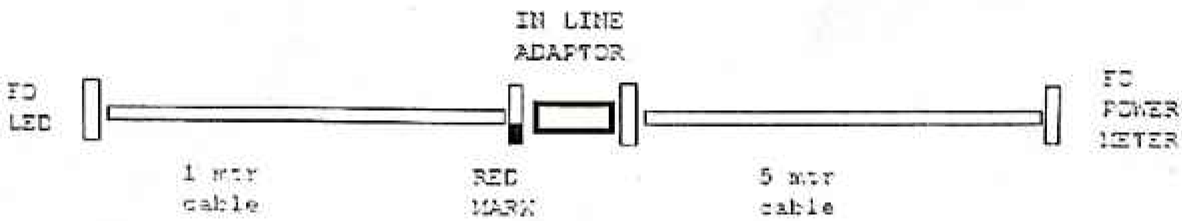
In-line adaptors are mechanical components, with which two optical fiber cables may be connected in series. These find application in all fibre optic systems. in line adaptors without air-gap facilitate low loss connectivity. A number of the other mechanical connector methods are available. However for reliable permanent connections between one fiber and another, fusion splices would be the solution. Many fibre optic communication systems require attenuators in the optical path to ensure proper matching of signals between the source and the detector. In case of too large a signal from the transmitter, the receiver may get saturated. To facilitate adjustments of optical signal levels in optical fibre networks, attenuators are used. Attenuators are based on a variety of methods. Variable attenuators are also essential fibre optic accessories.

One simple and popular way to attenuate power at fibre junction is to create a known (fixed or variable) air gap at the junction. All the light exiting from the transmitting side is not coupled to the receiving fibre, resulting in attenuation.

In the present experiment we shall be studying the loss difference arising out of a lateral air gap created in the in-line adaptor.

3.3 PROCEDURE WITH BLOCK SCHEMATIC

The schematic diagram to measure loss in an in-line adaptor is shown below and is self-explanatory.
The step by step procedure is given here.



Step1: connect one end of the 1- meter FO cable (designated as cable 1) to POWER METER keeping the connector with a red marking on the hexagonal lock nut free. Connect one end of the 4-metre FO cable (designed as cable 2) to Po of

Step2: Next connect the free end of cable 1(with the red marking) to the in-line adaptor by rotating three times. Connect the free end of cable 2 to the other side of the in-line adaptor tightly, but without force, ensuring physical contact.

Step3: Note the value on the power meter say P1

Step4: Next loosen the lock- nut with the red marking by one turn. Pull the cables gently apart so as to create an air gap that corresponds to one thread of the connector (=0.7mm). Note the meter reading as P2.

Unwind another full thread of cable 1 and pull the cables apart gently to create an air gap of 1.4 mm. Note the meter reading as P3.

Do not disturb cable2 position in the in-line adaptor.

Step5: The losses due to the air-gaps are given P2-P1 and P3-P1 (in dB)

*-- *--*

HYDROGEN SPRCTRUM AND DETERMINATION OF RYDBERG CONSTANT

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Abstract

Using deuterium gas discharge tube, spectrometer and grating Balmer series of spectral lines are observed. The wavelengths of the prominent Red (H_α) and Cyan (H_β) lines are determined and compared with the standard values. The Rydberg constant is calculated using wavelengths.

Introduction

Twentieth century started with the invention of Quantum mechanics by Max Planck [1]. His theory was proved by Albert Einstein by explaining photo electric effect. A complete theoretical explanation of the hydrogen atom based on the quantum mechanics was given by Neils Bhor. Hydrogen spectrum was first observed by Anders Angstrom in 1853. Later Johann Jakob Balmer derived an empirical formula to explain the spectral lines. Neil Bhor studied hydrogen atom based on Rutherford's atomic nucleus theory and applied Planck quanta. He believed in planetary motion and applied the same principle to the atom. As per his theory, electron revolves around the nucleus with prescribed orbit and it does not radiate any energy as far it is in its orbit. Radiation takes place only when the electrons are excited to the higher energy levels by external source. This was a new concept in 1915. He calculated the various energy levels of hydrogen and predicted various spectral lines for Hydrogen atom from ultra violet to infra red region.

Line Spectra

The yellow light produced by Sodium Vapor Lamp is monochromatic light meaning it contains only one wavelength. The light produced by electric bulb, white light LED, light coming from Sun are non-monochromatic meaning it contains more wavelengths. White light is a mixture of seven colors or wavelengths. The several wavelengths can be separated by passing the light through a prism or grating. A continuous color variation from violet to red is observed when the light is passed through a prism, which is called as continuous spectrum. Enclosing a gas inside the tube and reducing its pressure and applying a high voltage 2000-15000KV; colored lights are produced. Such glass tube is called gas discharge tube. The lighter gases such as hydrogen, Neon, Argon, Carbon diode etc gives colored lights. If these colored lights are used to illuminate objective of a spectrometer and grating; through the eye piece colored lines are seen. These colored lines are called line spectra [2]. Different colored lines are obtained for different gas discharge tubes. Hence these lines are spectral signatures of the gas inside the tube. The colored lines observed are the images of the slit with different colored wavelengths.

Hydrogen Gas Discharge Tube

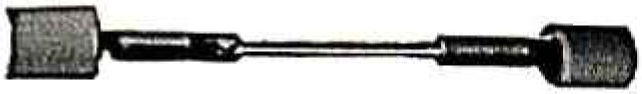


Figure-1, A gas discharge tube used in the experiment

The gas discharge tube used in this experiment contains deuterium gas an isotope of hydrogen. The gas is filled and pressure inside the tube is restricted to 0.5 to 10mm of Mercury. Discharge tubes containing gases such as Neon, Mercury, Argon, and Helium are more reliable and easily available for experiment. Discharge tubes containing hydrogen, nitrogen and carbon dioxide are also available which are not so reliable. Because of the atmospheric conditions such as the temperature, pressure, and light the gas inside the tube slowly evaporate and tube becomes empty and no light comes after few years of use. The discharge tube used in this experiment is show in Figure-1. Figure-2 shows the hydrogen discharge tube mounted on a adjustable stand. The tube is 10 inch long and bulb diameter is 20mm.

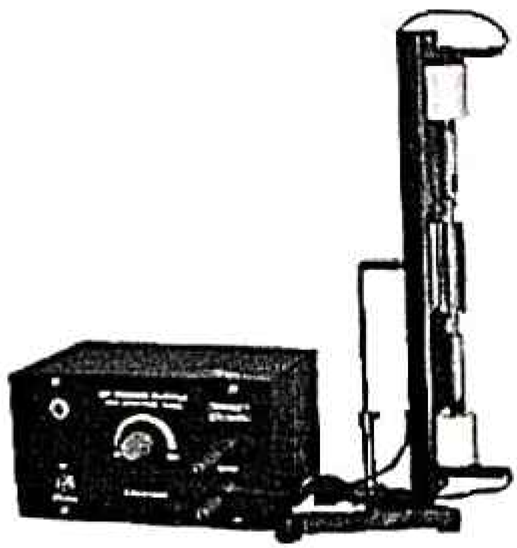


Figure-2, Hydrogen discharge tube fitted to adjustable stand

Bhors Hydrogen Atom

Hydrogen is the first element in periodic table with one electron revolving round the nucleus. The single electron is in the K shell (principle quantum number n =1) revolving in the 1s orbit. As far the electron revolves round the nucleus in this orbit there is no radiation of energy hence its orbit is a stable orbit. By enclosing the gas inside the tube, reducing its pressure and exciting it with a high voltage, results in pink light radiation. This is the characteristic property of hydrogen gas.

The high voltage applied excites the atoms to go to higher orbits. There will be thousands of atoms inside the discharge tube few of them will be pushed to L shell (n = 2), another few will be pushed to M shell (n = 3) and another few will be pushed to N (n = 4) shell by the applied voltage. The electrons come back to its original orbit radiating extra energy gained by excitation. This energy lies in visible region resulting spectra in the visible region. In addition to this there is radiations in UV and IR region resulting, transition from higher energy levels such as n = 5,6 and 7. Table-1 shows the complete set of transitions by the hydrogen atom. Bhor explained these spectral lines and determined their wavelengths. The spectrum in the visible region was known before this explanation by Bhor. All the other radiations are detected after his explanation by different people. Hence the series of spectra were named after the scientists who have observed it and studied it.

Table-1

Transitions		**Spectral Series**	**Wavelength (nm)**	**Spectral Region**
From	**To**			
n =6, n =5, n =4,n =3	n =2	Balmer	400-750	Visible
n = 4, n = 3, n = 2	n =1	Lymen	10-400	UV
n =6, n =5, n =4	n = 3	Paschen	750-900	IR
n = 7, n = 6, n = 5	n = 4	Brackett	2165-4051	
n =7, n = 6	n = 5	Pfund	7457-4652	

Complete transitions of hydrogen atom

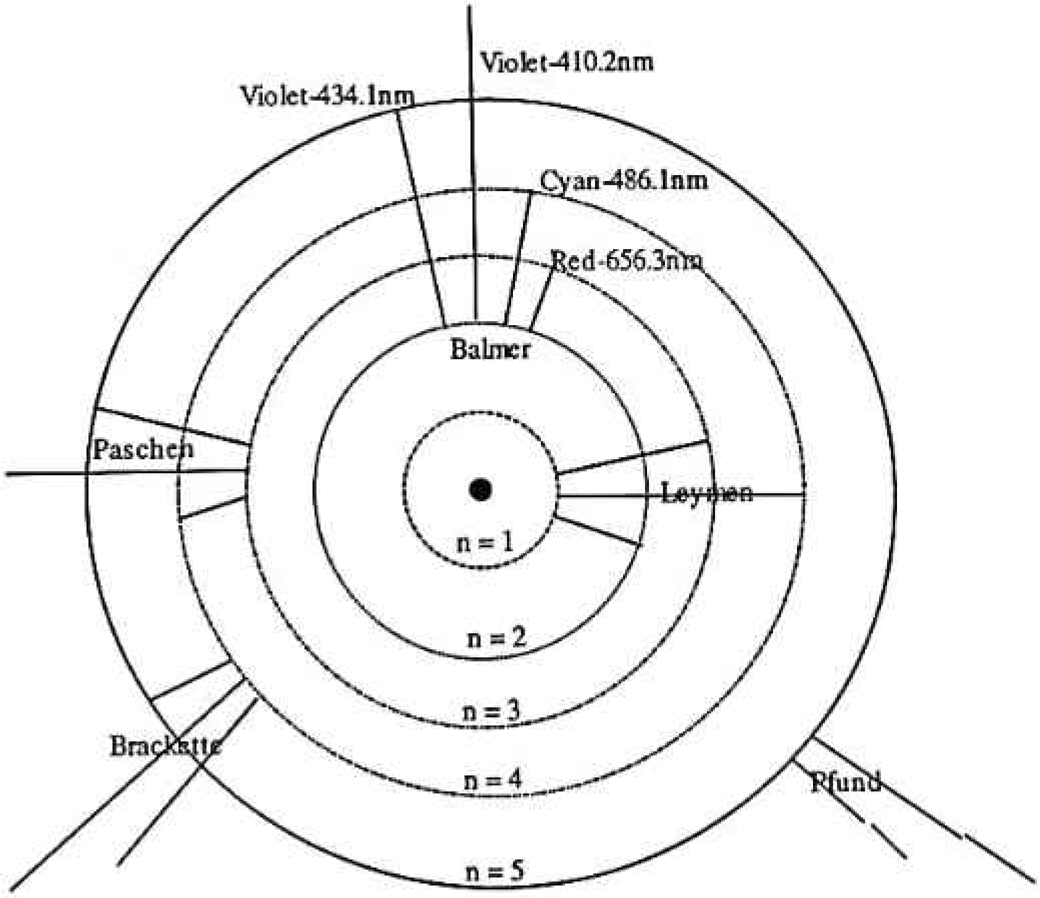


Figure-3, Possible transitions in hydrogen atom

Balmer Series of Spectral Lines

Out of four different series of spectral lines the Blamer series lines are in the visible region which can be observed though spectrometer- grating. Two very strong lines are observed in the Blamer series due to transitions to n = 2 levels from higher energy levels as shown in Table-2.

Table-2

Transition		Color	Wavelength (nm)	Nature
From	**To**			
n =6	n =2	Violet	410.2	Week
n =5	n =2	Violet	434.1	Medium
n = 4	n = 2	Cyan	486.1	Strong
n = 3	n = 2	Red	656.3	Strong

Balmer series of spectral lines and their wavelengths

The energies of the electrons in the orbit is given by

$$h\upsilon = \frac{me^4}{8\varepsilon_0{}^2h^2}\left[\frac{1}{n_n{}^2}-\frac{1}{n_2{}^2}\right] = -13.6\left[\frac{1}{n_1{}^2}-\frac{1}{n_2{}^2}\right]eV \qquad \ldots 1$$

Where n_1 is lower orbit
n_2 is next higher orbit

The wave number of the transition is given by

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_1{}^2}-\frac{1}{n_2{}^2}\right] \qquad \ldots 2$$

Where $R_H = \dfrac{me^4}{8\varepsilon^2{}_oh^3c} = \dfrac{9.1x10^{-31}x(1.6x10^{-19})^4}{8x(8.85x10^{-12})^2(6.625x10^{-34})^3 3x10^8} = 1.09x10^7 m^{-1}$ Is called Rydberg constant.

Johannes Robert Rydberg (1854-1919) observed hydrogen spectrum and obtained an empirical formula for spectral lines in 1890. In honor of his contributions to atomic structure, the constant appearing in the energy equation of hydrogen atom has been named after him. The Rydberg const R_H can be determined by measuring the angle of diffraction and knowing transition levels.

$$R_H = \frac{1}{\lambda}\left[\frac{n_1{}^2n_2{}^2}{n^2{}_2-n^2{}_1}\right] \qquad \ldots 3$$

Apparatus Used

The complete experimental setup used in this experiment is shown in Figure-4. The setup consists of hydrogen discharge tube, 2KV-5KV high voltage power supply, Spectrometer and an imported Paton Hawksley (UK) make grating.

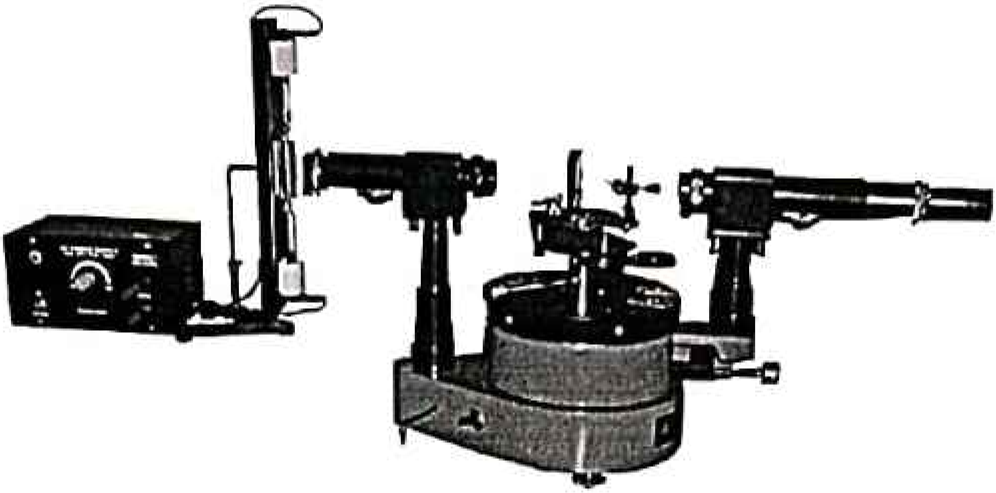


Figure-4, Rydberg constant experiment setup

Experimental Procedure

The preliminary adjustments of the spectrometer

1. The telescope of the spectrometer is focused towards a white wall and the eye piece is pulled or pushed so that the cross wire is distinctly seen. The vertical cross wire is made straight.

2. The Spectrometer telescope is now adjusted to a distant object and the inverted image of the distant object is observed. By adjusting the rack and pinion movement on the telescope tube the image is made very clear. With these adjustments the telescope is set to receive parallel rays. Hence these settings should not be disturbed throughout the experiment.

3. The spectrometer is now placed in front of the hydrogen light with the objective of the spectrometer close to light as shown in Figure-5. The slit is opened about 1mm to 1.5mm and the slit image is viewed through the telescope. The slit image is made sharp by adjusting the rack and pinion arrangements on the collimator tube.

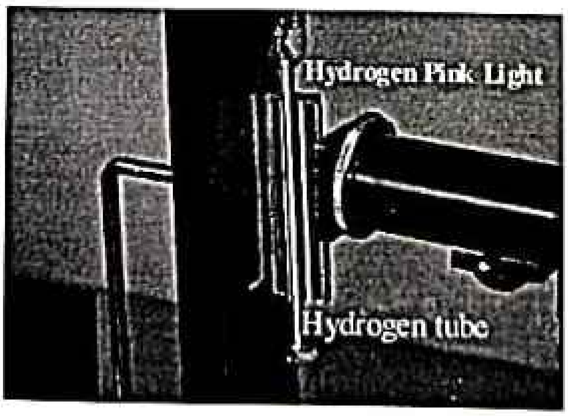


Figure-5, Collimator silt placed close to hydrogen light

Adjusting the spectrometer-grating to normal incidence

4. The direct reading of the spectrometer is taken by coinciding the slit image with the vertical cross wire. The telescope is now rotated exactly 90° from the direct ray reading and fixed at that position.

5. A grating is taken and grating constant is noted. The grating is mounted on grating holder fitted to prism table.

   Grating constant N =6x10^5 lines/ meter

   The prism table is now rotated towards the telescope, until the slit image reflected by the grating surface is seen through the telescope. The vertical cross wire is made to coincide with the slit image and the grating table is fixed at this position. The vernier table is rotated away from telescope exactly by 45° and clamped. At this position the rays from the collimator fall normally on the grating surface.

6. The telescope is brought back in line with the collimator tube and first order spectrum is observed on the left side and two prominent lines red and cyan are identified in addition a faint violet line as shown in Figure-6. The first order red line is coincided with the vertical cross wire and spectrometer reading is noted on the left vernier. The reading obtained is tabulated in Table-3. Similarly the cyan line coincided with the vertical cross wire and the vernier reading is noted in Table-3.

   Hydrogen Red line (Hα) Vernier reading = 287.585°
   Hydrogen Cyan line (H_β) Vernier reading = 117.950°

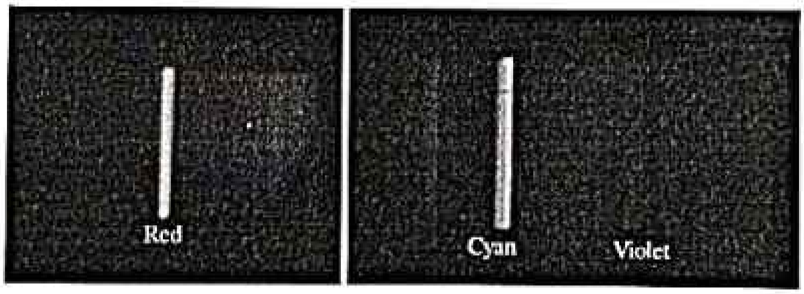


Figure-6, Balmer series lines of hydrogen spectrum

Table-3

Spectral line	Reading of diffracted ray		Angle of Diffraction	λ (nm)
	Left vernier θ_1)	Right vernier(θ_2)	$\theta = (\theta_1 \sim \theta_2)/2$	
H_α	287.585	321.900	23.417	662.36
H_β	117.950	152.066	17.057	488.87

Angle of diffraction and wavelength of H_α and H_β lines

7. The telescope of the spectrometer is now rotated to the right side and the same lines are observed on the other side again. By coinciding the red and cyan lines with vertical cross wire spectrometer reading is taken and recorded in Table-3. The difference in the two readings for the lines are calculated and presented in Table-3. Wavelengths of Red and Cyan lines are calculated using relation

$$\lambda = \frac{\sin\theta}{Nn} \qquad \ldots 4$$

Where θ is the angle of diffraction
N is grating constant
n is order of the spectrum n =1

$$\lambda_\alpha = \frac{\mathrm{Sin}23.417}{6x10^5} = 662.36\mathrm{nm}$$

Rydberg constant is determined using H_α and H_β line wavelengths in equation -3

$$R_H = \frac{1}{\lambda_\alpha}\left[\frac{n_1^2 n_2^2}{n^2_2 - n^2_1}\right] = \frac{1}{662.36x10^{-9}}\left[\frac{2^2x3^2}{3^2-2^2}\right] = 1.0869x10^7\,m^{-1}$$

$$R_H = \frac{1}{\lambda_\beta}\left[\frac{n_1^2 n_2^2}{n^2_2 - n^2_1}\right] = \frac{1}{488.87x10^{-9}}\left[\frac{2^2x4^2}{4^2-2^2}\right] = 1.0903x10^7\,m^{-1}$$

Results

The results obtained are tabulated in Table-4.

Table-4

Parameter	Expt (m^{-1})	Thet (m^{-1})
Rydberg constant	$1.0881x10^7$	$1.097X10^7$
H_α (Red)	662.36nm	656.3
H_β	488.87nm	486.1

Experimental results

Niels Bhor (1885-

Niels Henrik David Bhor

Picture courtesy: nobleprize.org/physics/laureates/1922/bhor-bio.html

Niels Henrik David Bhor was born on 7th Oct, 1885 in Copenhagen, Denmark [3]. His father Christian Bohr was a physiologist and mother was very rich. Bhor received very good education since from the beginning. Bhor was graduated at Copenhagen University and in 1909 he got his masters degree in Physics and 1911 he obtained PhD in Physics. After his PhD, Niles Bhor went to Cambridge University to join J J Thomson. However, he could not continue his studies in Cambridge because his ideas and JJ Thomson's ideas were conflicting. Bhor moved to Manchester in 1912 and joined Ernest Rutherford.

Rutherford's theory of atomic nucleus, Planck's quanta and Einstein's Photo electric effects were well understood by that time and believing in planetary motion Bhor using these ideas developed the theory of hydrogen atom and published it in 1913. He assigned coordinates to the revolving electron around the nucleus. The important concept of his paper was the energy of the revolving electron. There is no radiation of energy by the revolving electron in prescribed orbit. Radiation of energy takes place only when the excited electrons make transitions from the higher levels to the lower levels. This concept about the atom was new at that time. By that time hydrogen spectra was known and Balmer had determined wavelength using grating and spectrometer. Bhor made theoretical calculations and his wavelength matched with one obtained by Balmer. This gave him the confidence and he worked out all the possible transitions and calculated the wavelengths. After his prediction of possible the transitions; Theodore Lyman (1874-1954) US scientist detected transitions in UV region and the series is now named after his name. Friedrich Paschen an Austro-German detected transition in the IR region, now named after him. Frederick Sumner Brackette (1922) detected transitions beyond IR region now named after him. August Herman Pfund (1879-1949, US) detected transitions from n =5 orbit now named after him.

In honor of his work on atomic structure, Niels Bhor was awarded 1922 Noble prize in Physics. Among his other works, liquid drop and description of periodic table are well accepted by Physicist and Chemists. Bhor was a fellow Royal Society (1926) and he was recipient of World Peace Award (1957) and worked for universal peace latter in his life.

Bohr married Margrethe Norlund in 1913 and the two had six children. His fourth son Bhors N Aage became Physicist and he also obtained Noble Prize in Physics in the year 1975 for his work on " Collective motion and particle motion in atomic nuclei" [4]. From 1920 onwards Bhor became director of the Niels Bhor Institute of the Copenhagen University till his retirement.

Bhor also faced few hiccups during World War II. In 1943, being a Jewish he left the country along with family fearing attacks from the Nazis. He escaped to Norway in a fishing boat. He and his son Aage then escaped to US and helped US army to develop atom bomb. He donated his noble prize money to Finish people to aid them against Nazi attack.

Bhor was a scientist who has seen his work being used for the destruction of life on earth. He was aware of the consequences of atom bomb, before it was dropped. After seeing the destructions, he felt very bad and rest of his life was to work against the use of atom bomb in war. He promoted peaceful use of atomic energy and worked for universal peace.

References

[1] Dr Jeethendra Kumar P K, LE Vol-4, No-1, March-2004, Page-11.

[2] F A Jenkins and H E White, Fundamentals of Optics, IV Edition, Page-444.

[3] Nobleprize.org/physics/laureates/1922/bhor-bio.html

[4] Nobel prize.org/ physics/ lauretea/1975/index.html.

INSTRUCTION MANNUAL

THE MICHELSON INTERFEROMETER

INTRODUCTION

The Michelson Interferometer, first developed by Albert Michelson in 1881, has proved of vital importance in the development of modern physics. This versatile instrument was used to establish experimental evidence for the development for the validity of the special theory of relativity, to detect and measure hyperfine struture in line spectra, to measure the tidal effect of the moon on the earth and to provide a substitute standard for the meter in terms of wavelengths of light. Michelson himself pioneered much of this work.

We have made a unique Michelson interferometer which can be used with a helium neon laser as well as with sodium lamp.

WORKING PRINCIPLE AND CONSTRUCTIONAL DETAILS

A schematic of the Michelson interferometer is shown below in the figure 1. The interferometer

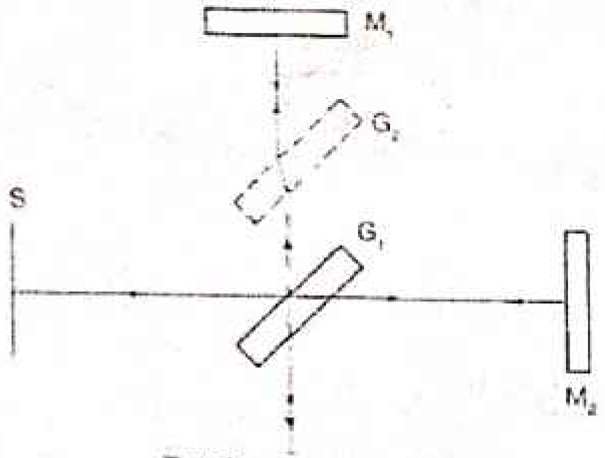


Fig. 1 Schematic of Michelson Interferometer

consists of two excellent optically worked plane mirrors M_1 and M_2, highly silvered on their front surfaces to avoid multiple internal reflections and two plane parallel glass plates have been cut from a single optically plane parallel plate to ensure the equality of thickness and the nature of the material. Both the plates have been mounted vertically, exactly parallel to each other, on a heavy frame and are inclined at 45° to the interferometer arm. Plate G_1 has been coated with silver or Aluminium such that it acts as a 50/50 beam splitter. The mirror M_2 is fixed while the other mirror M_1 is movable and has been mounted on a carriage C as shown in figure 2. The carriage has a precision back and forth movement. During the motion M_1 remains exactly parallel to its preceding positions. The mechanism which provides motion to the mirror M_1 consists of a large drum as shown in fig. 2. One turn of this drum displaces the mirror by one millimetre.

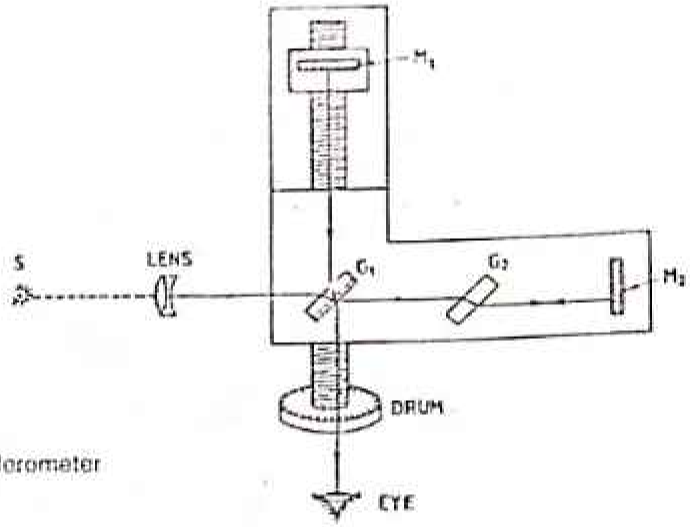


Fig. 2 Different parts of the Interferometer

There is another fine adjustment drum (smaller) visible at the right hand side. One turn of this drum displaces the mirror by 0.01 millimetre. One part of this slow motion drum gives a reading of 0.0001 mm (10^{-4} mm). The guide way also consists of a graduated scale in centimetres.

Mirrors M_1 and M_2 can be slightly tilted about the vertical as well as horizontal axes with the help of three screws provided at the back of each mirror and thus the mirrors may be adjusted mutually perpendicular.

Light from an extended monochromatic source S (Sodium light or He-Ne laser) rendered nearly parallel by the lens is incident on the instrument and on entering G_1 it is divided into two parts of equal intensities by partial reflection at its rear side. The reflected beam which proceeds to M_1 and the transmitted beam which proceeds to M_2 are incident normally on the mirrors when the instrument is in normal adjustment and accordingly after reflection, they retrace their paths. On return at the partially silvered surface, a part of the amplitude of the beam from M_2 is reflected while a part of beam from M_1 is transmitted along AE. Since the two waves are derived from the same wave, originally incident at A on G_1, hence the fundamental condition of interference is satisfied. Accordingly, one observes the fringes by looking from the position E into the mirror M_1 through the plate G_1.

The beam reflected at M_1, crosses the beam splitter G_1 twice while the optical path of the other wave, in the absence of G_2, lies wholly in air. Hence due to this an extra optical path $2(\mu-1)t$ (air) is introduced in the former beam where t is the thickness of the plate and μ is the refractive index of the material. Although, for the production of fringes with monochromatic light, this does not make any difference but with white light this presents a serious difficulty because of the variation of μ with wavelength. Hence, for white light, it is essential to compensate for this extra optical path $2(\mu-1)t$ for all wavelengths. This is accomplished by using a compensating plate G_2 in the beam AM_2. The plate is of the same thickness and same material and placed parallel to G_1.

Looking in the direction M_1 from E, one observes M_1 and also a virtual image M_2' of M_2 formed in G_1. Therefore, one of the interfering beams comes by reflection from M_1 and the other which is reflected from M_2 functions as if it had been reflected from M_2', the two reflected beams originating from the same incident beam. Michelson Interferometer is, therefore, optically equivalent to air film between M_1 and M_2' but without the phenomenon of multiple reflections with in the film. When the interferometer is in normal adjustment M_1 and M_2' are exactly parallel to each other and it is also possible depending upon the orientation of M_2 with respect to M_1 that a wedge shaped air film is formed between M_1 and M_2'. The interference fringes may be therefore, of different shapes-straight, circular, parabolic, elliptical and hyperbolic-depending upon the optical path difference and the angle between M_1 and M_2 but only straight and circular fringes are most commonly employed.

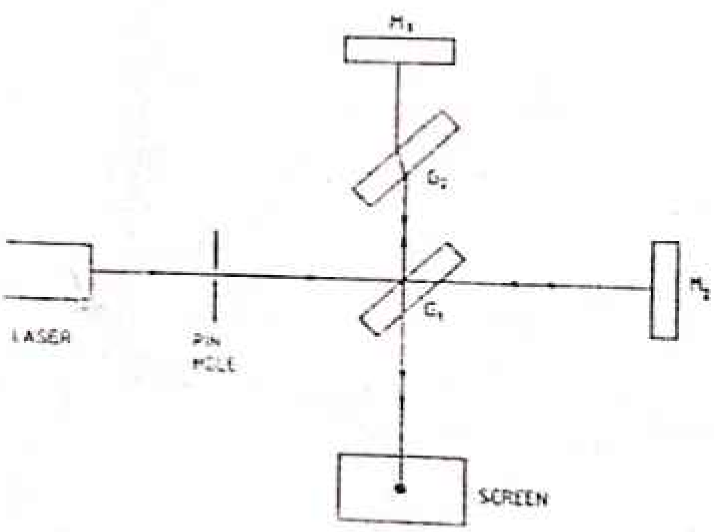
ADJUSTMENT OF MICHELSON INTERFEROMETER

Michelson Interferometer is said to be in normal adjustment when the partially silvered beam splitter surface G_1, accurately bisects the angle between the reflecting mirrors M_1 and M_2 and normal to their surfaces are exactly co-planer. Under this condition the image M_2' of M_2 in G_1 would be parallel to M_1 and the fringes could be concentric circles. This can be done with He-Ne laser or sodium lamp as source of light as follows :-

ADJUSTMENT WITH HE-NE LASER

To get the fringes with He-Ne laser adjust the instruement as follows : (Fig. 3)

Fig. 3 Alignment with He-Ne laser



(i) First put the interferometer on a rigid table and level the instrument with three levelling screws provided at the base.

(ii) Now put the Helium-Neon laser, about 50 to 60 cm away from the instrument such that its beam passes through the pin hole fitted in front of the instrument. Make sure that the laser beam falls at the middle of the Mirrors M_1 and M_2 after getting splitted from beam splitter plate G_1.

(iii) Make sure that the distances of M_1 and M_2 are almost equal from G_1.

(iv) The beam after the reflections will make four spots on the wall or on a screen as shown in the fig. 4. One pair 1 and 2 is formed due to partial reflections at the unsilvered surface of G_1 and reflections

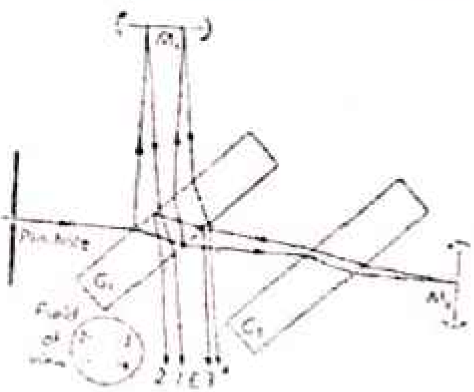


Fig. 4 Four spots on the screen

at M_1 and M_2 respectively. While the other pair 3 and 4 is formed due to partial reflections at M_1 and M_2 respectively. Out of these one pair is brighter than the other.

(v) Now mirrors M_1 and M_2 are tilted carefully such that the two brighter images coincide as shown in fig. 5.

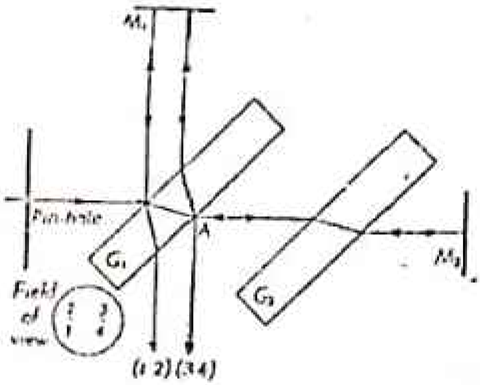


Fig. 5 Overlaping spots

(vi) Now the instrument is aligned. Introduce the lens in between the laser and pin hole and remove the pin hole out of the path of the beam. See that expanded beam falls on the two mirrors M_1 and M_2. You will see the fringes on the wall or screen.

(vii) By using fine tilt of fixed mirror and motion of the mirror M_1, you can adjust the centre of the circular fringes and can perform the experiments.

(viii) Do not use the telescope and do not see directly into the laser beam.

ADJUSTMENT WITH SODIUM LIGHT

(i) Put the interferometer on a rigid table and level it with the help of three leveling screws.

(ii) Adjust the position of movable mirror M_1 by using the coarse adjustment so that M_1 and M_2 are approximately equidistant from the beam splitter.

(iii) Place the sodium lamp at left handside of the interferometer at a distance of about 50 cm. Lamp should be approximately in line with the centres of the beam splitter G_1 and fixed mirror M_2 (fig. 6).

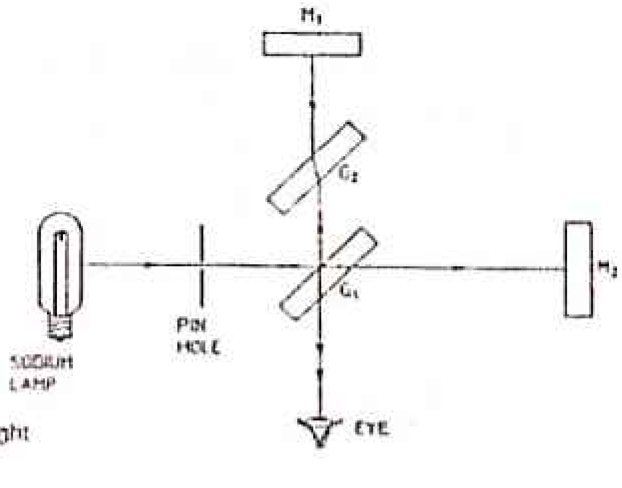


Fig. 6 Adjustment with sodium light

(iv) Bring the pin hole infront of the sodium lamp. Now put your eye close to the beam splitter. Two virtual images of the pin hole will be seen. Adjust the tilt screws of the fixed mirror so that the two line of their intersection is zero and therefore same for all wavelengths. As a consequence, with a white light source, along the line of intersection we shall get central achromatic fringe. The different colours overlap on each other and only the first few coloured fringes are visible.

APPLICATIONS OF MICHELSON INTERFEROMETER

This interferometer can be used to determine (a) the wavelength of a given monochromatic light say He-Ne laser (b) the difference of wavelength between D_1 and D_2 lines of sodium light (c) refractive index of transparent material and (d) the standardisation of meter in terms of wavelength of light.

Here we shall discuss only the first three applications, the fourth application reader can read in any standard optics book.

(a) Determination of the wavelength of monochromatic light (He-Ne laser) :

The mirrors M_1 and M_2 are adjusted so that circular fringes are visible in the field of view. If M_1 and M_2 are equidistant from the beam splitter G_1, the field of view will be perfectly dark. The mirror M_2 is kept fixed and the mirror M_1 is moved with the help of the fine movement screw and the number of fringes that cross the field of view is counted. Suppose for the monochromatic light of wavelength λ, the distance through which the morror is moved = d and the number of fringes that cross the centre of the field of view = n. Than $d = \frac{n\lambda}{2}$ because for one fringe shift, the mirror moves through a distance equal to half the wavelength. From the above relation λ can be determined.

(b) Determination of the difference in wavelength of D_1 and D_2 lines of sodium light.

There are two special lines D_1 and D_2 of sodium light. They are very near to each other and the difference in their wavelength is 6Å. Suppose the wavelength of D_1 line is λ_1 and the wavelength of D_2 line is λ_2. Each spectral line will give rise to its fringes in Michelson Interferometer. By adjusting the position of the mirror M_1 of the Michelson Interferometer, the position is found when the fringes are very bright. In this position, the bright fringe due to D_1 coincides with the bright fringe due to D_2. When the mirror M_1 is moved, the two sets of fringes get out of step because their wavelength are different. When the mirror M_1 has been moved through a certain distance, the bright fringe due to one set will coincide with dark fringe due to the other set and no fringes will be seen in this case. Again by moving the mirror M_1, a position is reached when a bright fringe of one set falls on the bright fringe of the other and the fringes are again distinct. This is possible when the other order of the longer wavelength coincides with the (n+1) th order of the shorter wavelength.

Let n_1 and n_2 be the changes in the order at the centre of the field when the mirror M_1 is displaced through a distance d between two consecutive positions of maximum distinctness of the fringes.

$$\therefore\ 2d = n_1\lambda_1 = n_2\lambda_2$$

If λ_1 is greater than λ_2

$$n_2 = n_1 + 1$$

Therefore
$$2d = n_1\lambda_1 = (n_1+1)\lambda_2 \qquad (1)$$

$$n_1\lambda_1 = (n_1+1)\lambda_2$$

$$n_1 = \frac{\lambda_2}{\lambda_1 - \lambda_2}$$

putting the value of n_1 in (1)

$$2d = \frac{\lambda_1\lambda_2}{\lambda_1 - \lambda_2}$$

$$\text{or } \lambda_1 - \lambda_2 = \frac{\lambda_1\lambda_2}{2d} \qquad (2)$$

virtual images coincide. For this, you may have to tilt also the three screws of the movable mirror M_1.

(v) Use the fine tilt adjustment of the fixed mirror to make the two virtual images of the pin hole coincide exactly.

(vi) Now remove the pin hole and put the ground glass plate between the sodium lamp and beam splitter. You will see fringes but may not be circular. Again use the fine tilt adjustment of the fixed mirror till the circular fringes centred in the field of view are seen.

(vii) Adjust the position of the movable mirror M_1 to get about 10 good contrast fringes, centred in the field of view.

(viii) Place the telescope focussed to infinity for about 30 cms. away from the beam splitter.

(ix) The telescope points towards the movable mirror. The fringes will be seen through the telescope. The centre of the fringes should not shift laterally, if the movable mirror is displaced by means of drum. If this condition is not achieved, repeat the steps 6, 7 & 8 till this condition is achieved.

TYPES OF FRINGES

(a) **Circular Fringes :** Circular fringes are produced with monochromatic light in Michelson interferometer. For this, the mirror M_1 and the virtual mirror M_2' which is the image of M_2 must be exactly parallel. When M_1 and M_2' coincide, the path difference is zero and the field of view is completely dark (Fig. 7 b).

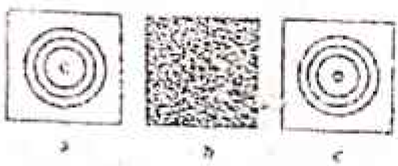
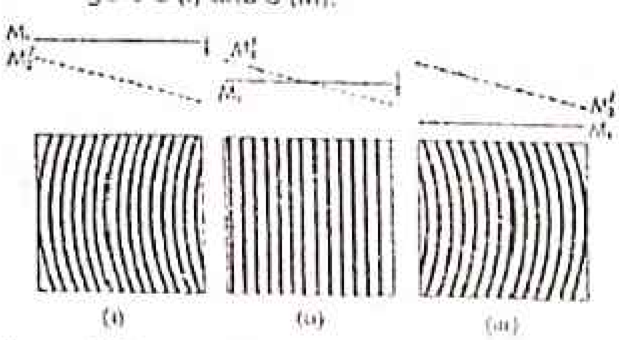


Fig. 7 Type of fringes

When M_2' is nearer the eye than M_1, the fringes are as shown in fig. 7a. When M_2' is farther from the eye than M_1 the fringes are as shown in fig. 7c.

(b) **Localized Fringes :** When the mirror M_1 and the virtual mirror M_2' (image of M_2) are inclined the air film enclosed is wedge shaped. In this situation straight line fringes are observed. The shape of the fringes observed for various values of path difference are shown in figure 8. The fringes are perfectly straight, when M_1 actually intersects M_2' the middle [fig. 8 (ii)]. When the wedge is not intersecting the fringes are curved like the figure 8 (i) and 8 (iii).

Fig. 8 Localized Fringes



(c) **White Light Fringes :** When the surfaces of M_1 and M_2' intersect, the path difference along the

$$2(\mu AD + DE - \mu t - BC) = n\lambda \quad \text{①}$$

Here $AD = \frac{t}{\cos\phi'}$; $DE = DC \sin\phi$

$DC = FC - FD = t\tan\phi - t\tan\phi'$

$BC = \frac{t}{\cos\phi} - t$

substituting these values in ①

$$\frac{\mu t}{\cos\phi'} + t\sin\phi(\tan\phi - \tan\phi') - \mu t - t\left[\frac{1}{\cos\phi} - 1\right] = \frac{n\lambda}{2} \quad \text{②}$$

But $\mu = \frac{\sin\phi}{\sin\phi'}$

then from ②

$$\frac{\mu}{\cos\phi'} + \sin\phi(\tan\phi - \tan\phi') - \frac{1}{\cos\phi} = \frac{n\lambda}{2t} - 1 + \mu$$

$$\frac{1}{\mu\cos\phi'}\left[\mu^2 - \sin^2\phi\right] - \frac{1}{\cos\phi}(1 - \sin^2\phi) = \frac{n\lambda}{2t} - 1 + \mu$$

But $\mu\cos\phi' = \sqrt{\mu^2 - \sin^2\phi}$

$$\therefore \sqrt{\mu^2 - \sin^2\phi} - \cos\phi = \frac{n\lambda}{2t} - 1 + \mu$$

$$\mu = \frac{(2t - n\lambda)(1 - \cos\phi) + \frac{n^2\lambda^2}{4t}}{2t(1 - \cos\phi) - n\lambda} \quad \text{③}$$

Hence μ can be determined from equation ③. The term $\frac{n^2\lambda^2}{4t}$ can be neglected as it is very small.

SPECIFICATIONS OF THE INSTRUMENT

1. Pin hole in a black aluminium disc.

2. Glass diffuser disc.

3. Beam splitter G_1 (optical glass) 50/50 size 50 mm X 45 mm, thickness 8 mm, surface $\lambda/10$ flat, parallelism better than 10 arc seconds coating Aluminium with silicon mono oxide protective coating.

4. Mirrors - 2 nos - (optical glass) fully reflecting, $\lambda/10$ flat, Aluminium coated with silicon mono-oxide overcoat.

5. Compensating plate like beam splitter but without coating.

6. Drum screw - one rotation produces a movement of 1 mm. Threaded length 200 mm, Dia 17 mm.

7. Fine movement - least count 10^{-4} mm.

8. Telescope : It is a short focal length telescope with rack and pinion arrangement to be mounted on a rod fitted in the instrument.

taking λ as the mean of λ_1 and λ_2

$$\therefore \Delta\lambda = \lambda_1 - \lambda_2 = \frac{\lambda^2}{2d} \qquad \text{③}$$

Hence the difference in wavelength λ_1-λ_2 can be calculated. In actual practice, readings for ten successive positions of maximum distinctness are taken and the mean value of d is calculated.

Also, wave number

$$\upsilon_1 = \frac{1}{\lambda_1} \quad \text{and} \quad \upsilon_2 = \frac{1}{\lambda_2}$$

from equation ②

$$\lambda_1 - \lambda_2 = \frac{\lambda_1\lambda_2}{2d}$$

$$\text{or } \frac{1}{\lambda_2} - \frac{1}{\lambda_1} = \frac{1}{2d}$$

$$\text{or } \upsilon_2 - \upsilon_1 = \frac{1}{2d}$$

This equation represents the difference in the wave numbers of the two spectral lines.

(c) Determination of refractive index of thin transparent material.

When a thin transparent material (mica) is introduced in the path of the beam going towards M_1, a path difference $2(\mu-1)t$ is introduced between the two interfering beams. With monochromatic light, this path difference introduces a displacement in the fringe system. Suppose N fringes have crossed the centre of the field of view. But experimentally it is not possible to count this number N.

The following method is used to count the number of fringes that cross the field of view.

(i) The given transparent plate is introduced in the path of the beam going towards M_1. The centre of the field of view is observed.

(ii) The plate is slowly rotated and the number of fringes that cross the field of view is counted. Suppose for an angle of rotation φ, the number of fringes that cross the field of view is n.

Suppose the thickness of the plate is t, the refractive index is μ and the plate has been rotated through an angle φ (Fig. 9). The optical path for ABC is μt+BC and for ADE it is μAD+DE.

The increase in optical path for n fringes that cross the field of view is given by

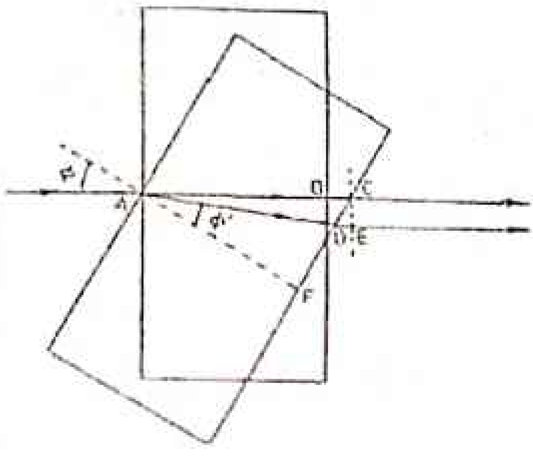


Fig. 9 Refractive index measurement

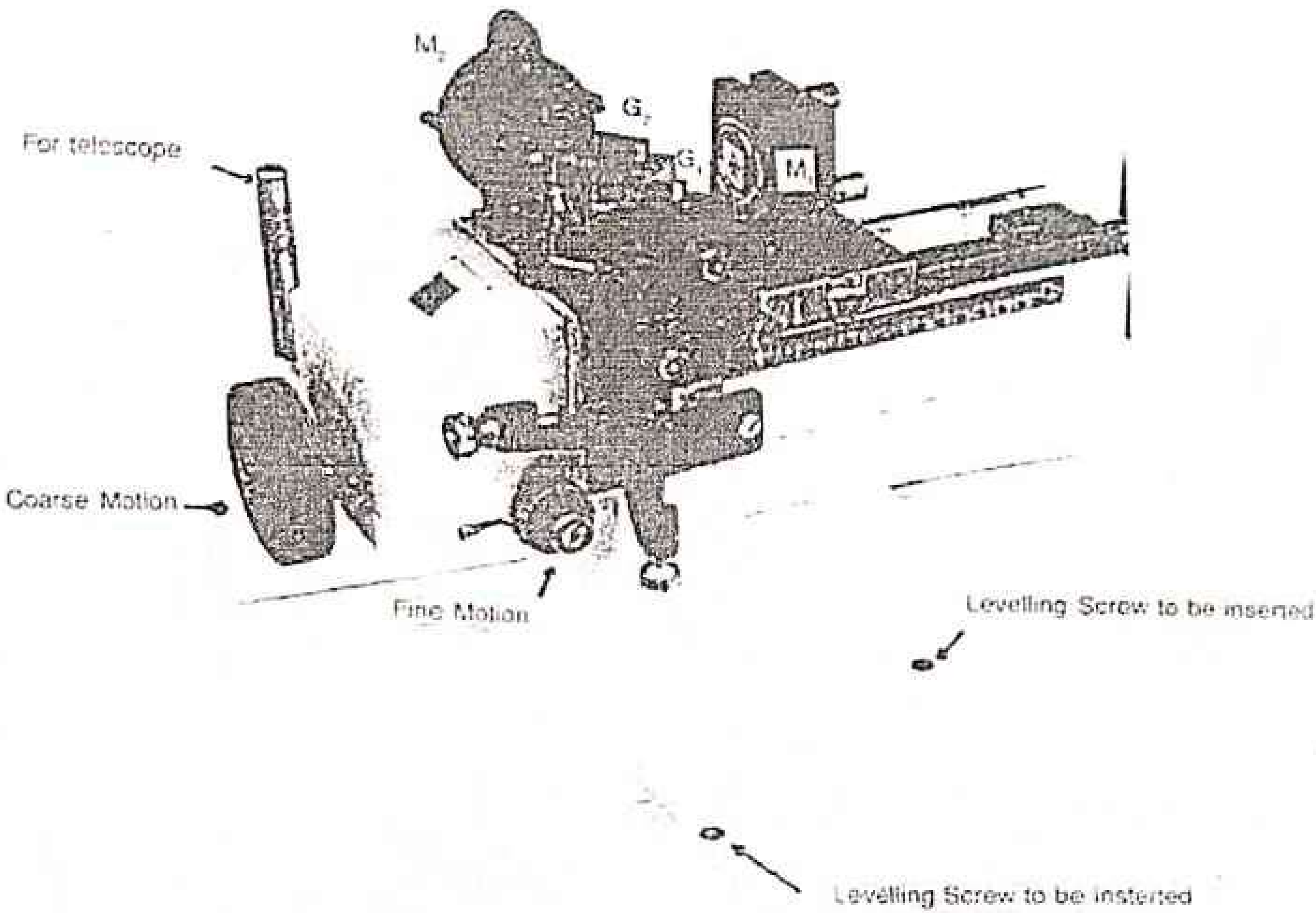


Fig. 10 : Constructional Details of the interferometer.

INSTRUCTION MANUAL
FOR
ENERGY BAND GAP BY FOUR PROBE METHOD
MODEL NO.

'MARS' made Energy Band Gap by Four Probe Method Apparatus has been designed to measure the value of Energy Band Gap in Germanium Material.

The Instrument comprises of the following built in parts :

1. **Probes Arrangement** : It has four individually spring loaded, coated with Zn at the tips. The probes are collinear and equally spaced. The Zn coating & individual spring ensure good electrical contacts with the sample. The probes are mounted in a teflon bush which ensure a good electrical insulation between the probe. A teflon spacer near the tips is also provided to keep the probes at equal distance. The whole arrangement is mounted on a suitable stand and leads are provided for current and voltage measurements.

2. **Sample** : Ge (Germanium) crystal in the form of a chip slice.

3. **Oven** : It is a small oven for the variation of temperature of the crystal from room temperture to about 200°C. Operating Temprature is 170°C.

4. **Four Probes Set-up : (Measuring Unit)** - It has three subunits all enclosed in one cabinet.

(i) Multirange Digital Voltmeter

In this unit 3.5 digit single chip A/D converter ICL 7107 has been used. It has high accuracy, auto zero to less than 10μV, zero drift-less than 1μV/°C, input bias current of 10 pA and roll over error of less than one count. Since the use of internal reference causes the degradation in performance due to internal heating, an external reference has been used.

SPECIFICATION

Range	:	(0 - 200.0 mV) &(0 - 2.000 V)
Resolution	:	100 μV at 200 mV range
Accuracy	:	± 0.1 % of reading ± 1 digit.
Impedence	:	10 MΩ
Display	:	3.5 digit, 7 segment, LED (12.5 mm height) with auto polarity and decimal indication

(ii) Constant Current Generator

It is a IC regulated current generator to provide a constant current to the outer probes irrespective of the changing resistance of the sample due to change in temperatures.

The basic scheme is to use the feedback principle to limit the load current of the supply to preset maximum value. Variations in the current are achieved by a potentiometer included for that purpose. The supply is a highly regulated and practically ripple free d.c. source. The current is measured by the digital panel meter.

SPECIFICATION

Open circuit voltage	: 18 Volts
Current range	: 0-20 mA
Resolution	: 10 μA
Accuracy	: ± 0.25 % of the reading ± 1 digit

(iii) Oven Power Supply

Suitable voltage for the oven is obtained through a step down transformer with a provision for low and high rates of heating. A glowing LED indicates. When the oven power supply is 'ON'.

INTRODUCTION

The properties of the bulk material used for the fabrication of transistors and other semiconductor devices are essential in determining the characteristics of the completed devices. Resistivity and lifetime (of minority carriers) measurements are generally made on germanium crystals to to determine their suitability. The resistivity, in particular, must be measured accurately since its value is critical in many devices. The value of some transistor parameters, like the equivalent base resistance, are at least linearly related to the resistivity.

ELECTRONIC CONDUCTION IN SOLIDS

The electrical properties of semiconductors involve the motion of charged particles within them. Therefore, we must have an understanding of the forces which control the motion of these particles. It is of course, the physical structure of the solid which exerts their control. This topic is very large, and hence only the high lights will be covered.

Atoms, of which a solid is composed, consist of positively charged nuclei with electron orbiting around them. The positive charge is compensated by negatively charged electrons, so that a complete atom is electrically neutral. Electrons are arranged in shells, and the closer they are to the nucleus the more strongly they are bound. If we take the particular case of silicon, a well known semiconductor, we find that it has 14 electrons which are accommodated in the shells as $(1S)^2$, $(2S)^2$, $(2P)^6$, $(3S)^2$, $(3P)^2$. Since the third shell is not even halif filled, the 4 electrons are available for chemical binding giving silicon a valency of four. (Germnium also has a chemical valency of 4, but from the fourth shell).

Let us now concentrate our attention on solids, if we bring many atoms close to one another, interatomic forces become quite strong as electronic orbits begin to overlap. The outer shell electons play an important role, because their orbits are the most disturbed. These electrons are no longer associated with a particular atom, the outer electron may make an orbit around one atom and continue about another. In this fashion, the outer shell or valency electrons are continually traded among atoms and wander all over the solid. The continuous interchange of valence electrons between atoms holds the solid together. This is the predominant type of bonding in silicon and germanium and is called the valence bonding.

FOUR PROBE METHOD

Many conventional methods for measuring resistivity are unsatisfactory for semiconductors because metal-semiconductor contacts are usually rectifying in nature. Also there is generally minority carrier injection by one of the current carrying contacts. An excess concentration of minority carriers will affect the potential of other contacts and modulate the resistance of the material.

The method described here overcomes the difficulties mentioned above and also offers several other advantages. It permits measurements of resistivity in samples having a wide variety of shapes, including the resistivity of small volumes within bigger pieces of semiconductor. In this manner the resistivity of both sides of PN Junction can be determined with good accuracy before the material is cut into bars for making devices. This method of measurement is also applicable to silicon and other semiconductor materials.

In order to use this four probe method in semiconductor crystals or slides it is necessay to assume that :

1. The resistivity of the material is uniform in the area of measurement.

2. If there is minority carrier injection into the semiconductor by the current - carrying electrodes most of the carriers recombine near the electrodes so that their effect on the conductivity in negligible. (This means that the measurements should be made on surface which have a high recombination rate, such as mechanical lapped surfaces).

3. The surface on which the probes rest is flat with no surface leakage.

4. The four probes used for resistivity measurements contact the surface at points that lie in a straight line.

5. The diameter of the contact between the metallic probes and the semiconductor should be small compared to the distance between probes.

6. The boundary between the current-carrying electrodes and the bulk material is hemispherical and small in diameter.

7. The surfaces of the semiconductor crystal may be either conducting or non-conducting.

   (a) A conducting boundary is one on which a material of much lower resistivity than semiconductor (such as copper) has been plated.

   (b) A non-conductibng boundary is produced when the surface of the crystal is in contact with an insulator.

EXPERIMENTAL PROCEDURES

1. Put the sample on the base plate of the four probe arrangement. Unscrew the pipe holding the four probes and let the four probes rest in the middle of the sample. Apply a very gentle pressure on the probes and tighten the pipe in this position. Check the continuity between the probes for proper electrical contacts.

<u>CAUTION</u> : The Ge crystal is very brittle. Therefore, use only the minimum pressure required for proper electrical contacts.

2. connect the outer pair of probes (Yellow/ Green leads) leads to the constant current power supply and the inner pair to the probe (red/ black leads) voltage terminals.

3. Place the four probe arrangement in the oven and fix the thermometer in the oven through the hole provided.

4. Switch ON the AC mains of Four Probe Set-up and put the digital panel meter in the current measuring mode through the selector switch. In this position LED facing mA would glow. Adjust the current to a desired value (Say 5mA).

S. No.	Temperature (°C)	Voltage (volts)	Temperature (T in K)	ρ (ohm. cm.)	$T^{-1} \times 10^3$	$Log_{10} \rho$

5. Now put the digital panel meter in voltage measuring mode. In this position LED facing mV would glow and the meter would read the voltage between the probes.

6. Connect the oven power supply. Rate of heating may be selected with the help of a switch Low or High as desired. Switch on the power to the Oven. The glowing LED indicates the power to the oven id 'ON'.

7. Now note down the reading of Milli Voltmeter at every increase in temprature. Note down reading in the Table No. (1). Plot a graph between $T^{-} \times 10^3$ & log 10 ρ by taking $T^{-} \times 10^3$ along X-axis & along log 10 ρ Y-axis.

TABLE G -7

Value of W/S	10.000	5.000	3.333	2.000	1.414	1.000	0.500	0.333	0.200	0.141	0.100
f (Corrective Factor) W/S	1.00045	1.0070	1.00228	1.094	1.223	1.504	2.780	4.159	6.931	9.704	13.863

TEST RESULTS

FOR

MEASUREMENT OF ENERGY BAND GAP USING FOUR PROBE METHOD

Instrument Serial No. : 18c1c914134

OBSERVATION & TABULATION :

Current (I) = 8.17 mA (Constant)

Sr. No.	Temp°C	Voltage (mV)	Temp. (In Kelvin)	ρ (ohm. cm)	$T^{-1} \times 10^{-3}$	$Log_{10} \rho$
1.	30	402	303	15.26	3.03	1.18
2.	40	402	313	15.[illegible]	3.19	1.16
3.	50	405	323	15.13	3.10	1.17
4.	60	382	333	14.45	3.00	1.15
5.	70	350	343	13.[illegible]	2.92	1.12
6.	80	222	353	8.3[illegible]	2.82	0.9[illegible]
7.	90	161	363	6.[illegible]	2.75	0.8[illegible]
8.	100	128	373	[illegible]	2.68	0.6[illegible]
9.	110	[illegible]	383	3.[illegible]	2.61	0.5[illegible]
10.	120	55	393	2.19	2.54	0.34
11.	130	[illegible]	403	1.58	2.48	0.19
12.	140	[illegible]	413	1.13	2.42	0.05
13.	150	[illegible]	423	1.09	2.36	0.0[illegible]
14.	160	[illegible]	433	1.05	2.30	0.0[illegible]
15.	170	[illegible]	443	0.94	2.25	-0.0[illegible]
16.	180	[illegible]	453	0.8[illegible]	2.20	-0.0[illegible]

TABLE (2)

Distance between probes (S) = 0.2 cm

Thickness of the crystal (W) = 0.050 cm

50 mm

5 cm

CALCULATION

$$\rho_o = \frac{V}{I} 2\pi S$$

$$\rho_o = \frac{V}{I} \times 1.256$$

0.070cm 0.2 cm

Since the thickness of the Crystal is very small compare to the probe distance, a correction factor for it has to be applied. In this present case the bottom surface is non-conducting, so the correction factor would be

$$\rho = \frac{\rho_0}{G7\ (W/S)}$$

Correction Factor corresponding to G7 = W/ S = W/ 0.2 = 0.07/0.2 = 0.35

Corrective Factor (G7) = 1.15

$$\text{or} \quad \rho = \frac{V}{I} \times \frac{1.256}{G7} = \frac{V}{5\times10^{-3}} \times \frac{1.256}{1.15} = V \times 37.83$$

Putting I = 8.00 mA (for whole set of Readings, constant)

$$\rho = V \times 37.83 \qquad \text{eq.} \text{———} (i)$$

Put the value of V (Voltage Read on DPM) in eq (i) and calculate the diff. value of ρ and Record in Table (2).

CALCULATIONS FOR ENERGY BANDGAP

We know that

$$E_g = \frac{2k \ \text{Loge}\ \rho}{1/T}$$

Where K is Boltzamann's constant = 8.6×10^{-5} ev/deg. & T is temperature in Kelvin, From the graph, slop of curve is

$$\frac{\text{Loge}\ \rho}{1/T} = \frac{2.3026 \times \text{Log}_{10}\rho}{1/T} = \frac{2.3026 \times 0.72}{0.44 \times 10^{-3}} = 4081$$

Hence Eg $= 2 \times 8.6 \times 10^{-5} \times$ slope of the curve $= 2 \times 8.6 \times 10^{-5} \times 4081 = 0.70$ eV

STANDARD ACCESSORIES

1.	Crystal (Germanium)	-	01 No.
2	Oven with cable	-	01 No.
3	Four probe	-	01 No
4	Thermometer 200°C	-	01 No
5	Power Cord	-	01 No.
6	Instruction Manual (DOC 545)	-	01 No.

Instrument Serial No : 12C1C91934

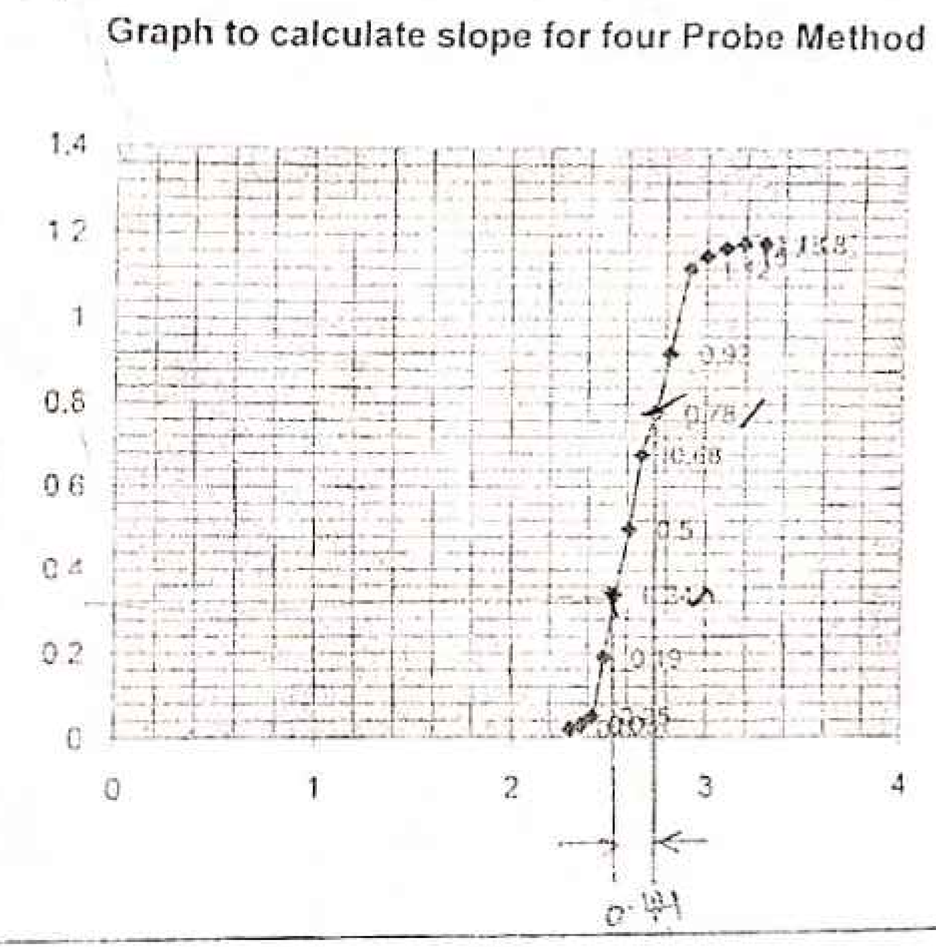
Date : 09/01/12

$T^{-1} \times 10^{-3}$	$Log_{10} \rho$
3.3	1.18
3.19	1.18
3.1	1.17
3	1.15
2.92	1.12
2.82	0.92
2.75	0.78
2.68	0.68
2.61	0.5
2.54	0.34
2.43	0.19
2.42	0.05
2.36	0.03
2.3	0.02

2.75
2.3
0.45

0.78
0.02
0.76

$Log_{10}\rho$



$T^{-1} \times 10^{-3}$

Checked By :

Final Inspection By :

User's Manual

MEASUREMENT OF SUSCEPTIBILITY OF A LIQUID OR A SOLUTION BY QUINCKE'S METHOD

Model : QTX-01

MEASUREMENT OF SUSCEPTIBILITY OF A LIQUID OR A SOLUTION BY QUINCKE'S METHOD

INTRODUCTION

The Quincke's method is used to determine magnetic susceptibility of diamagnetic or paramagnetic substances in the form of a liquid or an aqueous solution. When an object is placed in a magnetic field, a magnetic moment is induced in it. Magnetic susceptibility χ is the ratio of the magnetization I (magnetic moment per unit volume) to the applied magnetizing field intensity H. The magnetic moment can be measured either by force methods, which involve the measurement of the force exerted on the sample by an inhomogeneous magnetic field or induction methods where the voltage induced in an electrical circuit is measured by varying magnetic moment. The Quincke's method like the Gouy's method belongs to the former class. The force f on the sample is negative of the gradient of the change in energy density when the sample is placed,

$$f=\frac{d}{dx}\left[\frac{1}{2}\mu_0(\mu_r-\mu_{ra})H^2\right]=\frac{1}{2}\mu_0(\chi-\chi_a)\frac{d}{dx}H^2 \tag{1}$$

Here μ_0 is permeability of the free space and $\mu_r\chi$ and $\mu_{ra}\chi_a$ are respectively relative permeability and susceptibility of the sample and the air which the sample displaces. The force acting on an element of area A and length dx of the liquid column is $fAdx$, so the total force F on the liquid is

$$F=A\int fdx=\frac{A\mu_0}{2}(\chi-\chi_a)\left(H^2-H_0^2\right), \tag{2}$$

where the integral is taken over the whole liquid. This means that H is equal to the field at the liquid surface between the poles of the magnet and H_0 is the field at the other surface away from the magnet. The liquid (density ρ) moves under the action of this force until it is balanced by the pressure exerted over the area A due to a height difference h between the liquid surfaces in the two arms of the U-tube. It follows that

$$F=Ah(\rho-\rho_a)g$$

Or

$$\chi=\chi_a+\frac{2}{\mu_0}g(\rho-\rho_a)\frac{h}{\left(H^2-H_0^2\right)}\ . \tag{3}$$

In actual practice χ_a, density of air ρ_a and H_0 are negligible and can be ignored and the above expression simplifies to

$$\chi=\frac{2\rho gh}{\mu_0H^2}\ . \tag{4}$$

EXPERIMENTAL SET UP

A schematic diagram of Quincke's set up is shown in Fig.1. One limb of the glass U-tube is very narrow (about 2 - 3 mm in diameter) and the other one quite wide. The result is that a change in the level of the liquid in the narrow limb does not affect the level in the wider limb. The narrow limb is placed between the pole pieces of an electromagnet shown as N-S such that the meniscus of the liquid lies symmetrically between N-S. The length of the limb should be sufficient enough to keep the lower extreme end of this limb well outside the field of the magnet. The rise or fall h on applying the field is measured by means of a traveling microscope fitted with a micrometer scale of least count of order 10^{-3} cm.

EXPERIMENTAL PROCEDURE

1. Test and ensure that each unit (Electromagnet and Power Supply) is functioning properly.

2. Measure the density ρ of the specimen (liquid or solution) by specific gravity bottle. If the mass of empty bottle is w_1, filled with specimen w_2 and filled with water w_3, then

$$\rho = \rho_{water} \frac{w_2 - w_1}{w_3 - w_1} . \qquad (7)$$

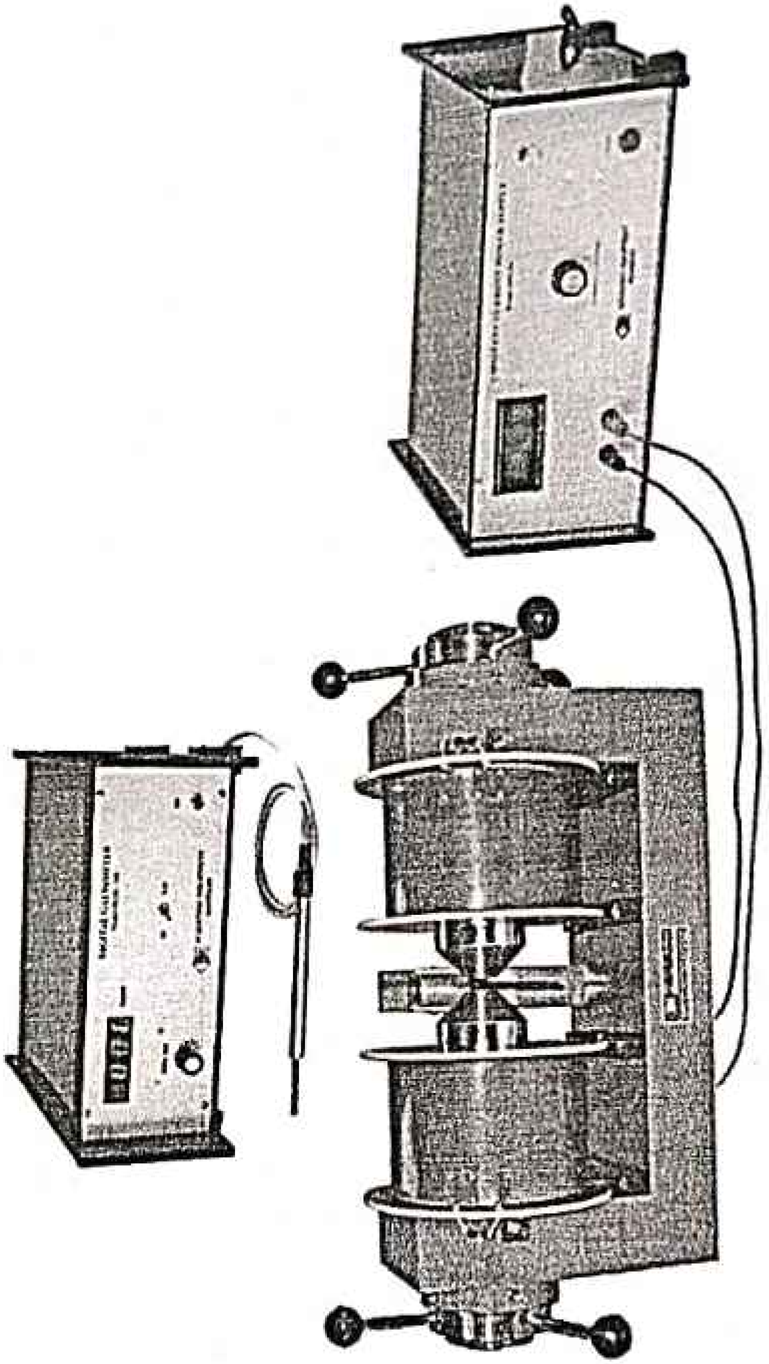
3. *Scrupulous* cleaning of the tube is essential. *Thoroughly* clean the Quincke's tube, rinse it well with distilled water and dry it (preferably with dry compressed air). Do not use the tube for longer than one laboratory period without recleaning it.

4. Keep the Quincke's tube between the pole pieces of the magnet as shown in Fig.1. The length of the horizontal connecting limb should be sufficient to keep the wide limb out of the magnetic field.

5. Fill the liquid in the tube and set the meniscus centrally within the pole pieces as shown. Focus the microscope on the meniscus and take reading.

6. Apply the magnetic field H and note its value from the calibration, which is done earlier as an auxiliary experiment. Note whether the meniscus rises up or descends down. It rises up for paramagnetic liquids and solutions while descends down for diamagnetics. Readjust the microscope on the meniscus and take reading. The difference of these two readings gives h for the field H. The magnetic field between the poles of the magnet does not drop to zero even when the current is switched off. There is a residual magnetic field R which requires a correction.

7. Measure the displacement h as a function of applied field H by changing the magnet current in small steps. Plot a graph of h as a function of H^2.



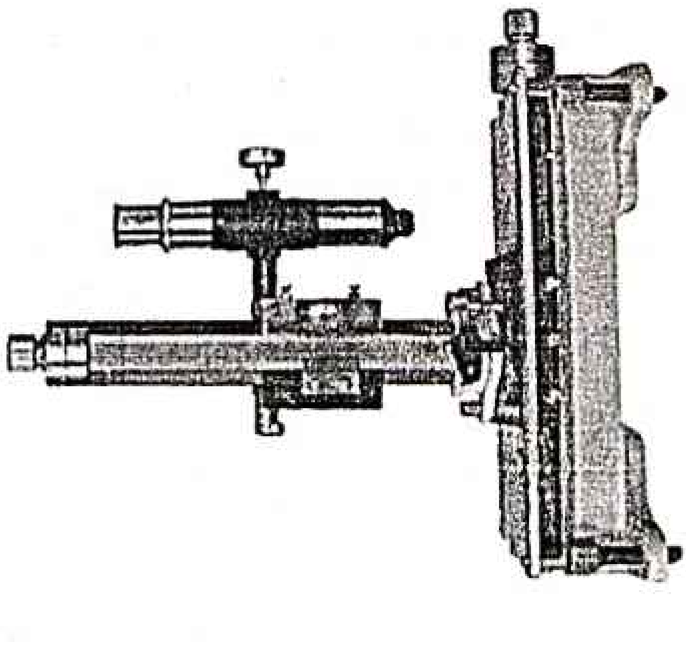
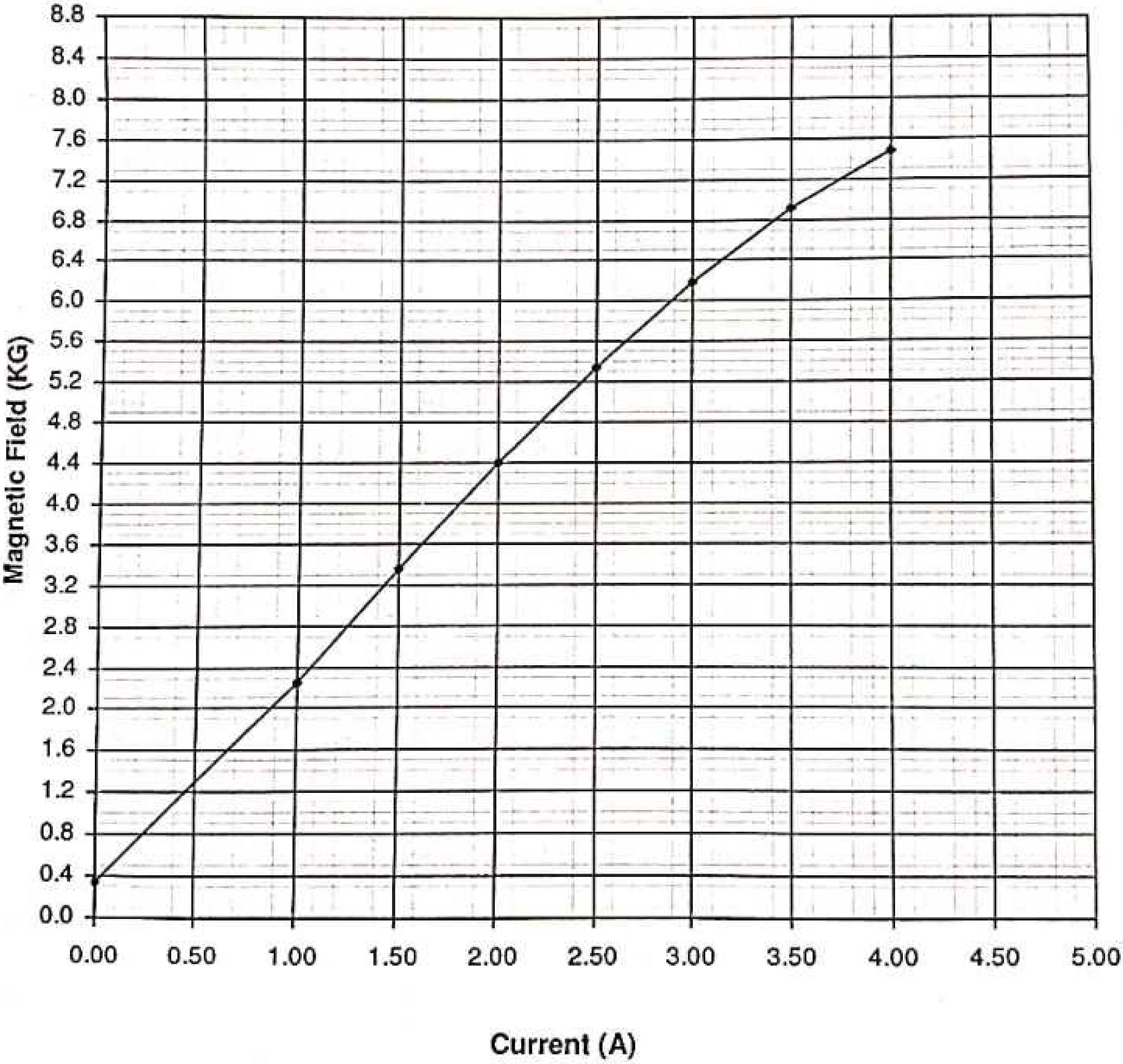


Table 1


Magnetic Field (KG)
8.8
8.4
8.0
7.6
7.2
6.8
6.4
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Current (A)

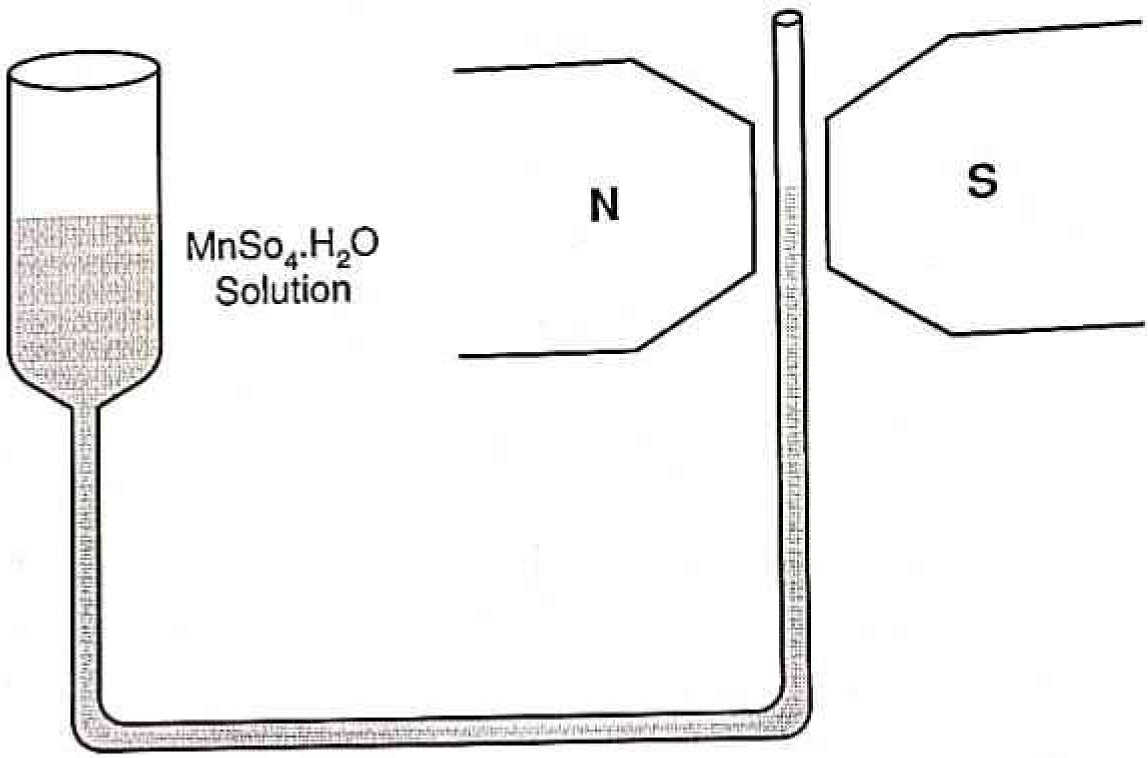


Fig. 1 : Schematic of Quinck's Setup

RESULTS

The mass susceptibility χ' is given by χ/ρ and the molar susceptibility χ'' by $M\chi'$ where M is the molecular weight of the specimen. In the case of solutions, correction must be made for the diamagnetic contribution of water. If the number of water molecules per unit volume is not very different in the solution from that in pure water,

$$\chi_{solution} = \chi_{salt} + \chi_{water} \;. \tag{8}$$

In general if m_s is the mass of the salt dissolved in m_w of water,

$$\chi'_{solution} = \frac{m_s}{m_s + m_w}\chi'_{salt} + \frac{m_w}{m_s + m_w}\chi'_{water} \;. \tag{9}$$

Mass susceptibility of the salt, χ'_{salt} can be obtained from this relation.

In a paramagnetic substance there are non-interacting permanent magnetic dipoles. The magnetizing field tends to align these parallel to the field. Thermal effects on the other hand tend to destroy this alignment. The result is that, for $kT >> \mu_0 \mu_B H$, the volume susceptibility χ_{salt} at temperature T is given by

$$\chi_{salt} = \frac{I}{H} = \frac{N\mu_0 (p\mu_B)^2}{3kT} = \frac{C}{T}, \qquad \text{(S.I. units)} \tag{10}$$

$$\chi_{salt} = \frac{N (p\mu_B)^2}{3kT} = \frac{C}{T}, \qquad \text{(C.G.S. units)}$$

where k is Boltzmann constant, $N (= N_A \rho_{salt}/M)$ is the number of ions per unit volume and μ_B is Bohr magneton. p is the magneton number which may be calculated from the measured value of χ_{salt} (or $\chi'_{salt} = \chi_{salt} / \rho_{salt}$) and compared with the theoretical value depending on L, S and J of the magnetic ion as given in *Appendix I.* Eq.10 expresses Curie law and the constant C is called the Curie constant. The above expression assumes that the magnetic field acting on each ion is just the applied field and contributions due to neighbouring magnetic ions are neglected. For dilute paramagnetic materials this approximation is valid.

RECORD OF OBSERVATIONS AND CALCULATION

(The following is a record of observations corresponding to an experiment performed with $M_nSO_4.H_2O$ in our laboratory).

1. **Preparation of solution:-**

(a) Mass of beaker (m_b)	=	29.857 g
Mass of beaker + water (m_{bw})	=	62.585 g
Mass of beaker + water + salt (m_{bws})	=	82.565 g
Mass of water ($m_w = m_{bw} - m_b$)	=	32.728 g
Mass of dissolved salt ($m_s = m_{bws} - m_{bw}$)	=	19.980 g

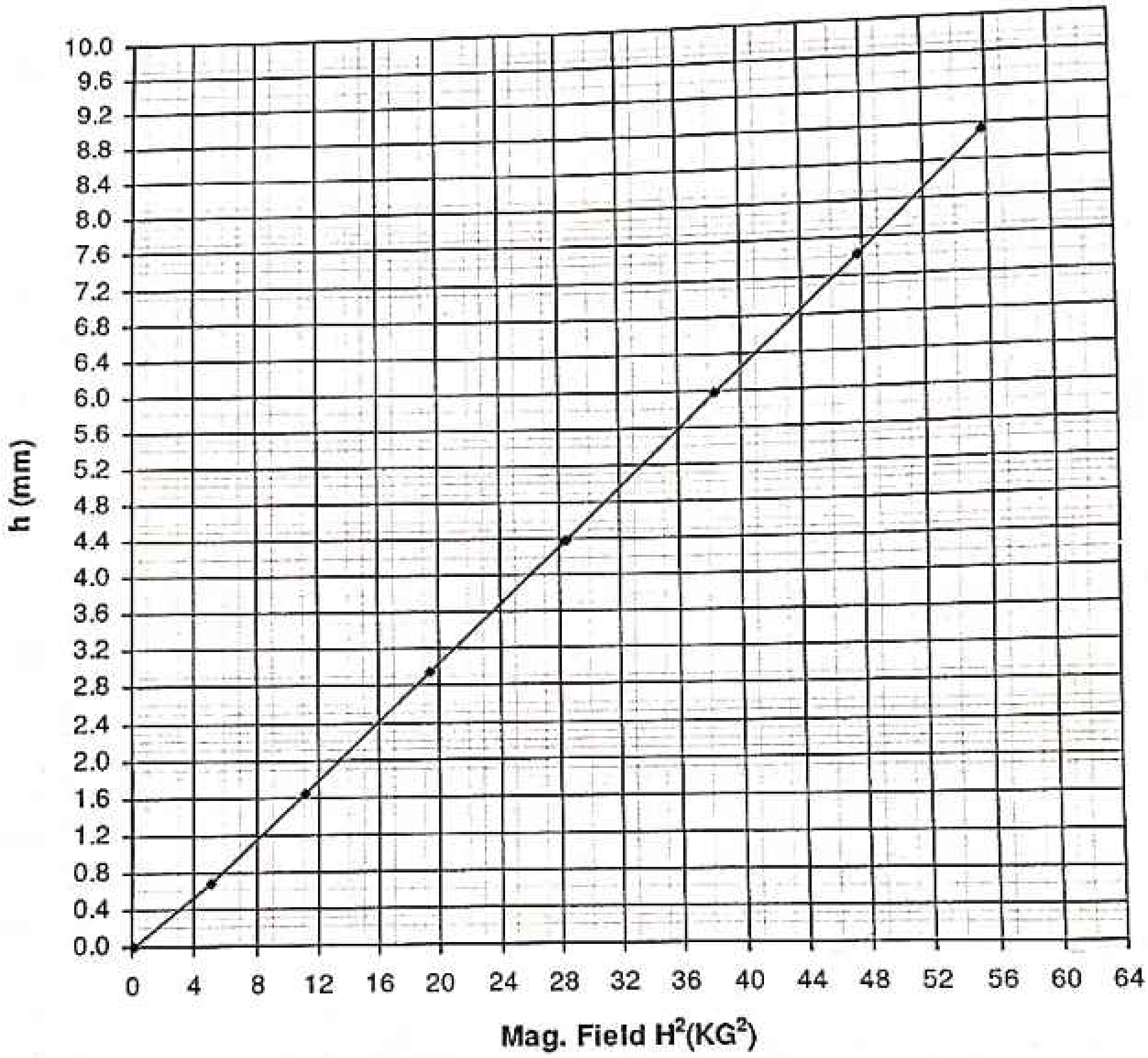


Fig.: Rise of solution level (h) as a function of magnetic field (H)

(b). Determination of density ρ:

Mass of specific gravity bottle (w_1) = 19.698 g
Mass of specific gravity bottle + water (w_3) = 44.973 g
Mass of specific gravity bottle + solution (w_2) = 56.173 g

$$\rho = \frac{w_2 - w_1}{w_3 - w_1} = \frac{36.475}{25.275} = 1.443 \text{ g/cm}^3$$

2. Ambient Temperature 293 K

3. **Calibration of magnetic filed as a function magnetizing current:-**

Procedure:

1. Fix the air gap between the pole pieces of the electromagnet to the minimum distance required to insert Quinck's tube without touching the pole pieces.
2. Measure the air gap. Each time the air gap changes, the graph will change.
3. Mount the Hall probe of the Digital Gaussmeter, DGM-102 in the wooden stand provided and place it at the centre of the air gap such that the surface of the probe is parallel to the pole pieces. The small black crystal in the probe is its transducer, so this part should be at the centre of the air gap.
4. Connect the leads of the Electromagnet to the Power Supply, bring the current potentiometer of the Power Supply to the minimum. Switch on the Power Supply and the Gaussmeter.
5. Slowly raise the current in the Power Supply and note the magnetic field reading in the Gaussmeter.
6. Plot the graph between the current and the magnetic field. This graph will be linear for small values of the current and then the slope will decrease as magnetic saturation occurs in the material of the pole pieces.

Table 1

S.No.	Current (A)	Magnetic Field (KG)
1.	0	0.34
2.	1.00	2.26
3.	1.50	3.35
4.	2.00	4.40
5.	2.50	5.34
6.	3.00	6.19
7.	3.50	6.91
8.	4.00	7.47

Putting, $\chi'_{sol} = 31.28 \times 10^{-6}$, $m_w = 32.728$ g, $m_s = 19.980$ g,

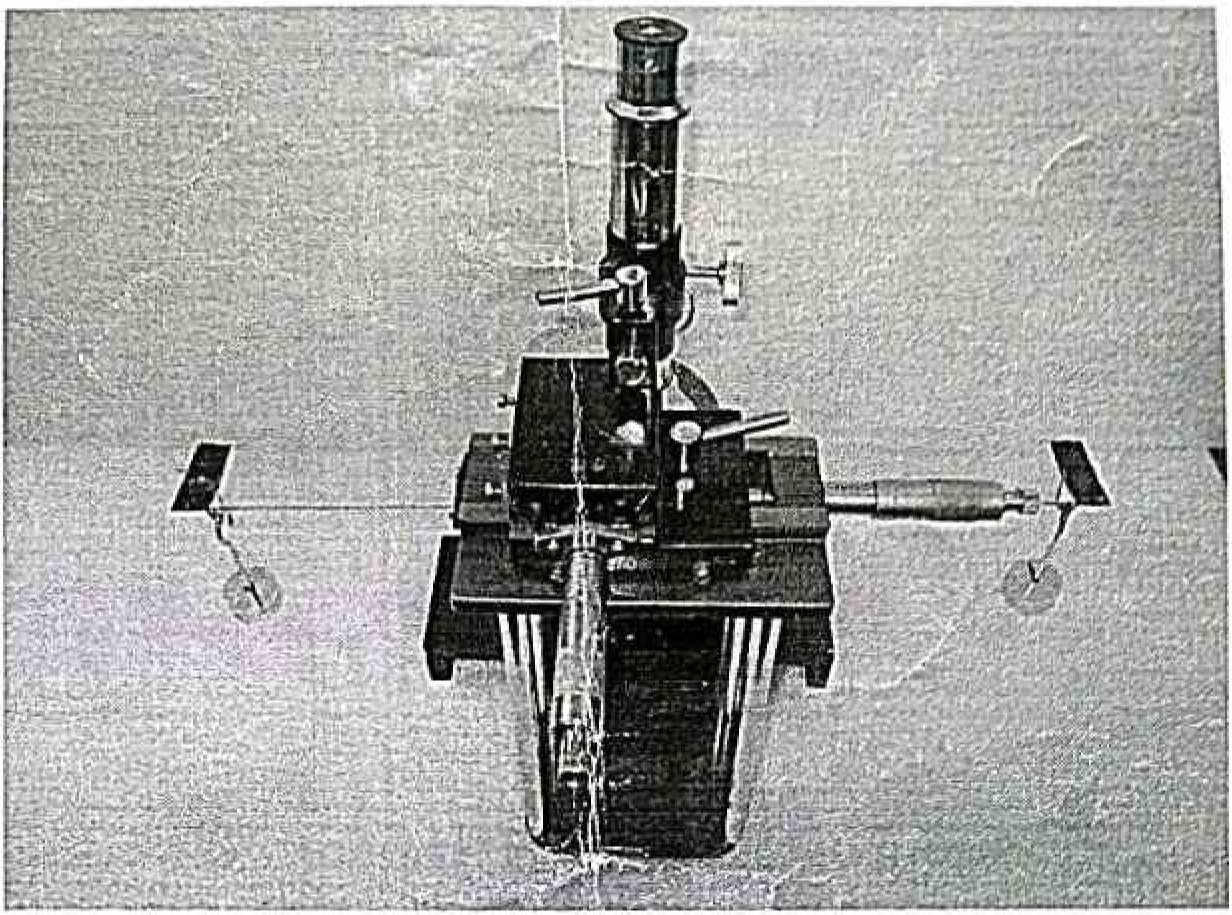
$\chi'_{water} = -0.72 \times 10^{-6}$ $\chi'_{salt} = 83.7 \times 10^{-6}$

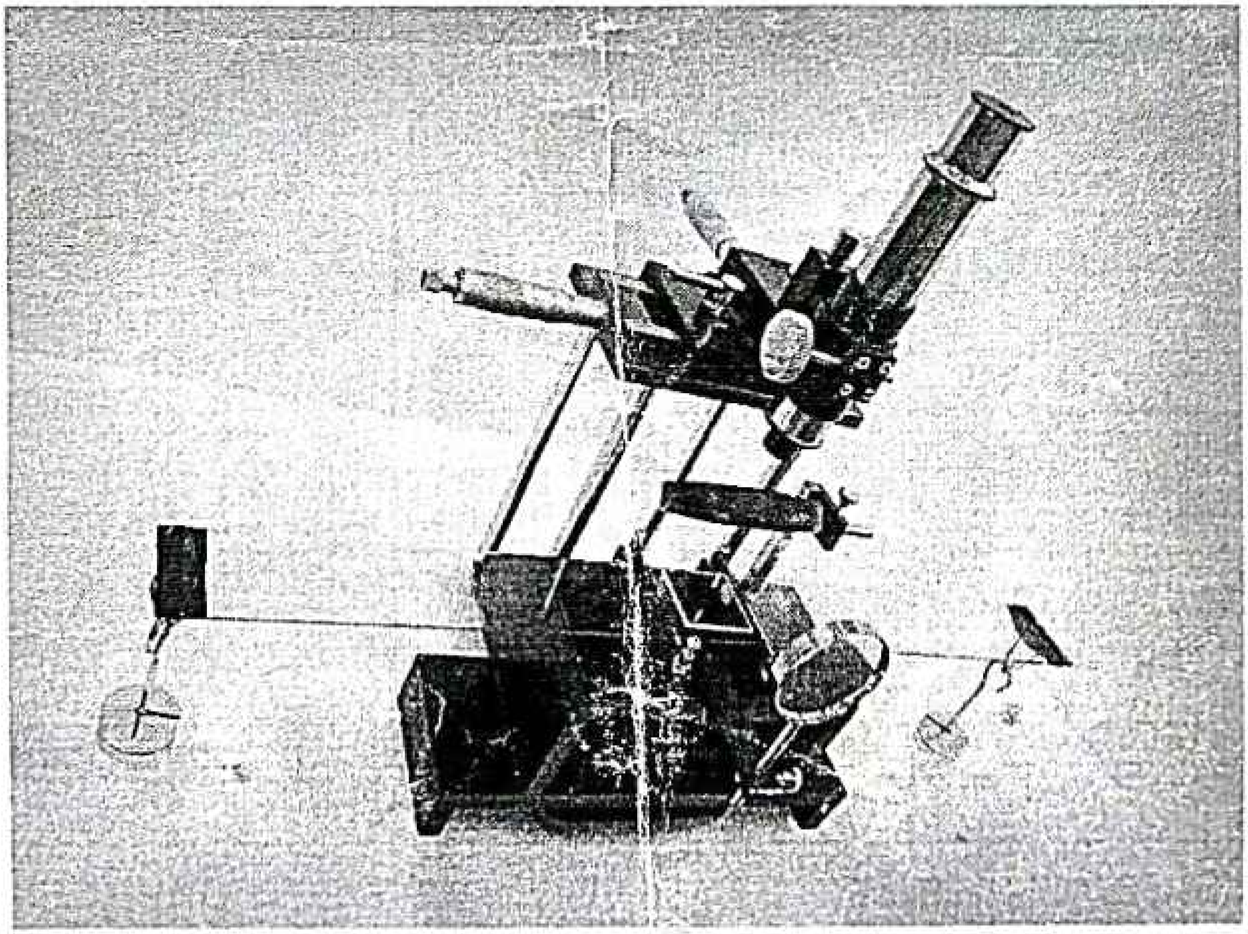
(iv). $\chi''_{salt} = \chi'_{salt}$ x molecular weight of $M_nSO_4.H_2O$

$= 83.7 \times 10^{-6} \times 169$

$= 14145 \times 10^{-6}$ C.G.S. unit

Internationally accepted value of χ'' for $M_nSO_4.H_2O$ at 293 °K is 14200×10^{-6}





CORNU'S APPARATUS For Elliptical & Hyperbolic Fringes

PICO CHENNAI-32

MAGNETIC SUSCEPTIBILITY USING A GOUY BALANCE

AIM:

To determine the magnetic susceptibility of a paramagnetic sample by measuring the force exerted on the sample by a magnetic field gradient

Introduction:

The electron has an intrinsic angular momentum characterized by a quantum number ½. The quantized angular momentum of a free electron is $S = \hbar\sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)}$. The intrinsic angular momentum can be crudely visualized as an intrinsic current loop which produced a magnetic moment. Thus each electron in the universe is a tiny magnet. (You will learn more about this in your quantum mechanics and atomic physics courses. Do not visualize the electron like a spinning top. Spin angular momentum is a truly intrinsic fundamental; property of the electron).

You maybe familiar with the filling of atomic shells for a many-electron atom (Hunds rule, Aufbau principle etc). Configurations in which the shell is fully filled results in zero net spin quantum number and net orbital angular momentum quantum number. Such atoms, eg. Argon, Neon etc., do not have a net magnetic moment and referred to as **diagmagents**. Atoms which do not have fully filled outer shell possess a net magnetic moment (eg. Fe, Ni etc.). A collection of such atoms which forms a gas, liquid of solid is magnetic since in the presence of an applied field the tiny moments can swing in the direction of the field. This behavior is affected by the temperature of the sample (more on this in your Statistical physics course). If the tiny moments do not 'interact' with each other the materials is referred to as a **paramagnet**. Interaction among moments results in **ferromagnets or antiferromagnets** (You will read about the origins of ferromagnetism in your statistical physics, condensed matter and atomic physics courses.[1])

Consider a paramagnet at room temperature subject to a magnetic field H. An obvious quantity of interest is the magnetization, M (magnetic moment (m_μ) per unit volume). The magnetic susceptibility (χ) is defined as ratio of the magnetization to the

---

[1] Just to get you interested we mention as astonishing fact: ferromagnetism arises due to a combination of the Coulomb repulsion between electrons and how it is influenced by Pauli's exclusion principle. Ferromagnetism cannot be modeled by considering dipole-dipole interactions!

applied magnetic field. The magnetization of a magnetic sample (paramagnet or ferromagnet) can be measured by a variety of methods a few of which you will be exposed to in the lab courses.

In this experiment we focus on the measurement of the force exerted on the sample by magnetic field gradient. The magnetic moment can also be measured in terms of an induced voltage in an electrical circuit (How this can be achieved ?).

Consider a solid in which each electron has an orbital angular momentum characterized by the quantum number, L, in addition to the spin angular momentum. Assuming spin-orbit coupling the total angular momentum quantum number is characterized by J. The total magnetic moment of the atom is given by $m_\mu = g\mu_B J$, where g is the Landè g factor of the atom and μ_o is the Bohr magneton ($\mu_B = e\hbar/2m$).

The difference in magnetic potential energy per unit volume between a substance of permeability μ and the displaced medium, usually air of permittivity μ_o is[2]

$$U = \left(\frac{H\cdot B}{2}\right)_{air} - \left(\frac{H\cdot B}{2\mu_o}\right)_{sample} = \frac{\mu_o H^2}{2} - \frac{\mu_o(1+\chi_m)H^2}{2} = -\mu_o \frac{H^2}{2}\chi_m \quad (1)$$

Here χ_m is the magnetic susceptibility. Which **for small magnetic fields**[3] is defined as $\chi_m = \frac{M}{H}$, where M is the magnetization.

When a magnetic field, B, is applied the energy changes by an amount

$$E = -m_\mu \cdot B = -VM\cdot B \quad (2)$$

where V is the volume of the sample. Connect equations (1) and (2).

If there is a gradient in the magnetic field along the z direction, the sample experiences a force per unit volume given by (assuming χ_m is uniform throughout the sample)

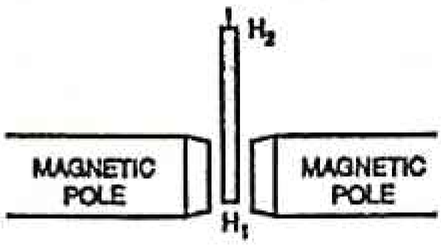
$$f = -\frac{dU}{dz} = \frac{\mu_o\chi_m}{2}\frac{d}{dz}\left(H^2\right) \quad (3)$$

---

[2] Consult a book on electromagnetic theory to understand the origin of this expression.

[3] You will learn the more general expression in the statistical physics course.

Thus the force is produced by the non-uniform field. A simple way to produce a field gradient is to use a specimen in the form of a long rod or tube filled with power or liquid placed between the pole pieces of an electromagnet which produced a uniform magnetic field as shown in the figure.



Since the length over which the uniform magnetic field is produced is much smaller than the sample length, the sample experiences a field gradient. In this case the total force is given by

$$F = \int_{l_2}^{l_1} fA dz = A\frac{\mu_o \chi_m}{2}\left(H_1^2 - H_2^2\right) \approx A\frac{\mu_o \chi_m}{2} H_1^2 \tag{4}$$

where l_1-l_2 is the length of the sample tube and A its area of cross-section and H_1 and H_2 are the magnetic field strengths along the z axis as indicated in the above figure. Now think of a physical balance in which the sample tube is hung from one side and is subject to a magnetic field. The other side has the standard weight pan as shown in figure 1. When the magnetic field is zero the weight of the sample is determined by the physical balance and is entirely due to gravity. When the field is switched on the magnetic force manifests as an apparent weight change of the sample (will the weight increase or decrease? How is this related to magnetic nature of the sample?). The force can easily be measured in terms of a weight by determining the new weight of the sample. This is known as a Guoy balance after the French physicist Louis Georges Gouy. A modern version of the Guoy balance available in the laboratory uses a digital balance instead of a physical balance.

Are you justified in neglecting H_2? If you keep decreasing the amount of power you take at what height does the method fail ? Verify this.

APPARATUS:

The Guoy balance, the powder specimen ($FeCl_2$ or Fe_2SO_4) in a glass tube, dc power supply for the magnet.

PROCEDURE:

The electromagnet is energized by a DC power supply. The variable magnetic field is provided by the wedge-shaped pole-pieces. The entire electromagnet is housed inside a wooden casing. The distance between the pole-pieces can be varied by means of a handle on top of the wooden casing. A digital balance is placed which carries a hook at the bottom for suspending the glass tube containing the material ($FeCl_2$, or Fe_2SO_4). The magnetic field between the pole pieces can be varied by changing the current through the coils using a DC power supply. The magnetic field corresponding to the current through the coils can be determined using a Gaussmeter (How does this work?).

1. Zero-adjust the digital balance.
2. Determine the area of cross-section of the tube. Suspend the empty glass tube as shown in Fig.1 and find its weight in zero magnetic field.
3. Using the D.C. power supply, vary the current from 0 to 3.5 A in steps of 0.2 A and in each case find the weight of the empty glass tube (Why do this?)
4. Fill the tube with the given sample (say $FeCl_2$) to about 3/4ths of the tube. Find the weight of the filled glass tube to an accuracy of 10 mg., in zero magnetic field.
5. As before, find the weight of the filled glass tube in different applied magnetic fields (both for the increasing and decreasing fields). (Why do this? When can you expect a difference in readings taken for increasing and decreasing fields)
6. Repeat the experiment with one or two more substances.

When the magnetic force is measured in terms of weight equation (3) becomes

$$mg = A\frac{\mu_o \chi_m}{2}\left(H_1^2 - H_2^2\right) \approx A\frac{\mu_o \chi_m}{2} H_1^2 \text{ (? can you make this appoxmation)} \qquad (5)$$

Plot a graph between *m* and H^2 to determine the susceptibility. This gives the susceptibility of a given volume. Compute the molar susceptibility of the sample. What is smallest susceptibility change that can be measured in the instrument? Is this sufficient to detect diamagnetism? Can you use this method for ferromagnets?

Are there gradients in the other two perpendicular directions? When can we neglect their effect?

IMPORTANT INSTRUCTIONS:

1. Reduce the current through the coils to zero slowly and then switch off the power supply.
2. DO NOT change the distance between the pole-pieces.
3. Switch off the digital balance. The glass tube is taken out of the balance and kept on the table. The power supply to the electro magnet is also turned off.

Tables

Table I

S.No.	Wt.of the empty glass tube (gm)	Current through the coils (A)	Magnetic field (Gauss)

Table II

S.No.	Wt. of the substance (gm)	Current through the coils (A)	Magnetic field (Gauss)

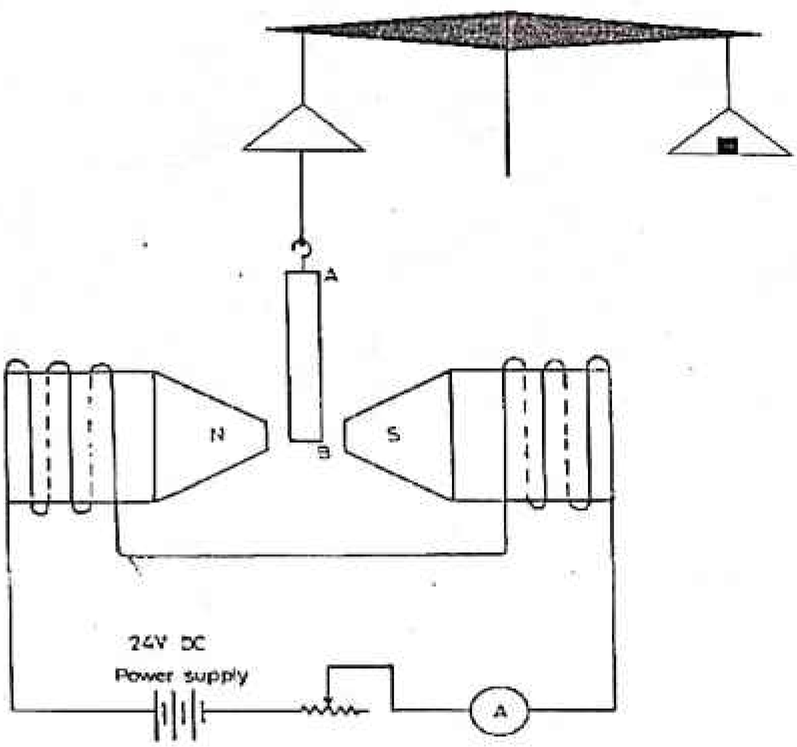


Fig. 1. The conventional Guoy balance. NS is an electromagnet with power supply and AB is the experimental glass tube. **<u>In your experiment the physical balance will be replaced by an accurate digital balance.</u>**

FURTHER READING:

1. Think of a way in which the susceptibility could be measured by holding the sample fixed and working with moving magnets (Known as Evan's design).
2. Think of other areas when magnetic forces play a role.

FORBIDDEN ENERGY BAND GAP

PROCEDURE

1, Switch ON the main supply.

2, connect the diode under investigation to jack marked "DIODE"
Circuit is connected for diode in reverse bias

3, Adjust the current through the diode for a convenient value, say 70 a by varying the potentiometer

4, Place the oil filled beaker in oven. Switch ON the Oven (with energy regulator knob at 70 mark) and heat the oil up to 100 C.

Measure the temperature using the thermometer.

NOTE: Graduation on Energy regulator knob does not indicate the temperature. They simply indicates the ON / OFF time of the heater.

5 Now place the diode in the oil and take the voltage across the diode as a function of temperature. Allow oil to cool and take at least 10 measurements in the range 25 – 100C. At each temperature adjust the diode current to the chosen value by adjusting the potentiometer.

6 Remove the diode from the oil bath and place it in ice and take a reading.

7, Tabulate the readings

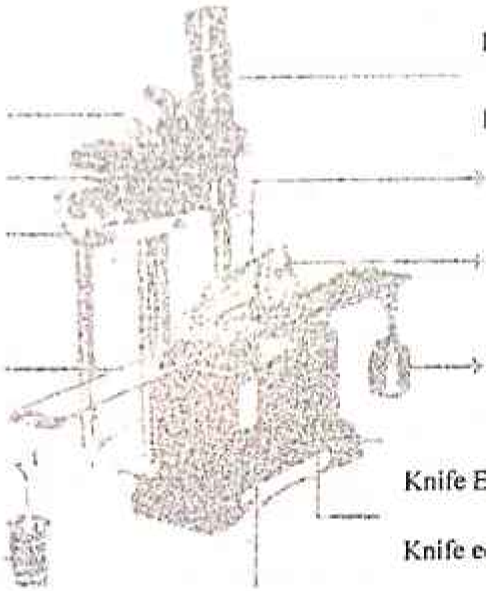
8 Draw a graph between the junction voltage and absolute temperature and calculate the slope "a" of the graph. Extrapolate the graph to O degree K and measure the intercept 'b'. Now using the relation calculate the energy band gap.

$E = -(b/a)e$

9, Repeat the experiment with other diode

USE OIL (ANY TRANSFORMER OIL OR COCONUT OIL).
DO NOT USE WATER – PLACE BEAKER INSIDE HEATER AND POUR.
DO NOT POUR DIRECTLY INTO BEAKER

OPERATING MANUAL



Experiment Setup:-

1. Measuring Microscope with Horizontal & Transverse movement to measure the diameters of Hyperbolic Fringes in both the directions.

2. Wooden Stand fitted with adjustable Reflecting plate & Magnifying Lens to throw parallel beam of light on the Hyperbolic Fringes.

3. Cover or Photographic Glass plate Rectangular: one.

4. Experimental Glass & Acrylic Beam: one each (total: - Two Nos.) Both the beams are provided with arrangement to suspend the weights near their ends.

Procedure

(I) Clamp the Microscope Slide and rotate the drum till its zero coincides with reference mark (zero mark). Re-clamp the slide after adjusted using the vernire (zero mark) at the zero mark of the scale.

(II) Mount the wooden stand at the stage of the Microscope (see fig. above) as shown. Adjust and clamp the Microscope tube in vertical position.

(III) Clean the Experimental Acrylic Beam with a soft cloth & mount it on the two knife edges of the wooden stand symmetrically ie. the distance between the knife edges and the hangers at both the ends of the beam should be made equal.

(IV) Clean the rectangular glass plate and mount it in the middle of the beam. Clamp the reflecting glass plate at its place & adjust it at an angle of 45 degrees. Clamp the Magnifying lens at the rear side of the wooden stand.

(V) Keep the Sodium Lamp Box at a distance of about 10 c ms from the lens, Fitted on the wooden stand. & Switch It On. Adjust the slit of the box so that light beam from the sodium lamp may felon the reflecting plate projected through the lens.

FOR BEST RESULTS THE SLIT OF THE SODIUM LAMP BOX SHOULD BE 1/2 INCH WIDE TO ILLUMINATE THE HYPERBOLIC FRINGES COMPLETELY.

(VI) Mark a cross on a white paper and keep it on the cover glass plate in the middle of the experimental beam. Re- adjusted the reflecting glass plate & the magnifying lens to illuminate the central part of the beam. Observe through the Microscope & focus the cross mark of the paper. Remove the paper & again adjust the Microscope tube, the reflecting glass plate & the lens to see well defined image of the hyperbolic fringes on the beam.

Some times the hyperbolic fringes may be seen at one side of the cover plate. In this case the Microscope should be adjusted in Horizontal Transverse directions such that the Fringes may be seen in all the four sides. This is the actual contact point between the cover plate and the beam.

The Interference Hyperbolic Fringes are formed between the lower face of the cover plate and the upper curved surface of the experimental beam. The Hyperbolic Fringes are shown in the Fig._1 below.

Now distance between the pair of Fringes may be measured with the help of Graduated Drum or the vernier-Scale of the Microscope in the horizontal direction towards the left hand & right hand side. Similarly the diameter of the Fringes may be measured in the transverse direction with the help of vernier – scale only on both side.

Place some weigh (say 100gm) on both the hangers. Adjust cross wire of the Microscope tangentially say on 13th fringes on left hand side along X' (horizontal direction) and note the reading. Move the cross fringe by fringe from Left Hand side to Right Hand Side and record the observations for suitable number of fringes.

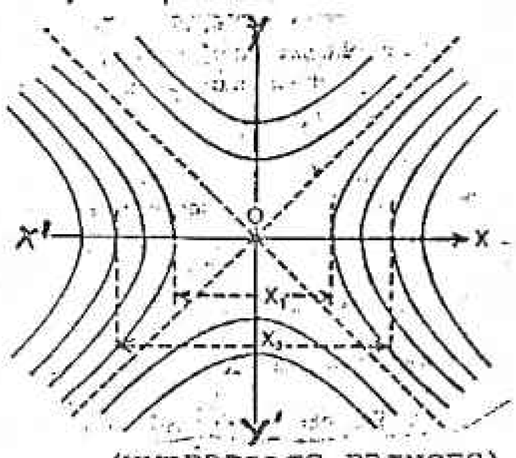
This gives either the separation or the diameters of the Fringes.

Make a table of your observations. Take different sets of readings by loading the Beam with different sets of weights say 150 gm. 200 gm, 250 gm and 300 gm. at both the sides.

With the help of these readings and the other constants, concerning the apparatus, the young's modulus & position ratio of glass can be calculated.

MOST IMPORTANT

We have provided two Nose Beams, Use both the beams for your Experiment One is of ACRYLIC & the other is Of glass. It will be much better if The Acrylic Beam is used first, As the Formation of Hyperbolic Fringes a more prominent as Compared to the glass beam.



(HYPERBOLIC FRINGES)

MOST IMPORTANT

1. The wooden frame should not touch with the stage or the rods of Microscope.
2. If the Hyperbolic fringes are not seen on the Un-loaded beam, it should be loaded with at least 100 gm weight at both sides.
3. For better illumination of the fringes, the slit of the sodium box should be wider than the normal circumstances.
4. The glass beam should be loaded with at least 200 gm weight at both the ends to get hyperbolic fringes easily. You may keep 200gm weight at both the ends on the upper side of the glass beam to get best results.

SOME MORE HINTS FOR MAKING THE EXPERIMENT ALL THE MORE EASY

In addition to the PROCEDURE in the operating manual, the following adjustments may be made to get the best result.

1. SETTING OF THE MICROSCOPE

Lock the Horizontal Slide of the Microscope by tightening the screw. Rotate the Graduated Drum in one direction; say in the Antic1ockwise, till it stops moving further. Now rotate it in the antic10ckwise direction till it covers 15 divisions on the scale. In this way the Microscope can be adjusted in the Centre of the Hyperbolic Fringes to read both ways 'for the same number of Fringes in the Horizontal Direction (Left or right)

2. <u>TO LOCATE CENTRE OF HYPERBOLIC FRINGES</u>

UN Clamp the horizontal Carriage (Slide) of the Microscope and Slide it to and fro and go on observing through the Eyepiece. When some curved fringes, are seen, adjust the Microscope in cross direction. In

this way hyperbolic Fringes can be seen on all the four sides of the cross wire. Thus the centre of the Fringes is located.

IF THE FRINGES ARE NOT SEEN CORRECTLY

I. Change the face of the cover plate.
II. Pat the cover plate with the wooden stick or
III. Shift the cover plate a little along the beam

With these adjustments you can see prefect fringes on all the four sides.

Books Recommended for this Experiment

1. Advance Practical Physics by S.P. Singh.
2. Practical Physics by Gupta – Kumar.

CONTENTS

8085 ASSEMBLY LANGUAGE PROGRAMS

8051 MICROCONTROLLER

ASSEMBLY LANGUAGE PROGRAMS

FLO-85 - 8085 TRAINER

INSTRUCTION FOR LOADING & EXECUTING PROGRAMMES

TO LOAD PROGRAM :

STEP:

I.	PRESS	**RESET** Key
II.	PRESS	**SUB/MEM** Key
III.	ENTER	**ADDRESS** in Address Field
IV.	PRESS	**INC** Key
V.	ENTER	**DATA** in Data Field
VI.	PRESS	**INC** Key
VII.	REPEAT	Steps V & VI till all Instructions are entered
VIII.	PRESS	**RESET** Key to Terminate loading operation.

TO LOAD DATA :

STEP:

I.	PRESS	**RESET** Key
II.	PRESS	**SUB/MEM** Key
III.	ENTER	**ADDRESS OF** Data in Address Field
IV.	PRESS	**INC** Key
V.	ENTER	**DATA** in Data Field
VI.	PRESS	**INC** Key
VII.	REPEAT	**Steps V & VI** till all Data are entered
VIII.	PRESS	**RESET** Key to Terminate loading operation

TO EXECUTE PROGRAM :

STEP:	PRESS	RESET Key
I.	PRESS	GO Key
II.	ENTER	*Starting* ADDRESS of Program
III.	PRESS	EXECUTE Key.

TO VERIFY RESULT AT MEMORY LOCATION

STEP:	PRESS	RESET Key
I.	PRESS	SUB/MEM Key
II.	ENTER	ADDRESS of Result location
III.	PRESS	INC Key
IV.	REPEAT	Pressing INC Key

TO VERIFY RESULT *AT REGISTER*

PRESS **RESET KEY**, followed by **(D/REG/3) KEY**, then the *required Register* Key. Repeat the same for other Registers.

TO DISPLAY DATA

In DATA Field - Move DATA into ACC & *Call* DISDAT [1380 H]

In ADDRESS Field- Move DATA into DE Reg Pair & *Call* DISADR [13C0 H]

In ALL SIX DIGITS – Move DATA into any three consecutive memory locations. Point HL to 1st memory location & *Call* DISPLAY [13FO H].

8085 INSTRUCTION SET

DATA TRANSFER GROUP		ARITHMETIC/LOGIC GROUP		BRANCH GROUP	
MOVE		**ADD**		**JUMP**	
MOV A,A	7F	ADD A	87	JMP adr	C3
MOV A,B	78	ADD B	80	JNZ adr	C2
MOV A,C	79	ADD C	81	JZ adr	CA
MOV A,D	7A	ADD D	82	JNC adr	D2
MOV A,E	7B	ADD E	83	JC adr	DA
MOV A,H	7C	ADD H	84	JPO adr	E2
MOV A,L	7D	ADD L	85	JPE adr	EA
MOV A,M	7E	ADD M	86	JP adr	F2
		ADC A	8F	JM adr	FA
MOV B,A	47	ADC B	88	PCHL	E9
MOV B,B	40	ADC C	89	**CALL**	
MOV B,C	41	ADC D	8A	CALL adr	CD
MOV B,D	42	ADC E	8B	CNZ adr	C4
MOV B,E	43	ADC H	8C	CZ adr	CC
MOV B,H	44	ADC L	8D	CNC adr	D4
MOV B,L	45	ADC M	8E	CC adr	DC
MOV B,M	46	**SUBTRACT**		CPO adr	E4
		SUB A	97	CPE adr	EC
MOV C,A	4F	SUB B	90	CP adr	F4
MOV C,B	48	SUB C	91	CM adr	FC
MOV C,C	49	SUB D	92	**RETURN**	
MOV C,D	4A	SUB E	93	RET	C9
MOV C,E	4B	SUB H	94	RNZ	C0
MOV C,H	4C	SUB L	95	RZ	C8
MOV C,L	4D	SUB M	96	RNC	D0
MOV C,M	4E	SBB A	9F	RC	D8
		SBB B	98	RPO	E0
MOV D,A	57	SBB C	99	RPE	E8
MOV D,B	50	SBB D	9A	RP	F0
MOV D,C	51	SBB E	9B	RM	F8
MOV D,D	52	SBB H	9C	**STACK**	
MOV D,E	53	SBB L	9D	PUSH B	C5
MOV D,H	54	SBB M	9E	PUSH D	D5
MOV D,L	55	**DOUBLE ADD**		PUSH H	E5
MOV D,M	56	DAD B	09	PUSH PS	F5
		DAD D	19	POP B	C1
MOV E,A	5F	DAD H	29	POP D	D1
MOV E,B	58	DAD SP	39	POP H	E1
MOV E,C	59	**INCREMENT**		POP PSW	F1
MOV E,D	5A	INR A	3C	XTHL	E3
MOV E,E	5B	INR B	04	SPHL	F9
MOV E,H	5C	INR C	0C	**INPUT-OUTPUT**	
MOV E,L	5D	INR D	14	OUT byte	D3
MOV E,M	5E	INR E	1C	IN byte	DB
MOV H,A	67	INR H	24	**CONTROL**	
MOV H,B	60	INR L	2C	DI	F3
MOV H,C	61	INR M	34	EI	FB
MOV H,D	62			NOP	00
MOV H,E	63	INX B	03	HLT	76
MOV H,H	64	INX D	13		
MOV H,L	65	INX H	23	RIM	20
MOV H,M	66	INX SP	33	SIM	30

MOV L,A	6F
MOV L,B	68
MOV L,C	69
MOV L,D	6A
MOV L,E	6B
MOV L,H	6C
MOV L,L	6D
MOV L,M	6E
MOV M,A	77
MOV M,B	70
MOV M,C	71
MOV M,D	72
MOV M,E	73
MOV M,H	74
MOV M,L	75
MOVE IMMEDIATE	
MVI A,byt	3E
MVI B,byt	O6
MVI C,byt	QE
MVI D,byt	16
MVI E,byt	1E
MVI H,byt	26
MVI L,byt	2E
MVI M,byt	36
LOAD IMMEDIATE	
LXI B,dble	O1
LXI D,dble	11
LXI H,dble	21
LXI SP,dbl	31
LOAD / STORE	
LDAX B	OA
LDAX D	1A
LHLD adr	2A
LDA adr	3A
STAX B	O2
STAX D	12
SHLD adr	22
STA adr	32
XCHG	EB
RESTART	
RST 0	C7
RST 1	CF
RST 2	D7
RST 3	DF
RST 4	E7
RST 5	EF
RST 6	F7
RST 7	FF

DECREMENT	
DCR A	3D
DCR B	O5
DCR C	OD
DCR D	15
DCR E	1D
DCR H	25
DCR L	2D
DCR M	35
DCX B	OB
DCX D	1B
DCX H	2B
DCX SP	3B
SPECIALS	
DAA	27
CMA	2F
STC	37
CMC	3F
ROTATE	
RLC	O7
RRC	OF
RAL	17
RAR	1F
LOGICAL	
ANA A	A7
ANA B	A0
ANA C	A1
ANA D	A2
ANA E	A3
ANA H	A4
ANA L	A5
ANA M	A6
XRA A	AF
XRA B	A8
XRA C	A9
XRA D	AA
XRA E	AB
XRA H	AC
XRA L	AD
XRA M	AE
ORA A	B7
ORA B	B0
ORA C	B1
ORA D	B2
ORA E	B3
ORA H	B4
ORA L	B5
ORA M	B6

Arith.& Logical Immediate	
ADI, byte	C6
ACI, byte	CE
SUI, byte	D6
SBI, byte	DE
ANI, byte	E6
XRI, byte	EE
ORI, byte	F6
CPI, byte	FE
COMPARE	
CMP A	BF
CMP B	B8
CMP C	B9
CMP D	BA
CMP E	BB
CMP H	BC
CMP L	BD
CMP M	BE

PROGRAM 1 **ADDITION**

1.1 8 BIT ADDITION - (Register with Register)

AIM : To add the contents of registers B and D and to store the sum in register C.

PROGRAM DESCRIPTION

Algorithm

- Registers B and D are loaded with the data to be added.
- Register C is cleared to store the sum.
- For any arithmetic or logic operation one of the data has to be in accumulator. Hence the contents of the registers either B or D is moved to the accumulator. Then the content of the other register is added to the accumulator.
- The resulting sum will be in the accumulator. So the sum has to be moved from A to C register.

Procedure

- Enter the instructions in the Program area starting from 8000H onwards.
- Execute the program from the starting address 8000H.
- Use **RST1** instruction to terminate the program & save the content of registers.
- Verify the result in the C register. For this press **RESET** key followed by **D/REG/3** key and **REG C** key.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	06,09	MVI B,09H
	80	02	16,05	MVI D,05H
	80	04	0E,00	MVI C,00H
	80	06	78	MOV A,B
	80	07	82	ADD D
	80	08	4F	MOV C,A
	80	09	CF	RST 1

1. 2 ADDITION OF 8 BIT NUMBERS - (in memory locations)

AIM

To add the contents of memory location 8010 H with 8011 H and store the result in 8012 H, using register Indirect-addressing mode.

PROGRAM DESCRIPTION

Algorithm

- The Memory Location in which the DATA is present is pointed by the HL register pair.
- The first data is moved to the accumulator for addition.
- The memory pointer (HL register pair) is incremented to point the next data.
- The data in the memory pointed by HL is added with the accumulator.
- The resulting sum will be in the accumulator. The sum is moved to the next memory location after incrementing the memory pointer HL.

Procedure

- Enter the instructions in the Program area starting from 8000 H onwards.
- Enter the data 05 H and 09 H in the memory location 8010 H and 8011 H.
- Clear location 8012 H by entering 00 H data at 8012 H.
- Execute the program from the starting address 8000 H.
- Verify the result at the memory location 8012 H.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,10,80	LXIH, 8010H
	80	03	7E	MOV A,M
	80	04	23	INX H
	80	05	86	ADD M
	80	06	23	INX H
	80	07	77	MOV M,A
	80	08	76	HLT

1.3 ADDITION of two 16 BIT BINARY NUMBERS - *(in memory locations)*

AIM

To add two sets of 16 bit Binary data stored in memory locations starting from 8050 H and 8060 H. Store the sum in memory locations starting from 8070 H.

PROGRAM DESCRIPTION

Algorithm

- Bring the data from memory locations 8050H & 8051H to the HL reg.pair.
- Move this data to the DE register pair by exchanging the contents of the HL and DE register pairs.
- Bring next data from memory locations 8060H & 8061H to the HL reg. pair.
- Add the register pairs DE and HL. The sum will be in the HL register pair.
- Store back the content of the HL register pair in the memory locations starting from 8070H.
- HALT.

Procedure

- Enter the instructions in the Program area starting from 8000 H onwards.
- Enter the 16 bit data in the memory locations 8050H,8051H and 8060H,8061H.(With LSB data loaded in 8050H and 8060H)
- Execute the program from the starting address 8000 H.
- Verify the result at the memory location 8070 H.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	2A,50,80	LHLD, 8050H
	80	03	EB	XCHG
	80	04	2A,60,80	LHLD,8060H
	80	07	19	DAD D
	80	08	22,70,80	SHLD,8070H
	80	0B	76	HLT

1.4 ADDITION OF TWO MULTI-BIT BINARY NUMBERS
-(in memory locations)

AIM

To add two 16 bit / 24 bit / 32 bit Binary numbers stored in memory.

PROGRAM DESCRIPTION

Algorithm

- Initialize Accumulator and carry flag to zero.
- Store the number of bytes to be added in reg. C.
- Initialize HL reg. pair with memory address where first data is stored.
- Initialize DE reg. pair with memory address where second data is stored.
- Load the byte from memory pointed by reg. pair DE to Accumulator.
- Add with carry the Accumulator content with a byte from memory pointed by reg. pair HL
- Store the result in memory.
- Increment address in HL to point to next byte of first data.
- Increment address in DE to point to next byte of second data.
- Decrement the count in C reg. by one.
- If the count in C reg. is not zero continue addition.
- HALT.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	AF	XRA A
	80	01	0E,**XX**	*MVIC,**XX**
	80	03	11,50,80	LXID, 8050H
	80	06	21,60,80	LXIH, 8060H
LOOP:	80	09	1A	LDAXD
	80	0A	8E	ADC M
	80	0B	77	MOV M,A
	80	0C	13	INX D
	80	0D	23	INX H
	80	0E	0D	DCR C
	80	0F	C2,09,80	JNZ, LOOP
	80	12	76	HLT

*At memory location **8002H**, LOAD XX → **02H, 03H or 04H** for 16, 24 & 32 bit additions respectively.

1.5 ADDITION OF TWO MULTI DIGIT BCD NUMBERS

AIM

To add two sets of multi digit BCD numbers stored in memory starting from address 8050 H onwards and 8060 H onwards and store the sum in memory starting from 8080H onwards.

PROGRAM DESCRIPTION

Each memory location can hold only 8 bits (2 nibbles). Two BCD digits can be stored in one location. Hence for N digit number N/2 locations are needed. So the ADD instruction should be performed ***N/2 times*** for a N digit BCD number.

Algorithm

- Number of times the addition to be performed is stored in the C register.
- Two Numbers to be added are pointed by the DE and HL register pairs.
- Accumulator is cleared for addition.
- Data pointed by the DE register is brought to the accumulator.
- The next data pointed by HL register pair is added with the accumulator and *the accumulator is adjusted for Decimal Addition*.
- The sum in the accumulator is stored in a temporary memory location.
- The DE pointer is incremented by 30 H and the sum is stored.
- The DE pointer is decremented by 30H to point the data.
- The data pointers are incremented to point the next digits to be added.
- The counter is decremented and the procedure is carried out until the counter (C register) becomes Zero.
- HALT.

Procedure

- Enter the instructions in the Program area starting from 8000 H onwards.
- Enter the data in the memory locations starting from 8050 H and 8060 H.
- Execute the program from the starting address 8000 H.
- Verify the result at the memory location starting from 8080 H.

Program : 1.5

ADDITION OF MULTI DIGIT BCD NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	0E,04	MVIC,04H
	80	02	11,50,80	LXID, 8050H
	80	05	21,60,80	LXIH, 8060H
	80	08	AF	XRA A
RPT:	80	09	1A	LDAX D
	80	0A	86	ADD M
	80	0B	27	*DAA*
	80	0C	32,70,80	STA, 8070H
	80	0F	7B	MOV A,E
	80	10	C6,30	ADI, 30H
	80	12	5F	MOV E,A
	80	13	3A,70,80	LDA, 8070H
	80	16	12	STAX D
	80	17	7B	MOV A,E
	80	18	D6,30	SUI,30H
	80	1A	5F	MOV E,A
	80	1B	23	INX H
	80	1C	13	INX D
	80	1D	0D	DCR C
	80	1E	C2,09,80	JNZ, RPT
	80	21	76	HLT

PROGRAM 2 SUBTRACTION

2.1 8 BIT BINARY NUMBERS - (in registers)

AIM

To subtract the content of register D from register B and store the remainder in the register C.

PROGRAM DESCRIPTION

Algorithm

- Registers B and D are loaded with the data to be subtracted.
- Register C is cleared to store the remainder.
- For Subtraction the content of register B has to be in the accumulator. Hence it is moved to the accumulator. Then the content of the other register is subtracted from the accumulator.
- The remainder will be in the accumulator. So the difference has to be moved from A to C register.

Procedure

- Enter the instructions in the Program area starting from 8000H onwards.
- Execute the program from the starting address 8000H.
- USE RST1 instruction to terminate the program.
- Verify the result in the C register. For this press **RESET** key followed by **D/REG/3** key and **REG C** key.

Program

SUBTRACTION OF 8BIT BINARYNUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	06,09	MVI B,09H
	80	02	16,05	MVI D,05H
	80	04	0E,00	MVI C,00H
	80	06	78	MOV A,B
	80	07	92	SUB D
	80	08	4F	MOV C,A
	80	09	CF	RST 1

2.2 SUBTRACTION of TWO MULTI BIT BINARY NUMBERS [in memory]

AIM

To subtract two 16 bit / 24 bit / 32 bit numbers stored in memory.

PROGRAM DESCRIPTION

Algorithm

- Initialize accumulator and carry flag to zero.
- Store the number of bytes to be subtracted in register C.
- Initialize HL register with memory address where the first data is stored.
- Initialize DE register with memory address where the second data is stored.
- Load a byte from memory whose address is in DE to accumulator.
- Subtract with borrow a byte in memory whose address is pointed by HL from the accumulator.
- Store the result in memory.
- Increment address in HL to point to the next byte of first data.
- Increment address in DE to point to the next byte of second data.
- Decrement the count in C register by one.
- If the count in C register is not zero continue the subtraction.
- HALT.

Program

SUBTRACTION OF MULTI BIT NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	AF	XRA A
	80	01	*0E,XX*	**MVIC,XX*
	80	03	11,50,80	LXID, 8050H
	80	06	21,60,80	LXIH, 8060H
LOOP:	80	09	1A	LDAX D
	80	0A	9E	SBB M
	80	0B	77	MOV M,A
	80	0C	13	INX D
	80	0D	23	INX H
	80	0E	0D	DCR C
	80	0F	C2,09,80	JNZ, LOOP
	80	12	76	HLT

Note:

*At Memory location 8002 H, load *XX ⇒ 02, 03 and 04* for 16, 24and 32 bit subtraction respectively.

2.3 SUBTRACTION of TWO BCD NUMBERS [in memory]

AIM

To subtract a BCD number from another BCD number.

PROGRAM DESCRIPTION

Algorithm

- Load the first number in the accumulator from memory.
- Transfer the first number to B register.
- Load the second number to accumulator from memory.
- Transfer the second number to the C register.
- Use accumulator to find 99's complement of the second number
- Add the first number with 100's complement of the second number(Ignore carry).
- Adjust the result for BCD.
- Store the result in memory
- HALT.

Program

SUBTRACTION OF BCD NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3A,50,80	LDA, 8050H
	80	03	47	MOV B,A
	80	04	3A,51,80	LDA, 8051H
	80	07	4F	MOV C,A
	80	08	3E,99	MVIA, 99H
	80	0A	91	SUB C
	80	0B	3C	INR A
	80	0C	80	ADD B
	80	0D	27	*DAA*
	80	0E	32,52,80	STA, 8052H
	80	12	76	HLT

PROGRAM 3 MULTIPLICATION

3.1 MULTIPLICATION of TWO 8 BIT BINARY NUMBERS

AIM

To multiply two 8 bit Binary numbers stored in the memory locations 8050 H and 8051 H and store the product in 8052 H.

PROGRAM DESCRIPTION

Algorithm

- Get the multiplicand and the multiplier to the B and C registers.
- Accumulator and the flags are cleared to store the product.
- Multiplication is done using the ***repeated addition method***.
- Result is moved to the next memory location.

Procedure

- Enter the instructions in the Program area starting from 8000 H onwards.
- Enter the multiplier and the multiplicand in the appropriate memory locations.
- Execute the program from the starting address 8000 H.
- Verify the product in the memory location 8052 H.

Program

MULTIPLICATION OF 8 BIT BINARY NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,50,80	LXIH,8050H
	80	03	46	MOV B,M
	80	04	23	INX H
	80	05	4E	MOV C,M
	80	06	AF	XRA A
RPT:	80	07	88	ADC B
	80	08	0D	DCR C
	80	09	C2,07,80	JNZ, RPT
	80	0C	23	INX H
	80	0D	77	MOV M,A
	80	0E	76	HLT

3.2 MULTIPLICATION of Multi Bit BINARY NUMBERS

[16 bit x 16 bit]

AIM

To multiply two 16 bit numbers and store the 32 bit result in four successive memory locations.

PROGRAM DESCRIPTION

Algorithm

- Initialize HL register with 0000H.
- Initialize memory locations where the result is to be stored with 00H.
- Load the 16 bit multiplicand and multiplier in BC and DE register pairs.
- Add BC content with HL content.
- If there is no carry go to END.
- Save the HL contents in stack.
- Load HL with 16 bit data from 8052 and 8053H.
- Increment the HL content and store it in 8052 and 8053H.
- Retrieve HL from stack.
- Decrement the register pair BC.
- If the content of BC is not zero go to RPT.
- Store the content of HL in 8050 and 8051
- HALT.

Program

MULTIPLICATION OF MULTI BIT BINARY NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,00,00	LXIH, 0000H
	80	03	22,52,80	SHLD, 8052H
	80	06	*01,yy,xx*	*LXIB, xx,yy H*
	80	09	*11,qq,pp*	*LXID, pp,qq H*
RPT:	80	0C	09	DAD B
	80	0D	D2,19,80	JNC, END
	80	10	E5	PUSH H
	80	11	2A,52,80	LHLD, 8052H
	80	14	23	INX H
	80	15	22,52,80	SHLD, 8052H
	80	18	E1	POP H
END:	80	19	1B	DCX D
	80	1A	7A	MOV A,D
	80	1B	B3	ORA E
	80	1C	C2,0C,80	JNZ, RPT
	80	1F	22,50,80	SHLD, 8050H
	80	22	76	HLT

3.3 MULTIPLICATION of Two BCD NUMBERS

AIM

To multiply two BCD numbers in memory and store the result in memory.

PROGRAM DESCRIPTION

Algorithm

- Load the first number to accumulator from memory.
- Transfer the first number to B register
- Load the second number to accumulator from memory.
- Transfer the second number to the C register.
- Clear the accumulator and carry flag.
- Add the register B with accumulator.
- *Adjust the result for BCD.*
- Decrement C register by one.
- If C register is not equal to zero go to LOOP.
- Store the result in memory
- HALT.

Program

MULTIPLICATION OF BCD NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3A,50,80	LDA, 8050H
	80	03	47	MOV B,A
	80	04	3A,51,80	LDA, 8051H
	80	07	4F	MOV C,A
	80	08	AF	XRA A
LOOP:	80	09	80	ADD B
	80	0A	27	*DAA*
	80	0B	0D	DCR C
	80	0C	C2,09,80	JNZ, LOOP
	80	0F	32,52,80	STA, 8052H
	80	12	76	HLT

3.4 DIVISION of [8 Bit / 8 Bit] NUMBERS

AIM

To divide two 8 bit numbers. The divisor and the dividend are stored in the memory locations 8150H and 8151H respectively and store the remainder and the quotient in 8152H and 8153H respetively.

PROGRAM DESCRIPTION

Algorithm

- Bring the divisor and dividend to register B and accumulator.
- C register is cleared to store the quotient.
- The divisor is subtracted from the dividend until the dividend is less than the divisor. The number of times the subtraction is carried out gives the quotient and the final dividend becomes the remainder.
- The Quotient and the remainder are moved to the memory.

Procedure

- Enter the instructions in the Program area starting from 8000H onwards.
- Enter the divisor and the dividend in the appropriate memory locations.
- Execute the program from the starting address 8000H.
- Verify the result in the memory location 8152H and 8153H.

Program

DIVISION OF TWO 8 BIT NUMBERS

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3A,50,81	LDA, 8150H
	80	03	47	MOV B,A
	80	04	3A,51,81	LDA, 8151H
	80	07	0E,00	MVIC, 00H
	80	09	B8	CMP B
	80	0A	DA,13,80	JC, END
RPT:	80	0D	90	SUB B
	80	0E	0C	INR C
	80	0F	B8	CMP B
	80	10	D2,0D,80	JNC, RPT
END:	80	13	32,52,81	STA, 8152H
	80	16	79	MOV A,C
	80	17	32,53,81	STA, 8153H
	80	1A	76	HLT

PROGRAM 4 **SEARCH & BLOCK MOVE**

4.1 Search for an element in an Array

AIM: To search for a given byte of data in an Array.
Place **FFH**, if present ; **00H**, if not. At location **8500H**.

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	16, **BYTE**	**MVID, BYTE**	Search **BYTE** in D
	80 12	0E, XX	**MVIC, XXH**	XX⇒ No. COUNT
	80 14	21, 50, 80	**LXIH, 8050H**	Point to given Array
LOOP:	80 17	7E	**MOV A,M**	Place 1st byte in Acc.
	80 18	BA	**CMP D**	Check Search byte If found go to END
	80 19	CA, 25, 80	**JZ, END**	
	80 1C	23	**INX H**	Else point to next byte
	80 1D	0D	**DCR C**	Decrement Count
	80 1E	C2, 17, 80	**JNZ, LOOP**	Repeat if count ≠ 0
	80 21	AF	**XRAA**	If Search BYTE not found clear Acc. & go to LAST.
	80 22	C3, 27, 80	**JMP, LAST**	
END:	80 25	3E, FF	**MVIA, FFH**	If Search BYTE found, place Acc.= FF
LAST:	80 27	21, 00, 85	**LXIH, 8500H**	Place in 8500H FF if found; 00 if not found
	80 2A	77	**MOV M,A**	
	80 2B	76	**HLT**	

4.2 'BLOCK MOVE' - an Array of bytes

AIM: To **Block Move** a given set of data **FROM** *SOURCE AREA* (**8501**H onwards)
TO *DESTINATION AREA* (**8601**H onwards)
No. of bytes to be moved:- stored at location NUM (8500H).

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	21, 00, 85	**LXIH, 8500H**	Point to no. count
	80 13	4E	**MOV C,M**	No. count in C reg.
	80 14	11, 01, 86	**LXID, 8601H**	Point⇒DestinationArea
	80 17	23	**INX H**	Point⇒Source Area
LOOP:	80 18	7E	**MOV A,M**	Source data to Acc. & move to Destination Area
	80 19	12	**STAX D**	
	80 1A	13	**INX D**	Next source location.
	80 1B	23	**INX H**	Next Destn. location
	80 1C	0D	**DCR C**	Decrement counter & repeat LOOP until count = 0.
	80 1D	C2, 18, 80	**JNZ, LOOP**	
	80 20	76	**HLT**	

PROGRAM 4.3

SELECTION OF LARGEST & SMALLEST ELEMENT FROM AN ARRAY

AIM

To pick up the largest and the smallest element from an array of unsigned numbers starting from ARRAY (8051H). The number of element in the array is available at NUMB (8050H). Store the result in the location BIG/SMALL.

PROGRAM DESCRIPTION

Algorithm

Method 1:

- Number of elements in the array is loaded to the B register.
- The starting element of the array is pointed by the HL register pair.
- By comparing with the elements in the memory, the Largest number is brought to the accumulator.
- The result is stored in the location BIG/SMALL.

Method 2:

- The starting element of the array is pointed by the HL register pair.
- The count of the element is loaded in the C register.
- (RPT)Move an element from the memory to the accumulator.
- Move the next element from the memory to the B register.
- Compare the data in A register with the data in the B register.
- If the data in the accumulator is smaller than the data in B register go to LOOP
- If the data in accumulator is greater than the data in B register "swap" first data with the second data stored in memory.
- (LOOP)Increment the memory pointer.
- Decrement the count in the C register.
- If the counter is not equal to zero go to RPT.

Program

SELECTION OF LARGEST & SMALLEST ELEMENT FROM AN ARRAY

Method 1:

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,50,80	LXIH, 8050H(NUMB)
	80	03	4E	MOV C,M
	80	04	35	DCR M
	80	05	21,51,80	LXIH,8051H(ARRAY)
	80	08	7E	MOV A,M
	80	09	23	INX H
NEXT:	80	0A	BE	CMP M
	80	0B	D2,0F,80	*JNC, SKIP
	80	0E	7E	MOV A,M
SKIP:	80	0F	23	INX H
	80	10	0D	DCR C
	80	11	C2,0A,80	JNZ, NEXT
	80	14	32,70,80	STA,8070H(BIG)
	80	17	76	HLT

Use JNC for largest & JC for smallest.

Method 2:

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,50,80	LXIH, 8050H(NUMB)
	80	03	4E	MOV C,M
	80	04	35	DCR M
	80	05	21,51,80	LXIH,8051H(ARRAY)
RPT:	80	08	7E	MOV A,M
	80	09	23	INX H
	80	0A	46	MOV B,M
	80	0B	B8	CMP B
	80	0C	DA,13,80	JC, LOOP
	80	0F	77	MOV M,A
	80	10	2B	DCX H
	80	11	70	MOV M,B
	80	12	23	INX H
LOOP:	80	13	0D	DCR C
	80	14	C2,08,80	JNZ, RPT
	80	17	76	HLT

PROGRAM 5 SORTING AN ARRAY

5.1 (Ascending / Descending – Bubble sort method)

AIM

Arrange the numbers in the array in descending, ascending order. The number of elements in the array is in the location 8050H. The array starts from 8051H.

PROGRAM DESCRIPTION

Algorithm

- Number of elements in the array is loaded to the B register.
- The starting element of the array is pointed by the HL register pair.
- Bubble sort method is used to arrange the array.

Procedure

- Enter the instructions in the Program area starting from 8000H onwards.
- Enter the no of elements in the array at the location 8050H.
- Feed in the array of elements starting from the address 8051H.
- Execute the program from the starting address 8000H.
- Verify the result.

Program

SORTING AN ARRAY - DESCENDING ORDER

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,50,80	LXIH,8050H
	80	03	46	MOV B,M
	80	04	05	DCR B
RPT:	80	05	21,51,80	LXIH,8051
	80	08	48	MOV C,B
NEXT:	80	09	7E	MOV A,M
	80	0A	23	INXH
	80	0B	BE	CMP M
	80	0C	D2,15,80	*JNC,NOINT
	80	0F	57	MOV D,A
END:	80	10	7E	MOV A,M
	80	11	72	MOV M,D
	80	12	2B	DCX H
	80	13	77	MOV M,A
	80	14	23	INX H
NOINT:	80	15	0D	DCR C
	80	16	C2,09,80	JNZ, NEXT
	80	19	05	DCR B
	80	1A	C2,05,80	JNZ, RPT
	80	1D	76	HLT

*** Use JC for Ascending & JNC for Descending.**

5.2 **REVERSING the order of data in an Array**

AIM: To reverse the order of a given set of data. Original Array starting from **8501**H New Array formed at **8601**H onwards. No. of bytes in the Array stored at **8500**H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	21, 00, 85	**LXIH, 8500H**	Point to no. count
	80 13	4E	**MOV C,M**	Store no. count in C
	80 14	11, XX, 86	**LXID, 86XXH**	Point to **end address** of New Array.
	80 17	23	**INX H**	Point to **start addr.** of Original Array
LOOP:	80 18	7E	**MOV A,M**	Original Array data move to Acc. & place in New Array.
	80 19	12	**STAX D**	
	80 1A	1B	**DCX D**	Update Pointers
	80 1B	23	**INX H**	
	80 1C	0D	**DCR C**	Decrement Count
	80 1D	C2, 18, 80	**JNZ, LOOP**	If count **not 0** repeat
	80 20	76	**HLT**	Else HALT

NOTE: **XXH**⇒ LSB byte of End address of New Array.

PROGRAM 6 CODE CONVERSION

AIM

1. BCD (Decimal) to BINARY (HEX) Conversion.
2. BINARY (HEX) to BCD (Decimal) Conversion.
3. BINARY to ASCII Conversion.
4. ASCII to BINARY Conversion.
5. ASCII to BCD Conversion.
6. BCD to ASCII Conversion.

6.1. BCD to HEX Conversion

PROGRAM DESCRIPTION

A TWO DIGIT PACKED BCD number between 00 and 99 is stored in memory location BCD (8050H). Store the BINARY equivalent (HEX) at location BCDBIN (8060H).

Algorithm

- BCD number in the memory is loaded to the accumulator.
- The lower and the upper nibble are separated using the masking techniques.
- The upper nibble is multiplied 0AH and the binary sum is added with the lower nibble to get the BINARY equivalent to the BCD number.
- The result is stored to the location 8060H.

Procedure

- Enter the instructions in the Program area starting from 8000H onwards.
- Enter the BCD number in the memory location BCD (8050H).
- Execute the program from the starting address 8000H.
- Verify the result in BINBCD location (8060H).

Program

6.1 BCD to HEX Conversion

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,50,80	LXIH, 8050H (BCD)
	80	03	7E	MOV A,M
	80	04	47	MOV B,A
	80	05	E6,0F	ANI, 0FH
	80	07	4F	MOV C,A
	80	08	78	MOV A,B
	80	09	E6,F0	ANI, F0H
	80	0B	0F	RRC
	80	0C	0F	RRC
	80	0D	0F	RRC
	80	0E	0F	RRC
	80	0F	57	MOV D,A
	80	10	AF	XRA A
	80	11	1E,0A	MVI E,OAH
SUM:	80	13	83	ADD E
	80	14	15	DCR D
	80	15	C2,13,80	JNZ, SUM
	80	18	81	ADD C
	80	19	32,60,80	STA, 8060H(BINBCD)
	80	1C	76	HLT

6.2. HEX to BCD Conversion

PROGRAM DESCRIPTION

An 8 bit Hex number between 00 and FF is stored in memory location HEX (8050H). Store the BINARY equivalent (BCD) at memory location starting from BCDBIN (8070H) in its unpacked form.

Algorithm

- HEX number in the memory is loaded to the accumulator.
- Four memory locations starting from BCDBIN1(8070H) are cleared for the results.
- 64H (hex equivalent of 100) is subtracted from the accumulator until the carry flag gets set. The number of times the subtraction done gives the number of hundreds.
- Similarly, the number of tens and ones are obtained by subtracting their hex equivalent.
- The results are stored starting from the location BCDBIN1 (8070H).

Procedure

- Enter the instructions in the Program area starting from 8000H onwards.
- Enter the HEX number in the memory location HEX (8050H).
- Execute the program from the starting address 8000H.
- Verify the results from the location BCDBIN1 (8070H).

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	21,50,80	LXIH, 8050H (HEX)
	80	03	7E	MOV A,M
	80	04	21,00,00	LXIH, 0000H
	80	07	22,70,80	SHLD,8070H(BCDBIN1)
	80	0A	22,72,80	SHLD,8072H(BCDBIN3)
	80	0D	21,70,80	LXIH, 8070H(BCDBIN1)
RPT:	80	10	D6,64	SUI, 64H
	80	12	DA,19,80	JC, BUF2
	80	15	34	INR M
	80	16	C3,10,80	JMP, RPT
BUF2:	80	19	C6,64	ADI, 64H
	80	1B	23	INX H
LOOP:	80	1C	D6,0A	SUI, 0AH
	80	1E	DA,25,80	JC, BUF3
	80	21	34	INR M
	80	22	C3,1C,80	JMP, LOOP
BUF3:	80	25	C6,0A	ADI, 0AH
	80	27	23	INX H
	80	28	77	MOV M,A
	80	29	76	HLT

6.3. BINARY to ASCII Conversion

Algorithm

- Load the binary number in accumulator.
- If the number is 0 to 9, add 30H to accumulator.
- If the number is 0A to 0F, add 7 in addition to 30H.
- Store the ACSII result in memory and HALT.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3E,0B	MVIA, 0BH(INPUT)
	80	02	FE,0A	CPI, 0AH
	80	04	DA,09,80	JC, LOOP
	80	07	C6,07	ADI, 07H
LOOP:	80	09	C6,30	ADI, 30H
	80	0B	32,50,80	STA, 8050H
	80	0E	76	HLT

6.4. ASCII to BINARY Conversion

Algorithm

- Load the ASCII number in accumulator.
- Subtract 30H from the accumulator.
- If the result is 0 to 0 transfer the result to memory.
- If result is greater than 9 subtract 7 from accumulator.
- Store the binary result in memory and HALT.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3E,42	MVIA, 42H(INPUT)
	80	02	D6,30	SUI, 30H
	80	04	FE,0A	CPI, 0AH
	80	06	DA,0B,80	JC, LOOP
	80	09	D6,07	SUI, 07H
LOOP:	80	0B	32,50,80	STA, 8050H
	80	0E	76	HLT

6.5. ASCII to BCD Conversion

Algorithm

- Load the ASCII number in accumulator.
- Subtract 30H from the accumulator.
- The BCD result is stored in memory and HALT.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3E,42	MVIA, 39H(INPUT)
	80	02	D6,30	SUI, 30H
	80	04	32,50,80	STA, 8050H
	80	07	76	HLT

6.6 BCD to ASCII Conversion

Algorithm

- Load the decimal number in accumulator.
- Add 30H with the accumulator.
- Store the ASCII result in memory and HALT.

Program

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	3E,42	MVIA, 09H(INPUT)
	80	02	C6,30	AD1, 30H
	80	04	32,50,80	STA, 8050H
	80	07	76	HLT

SQUARE & SQUARE ROOT of HEX & BCD NUMBERS

7.1 Square of a single byte Hex number

AIM

To evaluate the square and square root of hexadecimal and BCD numbers.

PROGRAM DESCRIPTION

Algorithm

- Load the number to the DE pair and make a copy of it in register C (Counter).
- Clear accumulator and HL pair.
- Add the number in the DE pair to HL pair.
- Decrement counter and check for zero. If C is not zero then repeat addition.
- If C = 0, then display the result from the HL pair
- To display the result [16 bit] at the ADDRESS FIELD transfer the data from HL to DE and Call subroutine DISADD at
- HALT.

Program

Square of a single byte Hex number:

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	AF	XRA A
	80	01	21,00,00	LXIH, 0000H
	80	04	3A,50,80	LDA, 8050H
	80	07	16,00	MVID, 00H
	80	09	4F	MOV C,A
	80	0A	5F	MOV E,A
RPT:	80	0B	19	DAD D
	80	0C	0D	DCR C
	80	0D	C2,0B,80	JNZ, RPT
	80	10	EB	XCHG
	80	11	CD,CO,13	CALL,DISADR
	80	14	76	HLT

7.2 Square of two digit BCD number:

Algorithm

- Load the BCD number in the accumulator. Copy of the number in counter.
- Add the number to the cleared accumulator (initially) and adjust the value. Store the partial sum in a temporary register.
- After addition check for carry. If there is carry add it to the sum of the carry from previous additions if any and store it to a register.
- If no carry decrement the counter by 100's complement BCD subtraction method. Check for zero in the counter.
- If C register is not equal to zero then repeat addition. If C register is zero then display the result and HALT.

Program Square of two digit BCD number:

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	AF	XRA A
	80	01	57	MOV D,A
	80	02	3A,50,80	LDA, 8050H(DATA)
	80	05	47	MOV B,A
	80	06	4F	MOV C,A
	80	07	IE,00	MVIE, 00H
	80	09	AF	XRA A
REP:	80	0A	7B	MOV A,E
	80	0B	80	ADD B
	80	0C	27	DAA
RES:	80	0D	5F	MOV E,A
	80	0E	D2,16,80	JNC, REDUC
	80	11	7A	MOV A,D
	80	12	C6,01	ADI, 01H
	80	14	27	DAA
	80	15	57	MOV D,A
REDUC:	80	16	CD,00,81	CALL, DECR
	80	19	C2,0A,80	JNZ, REP
	80	1C	CD,CO,13	CALL, DISADR
	80	1F	76	HLT

DECR subroutine:

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
DECR:	80	00	3E,99	MVIA, 99H
	80	02	D6,01	SUI, 01H
	80	04	3C	INR A
	80	05	81	ADD C
	80	06	27	DAA
	80	07	4F	MOV C,A
	80	08	C9	RET

7.3 Square root of a Single Byte HEX number

Algorithm

- Clear the accumulator and counter. Load the number to the accumulator.
- Initialize a register to hold the successive odd numbers.
- Subtract the odd number from the given number successively.
- After each subtraction, increment the counter. Test for carry from subtraction.
- If there is no carry, increment counter to the next odd value and repeat subtraction.
- If there occurs a carry, then decrement C once, ass the last odd number subtracted to get the reminder. The counter gives the nearest square root.
- HALT.

Program

Square root of a 8 bit HEX number

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	AF	XRA A
	80	01	4F	MOV C,A
	80	02	3A,50,80	LDA, 8050H(DATA)
	80	05	06,01	MVIB, 01H
CORTN:	80	07	90	SUB B
	80	08	0C	INR C
	80	09	DA,11,80	JC, CROSD
	80	0C	04	INR B
	80	0D	04	INR B
	80	0E	C3,07,80	JMP, CORTN
CROSD:	80	11	0D	DCR C
	80	12	80	ADD B
	80	13	59	MOV E,C
	80	14	57	MOV D,A
	80	15	CD,C0,13	CALL, DISADR
	80	18	76	HLT

7.4 Square root of a 2 digit BCD number

Algorithm

- Clear the accumulator and counter. Load the number to the accumulator.
- Set the B register to hold the odd numbers.
- Subtract the odd number from the BCD number and increment the counter. Check for zero from subtraction.
- If zero flag is set jump to display the square root. If not update B register to the next odd number and decimal adjust the value and perform 100's complement subtraction once again.
- Repeat subtraction until the carry is reset & Halt.

Program <u>Square root of a Two digit BCD number</u>

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
	80	00	AF	XRA A
	80	01	4F	MOV C,A
	80	02	3A,50,80	LDA, 8050H
	80	05	06,01	MVIB, 01H
	80	07	90	SUB B
	80	08	0C	INR C
	80	09	CA,20,80	JZ, DISP
REP:	80	0C	57	MOV D,A
	80	0D	04	INR B
	80	0E	04	INR B
	80	0F	CD,00,81	CALL, ADJ
	80	12	3E,99	MVIA, 99H
	80	14	90	SUB B
	80	15	3C	INR A
	80	16	82	ADD D
	80	17	27	DAA
	80	18	0C	INR C
	80	19	CA,20,80	JZ, DISP
	80	1C	DA,0C,80	JC, REP
	80	1F	0D	DCR C
DISP:	80	20	59	MOV E,C
	80	21	CD,C0,13	CALL, DISADR
	80	24	76	HLT

ADJ subroutine:

LABEL	ADDRESS HIGH	ADDRESS LOW	OPCODE	MNEMONICS
ADJ:	81	00	F5	PUSH PSW
	81	01	78	MOV A,B
	81	02	C6,00	ADI, 00H
	81	04	27	DAA
	81	05	47	MOV B,A
	81	06	F1	POP PSW
	81	07	C9	RET

7.5 TRAFFIC REGULATION SIMULATOR

AIM : To write a suitable software program to interface a Traffic regulation simulator to control a 4-Road junction.

Traffic Regulation Interface Hard ware

A '4-Road junction' traffic regulation interface consists of 28 traffic signal indicators. Each road has seven traffic signal LED's. They are

SG - Straight Green
RG - Right Green
LG - Left Green
R - Red
Y - Yellow
PG - Pedestrian Green
PR - Pedestrian Red

The symbols refer to different signal indicator LEDs as follows:
1SG – Straight Green from Road 1;**2SG** – Straight Green from Road 2; and so on.

BIT assignment of Ports A, B & C :

PORT	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
A	1RG	2RG	3RG	4RG	1PR	2PR	3PR	4PR
B	3SG	3LG	3Y	3R	4R	4Y	4LG	4SG
C	1SG	1LG	1Y	1R	2R	2Y	2LG	2SG

Logic ***'0' data*** in the appropriate bit position ***lights*** the corresponding LEDs. The 3-byte Hex code to Ports A, B & C control the 28 traffic LEDs. The *'Pedestrian Green'* signals are the inverted signals derived from *'Pedestrian Red'* signals.

TRAFFIC REGULATION SCHEMES

Scheme 1 - Straight and Left with Right turn
Scheme 2 - Vertical and Horizontal straight with Right turn
Scheme 3 - Straight and Right with simultaneous Pedestrian Crossing

SIGNAL	DURATION (sec)	TIME DELAY SELECT CODE
Red & Green (st., rt. & lt.)	15	00 H
Yellow	3	01 H

st.-Straight; rt.-Right; lt.-Left : **Each SCHEME will have different no. of states depending on the requirement.**

4- Byte CODE FORMAT for each state:

Time Delay Select code	Byte 1,
Code for Port A	Byte 2,
Code for Port B	Byte 3,
Code for Port C	Byte 4

SCHEME 1 (Fig.1)

SEQUENCE of STATES in SCHEME 1:

SIGNAL INDICATOR	ROAD No.	LEDs in '*ON*' state
STATE 1:	**ROAD 1 - 'GO' in all three directions (st., rt. & lt.)**	
GREEN LED [GO]	1	1SG, 1RG, 1LG
RED LED [STOP]	2, 3, 4	2R,3R,4R,1PR,2PR,3PR,4PR
TRANSITION STATE 1: ROAD 1 - 'caution' state		
YELLOW LED [SLOW]	1	1Y
RED LED [STOP]	2, 3, 4	2R,3R,4R,1PR,2PR,3PR,4PR
STATE 2:	**ROAD 2 - 'GO' in all three directions (st., rt. & lt.)**	
GREEN LED [GO]	2	2SG, 2RG, 2LG
RED LED [STOP]	1, 3, 4	1R,3R,4R,1PR,2PR,3PR,4PR
TRANSITION STATE 2: ROAD 2 - 'caution' state		
YELLOW LED [SLOW]	2	2Y
RED LED [STOP]	1, 3, 4	1R,3R,4R,1PR,2PR,3PR,4PR
STATE 3:	**ROAD 3 - 'GO' in all three directions (st., rt. & lt.)**	
GREEN LED [GO]	3	3SG, 3RG, 3LG
RED LED [STOP]	1, 2, 4	1R,2R,4R,1PR,2PR,3PR,4PR
TRANSITION STATE 3: ROAD 3 - 'caution' state		
YELLOW LED [SLOW]	3	3Y
RED LED [STOP]	1, 2, 4	1R,2R,4R,1PR,2PR,3PR,4PR
STATE 4:	**ROAD 4 - 'GO' in all three directions (st., rt. & lt.)**	
GREEN LED [GO]	4	4SG, 4RG, 4LG
RED LED [STOP]	1, 2, 3	1R,2R,3R,1PR,2PR,3PR,4PR
TRANSITION STATE 4: ROAD 4 - 'caution' state		
YELLOW LED [SLOW]	4	4Y
RED LED [STOP]	1, 2, 3	1R,2R,3R,1PR,2PR,3PR,4PR
STATE 5:	**PEDESTRIAN CROSSING 'GO' on all four roads**	
GREEN LED [GO]	-	1PG, 2PG, 3PG, 4PG
RED LED [STOP]	1, 2, 3, 4	1R,2R,3R,4R,
STATE 6:	**ALL ROADS & PEDESTRIAN CROSSINGS- 'STOP'**	
RED LED [STOP]	1, 2, 3, 4	1R,2R,3R,4R,1PR,2PR,3PR,4PR

Note: st.-Straight; rt.-Right; lt.-Left

CODE GENERATION :

STATE-1 - **4 byte instruction code: 00H, 70H, E7H, 37H.**

For 'GO' STATE Time Delay Select code • **00 H** . Byte 1

Port	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0		
A	*1RG*	*2RG*	*3RG*	*4RG*	*1PR*	*2PR*	*3PR*	*4PR*		
	0	1	1	1	0	0	0	0	**70 H**	. Byte 2
B	*3SG*	*3LG*	*3Y*	*3R*	*4R*	*4Y*	*4LG*	*4SG*		
	1	1	1	0	0	1	1	1	**E7 H**	. Byte 3
C	*1SG*	*1LG*	*1Y*	*1R*	*2R*	*2Y*	*2LG*	*2SG*		
	0	0	1	1	0	1	1	1	**37 H**	. Byte 4

Note: Negative Logic • '0' DATA for traffic LED to glow

The **codes** for the remaining states are generated as above and these *look up codes* follow the *Time Delay select codes* and they are stored, starting from location **8200H** onwards:

8200-**00**	8205-**F0**	820A-**E7**	820F-**EB**	8214-**01**	8219-**E0**	821E-**EB**	8223-**E7**
8201-**70**	8206-**E7**	820B-**EC**	8210-**00**	8215-**F0**	821A-**EC**	821F-**E7**	8224-**01**
8202-**E7**	8207-**D7**	820C-**01**	8211-**D0**	8216-**D7**	821B-**E7**	8220-**00**	8225-**F0**
8203-**37**	8208-**00**	820D-**F0**	8212-**37**	8217-**E7**	821C-**01**	8221-**FF**	8226-**E7**
8204-**01**	8209-**B0**	820E-**E7**	8213-**E7**	8218-**00**	821D-**F0**	8222-**E7**	8227-**E7**

Similarly, the *State codes* for **Schemes 2 & 3**, shown in **Figs.2 & 3** are generated and are stored starting from location **8300 H & 8400 H** onwards respectively.

SCHEME-2 (Fig-2)

8300-**00**	8305-**F0**	830A-**F7**	830F-**D7**	8314-**01**	8319-**A0**	831E-**EB**	8323-**E7**
8301-**F0**	8306-**D7**	830B-**F7**	8310-**00**	8315-**F0**	831A-**EF**	831F-**EB**	8324-**01**
8302-**37**	8307-**D7**	830C-**01**	8311-**F0**	8316-**EB**	831B-**EF**	8320-**00**	8325-**F0**
8303-**37**	8308-**00**	830D-**F0**	8312-**EC**	8317-**EB**	831C-**01**	8321-**FF**	8326-**E7**
8304-**01**	8309-**50**	830E-**D7**	8313-**EC**	8318-**00**	831D-**F0**	8322-**E7**	8327-**E7**

SCHEME-3 (Fig-3)

8400-**00**	8404-**01**	8408-**00**	840C-**01**	8410-**00**	8414-**01**	8418-**00**	841C-**01**
8401-**71**	8405-**F0**	8409-**B8**	840D-**F0**	8411-**D4**	8415-**F0**	8419-**E2**	841D-**F0**
8402-**E7**	8406-**E7**	840A-**B7**	840E-**D7**	8412-**7D**	8416-**DB**	841A-**EE**	841E-**EB**
8403-**7D**	8407-**DB**	840B-**EE**	840F-**EB**	8413-**E7**	8417-**E7**	841B-**B7**	841F-**D7**

SOFTWARE FOR TRAFFIC REGULATION:

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	81 00	3E,80	**MVIA, 80 H**	Initialize 8255(1)
	81 02	D3,DF	**OUT,[CR]DFH**	
START:	81 04	0E,0A	**MVIC, OA H***	Store count for no. of states
	81 06	21,00,82	**LXIH, 8200H****	Points to LOOK-UP codes
AGAIN:	81 09	46	**MOV B, M**	Store T.D. select code in Breg.
	81 0A	23	**INX H**	Points to next byte
	81 0B	7E	**MOV A, M**	1st code is output through Port A
	81 0C	D3,DC	**OUT, (PORTA) DC H**	
	81 0E	23	**INX H**	Points to next byte
	81 0F	7E	**MOV A, M**	2nd code is output through Port B
	81 10	D3,DD	**OUT, (PORTB) DD H**	
	81 12	23	**INX H**	Points to next byte
	81 13	7E	**MOV A, M**	3rd code is output through Port C
	81 14	D3,DE	**OUT, (PORTC) DE H**	
	81 16	78	**MOV A, B**	Is T.D. select code=00 H? If so, call long T.D.(TD2)
	81 17	0F	**RRC**	
	81 18	D2,21,81	**JNC, LTD**	
	81 1B	CD,50,81	**CALL TD1**	Else call short TD1
	81 1E	C3,24,81	**JMP, SKIP**	
LTD:	81 21	CD,70,81	**CALL TD2**	
SKIP:	81 24	23	**INX H**	Points to next state
	81 25	0D	**DCR C**	Update count of state
	81 26	C2,09,81	**JNZ, AGAIN**	Repeat the sequence
	81 29	C3,04,81	**JMP, START**	Repeat Traffic Regulation scheme

	No. of states
*For SCHEMES-1&2,	LOAD 0A H
For SCHEME-3,	LOAD 08 H

**To observe Traffic Scheme 1 POINT to 8200H
To observe Traffic Scheme 2 POINT to 8300H
To observe Traffic Scheme 3 POINT to 8400H

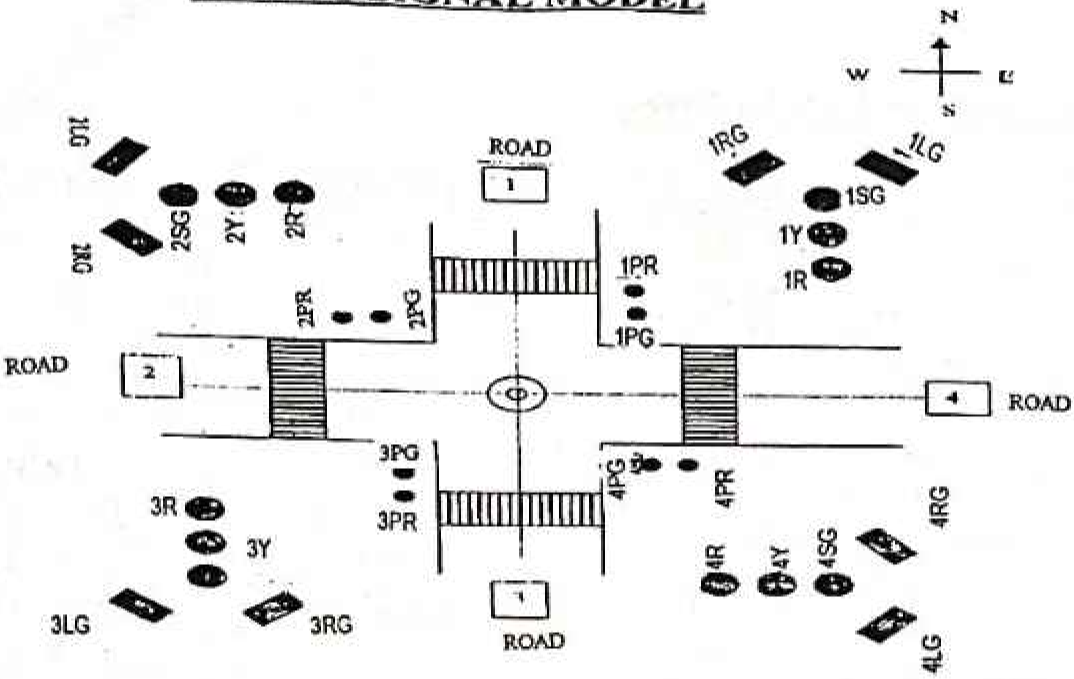
TD1 (SHORT TIME DELAY for **3** secs):

LABEL	ADDRESS	OPCODE	MNEMONICS
	81 50	C5	PUSH B
	81 51	D5	PUSH D
	81 52	06,0A	MVIB, 0AH
LOOP3:	81 54	0E,FF	MVIC, FFH
LOOP2:	81 56	16,FF	MVID, FFH
LOOP1:	81 58	15	DCR D
	81 59	C2,58,81	JNZ, LOOP1
	81 5C	0D	DCR C
	81 5D	C2,56,81	JNZ, LOOP2
	81 60	05	DCR B
	81 61	C2,54,81	JNZ, LOOP3
	81 64	D1	POP D
	81 65	C1	POPB
	81 66	C9	RET

TD2 (LONG TIME DELAY for 15 secs):

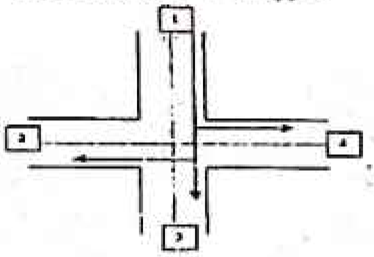
LABEL	ADDRESS	OPCODE	MNEMONICS
	81 70	C5	PUSH B
	81 71	D5	PUSH D
	81 72	06,32	MVIB, 32H
LOOP3:	81 74	0E,FF	MVIC, FFH
LOOP2:	81 76	16,FF	MVID, FFH
LOOP1:	81 78	15	DCR D
	81 79	C2,78,81	JNZ, LOOP1
	81 7C	0D	DCR C
	81 7D	C2,76,81	JNZ, LOOP2
	81 80	05	DCR B
	81 81	C2,74,81	JNZ, LOOP3
	81 84	D1	POP D
	81 85	C1	POPB
	81 86	C9	RET

TRAFIC SIGNAL MODEL

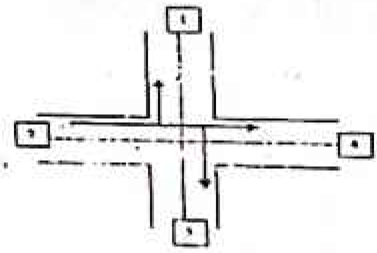


SG	- STRAIGHT GREEN	Y	- YELLOW
RG	- RIGHT GREEN	PG	- PEDESTRIAN GREEN
LG	- LEFT GREEN	PR	- PEDESTRIAN RED
R	- RED		

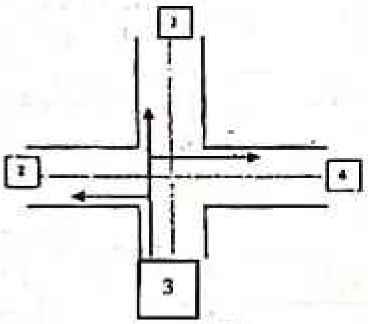
SCHEME 1 Fig. 1



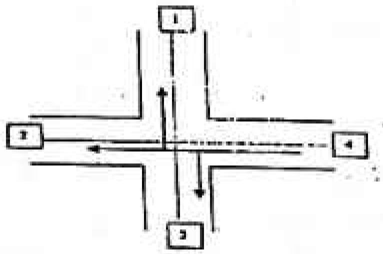
State 1



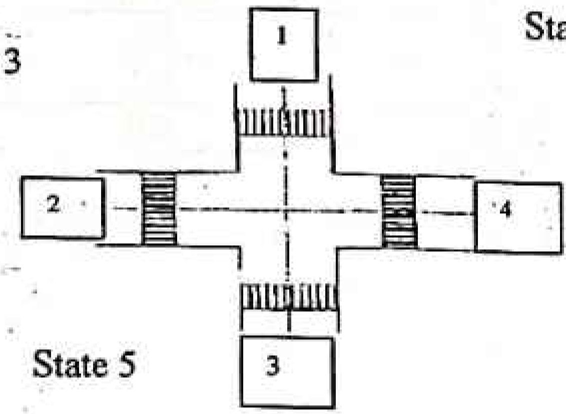
State 2



State 3

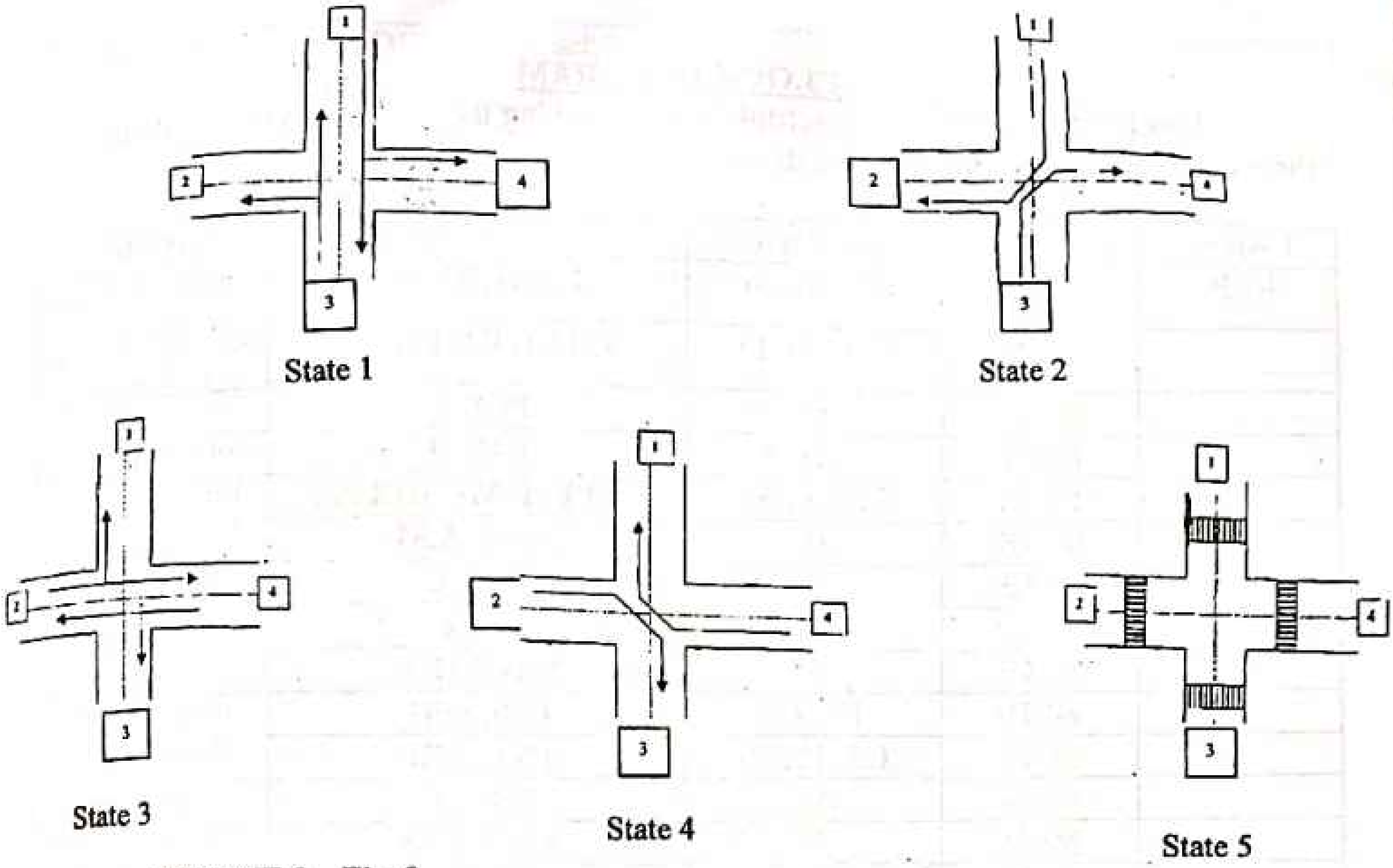


State 4

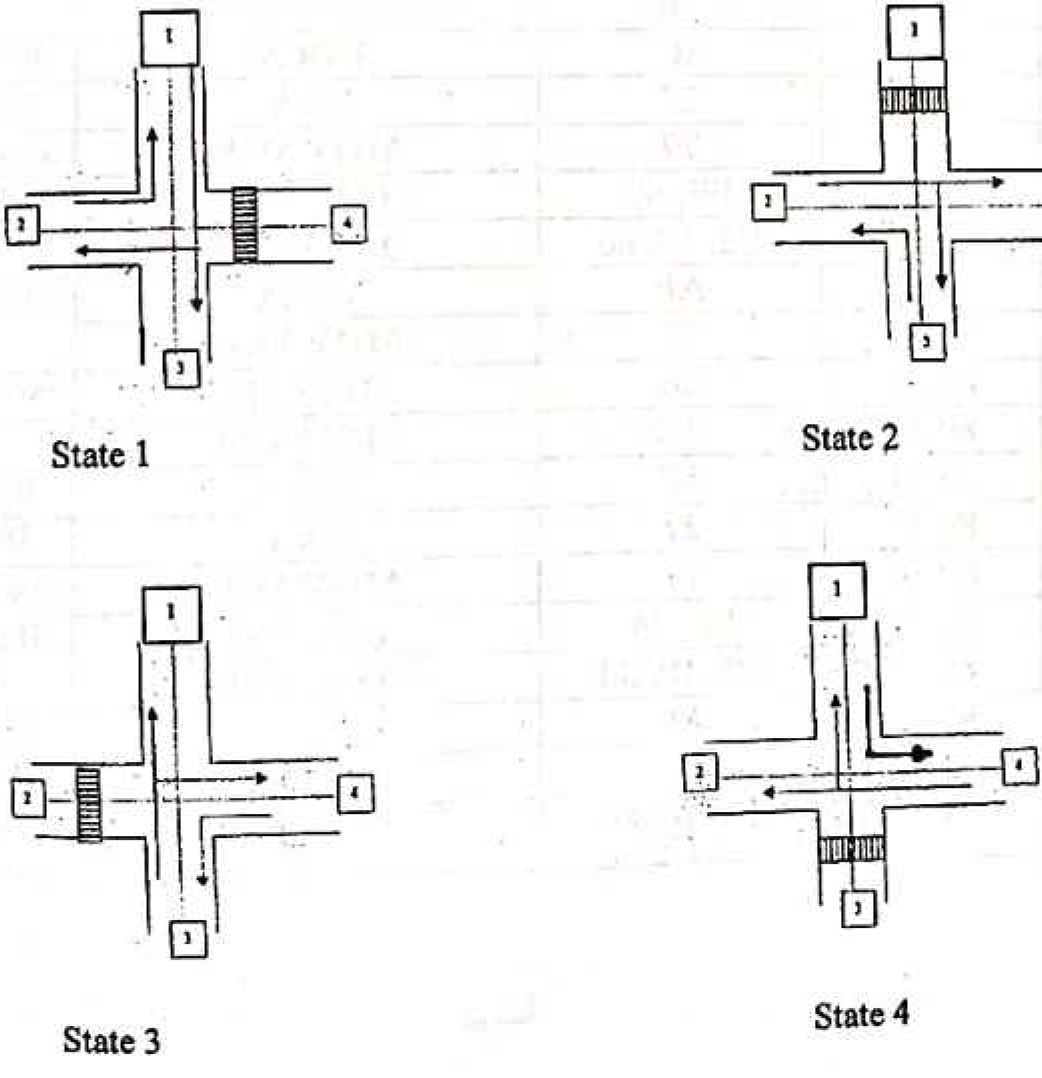


State 5

SCHEME 2 Fig. 2



SCHEME 3 Fig. 3



CLOCK PROGRAM

This Program displays the actual time by making use of the data stored at any three consecutive user-memory locations.

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
REP:	80 10	21, 00, 86	**LXIH, 8600H**	Points to User CLOCK setting area
	80 13	CD, F0, 13	**CALL DISPLAY**	Call DISPLAY program from Monitor
	80 16	23	**INX H**	
	80 17	23	**INX H**	Point to Sec.s Location
	80 18	CD, 00, 81	**CALL TIME DELAY**	Time delay (1sec)
	80 1B	7E	**MOV A,M**	
	80 1C	3C	**INR A**	Increment Sec.s
	80 1D	27	**DAA**	Decimal adjust
	80 1E	77	**MOV M,A**	Load in sec.s mem locn
	80 1F	FE, 60	**CPI, 60H**	If S≠ 60 Repeat Seconds Loop
	80 21	C2, 10, 80	**JNZ, REP**	
	80 24	AF	**XRAA**	Else clear Seconds Location
	80 25	77	**MOV M,A**	
	80 26	2B	**DCX H**	Point to minutelocation
	80 27	7E	**MOV A,M**	
	80 28	3C	**INR A**	Increment Min.s
	80 29	27	**DAA**	Decimal adjust
	80 2A	77	**MOV M,A**	Load in min.s memlocn
	80 2B	FE, 60	**CPI, 60H**	If M≠ 60 Repeat Minutes Loop
	80 2D	C2, 10, 80	**JNZ, REP**	
	80 30	AF	**XRAA**	Else clear Minutes Location
	80 31	77	**MOV M,A**	
	80 32	2B	**DCX H**	Point to Hour location
	80 33	7E	**MOV A,M**	
	80 34	3C	**INR A**	Increment Hour
	80 35	27	**DAA**	Decimal adjust
	80 36	77	**MOV M,A**	Load in hrs mem locn
	80 37	FE, 24	**CPI, 24H**	If H ≠ 60 Repeat Hours Loop
	80 39	C2, 10, 80	**JNZ, REP**	
	80 3C	AF	**XRAA**	Else clear Hours Location
	80 3D	77	**MOV M,A**	
	80 3E	C3, 10, 80	**JMP, REP**	Repeat Clock Program to Record Time

SUBROUTINE TIME DELAY (1 sec)

	81 00	E5	PUSH H	
	81 01	F5	PUSH PSW	
	81 02	06, 02	MVI B, 02H	
LOOP2:	81 04	21, FF, F5	LXIH, F5FFH	
LOOP1:	81 07	2B	DCX H	
	81 08	7C	MOV A,H	
	81 09	B5	ORA L	
	81 0A	C2, 07, 81	JNZ, LOOP1	
	81 0D	05	DCR B	
	81 0E	C2, 04, 81	JNZ, LOOP2	
	81 11	F1	POP PSW	
	81 12	E1	POP H	
	81 13	C9	RET	

SET DATA for Clock

AT **8600** ENTER **HOUR** **00** to **24** for **24** Hr Clock Program.
AT **8601** ENTER **MINUTES** **00 H** to **59 H**
AT **8602** ENTER **SECONDS** **00 H** to **59 H**
[NOTE: The Clock Program to display the **Hour, Minute & Second** at memory locations **9600H, 9601H & 9602H** respectively is available in ROM area with starting address **1CCCH**]

SAMPLE PROGRAM

AIM To complement the contents of a memory location.

- Enter the software program at the memory location **8000H**
- Enter the data (say 0FH) at **8050H**.
- Check the result (F0H for this case) at **8050H** after execution.

Program

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
REP:	80 00	3A	LDA, 8050H	Bring data from 8050H to Accumulator
	80 01	50		
	80 02	80		
	80 03	2F	CMA	Complement thedata
	80 04	32	STA, 8050H	Store back the data at 8050H
	80 05	50		
	80 06	80		
	80 07	76	HLT	

KEYS AND COMMANDS

RESET	BAUD
BLM	INC
GO	EXEC
SUB MEM	DEC

KBD C	PC D	E	F
PCH 8	PCL 9	SPH A	SPH B
E 4	H 5	L/6 LOAD	FLAG/7 SAVE
A 0	B 1	C 2	D/3 REG

A/0 This key is used to enter hex address/data value 0. As well as it is used to select register A when used in REG command key.

B/1 This key is used to enter hex address/data value 1. Also it is used to select register B when used in conjunction with REG command key.

C/2 This key is used to enter hex address/data value 2. Also it is used to select register 2 when used in conjunction with REG command key.

D/REG/3 This key is used as a hex key as well as a functional key it is used to enter hex address/data value 3. In command mode it is used to select/view registers contents. When used in conjunction with this REG Command, it selects Reg. D.

E/4 This key is used to enter hex address/data value 4 as well as to select register E when used in conjunction with REG command.

H/5 This key is used to enter hex address/data value 5 as well as to select register H when used in conjunction with REG command.

L/LOAD/6 This key is used to enter hex address/data value 6 as well as to select register L when used in conjunction with REG command. In command mode it is used to load a hex file to system from PC.

FLAG/SAVE/7 This key is used to enter hex address/data value 7 as well as to select FLAG register when used in conjunction with REG command. In command mode it is used to save a hex file from the system to PC.

PCH/8 This key is used to enter hex address/data value 8 as well as to select Program Counter High when used in conjunction with REG command.

PCL/9 This key is used to enter hex address/data value as well as to select Program counter Low when used in conjunction with REG command.

SPH/B	This key is used to enter hex address/data value A as well as to select stack pointer high when used in conjunction with REG command.
SPL/B	This key is used to enter hex address/data value B as well as to select stack pointer low when used in conjunction with REG command.
KBD/C	This key is used to enter hex address/data value C. This is also used to return- back to local keyboard mode from PC operating mode.
PC/D	This key is used to enter hex address/data value D. This is also used to go to PC operating mode.
E	This key is used to enter hex address/data value E.
F	This key is used to enter hex address/data value F.
RESET	This key is used to reset the system. This makes the system to execute from address 0000H.
BAUD	This key is used to select baud rate for serial communication when used with INC/DEC and EXE. It is used to select and set different baud rates.
SUB/MEM	This key is used to select/display all the 64KB program memory area. In conjunction with INC/DEC hex keys 0 to F, it is used to modify address and data.
INC	This key is used to increment memory address/baud rate/register in respective commands.
DEC	This key is used to decrement memory address/baud rate/register in respective commands.
GO	This key is used to execute the programs at specified addresses in conjunction with EXE key.
EXEC	This key is used as a terminating key for all functions/commands.
BLM	This key is used to move a block of the data from one memory area to another when used in conjunction with EXEC key and hex 0 to F.

Block move operation :

Press BLM key, press EXEC key, Enter STARTING ADDRESS of the block, press INC key, Enter ENDING ADDRESS of the block, press INC key, Enter DESTINATION ADDRESS (starting address of the new block), Press EXEC key.

BLM	⇒	EXEC	⇒	8200H	⇒	INC	⇒	820FH	⇒	INC	⇒	8300H	⇒	EXEC.
KEY		KEY		STARTING ADDRESS		KEY		ENDING ADDRESS		KEY		DESTINATION ADDRESS		KEY

MEMORY MAPPING

FLO - 85

Address	Memory space
FFFF – A000	USER EXPANSION MEMORY SPACE
9FFF – 9FC1	RAM SPACE USED FOR MONITOR PROGRAM
9FC0 – 8000	8KB USER RAM MEMORY SPACE
7FFF – 4000	DECODED MEMORY SPACE AVAILABLE TO USER THROUGH 50 pin FRC CONNECTOR
3FFF – 2000	8KB EPROM EXPANSION SOCKET PROVIDED
1FFF – 0000	8KB EPROM MONITOR MEMORY SPACE

PERIPHERAL I/O ADDRESS MAPPING

FLO - 85

1. 8255 (I) --- Port A --- DC H
   Port B --- DD H
   Port C --- DE H
   CONTROL PORT --- DF H
2. 8255 (II) --- Port A --- 7C H
   Port B --- 7D H
   Port C --- 7E H
   CONTROL PORT --- 7F H
3. 8279 Data Port --- BE H
   CONTROL PORT --- BF H
4. 8253 Timer/Counter 0 F4 H
   -do- 1 F5 H
   -do- 2 F6 H
   CONTROL PORT -- F7 H
5. 8259 Data Port ---- EF H
   CONTROL PORT -- EE H
6. 8251 Data Port --- F8 H
   CONTROL PORT -- F9 H

MEMORY ADDRESS

EPROM (8K)
Monitor .... 0000 H to 1FFF H

RAM (8K)
User Program.. 8000 H to 9FC0 H

DISPLAY SUB-ROUTINE ADDRESS

DISDAT ------ 13 80 H [DATA FIELD]
DISADR ------ 13C0 H [ADRES FIELD]
DISPLAY ------ 13_F0H [ALL 6 DIGITS]

MICRO CONTROLLER 8051 - TRAINER

INSTRUCTION for LOADING & EXECUTING PROGRAMS

TO LOAD PROGRAM :

STEP:

1. PRESS **RESET** Key
2. ENTER Starting ADDRESS IN Address Field
3. PRESS **INC** Key
4. ENTER OPCODE/DATA IN Data Field
5. PRESS **INC** Key
6. REPEAT **STEPS 4& 5** till all INSTRUCTIONS are entered

TO LOAD DATA :

STEP:

1. PRESS **RESET** Key
2. ENTER Starting ADDRESS IN Address Field
3. PRESS **INC** Key
4. ENTER DATA IN Data Field
5. PRESS **INC** Key
6. REPEAT **STEPS 4& 5** till all DATA are entered

TO EXECUTE PROGRAM :

STEP:

1. PRESS **RESET** Key
2. PRESS **EXEC** Key
3. ENTER Starting ADDRESS Of Program to be Executed
4. PRESS **INC** Key for Running the program

TO VERIFY RESULT AT MEMORY

STEP: **[Terminate program: JMP,Monitor :- 02,00,00]**

1. PRESS **RESET** Key
2. ENTER Starting ADDRESS of RESULT location
3. PRESS **INC** Key
4. OBSERVE the RESULT at DATA Field
5. REPEAT Pressing **INC** Key till all the RESULT are read

TO VERIFY RESULT AT REGISTER

STEP: **[Terminate program: JMP, Register :- 02,0F,00]**

1. PRESS **RESET** Key
2. PRESS **REG** Key
3. PRESS ♣ Key
4. ENTER **SFR Address** for the REGISTER
5. PRESS **INC** Key and Read the RESULT

****

8051 INSTRUCTION - HEXADECIMAL - OPCODES

OP CODE	MNEMONIC	OPERAND	BYTES	OPCODE	MNEMONIC	OPERAND	BYTES	OP CODE	MNEMONIC	OPERAND	BYTES
00	NOP	----	1	30	JNB	b,radd	1	60	JZ	radd	2
01	AJMP	sadd	2	31	ACALL	sadd	1	61	AJMP	sad	2
02	LJMP	ladd	3	32	RET1		1	62	XRL	add,A	2
03	RR	A	1	33	RLC	A	1	63	XRL	add,#n	3
04	INC	A	1	34	ADDC	A,#n	2	64	XRL	A,#n	2
05	INC	add	2	35	ADDC	A,add	2	65	XRL	A,add	2
06	INC	@R0	1	36	ADDC	A, @R0	1	66	XRL	A, @R0	1
07	INC	@R1	1	37	ADDC	A, @R1	1	67	XRL	A, @R1	1
08	INC	R0	1	38	ADDC	A,R0	1	68	XRL	A,R0	1
09	INC	R1	1	39	ADDC	A,R1	1	69	XRL	A,R1	1
0A	INC	R2	1	3A	ADDC	A,R2	1	6A	XRL	A,R2	1
0B	INC	R3	1	3B	ADDC	A,R3	1	6B	XRL	A,R3	1
0C	INC	R4	1	3C	ADDC	A,R4	1	6C	XRL	A,R4	1
0D	INC	R5	1	3D	ADDC	A,R5	1	6D	XRL	A,R5	1
0E	INC	R6	1	3E	ADDC	A,R6	1	6E	XRL	A,R6	1
0F	INC	R7	1	3F	ADDC	A,R7	1	6F	XRL	A,R7	1
10	JBC	B,radd	3	40	JC	radd	2	70	JNZ	radd	2
11	ACALL	sadd	2	41	AJMP	sadd	2	71	ACALL	sadd	2
12	LCALL	LADD	3	42	ORL	add,A	2	72	ORL	C,b	2
13	RRC	A	1	43	ORL	add,#N	3	73	JMP	@A+DPTR	1
14	DEC	A	1	44	ORL	A,#n	2	74	MOV	A,#n	2
15	DEC	add	1	45	ORL	A,add	2	75	MOV	Add,#n	3
16	DEC	@R0	1	46	ORL	A, @R0	1	76	MOV	@R0,#n	2
17	DEC	@R1	1	47	ORL	A, @R1	1	77	MOV	@R1,#n	2
18	DEC	R0	1	48	ORL	A,R0	1	78	MOV	R0,#n	2
19	DEC	R1	1	49	ORL	A,R1	1	79	MOV	R1,#n	2
1A	DEC	R2	1	4A	ORL	A,R2	1	7A	MOV	R2,#n	2
1B	DEC	R3	1	4B	ORL	A,R3	1	7B	MOV	R3,#n	2
1C	DEC	R4	1	4C	ORL	A,R4	1	7C	MOV	R4,#n	2
1D	DEC	R5	1	4D	ORL	A,R5	1	7D	MOV	R5,#n	2
1E	DEC	R6	1	4E	ORL	A,R6	1	7E	MOV	R6,#n	2
1F	DEC	R7	1	4F	ORL	A,R7	1	7F	MOV	R7,#n	2
20	JB	b,radd	3	50	JNC	radd	2	80	SJMP	radd	2
21	AJMP	sadd	2	51	ACALL	sadd	2	81	AJMP	sadd	2
22	RET		1	52	ANL	add,A	2	82	ANL	C,b	2
23	RL	A	1	53	ANL	add,#n	3	83	MOVC	A,@A+PC	1
24	ADD	A,#n	2	54	ANL	A,#n	2	84	DIV	AB	1
25	ADD	A,add	2	55	ANL	A,add	2	85	MOV	add,add	3
26	ADD	A, @R0	1	56	ANL	A, @R0	1	86	MOV	add,@R0	2
27	ADD	A, @R1	1	57	ANL	A, @R1	1	87	MOV	add,@R1	2
28	ADD	A,R0	1	58	ANL	A,R0	1	88	MOV	add,R0	2
29	ADD	A,R1	1	59	ANL	A,R1	1	89	MOV	add,R1	2
2A	ADD	A,R2	1	5A	ANL	A,R2	1	8A	MOV	add,R2	2
2B	ADD	A,R3	1	5B	ANL	A,R3	1	8B	MOV	add,R3	2
2C	ADD	A,R4	1	5C	ANL	A,R4	1	8C	MOV	add,R4	2
2D	ADD	A,R5	1	5D	ANL	A,R5	1	8D	MOV	add,R5	2
2E	ADD	A,R6	1	5E	ANL	A,R6	1	8E	MOV	add,R6	2
2F	ADD	A,R7	1	5F	ANL	A,R7	1	8F	MOV	add,R7	2

8051 INSTRUCTION - HEXADECIMAL - OPCODES

OP CODE	MNEMONIC	OPERAND	BYTES	OPCODE	MNEMONIC	OPERAND	BYTES	OP CODE	MNEMONIC	OPERAND	BYTES
90	MOV	DPTR,#nn	3	C0	PUSH	add	2	F0	MOVX	@DPTR,A	1
91	ACALL	sadd	2	C1	AJMP	sadd	2	F1	ACALL	sadd	2
92	MOV	b,C	2	C2	CLR	B	2	F2	MOVX	@R0,A	1
93	MOVC	A,@A+DPTR	1	C3	CLR	C	1	F3	MOVX	@R1,A	1
94	SUBB	A,#n	2	C4	SWAP	A	1	F4	CPL	A	1
95	SUBB	A,add	2	C5	XCH	A,add	2	F5	MOV	add,A	2
96	SUBB	A,@R0	1	C6	XCH	A,@R0	1	F6	MOV	@R0,A	1
97	SUBB	A,@R1	1	C7	XCH	A,@R1	1	F7	MOV	@R1,A	1
98	SUBB	A,R0	1	C8	XCH	A,R0	1	F8	MOV	R0,A	1
99	SUBB	A,R1	1	C9	XCH	A,R1	1	F9	MOV	R1,A	1
9A	SUBB	A,R2	1	CA	XCH	A,R2	1	FA	MOV	R2,A	1
9B	SUBB	A,R3	1	CB	XCH	A,R3	1	FB	MOV	R3,A	1
9C	SUBB	A,R4	1	CC	XCH	A,R4	1	FC	MOV	R4,A	1
9D	SUBB	A,R5	1	CD	XCH	A,R5	1	FD	MOV	R5,A	1
9E	SUBB	A,R6	1	CE	XCH	A,R6	1	FE	MOV	R6,A	1
9F	SUBB	A,R7	1	CF	XCH	A,R7	1	FF	MOV	R7,A	1
A0	ORL	C,b	2	D0	POP	add	2				
A1	AJMP	sadd	2	D1	ACALL	sadd	2				
A2	MOV	C,b	2	D2	SETB	b	2				
A3	INC	DPTR	2	D3	SETB	C	1				
A4	MUL	AB	1	D4	DA	A	1				
A5	Unused	-------	1	D5	DJNZ	add,radd	3				
A6	MOV	@R0,add	2	D6	XCHD	A,@R0	1				
A7	MOV	@R1,add	2	D7	XCHD	A,@R1	1				
A8	MOV	R0,add	2	D8	DJNZ	R0,radd	2				
A9	MOV	R1,add	2	D9	DJNZ	R1,radd	2				
AA	MOV	R2,add	2	DA	DJNZ	R2,radd	2				
AB	MOV	R3,add	2	DB	DJNZ	R3,radd	2				
AC	MOV	R4,add	2	DC	DJNZ	R4,radd	2				
AD	MOV	R5,add	2	DD	DJNZ	R5,radd	2				
AE	MOV	R6,add	2	DE	DJNZ	R6,radd	2				
AF	MOV	R7,add	2	DF	DJNZ	R7,radd	2				
B0	ANL	C,b	2	E0	MOVX	A,@DPTR	1				
B1	ACALL	sadd	2	E1	AJMP	sadd	2				
B2	CPL	b	2	E2	MOVX	A,@R0	1				
B3	CPL	C	1	E3	MOVX	A,@R1	1				
B4	CJNE	A,#n,radd	3	E4	CLR	A	1				
B5	CJNE	A,add,radd	3	E5	MOV	A,add	2				
B6	CJNE	@R0,#n,radd	3	E6	MOV	A,@R0	1				
B7	CJNE	@R1,#n,radd	3	E7	MOV	A,@R1	1				
B8	CJNE	R0,#n,radd	3	E8	MOV	A,R0	1				
B9	CJNE	R1,#n,radd	3	E9	MOV	A,R1	1				
BA	CJNE	R2,#n,radd	3	EA	MOV	A,R2	1				
BB	CJNE	R3,#n,radd	3	EB	MOV	A,R3	1				
BC	CJNE	R4,#n,radd	3	EC	MOV	A,R4	1				
BD	CJNE	R5,#n,radd	3	ED	MOV	A,R5	1				
BE	CJNE	R6,#n,radd	3	EE	MOV	A,R6	1				
BF	CJNE	R7,#n,radd	3	EF	MOV	A,R7	1				

8255 – I/O

PORT Address

CR → FF23 H

PORT A → FF20 H

PORT B → FF21 H

PORT C → FF22 H

SFR - ADDRESS

A → E0 H

B → F0 H

PSW → D0 H

DPH → 83 H

DPL → 82 H

FOR TERMINATING the program after saving all registers SFRs & return to power-on Ljump to Monitor at ROM Address → 0000 H

Base Address of:

8251A → FF10 H

8253 → FF30 H

8279 → FF08 H

8259A → FF28 H

1.a). ADDITION: [Two 8-Bit Numbers in MEMORY]

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8100	90,90,00	MOV DPTR,#9000	Point DPTR to NUM1
	8103	E0	MOVX A,@DPTR	Move NUM 1 to A
	8104	F8	MOV R0,A	Save NUM1 in R0
	8105	A3	INC DPTR	Point DPTR to NUM2
	8106	E0	MOVX A,@DPTR	Move NUM2 to A
	8107	28	ADD A,R0	Add NUM2 with NUM1 in R0
	8108	A3	INC DPTR	Point DPTR to Result Location
	8109	F0	MOVX@DPTR,A	Move SUM to Result Location
	810A	02,00,00	JMPMONITOR	Terminate Processing

STORE DATA AT : **9000 H – 1ST NUMBER; 9001 H – 2ND NUMBER**

OBSERVE RESULT AT: **9002 H – SUM → (Num1+Num2)**

1.b). SUBTRACTION: [Two 8-Bit Numbers in MEMORY]

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8200	90,91,00	MOV DPTR,#9100	Point DPTR to NUM1
	8203	E0	MOVX A,@DPTR	Move NUM 1 to A
	8204	F8	MOV R0,A	Save NUM1 in R0
	8205	A3	INC DPTR	Point DPTR to NUM2
	8206	E0	MOVX A,@DPTR	Move NUM2 to A
	8207	C3	CLR C	Clear CARRY Flag
	8208	98	SUBB A,R0	Subtract NUM1fromNUM2in R0
	8209	A3	INC DPTR	Point DPTR to Result Location
	820A	F0	MOVX@DPTR,A	Move DIFF to Result Location
	820B	02,00,00	JMP,MONITOR	Terminate Processing

STORE DATA AT : **9100 H – 1ST NUMBER; 9101 H – 2ND NUMBER (bigger than 1ST NUMBER)**

OBSERVE RESULT AT: **9102 H – DIFFERENCE → (Num2 — Num1) (Positive Result)**

1.c). MULTIPLICATION: [Two 8-Bit Numbers in MEMORY]

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8300	90,92,00	MOV DPTR,#9200	Point DPTR to NUM1
	8303	E0	MOVX A,@DPTR	Move NUM 1 to A
	8304	F5,F0	MOV B,A	Save NUM1 in B reg
	8306	A3	INC DPTR	Point DPTR to NUM2
	8307	E0	MOVX A,@DPTR	Move NUM2 to A
	8308	A4	MUL AB	Multiply NUM1 and NUM2in B
	8309	A3	INC DPTR	Point DPTR to Result Location
	830A	F0	MOVX@DPTR,A	Move PROD to Result Location
	830B	02,00,00	JMP,MONITOR	Terminate Processing

STORE DATA AT: 9200 H – 1ST NUMBER 9201 H – 2ND NUMBER

OBSERVE RESULT AT: 9202 H – PRODUCT → (Num1 x Num 2)

1.d). DIVISION: 8bitDividend/8bitDivisor [Two 8-Bit Numbers in MEMORY]

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8400	90,93,00	MOV DPTR,#9300	Point DPTR to NUM1 (DIVSR)
	8403	E0	MOVX A,@DPTR	Move NUM 1(DIVISR) to A
	8404	F5,F0	MOV B,A	Save NUM1(DIVISR) in B reg
	8406	A3	INC DPTR	Point DPTR to NUM2 (DVND)
	8407	E0	MOVX A,@DPTR	Move NUM2(DVND) to A
	8408	84	DIV AB	DIVIDE : DVND/DIVSR
	8409	A3	INC DPTR	Point to Result
	840A	F0	MOVX@DPTR,A	Move Result to QUOTE
	840B	E5,F0	MOV A,B	Move REMAINTER to A
	840D	A3	INC DPTR	Point to REM Location
	840E	F0	MOVX@DPTR,A	Move Remainder to REM locatn
	840F	02,00,00	JMP,MONITOR	Terminate Processing

STORE DATA AT: 9300 H – 1ST NUMBER (8bit Divisor)
9301 H – 2ND NUMBER (8bit Dividend Bigger than Divisor)

OBSERVE RESULT AT: 9302 H – QUOTIENT → (Num2/Num1)
9303 H - REMAINDER

2.(a) CHOOSING THE MAXIMA / MINIMA:

STORE AT : 9400 H – Number of bytes in array : STORE the MAXIMA or the MINIMA at LAST LOCATION

9401 H - onwards – Array Starts . PROGRAM FOR CHOOSING THE MAXIMA

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8600	90,94,00	MOV DPTR,9400	Point DPTR to move No. of BYTES in the ARRAY to A reg
	8603	E0	MOVX A,@DPTR	
	8604	F8	MOV R0,A	Save it in R0 reg
	8605	A3	INC DPTR	Point to 1st DATA in memory
	8606	E0	MOVX A,@DPTR	Bring 1st DATA to Areg
AGAIN:	8607	F5,F0	MOV B,A	STORE 1st DATA IN B reg
	8609	A3	INC DPTR	Point to Next Data In Memory
	860A	E0	MOVX A,@DPTR	Bring the 2nd DATA to A reg
	860B	B5,F0,00	CJNE A,B REPEAT	Compare TWO BYTES.
REPEAT:	860E	*50,02	*JNC,NXT	IF A>B, GO TO NXT, otherwise
	8610	C5,F0	XCH A,B	IF B>A , EXCHANGE A&B
NXT:	8612	D8,F3	DJNZ R0,AGAIN	Repeat for the No. of Bytes in The ARRAY
	8614	A3	INC DPTR	Point DPTR to Result Location
	8615	F0	MOVX@DPTR,A	Move the MAXIMA to RESULT Location ; next to the LAST data Stored in memory
	8616	02,00,00	JMP,MONITOR	Terminate Processing

FOR CHOOSING THE MINIMA

STORE AT 860E & 860F : the OPCODES 40,02 for * JC NXC

RESULT: MAXIMA/MINIMA DATA will be STORED at Memory Location NEXT to the Last DATA of the Array stored in memory.

2(b). ARRAY SORTING – LINEAR SORT METHOD: [8-Bit Data bytes in MEMORY]

STORE AT : 8B00 H – Number of bytes in array ; Array starts **8B01 H** onwards

For Ascending Order

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8A00	90,8B,00	MOV DPTR,#8B00	Point DPTR to no of data
	8A03	E0	MOVX A,@DPTR	Move no of data to A
	8A04	F8	MOV R0,A	Copy the same in R0
	8A05	18	DEC R0	Deduce n-1
	8A06	7B,01	MOV R3,01 H	Prepare pointer for 1st data
NEXT:	8A08	8B,04	MOV 04,R3	mov 04H, R3
	8A0A	0C	INC R4	Prepare pointer for 2nd data
	8A0B	8B,01	MOV 01,R0	Copy n-1 value to R1 mov 01H, R0
LOOP:	8A0D	8B,82	MOV DPL,R3	Point DPTR to 1st data
	8A0F	E0	MOVX A, @DPTR	Load 1st data in A
	8A10	F5,F0	MOV B,A	Store 1st data in B
	8A12	8C,82	MOV DPL,R4	Point DPTR to 2nd data
	8A14	E0	MOVX A, @DPTR	Load 2nd data
	8A15	B5,F0,00	CJNE A,B, **CONT**	Compare data bytes
CONT:	**8A18**	***50,08**	***JNC,NOEX**	**If A>=B, skip exchange**
EXCH:	8A1A	8B,82	MOV DPL,R3	If A< B, point to 1st location
	8A1C	F0	MOVX @DPTR,A	Store 2nd data in 1st location
	8A1D	8C,82	MOV DPL,R4	Point to 2nd location
	8A1F	E5,F0	MOV A,B	Move 1st data back to A
	8A21	F0	MOVX @DPTR,A	Store 1st data in 2nd location
NOEX:	8A22	0C	INC R4	Advance 2nd data pointer once
	8A23	D9,E8	DJNZ R1,**LOOP**	Sort 1st data with all (n-1) data
	8A25	0B	INC R3	Advance 1st data pointer once
	8A26	D8,E0	DJNZ R0,**NEXT**	Sort all data with all (n-1) data
	8A28	02,00,00	LJMP MONITOR	Terminate Processing

FOR SORTING IN DESCENDING ORDER

STORE AT : **8A18 H & 8A19 H the opcodes 40,08 for JC,NOEX**

3. MULTIBYTE ADDITION / SUBTRACTION :

Store 1st number : from 9500 H Onwards & Store 2nd number : from 9510 H Onwards

Sum will be stored at : 9520 H Onwards **For MULTI BYTE ADDITION**

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8700	78,40	MOV R0,40 H	**Point to internal RAM address 40 H** with R0 as TEMPORARY LOCATION
	8702	90,95,00	MOV DPTR,#9500	Point DPTR to 1st byte of 1st number
	8705	79,**0X**	MOV R1,**0X H**	**Load no of bytes** in R1
	8707	AA,01	MOV R2,01 H	Copy the same in R2
	8709	C3	CLR C	Clear Carry flag to detect carry-over
CONT:	870A	E0	MOVX A,@DPTR	Load 1st byte of 1st number in A
	870B	F5,F0	MOV B,A	Store the same in B
	870D	74,10	MOV A,10 H	
	870F	93	MOVC A,@A+DPTR	Point DPTR to 1st byte of 2nd number
	8710	***35,F0**	***ADDC A,B**	Add the numbers in A & B
	8712	F6	MOV @R0,A	Store sum in the internal RAM
	8713	08	INC R0	Advance internal RAM pointer once
	8714	A3	INC DPTR	Advance DPTR to next byte of 1st number
	8715	D9,F3	DJNZ R1,**CONT**	Repeat addition for total no of bytes
	8717	90,95,20	MOV DPTR,#9520 H	Point DPTR to Sum location
	871A	78,40	MOV R0,40 H	Point to internal RAM address 40 H with R0
RPT:	871C	E6	MOV A,@R0	Load 1st byte of Sum in A
	871D	F0	MOVX @DPTR,A	Store 1st byte of Sum in 1st Sum location
	871E	08	INC R0	Advance internal RAM pointer once
	871F	A3	INC DPTR	Advance DPTR to next byte of Sum
	8720	DA,FA	DJNZ R2,**RPT**	Repeat storing for total no of bytes
	8722	50,03	JNC,**END**	If no Carry, go to terminate processing
	8724	74,01	MOV A,01 H	If Carry occurs, load 01H in A and store the same in next byte of Sum location
	8726	F0	MOVX @DPTR,A	
END:	8727	02,00,00	LJMP MONITOR	Terminate processing

FOR X → AT 8706 H, LOAD the No. OF BYTES in the MULTIBYTE Number. (any value between 02 H to 0F H)

FOR MULTI BYTE SUBTRACTION : STORE AT : *8710 H & 8711 H – the opcodes -- 95,F0 for SUBB A,B

4. BLOCK TRANSFER: STORE the SOURCE Address at 9700 H (high byte) and at 9701 H (low byte) STORE DESTINATION Address at 9702 H (high byte) and at 9703 H (low byte). No.of BYTES at 9704 H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	8900	90,97,00	MOV DPTR,#9700	Point DPTR to Memory location having the High Byte of SOURCE Address .Bring it to A & Save it In R0 reg
	8903	E0	MOVX A,@DPTR	
	8904	F8	MOV R0,A	
	8905	A3	INC DPTR	Point DPTR to Memory location having the LOW Byte of SOURCE Address .Bring it to A & Save it In R1 reg
	8906	E0	MOVX A,@DPTR	
	8907	F9	MOV R1,A	
	8908	A3	INC DPTR	Point DPTR to Memory location having the High Byte of DESTINATION Address .Bring it to A & Save it In R2 reg
	8909	E0	MOVX A,@DPTR	
	890A	FA	MOV R2,A	
	890B	A3	INC DPTR	Point DPTR to Memory location having the LOW Byte of DESTINATION Address .Bring it to A & Save it In R3 reg
	890C	E0	MOVX A,@DPTR	
	890D	FB	MOV R3,A	
	890E	A3	INC DPTR	Point DPTR to Memory location having the No. of Bytes in the ARRAY .Bring it to A & Save it In R4 reg
	890F	E0	MOVX A,@DPTR	
	8910	FC	MOV R4,A	
	8911	88,82	MOV DPL,R0	LOAD DPTR with SOURCE ADDRESS from R0 & R1 regs.
	8913	89,83	MOV DPH,R1	
LOOP:	8915	E0	MOVX A,@DPTR	BRING the BYTE to A reg.
	8916	C0,83	PUSH DPH	SAVE Source Address in STACK by pushing higher order addres first & then lower order adrs
	8918	C0,82	PUSH DPL	
	891A	8A,82	MOV DPL,R2	LOAD DPTR with DESTINATION ADDRESS from R2 & R3 regs
	891C	8B,83	MOV DPH,R3	
	891E	F0	MOVX@DPTR,A	MOVE the DATA BYTE in A to The NEW DESTINATION area
	891F	A3	INC DPTR	POINT to NEXT destination adrs
	8920	AA,82	MOV R2,DPL	SAVE Next destination address In R2 & R3
	8922	AB,83	MOV R3,DPH	
	8924	D0,82	POP DPL	RETRIEVE SOURCE ADDRESS From STACK to DPTR
	8926	D0,83	POP DPH	
	8928	A3	INC DPTR	POINT to NEXT SOURCE address
	8929	DC,EA	DJNZ R4,**LOOP**	Decrement No.of Bytes & Repeat Till ALL BYTES are Moved
	892B	02,00,00	JMP MONITOR	Terminate Processing

DATA TRANSFER INSTRUCTIONS

MNEMONIC	DESCRIPTION	OPERATION
MOV A,Rn	A←Rn	Move register to the accumulator
MOV A,direct	A←(addr)	Move direct byte accumulator
MOV A,@Ri	A←(Ri)	Move indirect RAM to accumulator
MOV A,#Data	A←data	Move immediate data to accumulator
MOV Rn,A	Rn←A	Move accumulator to register
MOV Rn,direct	Rn←(addr)	Move direct byte to register
MOV Rn,#data	Rn←data	Move immediate data to register
MOV direct,A	(addr) ←A	Move accumulator to direct byte
Mov direct,Rn	(addr) ←Rn	Move register to direct byte
MOV direct, direct	(addr1) ← (addr2)	Move direct byte by direct byte
MOV direct,@Ri	(addr) ←(Ri)	Move indirect RAM to direct byte
MOV direct, #data	(addr) ←data	Move immediate data to direct byte
MOV, @Ri,A	(Ri) ←A	Move accumulator to indirect RAM
MOV @Ri,direct	(Ri) ←(addr)	Move direct byte into indirect RAM
MOV DPTR, #data 16	DPTR← data 16	Load data pointer with 16bit constant
MOV C A, @A+DPTR	A←(A+DPTR)	Move code byte relative to DPTR to accumulator
MOVC A, @A+PC	A←(A+PC)	Move code byte relative to PC accumulator
MOV X A,@Ri	A←(Ri)^	Move external RAM(8 bit address) to accumulator
MOV X A, @DPTR	A←(DPTR)^	Move external RAM(16 bit address) to accumulator
MOV X @Ri,A	(Ri)^ ←A	Move accumulator to external RAM(8 bit address)
MOV X @DPTR, A	(DPTR)^ ←A	Move accumulator to external RAM(16 bit address)
PUSH direct	(SP) ←ADDR	Push direct byte onto stack
POP direct	(addr)← (SP)	Pop direct byte from stack
XCH A,Rn	A ↔Rn	Exchange register with accumulator
XCH A,direct	A↔(addr)	Exchange direct byte with accumulator
XCH A, direct	A↔(addr)	Exchange direct byte with accumulator
XCH a,@Ri	A↔(Ri)	Exchange indirect RAM with accumulator
XCHD A, @Ri	AL↔(Ri)L	Exchange low order digit indirect RAM with accumulator

ARITHMETIC INSTRUCTIONS

MNEMONICS	DESCRIPTION	OPERATION
ADD, A,Rn	A←A+Rn	Add register to accumulator
ADD A,direct	A←A+(addr)	Add direct byte to accumulator
ADD A,@RI	A←A+(Ri)	Add indirect RAM to accumulator
ADD A,#data	A←A+data	Add immediate data to accumulator
ADDC A, Rn	A←A+Rn+C	Add register to accumulator with carry
ADDC A, direct	A←A+(addr)+C	Add direct byte to accumulator with carry
ADDC A,@Ri	A←A+(Ri)+C	Add indirect RAM to accumulator with carry
ADDC A, #data	A←A+data	Add immediate data to accumulator with carry
SUBB A, Rn	A←A-Rn-C	Subtract register from accumulator with borrow
SUBB A, direct	A←A-(addr)-C	Subtact direct byte from accumulator with borrow
SUBB A, @Ri	A←A-(Ri)-C	Subtract indirect RAM from acc with borrow
SUBB A, #data	A←A-data-C	Subtract immediate data from acc with borrow
INC A	A←A+1	Increment accumulator
INC Rn	Rn←Rn+1	Increment register

INC direct	(addr)←(addr)+1	Increment direct byte
INC @Ri	(Ri)←(Ri)+1	Increment indirect RAM
INC DPTR	DPTR←DPTR+1	Increment data pointer
CED A	A←A-1	Decrement accumulator
DEC Rn	Rn←Rn-1	Decrement register
DEC direct	(addr)←(addr)-1	Decrement direct byte
DEC@Ri	(Ri)←(Ri) -1	Decrement Indirect RAM
MUL AB	AB←AxB	Multiply Aand B
DIV AB	AB←A/B	Divide A and B
DAA		Decimal adjust accumulator

LOGICAL INSTRUCTIONS

MNEMONICS	DESCRIPTION	OPERATION
ANL A,Rn	(A)AND(Rn)	AND register to accumulator
ANL A,direct	(A)AND(addr)	AND direct byte to accumulator
ANL A,@Ri	(A)AND((Ri))	AND indirect RAM to accumulator
ANL A,#data	(A)AND data	AND immediate data to accumulator
ANL direct, A	(addr)AND(A)	AND accumulator to direct byte
ANL direct,#data	(addr)AND data	AND immediate data to direct byte
ORL A, Rn	(A)OR(Rn)	OR register to accumulator
ORL A, direct	(A)OR(addr)	OR direct byte to accumulator
ORL A, @Ri	(A)OR((Ri))	OR indirect RAM to accumulator
ORL A, #data	(A)OR data	OR immediate data to accumulator
ORL direct, A	(addr)OR(A)	OR accumulator to direct byte
ORL direct,#data	(addr)OR data	OR immediate data to direct byte
XRL A, Rn	(A)XOR(Rn)	Ex – OR register to accumulator
XRL A, direct	(A)XOR(addr)	Ex –OR direct byte to accumulator
XRL A, @Ri	(A)XOR((Ri))	Ex –OR indirect RAM to accumulator
XRL A, #data	(A)XOR data	Ex –OR immediate data to accumulator
XRL direct, A	(addr)XOR(A)	Ex –OR accumulator to direct byte
XRL direct,#data	(addr)XOR data	Ex –OR immediate data to direct byte
RL A	$A_0 \leftarrow A_7 \leftarrow A_6 \ldots\ldots A_1 \leftarrow A_0$	Rotate accumulator left
RLC A	$C \leftarrow A_7 \leftarrow A_6 \ldots\ldots \leftarrow A_0 \leftarrow C$	Rotate accumulator left through carry
RR A	$A_0 \rightarrow A_7 \rightarrow A_6 \ldots\ldots \rightarrow A_1 \rightarrow A_0$	Rotate accumulator right
RRC A	$C \rightarrow A_7 \rightarrow A_6 \ldots \rightarrow A_0 \rightarrow C$	Rotate accumulator right through carry
LR A	A←00	Clear accumulator
CPL A	$A \leftarrow \bar{A}$	Complement accumulator
SWAP A	$A_L \leftrightarrow A_H$	Swap nibbles within the accumulator

BOOLEAN VARIABLES MANIPULATION INSTRUCTIONS

MNEMONICS	DESCRIPTION	OPERATION
CLR C	C←0	Clear carry
CLR bit	bit←0	Clear direct bit
SETB C	C←1	Set carry
SETB bit	bit ←1	Set direct bit

CPL C	C← $\overline{C}$	Complementary carry
CPL bit	bit← $\overline{bit}$	Complementary direct bit
ANL C bit	(C)AND bit	AND direct bit to carry
ANL C, $\overline{bit}$	(C)AND $\overline{bit}$	AND complementary direct bit to carry
ORL C bit	(C)OR bit	OR direct bit to carry
ORL C, $\overline{bit}$	(C)OR $\overline{bit}$	OR complementary of direct bit to carry
MOV C,bit	C←bit	Move direct bit to carry
MOV bit,C	bit←C	Move carry to direct bit
JC radd	[C=1];PC←PC+2+radd	Jump if carry is set
JNC radd	[C=0];PC←PC+2+radd	Jump if carry is not set
JB bit,radd	[bit=1];PC←PC+3+radd	Jump if direct bit is set
JNB bit,radd	[bit=0];PC←PC+3+radd	Jump if direct bit is not set
JBC bit,radd	[bit=1];PC←PC+3+radd	Jump if direct bit is set and clear bit

PROGRAM BRANCHING INSTRUCTIONS

MNEMONICS	DESCRIPTION	OPERATION
ACALL sadd	(SP)← PC+2 PC← sadd	Absolute subroutine call
LCALL ladd	(SP)← PC+3 PC← ladd	Long subroutine call
RET	PC←(SP)	Return from sub-routine
RETI	PC←(SP);EI	Return from interrupt
AJUMP sadd	PC←sadd	Absolute jump
LJUMP ladd	PC←ladd	Long jump
SJUMP radd	PC←PC+2+radd	Short jump(relative address)
JMP @A +dptr	PC←DPTR+A	Jump indirect relative to the DPTR
JZ radd	[A=00]; PC←PC+2+radd	Jump if accumulator is zero
JNZ radd	[A>00]; PC←PC+2+radd	Jump if accumulator is not zero
CJNE A, direct,radd	[A<>(addr)]; PC←PC+3+radd	Compare direct byte to acc and jump if not equal
CJNE A#data,radd	[A<>(data)]; PC←PC+3+radd	Compare immediate data to acc and jump if not equal.
CJNE Rn, #data,radd	[(R_n)<>(data]; PC←PC+3+radd	Compare immediate data to register and jump if not equal.
DJNZ Rn,radd	[R_n-1<>00]; PC←PC+3+radd	Decrement regidter and jump if not zero
DJNZ direct,radd	[(add)-1<>00]; PC←PC+3+radd	Decrement direct byte and jump if not zero
NOP	PC←PC+1	No operation

8086 - Basic Program

ADDITION - 16 BIT

Place two 16-bit data to be added at 8500H, 8501H and 8502H, 8503H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, 00, 85	MOV SI,8500 H	Point to 1st 16 bit data
	84 03	8B, 04	MOV AX,[SI]	
	84 05	46	INC SI	
	84 06	46	INC SI	Point to 2nd 16 bit data
	84 07	03, 04	ADD AX,[SI]	
	84 09	89, 44, 02	MOV [SI+2],AX	Store result at 8504H
	84 0C	73, 06	JNC, SKIP	If addn. results in carry
	84 0E	C6, 44, 04, 01	MOV [SI+4],01H	load 01H at 8506H
	84 12	EB, 04	JMP END	
SKIP:	84 14	C6, 44, 04, 00	MOV [SI+4],00H	Else store 00H at 8506H
END:	84 15	F4	HLT	

SUBTRACTION - 16 BIT

Place two 16-bit data to be subtracted at 8500H, 8501H and 8502H, 8503H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, 00, 85	MOV SI,8500 H	Point to 1st 16 bit data
	84 03	8B, 04	MOV AX,[SI]	
	84 05	46	INC SI	
	84 06	46	INC SI	Point to 2nd 16 bit data
	84 07	3B, 04	CMP AX,[SI]	
	84 09	73, 02	JNC SKIP	
	84 0B	87, 04	XCHG AX,[SI]	
SKIP:	84 0D	2B, 04	SUB AX,[SI]	
	84 0F	89, 44, 02	MOV [SI+2],AX	Store result at 8504H
	84 12	F4	HLT	

MULTIPLICATION - 16 BIT

Place two 16-bit data to be multiplied at 8500H, 8501H and 8502H, 8503H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, 00, 85	MOV SI,8500H	Point to 1st 16 bit data
	84 03	8B, 04	MOV AX,[SI]	
	84 05	46	INC SI	
	84 06	46	INC SI	Point to 2nd 16 bit data
	84 07	BA, 00, 00	MOV DX,0000H	
	84 0A	F7, 24	MUL [SI]	
	84 0C	89, 44, 02	MOV [SI+2],AX	Product
	84 0F	89, 54, 04	MOV [SI+4],DX	8504H, 8505H (LSW) 8506H,8507H (MSW)
	84 12	F4	HLT	

DIVISION - 16 BIT

Place 16-bit DIVIDEND at 8500H, 8501H and DIVISOR at 8502H, 8503H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, 00, 85	**MOV SI,8500 H**	Point to 1ST 16 bit data
	84 03	8B, 04	**MOV AX,[SI]**	
	84 05	46	**INC SI**	
	84 06	46	**INC SI**	Point to 2nd 16 bit data
	84 07	BA, 00, 00	**MOV DX,0000H**	
	84 0A	F7, 34	**DIV [SI]**	
	84 0C	89, 44, 02	**MOV [SI+2],AX**	Result Quotient: 8504H, 8505H
	84 0F	89, 54, 04	**MOV [SI+4],DX**	Remainder: 8506H, 8507H
	84 12	F4	**HLT**	

ASCENDING/DESCENDING ORDER

Place data randomly in an array starting from Memory Location 8500H onwards

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, 00, 85	**MOV SI,8500 H**	Point to START address of Array
	84 03	BB, XX, 90	**MOV BX,85XXH**	Point to END address of Array
AA:	84 06	8B, FE	**MOV DI,SI**	
	84 08	47	**INC DI**	
BB:	84 09	8A, 04	**MOV AL,[SI]**	
	84 0B	3A, 05	**CMP AL,[DI]**	
	84 0D	72, 06	**JC, SKIP@**	
	84 0F	8A, 15	**MOV DL,[DI]**	
	84 11	88, 14	**MOV [SI],DL**	
	84 13	88, 05	**MOV [DI],AL**	
SKIP:	84 15	47	**INC DI**	
	84 16	3B, DF	**CMP BX,DI**	
	84 18	73, EF	**JNC, BB**	
	84 1A	46	**INC SI**	
	84 1B	3B, F3	**CMP SI,BX**	
	84 1D	72, E7	**JC, AA**	
	84 1F	F4	**HLT**	

@ Use 73H (opcode for *JNC*) at memory location 840DH for *descending order*

BLOCK MOVEMENT OF DATA

Place a BLOCK of data starting from 8500H to 85XXH

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, 00, 85	**MOV SI,8500 H**	Point to start address of BLOCK
	84 03	BB, XX, 85	**MOV BX,85XXH**	Point to end address of BLOCK
	84 06	BF, 00, 90	**MOV DI,9000H**	Point to destination address
	84 09	8B, CB	**MOV CX,BX**	Calculate COUNT of DATA in BLOCK
	84 0B	2B, CE	**SUB CX,SI**	
	84 0D	41	**INC CX**	
	84 0E	FC	**CLD**	Clear Dirn. Flag to autoincrement SI,DI
	84 0F	F3, A4	**REP MOVSB**	
	84 11	F4	**HLT**	

REVERSAL OF STRING OF DATA

Place a BLOCK of data starting from 8500H to 85XXH

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	84 00	BE, XX, 85	**MOV SI,85XX H**	Point to END address of STRING
	84 03	BF, 00, 90	**MOV DI,9000H**	Point to destination address
NXT:	84 06	8A, 04	**MOV AL,[SI]**	
	84 08	88, 05	**MOV [DI],AL**	
	84 0A	4E	**DEC SI**	
	84 0B	47	**INC DI**	
	84 0C	81, FE, 00, 85	**CMP SI,8500H**	
	84 10	73, F4	**JNC, NXT**	
	84 12	F4	**HLT**	

8255 I/O DISPLAY/ COUNTER INTERFACE with 8085

PROGRAMMABLE PERIPHERAL INTERFACE (PPI) CHIP 8255

There are TWO nos. of 8255 PPI chips available on FLO-85 Board.

The PORT ADDRESSES of the two chips are as given below:

8255[1]-upper- -[P_2-Socket]	8255[2]-lower- -[P_3-Socket]
Port A- DC H	**Port A- 7C H**
Port B- DD H	**Port B- 7D H**
Port C- DE H	**Port C- 7E H**
Control	**Control**
Port C- DF H	**Port C- 7F H**

INITIALISATION of 8255 chip:

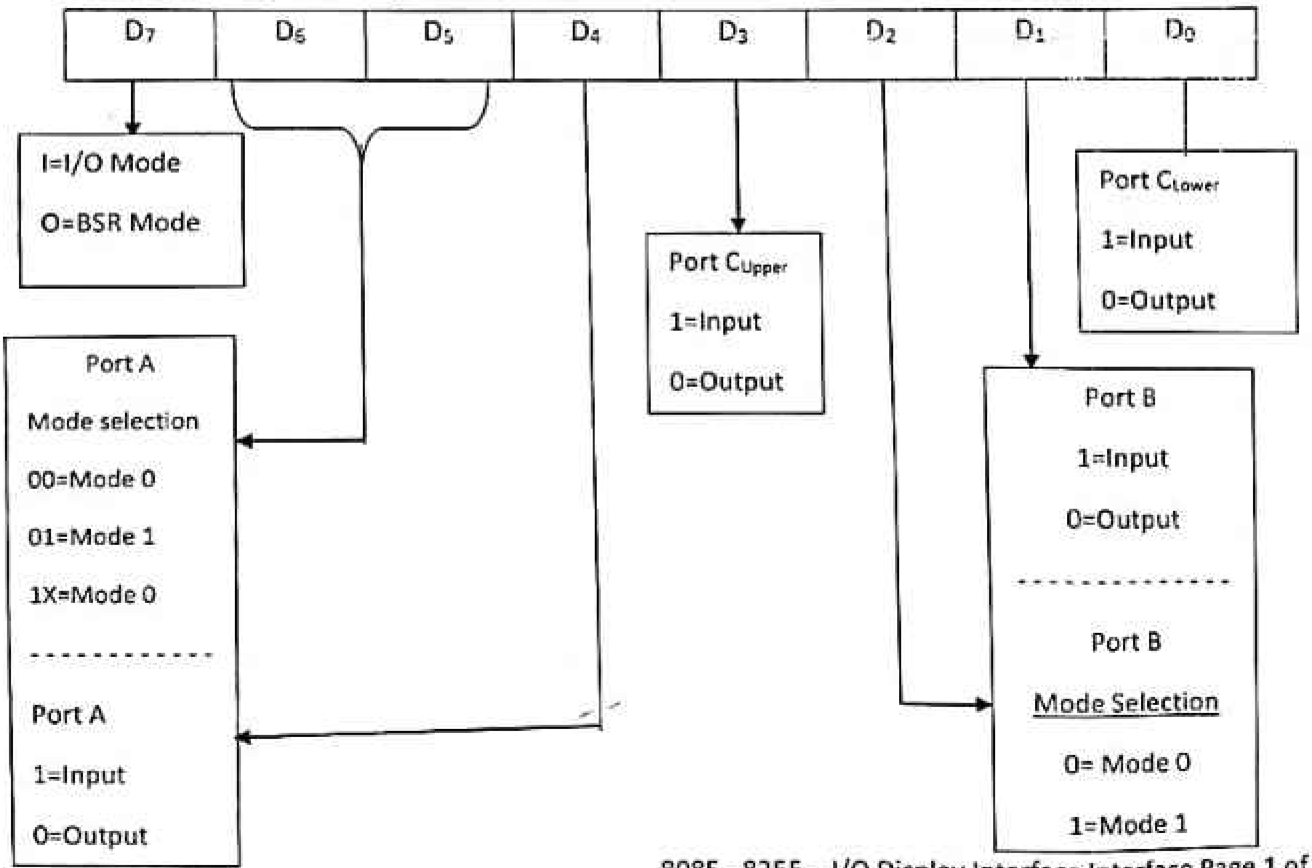
Choose the appropriate 8-bitcode for the **CONTROL WORD** from the Table provided for MODE 0 operation *or* generate it using the CONTROL WORD format.

Using the instructions **MVI A, CODE**

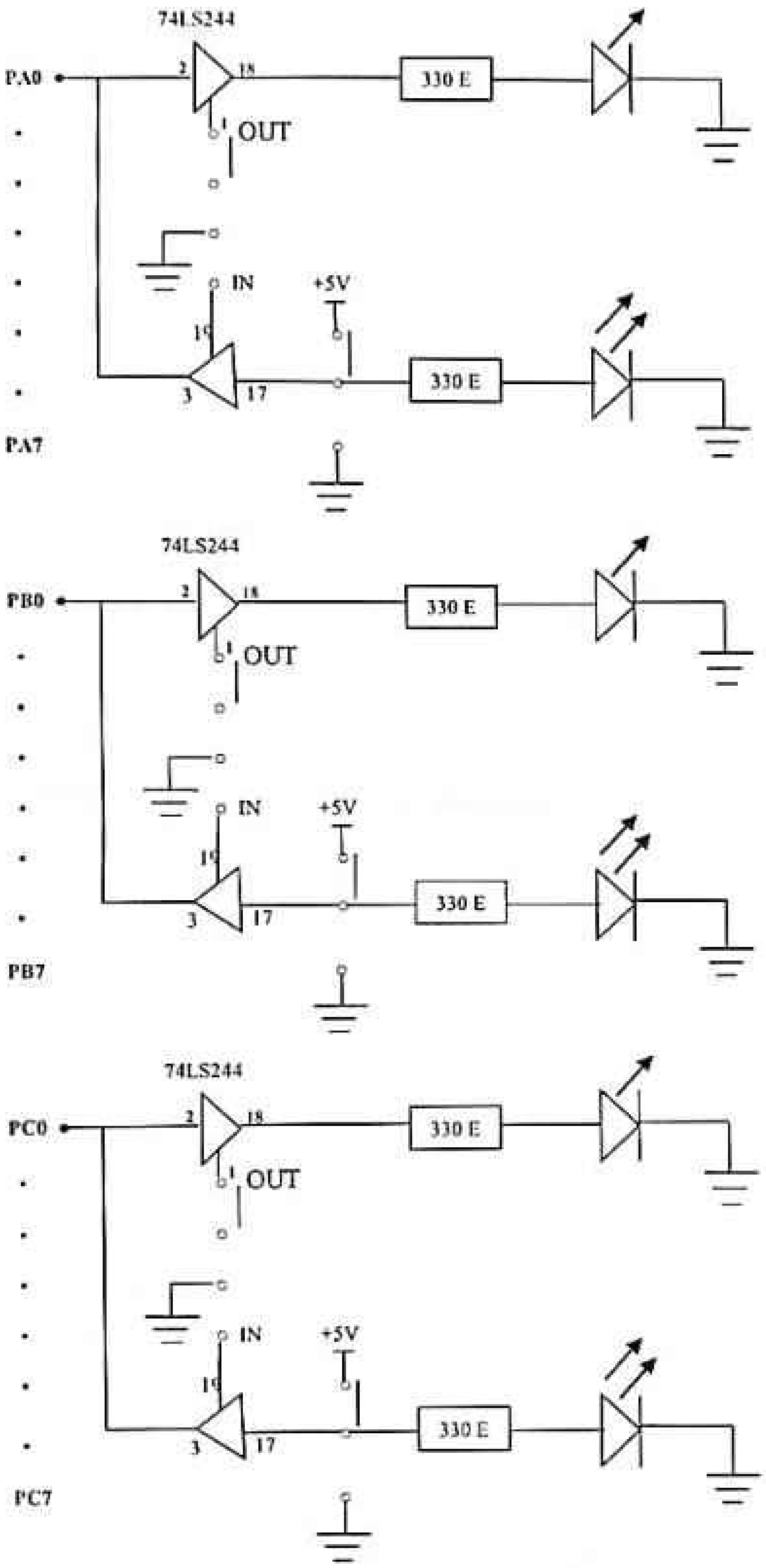
OUT, CONTROL REGISTER [DF]

the chip can be programmed to serve as per the requirement.

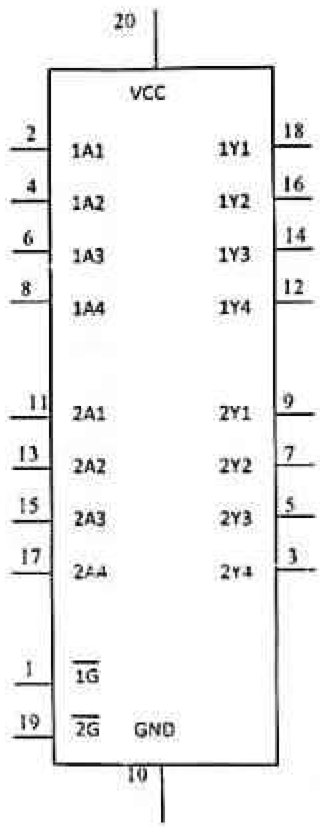
Control Word Format



FLORANIX – I/O CARD DIAGRAM



74LS244 PIN DETAILS



CONTROL WORDS for 8255A in MODE 0 OPERATION

CONTROL WORD BITS 7 6 5 4 3 2 1 0	CONTROL WORD	PORT A	PORT C UPPER	PORT B	PORT C LOWER
1 0 0 0 0 0 0 0	80	O/P	O/P	O/P	O/P
1 0 0 0 0 0 0 1	81	O/P	O/P	O/P	I/P
1 0 0 0 0 0 1 0	82	O/P	O/P	I/P	O/P
1 0 0 0 0 0 1 1	83	O/P	O/P	I/P	I/P
1 0 0 0 1 0 0 0	88	O/P	I/P	O/P	O/P
1 0 0 0 1 0 0 1	89	O/P	I/P	O/P	I/P
1 0 0 0 1 0 1 0	8A	O/P	I/P	I/P	O/P
1 0 0 0 1 0 1 1	8B	O/P	I/P	I/P	I/P
1 0 0 1 0 0 0 0	90	I/P	O/P	O/P	O/P
1 0 0 1 0 0 0 1	91	I/P	O/P	O/P	I/P
1 0 0 1 0 0 1 0	92	I/P	O/P	I/P	O/P
1 0 0 1 0 0 1 1	93	I/P	O/P	I/P	I/P
1 0 0 1 1 0 0 0	98	I/P	I/P	O/P	O/P
1 0 0 1 1 0 0 1	99	I/P	I/P	O/P	I/P
1 0 0 1 1 0 1 0	9A	I/P	I/P	I/P	O/P
1 0 0 1 1 0 1 1	9B	I/P	I/P	I/P	I/P

8255 I/O INTERFACE CARD makes use of Three pairs of **74LS244** Bi-directional Buffers to enable **PORTS A,B&C** to act as **INPUT** or **OUTPUT** Ports.

SELECTION of PORT as INPUT or OUTPUT port:

There are 4 nos. of **JUMPERS** one each for **Port A, Port B, Port C_{UPPER} & Port C_{LOWER}** to enable each port to act as either **INPUT** or **OUTPUT** port.

To make a **PORT** as **INPUT PORT** *place the jumper on the left side* connecting the middle pin and the left side pin. **Green LED** glows.

To make a **PORT** as **OUTPUT PORT** *place the jumper on the right side* connecting the middle pin and the right side pin. **Red LED** glows.

SELECTION of INPUT DATA:

For Ports selected as **INPUT PORT** use the 8 nos. of jumpers to set the desired data either in the **PA_0** to **PA_7** or **PB_0** to **PB_7** or **PC_0** to **PC_7**.

Logic **0** is selected when the *jumper link is placed on the left side*.

Logic **1** is selected when the *jumper link is placed on the right side*.

The **GREEN LEDs** indicate the **INPUT DATA** selected on the input side.

This DATA serves as the **INPUT DATA** for the ***IN,Port*** command.

DISPLAY of OUTPUT DATA:

The **RED LEDs** indicate the **OUTPUT DATA** on the output side of the **PORTS** slected as **OUTPUT PORT** during the ***OUT, Port*** command.

CONTROL WORD FORMAT

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	0	0	0	1	1
I/O FUNCT	**PORT A in mode0**		**PORTA O/P**	**PORTC$_U$ O/P**	**PORTB in MODE0**	**PORTB I/P**	**PORTC$_L$ I/P**

The **appropriate** code for the **CONTROL WORD : 83H**
PORT ADDRESS of **CONTROL REGISTER : DFH**

PORT A : DCH ; PORT B : DDH ; PORT C : DEH

PROGRAM :

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 83	**MVIA, 83H**	Control Word
	80 12	D3, DF	**OUT, DF H(CR)**	Control Register
	80 14	DB, DD	**IN DDH(PORT B)**	Input through PORT
	80 16	D3, DC	**OUT, DCH (PORT B)**	Output at PORT A
	80 18	DB, DE	**IN DEH(PORT C)**	Input PC$_L$ thro' portc
	80 1A	E6, 0F	**ANI, 0FH**	Mask of uppernibbl
	80 1C	07	**RLC**	Rotate left 4 times to bring PC$_L$ to PC$_U$ position
	80 1D	07	**RLC**	
	80 1E	07	**RLC**	
	80 1F	07	**RLC**	
	80 20	D3,DE	**OUT, DEH (PORT C)**	Output PC$_U$ at PORT
	80 22	76	**HLT**	

BSR MODE APPLICATIONS: - 8085

RING COUNTER, SHIFT COUNTER & MODULUS COUNTER

It affects only the 8 bits of PORT C, one bit at a time.
The **I/O operations of PORT A & PORT B** ***are not affected*** **by BSR Control Word**

CONTROL WORD FORMAT

D_7	D_6	D_5	D_4	D_3	D_2	D_1		D_0
0	X	X	X	P_C BIT SELECT				S/R
BSR MODE	NOT USED			0	0	0	BIT 0	SET=1; RESET= 0
				0	0	1	BIT 1	*
				0	1	0	BIT 2	*
				0	1	1	BIT 3	*
				1	0	0	BIT 4	*
				1	0	1	BIT 5	*
				1	1	0	BIT 6	*
				1	1	1	BIT 7	*

To SET or RESET BITS in PORT C ,
The CONTROL WORD is written in CONTROL REGISTER

RING COUNTER, SHIFT COUNTER & MODULUS COUNTER can be programmed in BSR mode settings using ***LOOK-UP TABLE*** for **SET & REST CODES** to be sent to the ***Control Register.***

RING COUNTER IN BSR MODE:

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80 H**	Initialize 8255
	80 12	D3, DF	**OUT, DF H(CR)**	
LOOP:	80 14	0E, 08	**MVIC,08H**	
	80 16	21, 00, 85	**LXIH, 8500H**	Points to SET codes
REP:	80 19	7E	**MOV A,M**	Output the BIT SET code to CR
	80 1A	D3, DF	**OUT, DFH (CR)**	
	80 1C	CD, 00, 81	**CALL TIME DELAY**	
	80 1F	3D	**DCR A**	RESET the previously SET bit & output it.
	80 20	D3, DF	**OUT, DFH (CR)**	
	80 22	23	**INX H**	
	80 23	0D	**DCR C**	Continue the process for 8 such bits
	80 24	C2, 19, 80	**JNZ, REP**	
	80 27	C3, 14, 80	**JMP, LOOP**	

LOAD the SET CODES as shown below in Memory:

8500-01	8501-03	8502-05	8503-07	8504-09	8505-0B	8506-0D	8507-0F

****

SHIFT COUNTER IN BSR MODE: - 8085

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 90	MVIA, 80 H	Initialize 8255 in I/O mode
	80 12	D3, DF	OUT, DF H(CR)	
REP:	80 14	0E, 08	MVIC, 08H	
	80 16	21, 00, 85	LXIH, 8500H	Point to SET codes & output them for 8 bits
LOOP 1:	80 19	7E	MOV A,M	
	80 1A	D3, DF	OUT, DFH (CR)	
	80 1C	CD, 00, 81	CALL TIME DELAY	
	80 1F	23	INX H	
	80 20	0D	DCR C	
	80 21	C2, 19, 80	JNZ, LOOP1	
	80 24	CD, 00, 81	CALL TIME DELAY	
	80 27	0E, 08	MVIC, 08H	
	80 29	21, 00, 86	LXIH, 8510H	Point to RESET codes
LOOP 2:	80 2C	7E	MOV A,M	Output the codes for the same 8 bits
	80 2D	D3, DF	OUT, DFH (CR)	
	80 2F	CD, 00, 81	CALL TIME DELAY	
	80 32	23	INX H	
	80 33	OD	DCR C	
	80 34	C2, 2C, 80	JNZ, LOOP2	
	80 37	C3, 14, 80	JMP, REP	

LOAD SET CODES as shown below in Memory:

8500-01	8501-03	8502-05	8503-07	8504-09	8505-0B	8506-0D	8507-0F

LOAD RESET CODES as shown below in Memory:

8600-00	8601-02	8602-04	8603-06	8604-08	8605-0A	8606-0C	8607-0E

MOD COUNTERS (UP SEQUENCE)- BCD in BSR MODE:

Place the desired MOD COUNT to be displayed at Memory Location 8700 H

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80H**	Initialize 8255 in I/O mode
	80 12	D3, DF	**OUT, DF H(CR)**	
REP:	80 14	AF	**XRAA**	Send 1st RESET cod to Port C in BSR mod
	80 15	D3, DF	**OUT, DF H(CR)**	
	80 17	21, 00, 86	**LXIH, 8600**	Store the desired count in reg.s DH & DL
	80 1A	7E	**MOV A,M**	
	80 1B	32, 00, 88	**STA, 8800H**	Point to the corresponding MOD count memory location
	80 1E	11, 00, 89	**LXID, 8900**	
	80 21	07	**RLC**	
	80 22	07	**RLC**	
	80 23	07	**RLC**	
	80 24	07	**RLC**	
	80 25	5F	**MOV E,A**	

			PAGE 7	[8255 i/o BSR– 7/9 – 8085]
LOOP2:	80 26	1A	**LDAX D**	Point to SET codes
	80 27	21, 00, 85	**LXIH, 8500H**	Set counter for each bit in MOD count state.
	80 2A	0E, 08	**MVIC, 08H**	
LOOP1:	80 2C	0F	**RRC**	Is any bit in the MOD count state 1?If so output corresponding SET code
	80 2D	47	**MOV B,A**	
	80 2E	D2, 37, 80	**JNC, GO**	
	80 31	7E	**MOV A,M**	Else point to next SET code
	80 32	D3, DF	**OUT DFH**	
	80 34	CD, 00, 81	**CALL TIME DELAY**	Continue The process for all 8 bits of the ponted MOD count state.
	80 37	23	**INX H**	
	80 38	78	**MOV A,B**	
	80 39	0D	**DCR C**	Point to the next MOD count state.
	80 3A	C2, 2C, 80	**JNZ, LOOP 1**	
	80 3D	13	**INX D**	
	80 3E	CD, 00, 81	**CALL TIME DELAY**	Update the no. of MOD counts.
	80 41	AF	**XRA A**	
	80 42	D3,DE	**OUT DEH**	
	80 44	21, 00, 88	**LXIH, 8800H**	
	80 47	35	**DCR M**	
	80 48	C2, 26, 80	**JNZ, LOOP2**	
	80 4B	CD, 00, 81	**CALL T,TIME DELAY**	
	80 4E	C3, 14, 80	**JMP, REP**	

LOAD MOD COUNTS in MEMORY as follows :

	MEMORY	DATA
MOD 2	8920 H	00,01
MOD 3	8930 H	00,01,02
MOD 4	8940 H	00,01,02,03
MOD 5	8950 H	00,01,02,03,04
MOD 6	8960 H	00,01,02,03,04,05
MOD 7	8970 H	00,01,02,03,04,05,06
MOD 8	8980 H	00,01,02,03,04,05,06,07
MOD 9	8990 H	00,01,02,03,04,05,06,07,08
MOD 10	89A0 H	00,01,02,03,04,05,06,07,08,09

SUBROUTINE TIME DELAY

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	81 00	F5	PUSH PSW	
	81 01	E5	PUSH H	
	81 02	21,FF,FF	LXIH, FFFFH	
LOOP1:	81 05	2B	DCX H	
	81 06	7C	MOV A,H	
	81 07	B5	ORA L	
	81 08	C2, 05, 81	JNZ, LOOP1	
	81 0B	E1	POP H	
	81 0C	F1	POP PSW	
	81 0D	C9	RET	

I/O MODE APPLICATION – 8085

SHIFT COUNTER in I/O MODE: - 8085

LABEL	ADRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80 H**	Initialize 8255 in I/O mode
	80 12	D3, DF	**OUT, DF H(CR)**	
	80 14	AF	**XRA A**	Clear Acc. & flags
START:	80 15	D3, DC	**OUT, DCH (PORT A)**	
	80 17	CD, 00, 81	**CALL TIME DELAY**	
	80 1A	3F	**CMC**	Prepare next consecutive state
	80 1B	17	**RAL**	
	80 1C	C3, 15, 80	**JMP, START**	o shift counter again

RING COUNTER in I/O MODE: - 8085

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80 H**	Initialize 8255 in I/O mode
	80 12	D3, DF	**OUT, DF H(CR)**	
	80 14	AF	**XRAA**	Clear Acc. & flags
	80 15	37	**STC**	Set CY=1 for rotation
START:	80 16	17	**RAL**	
	80 17	B7	**ORA A**	If Acc.≠0 the current (ring counter) state is o/p
	80 18	C2, 1D, 80	**JNZ, SKIP**	
	80 1B	37	**STC**	Else Acc.(00) is adjusted for a ring counter state (01) & then o/p
	80 1C	17	**RAL**	
SKIP:	80 1D	D3, DC	**OUT, DCH (PORT A)**	
	80 1F	CD, 00, 81	**CALL TIME DELAY**	
	80 22	C3, 16, 80	**JMP, START**	Do ring counter again

BINARY 2 DIGIT UP/DOWN COUNTER: - 8085

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80 H**	Initialize 8255 in I/O mode
	80 12	D3, DF	**OUT, DF H(CR)**	
	80 14	3E, 00	**MVIA, 00H@**	Clear Acc.
START:	80 16	D3, DC	**OUT, DC H(PORT A)**	Output to PORT A
	80 18	CD, 00, 81	**CALL TIME DELAY**	
	80 1B	3C	**INR A**	Increment Acc.
	80 1C	C3, 16, 80	**JMP, START**	Repeat START

@ For DOWN counter action load FFH at **8015H** & **3D** (opcode for **DCR A**) at **801BH**.

BCD(2 DIGIT) UP COUNTER: - 8085

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80H**	Initialize 8255 in I/O mode
	80 12	D3, DF	**OUT, DF H(CR)**	
	80 14	AF	**XRAA**	Clear Acc. & flags
START:	80 15	D3, DC	**OUT, DC H(PORT A)**	Output to PORT A
	80 17	CD, 00, 81	**CALL TIME DELAY**	
	80 1A	3C	**INR A**	Increment Acc.
	80 1B	27	**DAA**	
	80 1C	C3, 15, 80	**JMP, START**	Repeat START

BCD(2 DIGIT) DOWN COUNTER: - 8085

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 10	3E, 80	**MVIA, 80 H**	Initialize 8255 in I/O mode
	80 12	D3, DF	**OUT, DF H(CR)**	
	80 14	3E, 99	**MVIA, 99 H**	Load 99-biggest 2 digit BCD no.
	80 16	4F	**MOV C,A**	Store in C for 100s complement subtraction
START:	80 17	D3, DC	**OUT, DC H(PORT A)**	Output to PORT A
	80 19	CD, 00, 81	**CALL TIME DELAY**	
	80 1C	81	**ADD C**	Subtract 1 decimally
	80 1D	27	**DAA**	
	80 1E	C3, 17, 80	**JMP, START**	Repeat START

SUBROUTINE TIME DELAY - 8085

LABEL	ADDRESS	OPCODE	MNEMONICS	COMMENTS
	80 00	F5	**PUSH PSW**	
	80 01	21, FF, FF	**LXIH, FFFFH**	
LOOP 1:	80 04	2B	**DCX H**	
	80 05	7C	**MOV A,H**	
	81 06	B5	**ORA L**	
	81 07	C2, 04, 81	**JNZ, LOOP1**	
	81 0A	F1	**POP PSW**	
	81 0B	C9	**RET**	

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ELECTRONICS LABORATORY MANUAL

CONTENT:

1. Log and antilog amplifiers.

2. Voltage comparator and zero crossing detectors.

3. Second order filters using operational amplifier for–
   a. Low pass filter of cutoff frequency 1 KHz.
   b. High pass filter of frequency 12 KHz.
   c. Band pass filter with unit gain of pass band from 1 KHz to 12 KHz.

4. Wien bridge oscillator using operational amplifier.

5. Determine capture range; lock in range and free running frequency of PLL.

6. Voltage regulator using operational amplifier to produce output of 12V with maximum load current of 50 mA.

7. A/D and D/A convertor.

8. Voltage to current and current to voltage convertors.

9. Function generator using operational amplifier (sine, triangular & square wave)

10. Astable and monostable multivibrator using IC 555.

Experiment Number-1

Design of Active Filters

Aim: To design and obtain the frequency response of second order Low Pass Filter (LPF)

APPARATUS:

S.NO.	Name of the Equipment	Values	Quantity
1	Resistor	33KΩ,27 kΩ,10 kΩ	2 ,1,1
2	Potentiometer	20k	1
3	Capacitor	0.0047 μF	2
4	I.C. 741 OP-AMP		1
	Function Generator	1MHz	1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

THEORY:

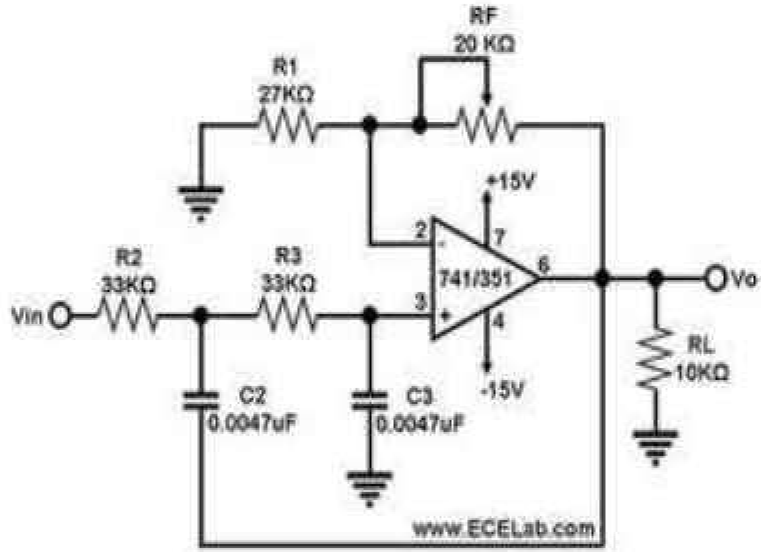
A LPF allows frequencies from 0 to higher cut of frequency, f_H. At f_H, the gain is 0.707 A_{max}, and after f_H gain decreases at a constant rate with an increase in frequency. The gain decreases 20dB each time the frequency is increased by 10. Hence the rate at which the gain rolls off after f_H is 20dB/decade or 6 dB/ octave, where octave signifies a two fold increase in frequency. The frequency f= f_H is called the cut off frequency because the gain of the filter at this frequency is down by 3 dB from 0 Hz. Other equivalent terms for cut-off frequency are - 3dB frequency, break frequency, or corner frequency. The cutoff frequency is given as

$$f_H = \frac{1}{2\pi\sqrt{R_2R_3C_2C_3}}$$

For the sake of simplicity let us take $R_2 = R_3 = R$, $C_2 = C_3 = C$ then

$$f_H = \frac{1}{2\pi RC}$$

Circuit Diagram:



Design:

1. Let the cutoff frequency f_H = 1 kHz.
2. Let us take a capacitor of value 0.0047 μF.

So the value of R can be calculated as

$$R = \frac{1}{2\pi C f_H} = \frac{1}{2\pi * 47 * 10^{-10} * 1 * 10^3} = 33.86\ \text{k}\Omega$$

Now $R_F = 0.586\ R_1$

Let R_1 = 27 kΩ so R_F = 15.82 kΩ.

PROCEDURE:

1. Connect the circuit as shown in the figure.
2. Apply sinusoidal wave of constant amplitude at the input such that op-amp does not go into saturation.
3. Vary the input frequency and note down the output amplitude at each step as shown in Table.

Observation Table:

Input frequency, f (Hz)	Gain magnitude, $\lvert v_o/v_i \rvert$	Magnitude (dB) = $20\log\lvert v_o/v_i \rvert$

RESULT: The frequency response is drawn and is found similar to that of theoretical one.

Experiment Number –2

Design of Active Filters

Aim: To design and obtain the frequency response of second order High Pass Filter (HPF)

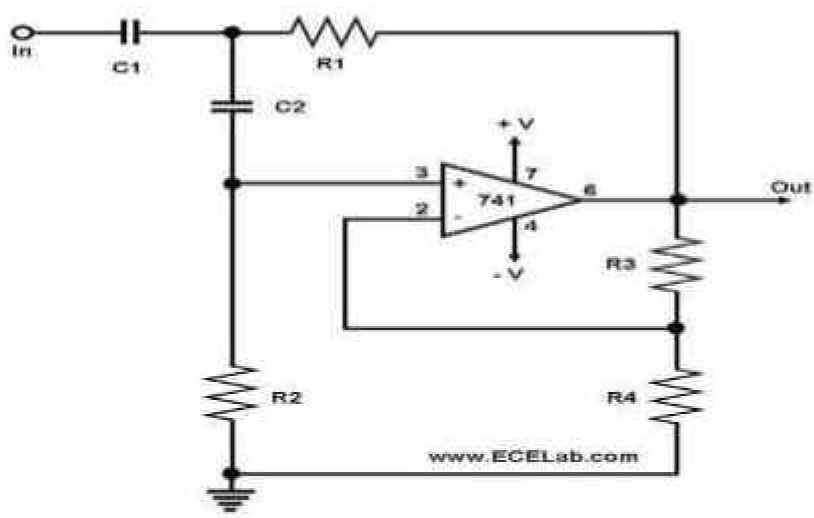
APPARATUS:

S.NO.	Name of the Equipment	Values	Quantity
1	Resistor	10KΩ	4
2	Potentiometer	20k,50k	1
3	Function Generator	1MHz	1
4	I.C. 741 OP-AMP		1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

THEORY:

The high pass filter can be obtained from the low pass by simply interchanging the frequency determining resistors and capacitors. The frequency at which the magnitude of the gain is 0.707 times the maximum value of gain is called lower cut off frequency. Obviously, all frequencies higher than f_L are pass band frequencies with the highest frequency determined by the closed loop band width of the op-amp.

Circuit Diagram:



Design:

3. Let the cutoff frequency f_L = 1 kHz.
4. Let us take a capacitor of value 0.0047 μF.

So the value of R can be calculated as

$$R = \frac{1}{2\pi C f_L} = \frac{1}{2\pi * 47 * 10^{-10} * 1 * 10^{3}} = 33.86\ k\Omega$$

Now $R_F = 0.586\ R_1$

Let $R_1 = 27\ k\Omega$ so $R_F = 15.82\ k\Omega$.

PROCEDURE:

1. Connections are made as per the circuit diagrams shown in figure.
2. Apply sinusoidal wave of constant amplitude at the input such that op-amp does not go into saturation.
3. Vary the input frequency and note down the output amplitude at each step as shown in Table.

Observation Table:

Input frequency, f (Hz)	**Gain magnitude, $\|v_o/v_i\|$**	**Magnitude (dB) = 20log $\|v_o/v_i\|$**

RESULT: The frequency response is drawn and is found similar to that of theoretical one.

Experiment Number- 3

Design of Log and Antilog Amplifier

AIM: To construct and study the behavior of logarithmic and antilogarithmic amplifier.

APPARATUS:

S.NO.	Name of the Equipment	Values	Quantity
1	Op-Amp 741 IC		1
2	Resistor	100 KΩ , 10 KΩ	2
3	NPN transistor BC 548		1
4	Function Generator	1MHz	1
5	CRO	20 MHz	1
6	Bread Board, Dc power supply		1
7	Connecting Wires and Probes		

THEORY:

The log and antilog amplifiers are the non linear application mode circuits. The grounded base NPN transistor behaves like a diode. Because the inverting terminal is on virtual ground the collector-base potential is zero and thereby it is behaving like a diode. So

$$I_E = I_S(e^{\frac{qV_E}{kT}} - 1)$$

Since $I_C = I_E$ for a grounded base transistor,

$$I_C = I_S\,(e^{\frac{qV_E}{kT}} - 1)$$

Where

I_S = emitter saturation current ≈ 10^{-13} A

k = Boltzmann's Constant

T = absolute temperature (in °K)

Therefore, $e^{\frac{qV_E}{kT}} = \frac{I_C}{I_S} + 1$

$\approx \frac{I_C}{I_S}$

Taking natural log on both sides, we get

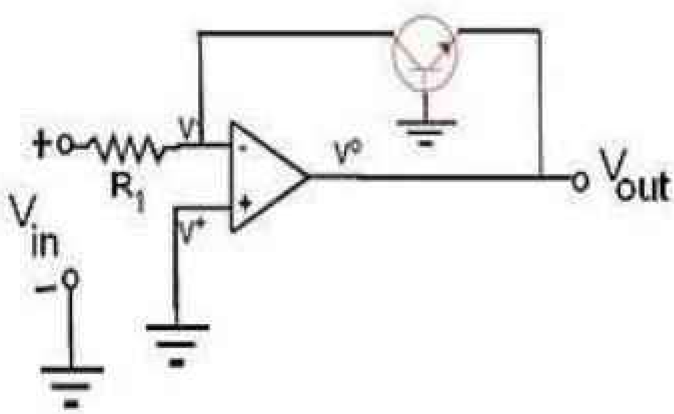
$V_E = \frac{kT}{q} \ln\left(\frac{I_C}{I_S}\right)$, also $V_E = - V_0$

$V_0 = -\frac{kT}{q} \ln\left(\frac{V_i}{I_S R_1}\right)$

Similarly for antilog amplifier

$$V_0 = -R_F I_S e^{(V_{in}/V_T)}$$

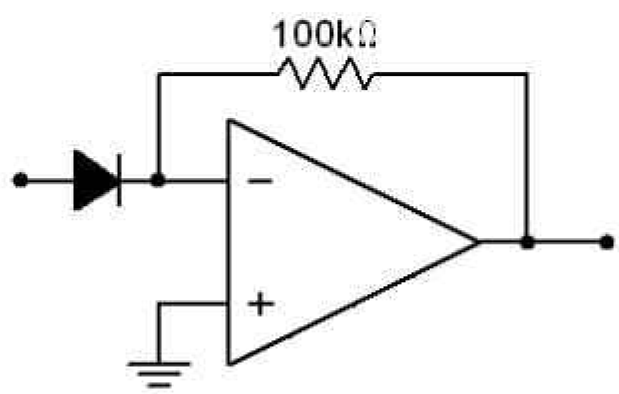
Circuit Diagram: (Log Amplifier)



Procedure:

1. Connect the circuit as shown in figure.
2. Set the input voltage to 1V.
3. See the voltage across the output terminal. Note the negative sign.
4. Increase the input voltage in the step of 1V up to 20V.
5. Plot the characteristics of input voltage and output voltage.

Antilog:



Procedure:

1. Set the input voltage to 100mV.
2. See the voltage across the Resistor. Note the negative sign.
3. Increase the input voltage in the step of 50mV up to 500mV.
4. Plot the characteristics of input voltage and output voltage.
5. Reverse the polarity of the diode and see the effect for positive input voltage.

Observation Table:

Input Voltage	Output Voltage

Result & Discussion: Graph is drawn and verified.

Experiment Number-4

Design of Voltage Comparator and Zero Crossing Detector

Aim: To design a Voltage comparator and Zero Crossing Detector.

Apparatus:

S.NO.	Name of the Equipment	Values	Quantity
1	Resistor	10KΩ	1
2	Resistor	1KΩ	2
3	Function Generator	1MHz	1
4	I.C. 741 OP-AMP		1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

THEORY:

Comparator:

A comparator circuit is one which compares a voltage signal at one input with a known reference signal at the other input. It works in open loop mode. There are basically two types of comparator namely inverting and non-inverting comparators. The output will be either $+V_{sat}$ or $-V_{sat}$ depending upon the amplitude of the signal at the input terminal. If the amplitude of the non-inverting terminal signal is greater than the inverting terminal signal then the output will be $+V_{sat}$ and vice-versa.

Zero Crossing Detector:

The zero crossing detector is a special case basic comparator circuit. If we set reference voltage zero then a comparator behaves like a zero crossing detector.

Design: Not required

PROCEDURE:

Comparator:

1. Connect the IC on the base and connect power supply on respective terminals.
2. Connect input signal through a resistor in series to inverting terminal and reference signal through a resistor to non inverting terminal.
3. Connect the load resistor to the output terminal and also the probe of CRO to the output terminal.

Observation Table: Not required

Zero Crossing Detector:

In comparator circuit set the reference voltage to ground and keep everything same.

Observation Table: Not Required

Result: The waveforms are verified and it satisfied the stated conditions.

Experiment Number-5

Design of Wien Bridge Oscillator using Operational Amplifier.

Aim: To design a Wien-bridge oscillator using operational amplifier having resonant frequency 965 Hz.

Apparatus:

S.NO.	Name of the Equipment	Values	Quantity
1	Resistor	10KΩ	1
2	Resistor	3.3 KΩ	1
3	Function Generator	1MHz	1
4	I.C. 741 OP-AMP		1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		
8	Potentiometer	50 kΩ	1

Theory/Design:

Suppose we have to design oscillator of resonant frequency 965 Hz.

We know that the resonant frequency f_0 is given by

$$f_0 = \frac{1}{2\pi RC} = \frac{0.159}{RC}$$

Let C = 0.05 μF therefore R will can be calculated as

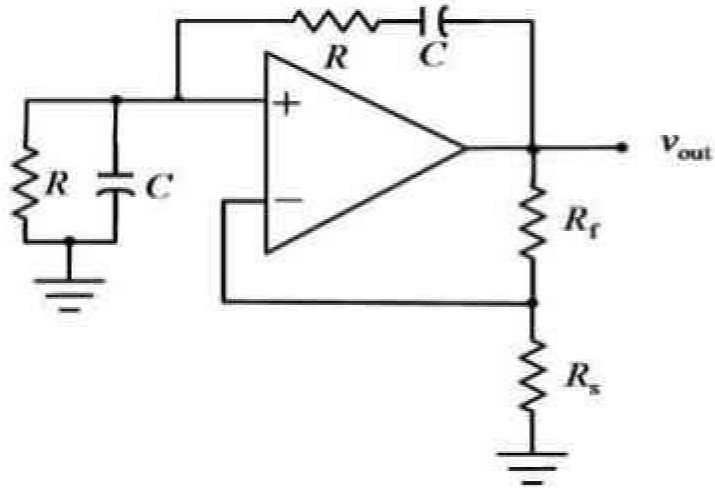
$$R = \frac{0.159}{(965)0.05\times10^{-6}} = 3.3\ k\Omega$$

Let $R_s = 10\ k\Omega$

$R_f = 2R_s$

Therefore $R_f = 20\ k\Omega$

Circuit Diagram:



Procedure:

Connect the circuit as shown in figure and observe the output at pin number 6. Trace it on CRO screen.

Observation:

Trace the waveform and measure the frequency.

Result: Sinusoidal waveform was traced on pin 6 and verified with stated condition.

Experiment Number-6

Design of Monostable Multivibrator Circuit using 555 Timer:

AIM: To construct and study the operation of a monostable multivibrator using 555 IC timer.

APPARATUS:

S.NO.	Name of the Equipment	Values	Quantity
1	555 IC Timer		1
2	Resistor	10 KΩ	1
3	Capacitors	10nF, 0.1μF, 0.01μF	1
4	Function Generator	1MHz	1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

THEORY:

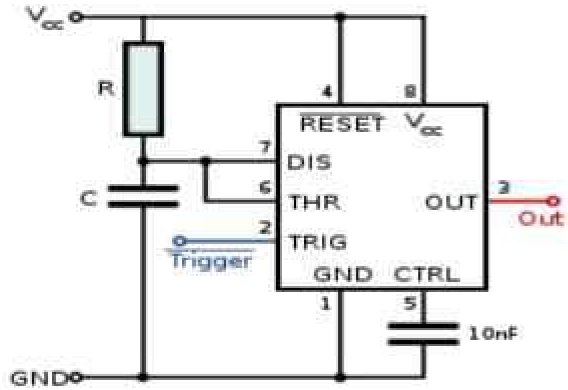
It has one stable and one quasi stable state. The circuit is useful for generating single output pulse of time duration in response to a triggering signal. The width of the output pulse depends only on external components connected to the op-amp. The diode gives a negative triggering pulse. When the output is +Vsat, a diode clamps the capacitor voltage to 0.7V then, a negative going triggering impulse magnitude Vi passing through RC and the negative triggering pulse is applied to the positive terminal. Let us assume that the circuit is instable state. The output V0i is at +Vsat. The diode D1 conducts and Vc the voltage across the capacitor 'C' gets clamped to 0.7V,the voltage at the positive input terminal through R1R2 potentiometer divider is +ßVsat. Now, if a negative trigger of magnitude Vi is applied to the positive terminal so that the effective signal is less than 0.7V.the output of the Op-Amp will switch from +Vsat to −Vsat. The diode will now get reverse biased and the capacitor starts charging exponentially to −Vsat. When the capacitor charge Vc becomes slightly more negative than −ßVsat, the output of the op-amp switches back to +Vsat. The capacitor 'C' now starts charging to +Vsat through R until Vc is 0.7V.

$V_0 = V_f + (V_i - V_f)\, e^{t/RC}$, ß = R2/(R1+R2)

If Vsat >> Vp and R1=R2 and ß = 0.5,

Then, T = 0.69RC

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in the circuit diagram.
2. Apply Negative triggering pulses at pin 2 of frequency 1 KHz as shown in Fig.
3. Observe the output waveform and capacitor voltage as shown in Figure and measure the pulse duration.
4. Theoretically calculate the pulse duration as $T_{high} = 1.1\ RC$
5. Compare it with experimental values.

Observation: Trace the time period of the output wave form and compare it with the given one.

Result & Discussion: The waveform is observed and verified with stated condition.

Experiment Number-7

Design of Astable Multivibrator Circuit using 555 Timer:

AIM: To construct and study the operation of a monostable multivibrator using 555 IC timer.

APPARATUS:

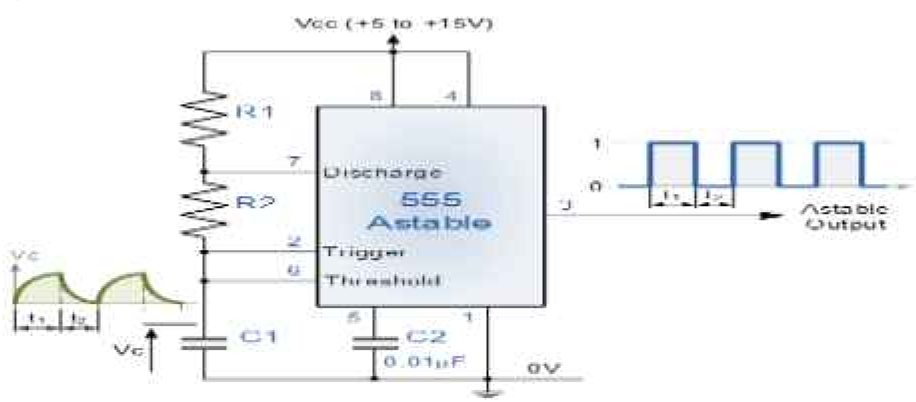
S.NO.	Name of the Equipment	Values	Quantity
1	555 IC Timer		1
2	Resistor	10 KΩ	1
3	Capacitors	10nF, 0.1μF, 0.01μF	1
4	Function Generator	1MHz	1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

THEORY:

In the 555 Oscillator above, pin 2 and pin 6 are connected together allowing the circuit to re-trigger itself on each and every cycle allowing it to operate as a free running oscillator. During each cycle capacitor, C charges up through both timing resistors, R1 and R2 but discharges itself only through resistor, R2 as the other side of R_2 is connected to the discharge terminal, pin 7. Then the capacitor charges up to 2/3Vcc (the upper comparator limit) which is determined by the $0.693(R_1+R_2)C$ combination and discharges itself down to 1/3Vcc (the lower comparator limit) determined by the 0.693(R2.C) combination. This results in an output waveform whose voltage level is approximately equal to Vcc - 1.5V and whose output "ON" and "OFF" time periods are determined by the capacitor and resistors combinations. The individual times required completing one charge and discharge cycle of the output is therefore given as:

$t_1 = 0.693\ (R_1+R_2)C$, $t_2 = 0.693\ R_2C$, $T = t_1 + t_2$

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in the figure.
2. Use potentiometer in case output is not proper.

Observation: Trace the output waveform and calculate the frequency from the fundamental period of the wave.

Result & Discussion: The waveform was traced and compared with the designed theoretical one.

Experiment Number – 8

Aim: To construct and study the voltage to current convertor.

Apparatus:

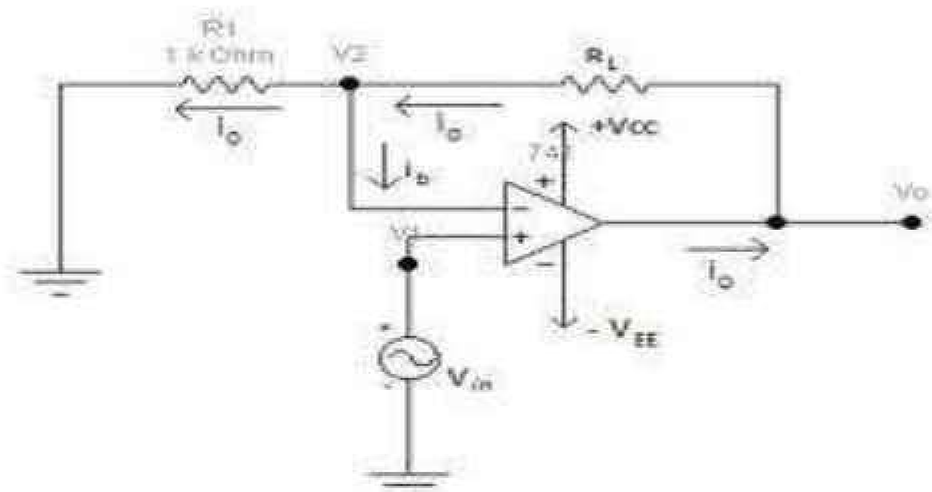
S.NO.	Name of the Equipment	Values	Quantity
1	Resistor	1KΩ, 10kΩ	1
2	Potentiometer	10 kΩ	1
3	Function Generator	1MHz	1
4	IC 741 OP-AMP		1
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

Theory: In the circuit shown in figure in which load R_L is floating. Since voltage at node 'a' is v_i, therefore,

$$i_L = \frac{v_i}{R1}$$

That is the input voltage v_i is converted into an output current of $\frac{v_i}{R_1}$. It may be seen that the same current flows through the signal source and load, therefore signal source should be capable of providing this load current.

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in figure.
2. Connect a 10kΩ load resistor at the output pin number 6.
3. Connect an ammeter in series with R_L to measure the load current.

Observation Table:

Input Voltage (Volts)	Output Current (mA)

Result & Discussion: The graph between input voltage and output current is drawn and verified in linear range.

Experiment Number – 9

FUNCTION GENERATOR USING OP AMPS

AIM: To generate triangular and square wave forms and to determine the time period of the waveforms.

APPARATUS:

S.NO.	Name of the Equipment	Values	Quantity
1	Op-Amp IC 741		2
2	Resistor	10 KΩ,150kΩ,1.5kΩ,1MΩ,8.2kΩ	1
3	Capacitors	10nF, 0.1μF, 0.01μF	1
4	Zener diodes	6.2V	2
5	CRO	20 MHz	1
6	Bread Board		1
7	Connecting Wires and Probes		

THEORY:

The function generator consists of a comparator U1 and an integrator A2.The comparator U2 compares the voltage at point P continuously with the inverting input i.e., at zero volts. When voltage at P goes slightly below or above zero volts, the output of U1 is at the negative or positive saturation level, respectively. To illustrate the circuit operation let us set the output of U1 at positive saturation +Vsat (approximately +Vcc). This +Vsat is an input to the integrator U2. The output of U2, therefore will be a negative going ramp. Thus, one end of the voltage divider R2-R3 is the positive saturation voltage +Vast of U1 and the other is the negative going ramp of U2. When the negative going ramp attains a certain value −Vramp, point p is slightly below zero valts; hence the output of U1 will switch from positive saturation to negative saturation −Vsat (approximately −Vcc). This means that the output of U2 will now stop going negatively and will begin to go positively. The output of U2 will continue to increase until it reaches +Vramp. At this time the point P is slightly above zero volts. The sequence then repeats. The frequencies of the square are a function of the d.c supply voltage. Desired amplitude can be obtained by using approximate zeners at the output of U1.

THEORETICAL VALUES: Time period, $T = 4R_5C\,(R_3+R_4)/\,(R_1+R_2)$ = 0.492 msec.

Positive peak ramp = $V_ZR_5/\,(R_1+R_2)$ = 0.05 volts.

PRACTICAL VALUES:

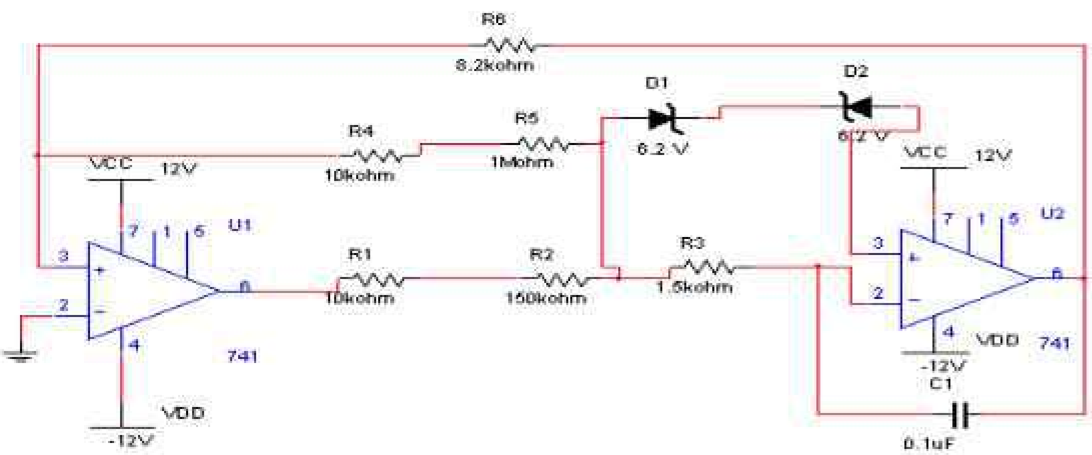
Time periods of triangular wave=

Time periods of square wave=

Positive peak ramp=

Voltage of square wave=

CIRCUIT DIAGRAM:



PROCEDURE:

1. The circuit is connected as shown in the figure.

2. The output of the comparator U1 is connected to the CRO through chennal1, to generate a square wave.

3. The output of the comparator U2 is connected to the CRO through chennal2, to generate a triangular wave.

4. The time periods of the square wave and triangular waves are noted and they are found to be equal.

PRECAUTIONS:

1. Make null adjustment before applying the input signal.

2. Maintain proper Vcc levels.

RESULT: The theoretical and practical values of time periods are found to be equal.

Experiment Number –10

4 BIT DAC USING OP AMP

AIM: To construct and study digital to analog converter circuit.

APPARATUS:

S.NO.	Name of the Equipment	Values	Quantity
1	Op-Amp IC 741		2
2	Resistors	1 KΩ,2kΩ,4kΩ,8kΩ,10kΩ	5 each
3	Multimeter		
4	CRO	20 MHz	1
5	IC Bread Board Trainer		1
6	Connecting Wires and Probes		

Theory: A digital to analog converter is used when a binary output from a digital system must be converted to equivalent analog voltage or current. A DAC converter uses an op-amp and binary weighted resistors or R-2r ladder resistors.
In binary weighted resistors method are used. This can be avoided by using R-2R ladder type DAC where only 2 values of resistors are required .The binary inputs are simulated by switches B0-B3 and output is proportional to the binary inputs. Binary inputs can be high (+5V) or low (0V).

PROCEDURE:

1. Connections are made as per circuit diagram.

2. Pin2 is connected to resistor 1MΩand ground.

3. +Vcc are available at Pin7 and –Vcc is applied at Pin4.

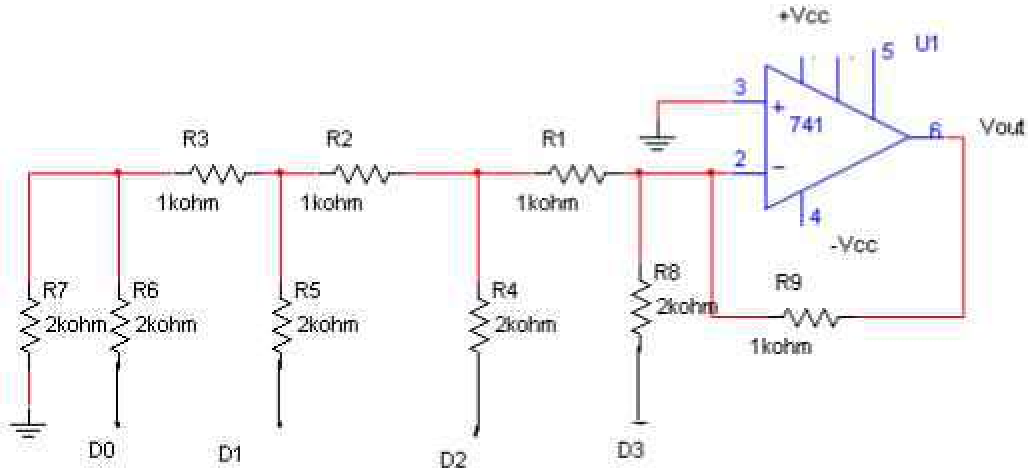
4. Output is taken between pin6 and ground

5. Voltage at each bit (vr) is found at bits b0, b1, b2, b3.

6. Pin3 of op amp is connected to resistor 1kΩ and is given to b3 (MSB).

7. A resistor of 2kΩ is connected between pin2 and pin 6 of op amp.

CIRCUIT DIAGRAM:



Observation:

D_3	D_2	D_1	D_0	Analog Output	
				Theoretical	Practical

RESULT: Thus digital to analog converter is constructed and studied.