Exp.No.1.13

Liquid Lens

Refractive index of a liquid and material of the lens with mercury

Aim: To determine the refractive index of a given liquid and the material of a lens by forming a liquid lens and by using mercury to find the radius of curvature of the lens.

Apparatus: A convex lens of focal length 10 or 15 cm, given liquid, a plane mirror, a pointer (a knitting needle or pin fixed on an eraser) arranged on a retort stand, mercury in a dish, scale, etc.

Theory: The relationship between the focal length, radii of curvature and the refractive index of a lens is given by the lens maker's formula,

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

where, 'f' is the focal length, R_1 and R_2 are the radii of curvature of the lens and μ is the refractive index of the material of the lens. Applying sign convention R_1 is positive and R_2 is negative. Thus eqn.1 becomes,

$$\frac{1}{f} = (\mu-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right) \quad (2)$$

$$= (\mu-1)\left(\frac{R_1+R_2}{R_1R_2}\right)$$

i.e. $$\mu-1 = \frac{R_1R_2}{f(R_1+R_2)}$$

Refractive index of the lens, $$\mu = 1+\frac{R_1R_2}{f(R_1+R_2)} \quad (3)$$

The radius of curvature is determined by Boy's method. When the image is formed side by side of the object by the reflected light from the corresponding concave surface, the radius of curvature is given by,

$$R = \frac{fd}{f-d} \quad (4)$$

where, d is the distance between the lens and the object when the reflected image is formed side by side of the object and f is the focal length of the lens.

If a plano-concave liquid lens is formed in between the first face of the lens and a plane mirror, as shown in fig.b, the radius of curvature of its upper side is $R = -R_1$ and that of the second face is infinity. Then for the liquid lens eqn.1 becomes,

$$\frac{1}{f_l} = (\mu_l-1)\left(-\frac{1}{R_1}-\frac{1}{\infty}\right)$$

$$\mu_l-1 = -\frac{R_1}{f_l}$$

$$\therefore \qquad \mu_l = 1 - \frac{R_1}{f_l} \qquad (5)$$

where, R_1 is the radius of curvature of that face of the lens in contact with the liquid and f_l is the focal length of the liquid lens. In experiments we usually find out the focal length of the combination of lens and the liquid lens. If it is F, we can write,

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f_l} \qquad (6)$$

$$f_l = \frac{Ff}{f - F} \qquad (7)$$

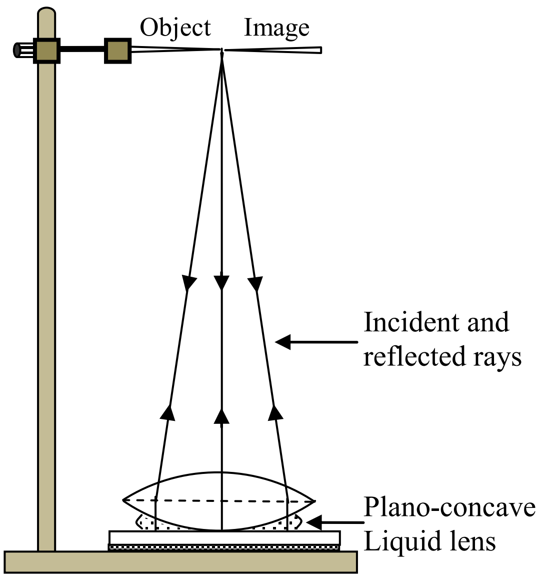


Fig.b: Lens and liquid lens combination

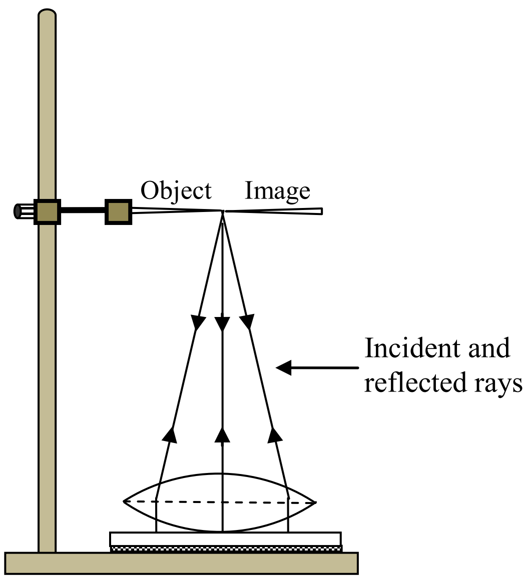


Fig.a: Lens alone

Procedure

To determine the focal length of the convex lens:

A plane mirror is placed horizontally on the base of a retort stand as shown in fig.a. A convex lens of 10 or 15 cm is placed on the mirror strip with its marked face is in contact with the mirror. The pointer (object) is arranged above the lens as shown in fig.a. Looking from vertically above with one eye closed, the lens and mirror arrangement is adjusted so that the tip of the object and the tip of the image coincide. Then looking from above, move your head forward and backward (or left and right). If the image gets separated from the object, the pointer is slowly lowered or raised till the image and object does not get separated when you move your head forward or backward. There is only one position of the pointer for the given lens at which the object and the image move together without parallax when you move your head forward or backward. At this position the object is at the principal focus of the lens and the image has the same size as that of the object.

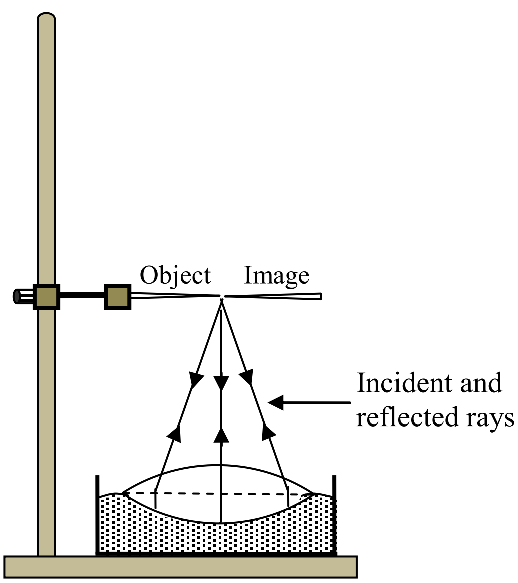


Fig.c: Lens floating in mercury

The distances of the pointer from the top of the lens and the plane mirror (bottom of the lens) are measured. Their average gives the focal length of the lens. Repeat the entire process two or three times and the mean value of 'f' is determined.

To determine the focal length F of the combination of lens and the liquid lens

The convex lens is removed. Two or three drops of liquid are placed on the mirror. Then the convex lens is placed on the liquid drops with its marked face in contact with the mirror. Now a plano-concave liquid lens is formed in between the convex lens and the plane mirror as shown in fig.b. The radius of curvature of its curved face is same as that of the marked face of the convex lens. The average focal length F of the combination is determined as described in the case of convex lens alone. The focal length of the liquid lens f_l is calculated using eqn.7.

To determine the radius of curvature of the marked face and the other face using mercury

The radii of curvature of the convex lens are determined by Boy's method. The method is as follows. The convex lens is floated in mercury, contained in a dish, with the marked face of the lens in contact with mercury. The position of the pointer for which the image is seen without parallax is determined as described in the case of convex lens alone. The height of the pointer from the top of the lens is measured. Adding to it half the thickness of the lens (obtained in the previous cases) we get the distance 'd'. Using 'd' in eqn.4 we get the radius of curvature of the marked face of the lens. By similar method the radius of curvature of the other face of the lens also is determined. The refractive index of the material of the lens is calculated using eqn.3 and the refractive index of the liquid by the eqn.5.

- When looking above you may see the image of the tip of the retort stand. So make sure that you are viewing the image of the pointer. We can identify the image of the pointer by moving the pointer to and fro sidewise slightly. If the image also moves you can identify it.

Observation and tabulation

To determine the focal length of the convex lens

Trial No.	Distance of the pointer from the top of the convex lens in cm.	Distance of the pointer from the surface of the plane mirror in cm.	Focal length of the convex lens 'f' in cm
1			
2			
3			

Mean ………………

Focal length of the convex lens, f = …….. cm = …….. m

To determine the focal length of the combination of convex lens and liquid lens

Trial No.	Distance of the pointer from the top of the convex lens in cm.	Distance of the pointer from the surface of the plane mirror in cm.	Focal length of the combination of lens and liquid lens 'F' in cm
1			
2			
3			

Mean ………………

Focal length of the combination of convex lens and liquid lens,

$F = \ldots\ldots\text{ cm} = \ldots\ldots\text{ m}$

Focal length of liquid lens, $f_l = \dfrac{Ff}{f-F} = \ldots\ldots\text{ cm} = \ldots\ldots\text{ m}$

To determine the radii of curvature of the convex lens

	Trial No.	Distance of the pointer from the top of the convex lens in cm.	Half the thickness of the lens in cm.	'd' cm	Mean 'd' cm
Marked face of the lens in contact with mercury	1				
	2				
	3				
Other face in contact with mercury	1				
	2				
	3				

Radius of curvature of the marked face of the lens, $R_1 = \dfrac{fd}{f-d} = \ldots\ldots\text{ cm} = \ldots\text{ m}$

Radius of curvature of the other face of the lens, $R_2 = \dfrac{fd}{f-d} = \ldots\ldots\text{ cm} = \ldots\text{ m}$

Refractive index of the material of the lens, $\mu = 1 + \dfrac{R_1R_2}{f(R_1+R_2)} = \ldots\ldots$

$= \ldots\ldots$

Radius of curvature of the liquid lens (radius of curvature of marked face of the lens)

$R_1 = \ldots\ldots\text{ cm} = \ldots\ldots\text{ m}$

Refractive index of the liquid, $\mu_l = 1 - \dfrac{R_1}{f_l} = \ldots\ldots$

$= \ldots\ldots$

Result

Refractive index of the material of the lens = ………

Refractive index of the given liquid = ………

*Standard data

Material	Refractive index
Water	1.33
Glycerin (glycerol)	1.473
Turpentine	1.48
Olive oil	1.48
Glass (crown)	1.48~1.61
Glass (flint)	1.53~1.96

Exp.No.1.14

Liquid Lens

Refractive index of a liquid and material of the lens with another liquid of known refractive index

Aim: To determine the refractive index of a liquid and the material of a lens by forming liquid lenses with the given liquid and another liquid of known refractive index.

Apparatus: A convex lens of focal length 10 or 15 cm, given liquid, liquid of known refractive index (water), a plane mirror, a pointer (a knitting needle or pin fixed on an eraser) arranged on a retort stand, scale, etc.

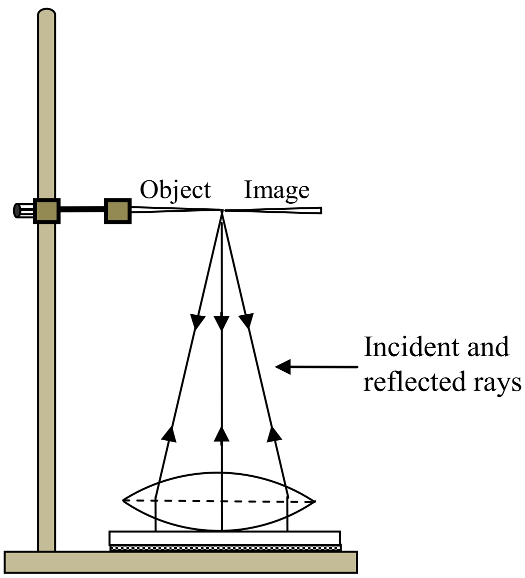


Fig.a: Lens alone

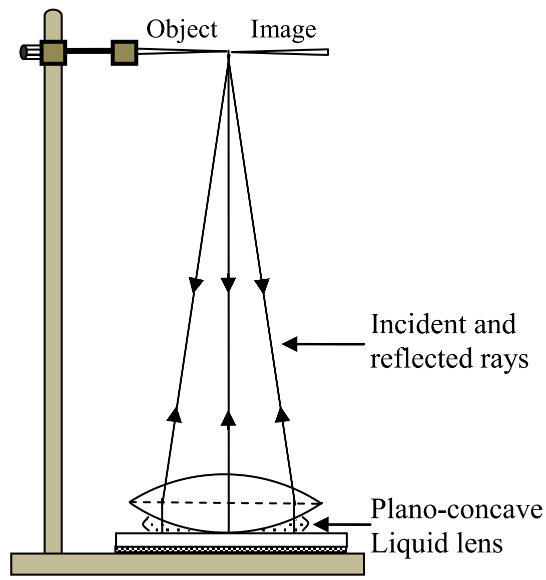


Fig.b: Lens and liquid lens combination

Theory: The relationship between the focal length, radii of curvature and the refractive index of a lens is given by the lens maker's formula,

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

where, 'f' is the focal length, R_1 and R_2 are the radii of curvature of the lens and μ is the refractive index of the material of the lens. Applying sign convention R_1 is positive and R_2 is negative. Thus eqn.1 becomes,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad (2)$$

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

i.e. $$\mu - 1 = \frac{R_1 R_2}{f(R_1 + R_2)}$$

Refractive index of the lens, $$\mu = 1+\frac{R_1R_2}{f(R_1+R_2)} \tag{3}$$

The radius of curvature is determined by Boy's method. When the image is formed side by side of the object by the reflected light from the corresponding concave surface, the radius of curvature is given by,

$$R = \frac{fd}{f-d} \tag{4}$$

where, d is the distance between the lens and the object when the reflected image is formed side by side of the object and f is the focal length of the lens.

If a plano-concave lens is formed in between the first face of the lens and a plane mirror, as shown in fig.b, the radius of curvature of its upper side is $R = -R_1$ and that of the second face is infinity. Then for the liquid lens eqn.1 becomes,

$$\frac{1}{f_l} = (\mu_l - 1)\left(-\frac{1}{R_1} - \frac{1}{\infty}\right)$$

$$\mu_l - 1 = -\frac{R_1}{f_l}$$

$$\therefore \quad \mu_l = 1 - \frac{R_1}{f_l} \tag{5}$$

where, R_1 is the radius of curvature of that face of the lens in contact with the liquid and f_l is the focal length of the liquid lens. In experiments we usually find out the focal length of the combination of lens and the liquid lens. If it is F, we can write,

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f_l} \tag{6}$$

$$f_l = \frac{Ff}{f-F} \tag{7}$$

In this experiment we use a liquid of known refractive index, say water, to find out the radii of curvature of the lens. If the first face of the convex lens is in contact with water, eqns.5 and 7 become,

$$\mu_w = 1 - \frac{R_1}{f_{w1}}$$

$$1.333 = 1 - \frac{R_1}{f_{w1}}$$

$$\therefore \quad R_1 = -0.333 f_{w1} \tag{8a}$$

where, $$f_{w1} = \frac{F_{w1} f}{f - F_{w1}} \tag{9a}$$

When the second face of the lens is in contact with water,

$$R_2 = -0.333 f_{w2} \tag{8b}$$

where,
$$f_{w2} = \frac{F_{w2} f}{f - F_{w2}} \tag{9b}$$

F_{w1} and F_{w2} are the focal lengths of the combination of convex lens and water lens when the first face and the second face, respectively, are in contact with water.

Procedure: Find out the focal length 'f' of the convex lens, the focal length 'F_{w1}' of the combination of convex lens and water lens when the first face of the convex lens in contact with water, the focal length 'F_{w2}' of the combination of convex lens and water lens when the second face of the convex lens in contact with water and the focal length 'F' of the combination of convex lens and the liquid lens (with first face in contact with the liquid) as described in exp.No.13. Calculate R_1, R_2, f_{w1}, f_{w2}, f_l, μ and μ_l using eqns.8a, 8b, 9a, 9b, 7, 3 and 5 respectively.

Observation and tabulation

To determine the focal length of the convex lens

Trial No.	Distance of the pointer from the top of the convex lens in cm.	Distance of the pointer from the surface of the plane mirror in cm.	Focal length of the convex lens 'f' in cm
1			
2			
3			

Mean ………………

Focal length of the convex lens, f = …….. cm = …….. m

To determine the focal length of the combination of convex lens and water lens with first face in contact with water

Trial No.	Distance of the pointer from the top of the convex lens in cm.	Distance of the pointer from the surface of the plane mirror in cm.	Focal length of the combination of lens and water lens 'F_{w1}' in cm
1			
2			
3			

Mean ………………

Focal length of the combination of convex lens and water lens,

F_{w1} = …….. cm = …….. m

Focal length of water lens with first face in contact with water,

$$f_{w1} = \frac{F_{w1} f}{f - F_{w1}} = \text{…… cm} = \text{…….. m}$$

To determine the focal length of the combination of convex lens and water lens with second face in contact with water

Trial No.	Distance of the pointer from the top of the convex lens in cm.	Distance of the pointer from the surface of the plane mirror in cm.	Focal length of the combination of lens and water lens 'F_{w2}' in cm
1			
2			
3			

Mean ………………

Focal length of the combination of convex lens and water lens,

F_{w2} = …….. cm = …….. m

Focal length of water lens with second face in contact with water,

$$f_{w2} = \frac{F_{w2}f}{f - F_{w2}} = \text{…… cm} = \text{…….. m}$$

To determine the focal length of the combination of convex lens and liquid lens

Trial No.	Distance of the pointer from the top of the convex lens in cm.	Distance of the pointer from the surface of the plane mirror in cm.	Focal length of the combination of lens and liquid lens 'F' in cm
1			
2			
3			

Mean ………………

Focal length of the combination of convex lens and liquid lens,

F = …….. cm = …….. m

Focal length of liquid lens, $f_l = \frac{Ff}{f - F}$ = …… cm = …….. m

Radius of curvature of the first face of the convex lens, $R_1 = -0.333f_{w1}$ = …… cm

Radius of curvature of the second face of the convex lens, $R_2 = -0.333f_{w2}$ = …… cm

Refractive index of the convex lens, $\mu = 1 + \frac{R_1R_2}{f(R_1 + R_2)}$ = ……. = ……..

Refractive index of the given liquid, $\mu_l = 1 - \frac{R_1}{f_l}$ = …………… = ……..

Result

Refractive index of the material of the lens = ……….

Refractive index of the given liquid = ……….

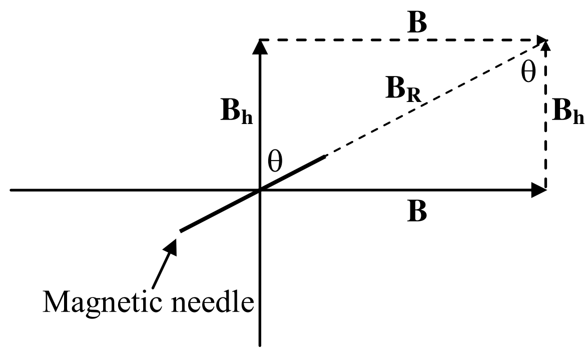
***Standard data**: Refer exp.No1.13

Exp.No.1.15
Deflection Magnetometer- Tan A and Tan B

Aim: To find the moment of a bar magnet using deflection magnetometer in Tan A position and Tan B position.

Apparatus: A deflection magnetometer consisting of a rectangular wooden frame with a compass box at the middle, given bar magnet, etc.

Theory: The principle of the deflection magnetometer is that a magnetic needle will align itself in the direction of the resultant magnetic field. Let **B** and $\mathbf{B_h}$ are two mutually perpendicular fields. The direction of their resultant field is given by,

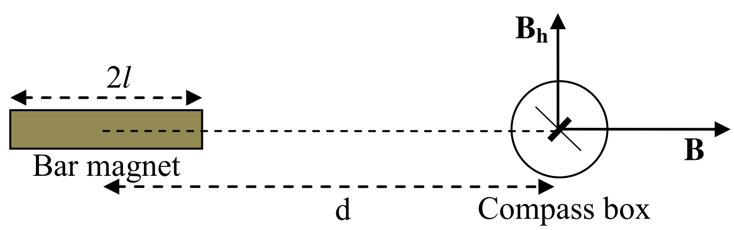


$$\tan\theta = \frac{B}{B_h}$$

Or, $$B = B_h \tan\theta \qquad (1)$$

where, θ is the angle made by the resultant field with the field $\mathbf{B_h}$. In the deflection magnetometer experiment $\mathbf{B_h}$ is the horizontal component of the earth's magnetic field and **B** is the magnetic field produced by a bar magnet.

Tan A position: In this case the bar magnet is placed on the deflection magnetometer such that the axial field (in the horizontal plane) produced by it is perpendicular to the horizontal component of earth's magnetic field. Then the magnetic needle of the compass box aligns in the direction of the resultant magnetic field. Let θ be the deflection produced in the compass box, when the bar magnet of moment 'm' and length $2l$ is placed at a distance 'd' from the centre of the compass box. Then eqn.1 becomes,

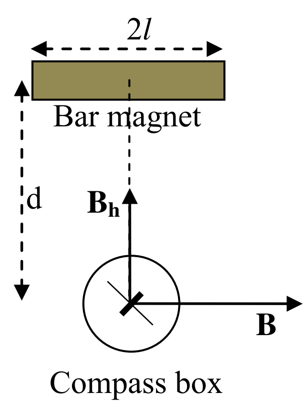


$$\frac{\mu_0}{4\pi}\frac{2md}{\left(d^2 - l^2\right)^2} = B_h \tan\theta$$

$$m = \frac{4\pi}{\mu_0}\frac{\left(d^2 - l^2\right)^2}{2d} B_h \tan\theta \qquad (2)$$

where, $\mu_0 = 4\pi\times10^{-7}\ \mathrm{NA^{-2}}$ is the permeability of the free space.

Tan B position: In this arrangement of the deflection magnetometer, the bar magnet is placed such the equatorial field (in the horizontal plane) produced by it is perpendicular to the horizontal component of earth's magnetic field. If θ is the deflection produced in this case,



$$\frac{\mu_0}{4\pi}\frac{m}{\left(d^2 + l^2\right)^{3/2}} = B_h \tan\theta$$

$$m = \frac{4\pi}{\mu_0}\left(d^2 + l^2\right)^{3/2} B_h \tan\theta \qquad (3)$$

Procedure:

The deflection magnetometer consists of a rectangular wooden frame with a compass box at the centre of it. A small magnetic needle is pivoted at the centre of the compass box. An aluminum pointer is attached perpendicular to the magnetic needle. A scale is fixed on the wooden frame. The circular scale in the compass box is graduated in degrees. It has four quadrants with two 0 and two 90 markings.

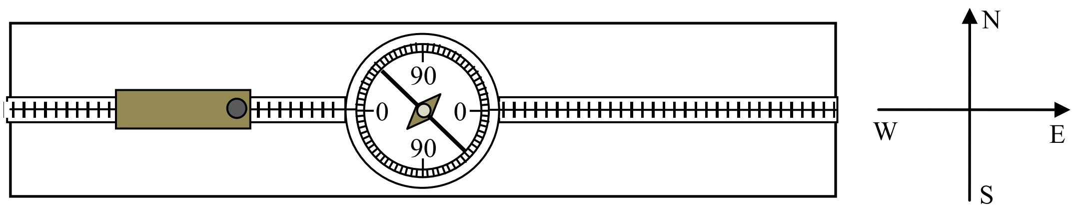


Fig.a: Tan A position

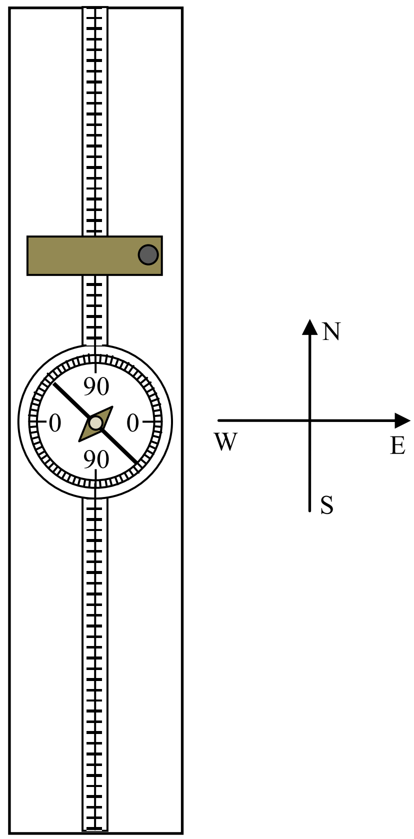


Fig.b: Tan B position

Tan A position: The deflection magnetometer is placed on a table or on a wooden stool (It is easy to rotate the magnetometer and to take readings of the compass box if it is placed on a stool). Remove all magnets and magnetic materials from the vicinity of the magnetometer. In order to set the deflection magnetometer in the Tan A position, the compass box alone is rotated such that the 0-0 line is along the axis of the magnetometer as shown in the fig.a. Then the magnetometer as a whole is rotated till the aluminum pointer reads 0-0. Now the arms of the magnetometer are in the west-east direction and the compass needle is along the south-North direction.

Now the given bar magnet, whose moment is to be determined, is placed on one of the arms of the magnetometer at a distance ‘d’ from the centre of the compass box with its axis coincides with the axis of the magnetometer as shown in fig.a (‘d’ is the distance between the centre of the magnet to the centre of the compass box). Take two readings corresponding to the two ends of the aluminum pointer. Now the magnet is reversed at this position without changing ‘d’ and two more deflections are noted. Then the magnet is taken to the other arm of the magnetometer and is placed at the same distance ‘d’ and the corresponding two deflections are noted. The magnet is reversed there and two more readings are noted. The average of these eight readings gives the deflection ‘θ’ corresponding to the distance ‘d’. The entire experiment is repeated for other distances. Measure the length ($L = 2l$) of the magnet using a vernier calipers. The moment of the magnet is calculated using eqn.2.

Tan B position: In order to set the deflection magnetometer in the Tan B position, the compass box alone is rotated such that the 90-90 line is along the axis of the magnetometer as shown in the fig.b. Then the magnetometer as a whole is rotated till the aluminum pointer reads 0-0. Now the arms of the magnetometer are in the south-north direction and the compass needle is along the west-east direction. In this case the bar magnet is to be placed such that its equatorial field at the centre of the compass box is along the west-east direction as shown in the fig.b. Find out the eight deflections of the pointer as described in the case of tan A position and the average θ is calculated. The moment of the magnet is calculated using eqn.3.

- 'd' is the distance between the centre of the magnet to the centre of the compass box.
- The distance 'd' is such that the deflection is in between 30° and 60°.

Observation and tabulation

To determine the length of the magnet using vernier calipers

Value of one main scale division (1 m s d) = ………. cm

Number of divisions on the vernier scale, x = ……….

$$\text{Least count,}\quad L.C = \frac{\text{Value of one main scale division}}{\text{Number of divisions on the vernier scale}} = \frac{1\text{ m s d}}{x} = \ldots\ldots\text{ cm}$$

Trial No.	M S R cm	V S R	L = M S R + V S R×L C cm	Mean length L cm

Length of the magnet L = …….. cm = ……… m

Half the length of the magnet, l = L/2 = ……… m

Tan A position

Distance 'd' m	Deflections in degree								Mean θ degree	Moment 'm' Am^2
	1	2	3	4	5	6	7	8		

Mean ………….

Tan B position

Distance 'd' m	Deflections in degree								Mean θ degree	Moment 'm' Am^2
	1	2	3	4	5	6	7	8		

Mean ………….

Result

Moment of the magnet using Tan A position, m = ………. Am^2

Moment of the magnet using Tan B position, m = ………. Am^2

*Standard data

Permeability of the free space, $\mu_0 = 4\pi\times10^{-7}\ NA^{-2}$

Horizontal component of earth's magnetic field $B_h = 0.38\times10^{-4}$ T

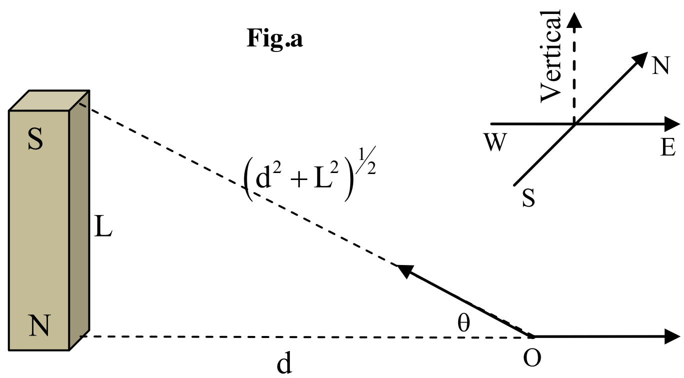
Exp.No.1.16
Deflection Magnetometer-Tan C position

Aim: To determine the pole strength and hence the moment of a bar magnet in Tan C position using a deflection magnetometer.

Apparatus: Deflection magnetometer, the given bar magnet, etc.

Theory: Even though the Hilbert model of magnetic dipole is unphysical we can use it to calculate the field due to a bar magnet. According to this model a magnet consists of two magnetic poles (a north pole and a south pole) of pole strength 'P'. In the Tan C arrangement the horizontal components of the fields due the two poles are in the west-east direction.

Fig.a



Magnetic field at O due to the north pole, $B_N = \frac{\mu_0}{4\pi}\frac{P}{d^2}$ (West-east direction) (1)

Magnetic field at O due to the south pole, $B_S = \frac{\mu_0}{4\pi}\frac{P}{(d^2+L^2)}$ (2)

Horizontal component of the field due to the south pole, $B_{Sh} = B_S \cos\theta$

$$= \frac{\mu_0}{4\pi}\frac{P}{(d^2+L^2)}\frac{d}{(d^2+L^2)^{1/2}} = \frac{\mu_0}{4\pi}\frac{Pd}{(d^2+L^2)^{3/2}} \quad (3)$$

$\therefore$ Resultant horizontal field due to the bar magnet, $B = \frac{\mu_0}{4\pi}\frac{P}{d^2} - \frac{\mu_0}{4\pi}\frac{Pd}{(d^2+L^2)^{3/2}}$

$$= \frac{\mu_0 P}{4\pi}\left[\frac{1}{d^2} - \frac{d}{(d^2+L^2)^{3/2}}\right] \quad (4)$$

This field is in the west-east direction. In the Tan C position, we arrange the deflection magnetometer in the Tan A position. Therefore the remaining theory is same as the case of Tan A position. If the compass needle makes a deflection θ, we can write,

$$B = B_h \tan\theta$$

$$\frac{\mu_0 P}{4\pi}\left[\frac{1}{d^2} - \frac{d}{(d^2+L^2)^{3/2}}\right] = B_h \tan\theta$$

$$P = \frac{4\pi}{\mu_0}\frac{B_h \tan\theta}{\left[\frac{1}{d^2} - \frac{d}{(d^2+L^2)^{3/2}}\right]} \quad (5)$$

Dipole moment of the magnet, $m = PL$ (6)

Procedure

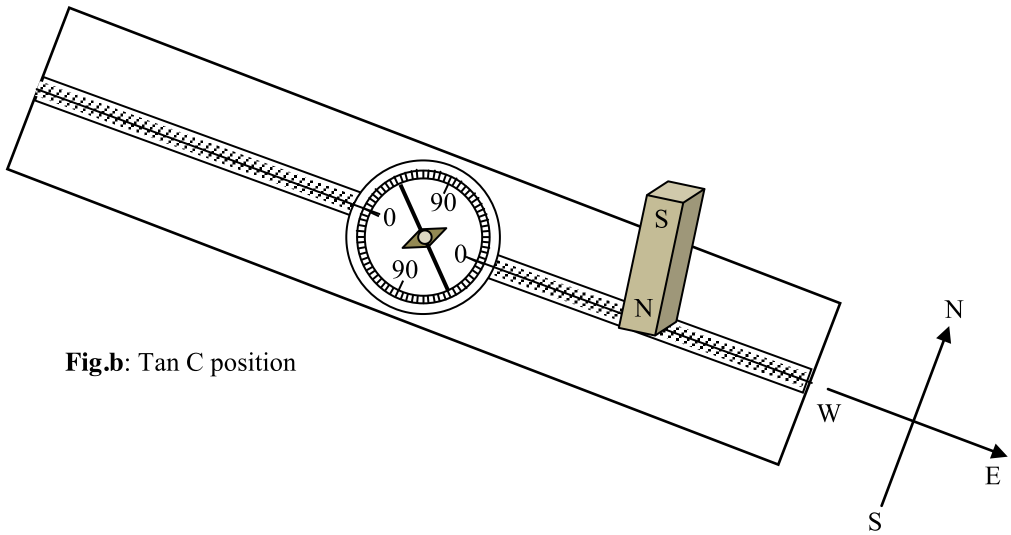


Fig.b: Tan C position

The deflection magnetometer is arranged in the Tan A position. The given bar magnet is placed vertically on one of the arms of the deflection magnetometer at a distance ‘d’ from the centre of the compass box as shown in the fig.b. Take two readings corresponding to the two ends of the aluminum pointer. Now the magnet is reversed at this position without changing ‘d’ and two more deflections are noted. Then the magnet is taken to the other arm of the magnetometer and is placed at the same distance ‘d’ and the corresponding two deflections are noted. The magnet is reversed there and two more readings are noted. The average of these eight readings gives the deflection ‘θ’ corresponding to the distance ‘d’. The entire experiment is repeated for other distances. Measure the length, L, of the magnet using a vernier calipers. The pole strength of the magnet is calculated using eqn.5 and the dipole moment by eqn.6.

Observation and tabulation

To determine the length of the magnet using vernier calipers

Value of one main scale division (1 m s d) = ………. cm

Number of divisions on the vernier scale, x = ……….

$$\text{Least count,} \quad L.C = \frac{\text{Value of one main scale division}}{\text{Number of divisions on the vernier scale}} = \frac{1 \text{ m s d}}{x} = \ldots\ldots \text{ cm}$$

Trial No.	M S R cm	V S R	D = M S R + V S R×L C cm	Mean length L cm

Tan C position

Distance 'd' m	Deflections in degree								Mean θ degree	Pole strength 'P' A.m
	1	2	3	4	5	6	7	8		

Mean ………….

Dipole moment of the magnet, $m = PL =$ …….. $A.m^2$

Result

Pole strength of the given bar magnet = ………. A.m

Dipole moment of the given bar magnet = ………. $A.m^2$

*Standard data

Permeability of the free space, $\mu_0 = 4\pi\times10^{-7}\ NA^{-2}$

Horizontal component of earth's magnetic field $B_h = 0.38\times10^{-4}$ T

Exp.No.1.17

Deflection Magnetometer & Box type vibration magnetometer- Determination of m and B_h

Aim: To determine the dipole moment 'm' and the horizontal component of earth's magnetic field 'B_h' using deflection magnetometer and box type vibration magnetometer.

Apparatus: A deflection magnetometer, a box type vibration magnetometer, given magnet, etc.

Theory

(a) Deflection magnetometer: We have discussed the theory of deflection magnetometer in exp.No.15. When the deflection magnetometer is arranged in the Tan A position,

$$\frac{\mu_0}{4\pi}\frac{2md}{\left(d^2-l^2\right)^2} = B_h \tan\theta$$

$$\frac{m}{B_h} = \frac{4\pi}{\mu_0}\frac{\left(d^2-l^2\right)^2}{2d}\tan\theta \qquad (1)$$

where, 'm' is the dipole moment of the given bar magnet, B_h is the horizontal component of earth's magnetic field, μ_0 is the permeability of the free space, 'd' is the distance between the centre of the magnet and the centre of the compass box, *'l'* is the half the length of the magnet and θ is the average deflection made by the compass needle.

When the magnetometer is arranged in the Tan B position,

$$\frac{\mu_0}{4\pi}\frac{m}{\left(d^2+l^2\right)^{3/2}} = B_h \tan\theta$$

$$\frac{m}{B_h} = \frac{4\pi}{\mu_0}\left(d^2+l^2\right)^{3/2}\tan\theta \qquad (2)$$

(b) Box type vibration magnetometer: When a magnet suspended in a magnetic field of strength 'B' is slightly tilted to one side and is released, it will execute simple harmonic motion with a time period,

$$T = 2\pi\sqrt{\frac{I}{mB}} \qquad (3)$$

where, I is the moment of inertia of the suspended magnet. For a bar magnet of length L and breadth 'b', the moment of inertia about an axis perpendicular to its length and passing through its centre is,

$$I = M\left(\frac{L^2+b^2}{12}\right) \qquad (4)$$

where, M is the mass of the bar magnet. If the bar magnet is suspended in the earth's magnetic field eqn.3 becomes,

$$T = 2\pi\sqrt{\frac{I}{mB_h}}$$

$$mB_h = \frac{4\pi^2 I}{T^2} \qquad (5)$$

Let $mB_h = x$ and $\frac{m}{B_h} = y$, then,

$$xy = m^2$$

$\therefore$ Moment of the magnet, $m = \sqrt{xy}$ (6)

$$\frac{x}{y} = B_h^2$$

Box type vibration magnetometer

$\therefore$ Horizontal component of earth's magnetic field, $B_h = \sqrt{\frac{x}{y}}$ (7)

Procedure

To find $\frac{m}{B_h}$ using deflection magnetometer: As described in Exp.No.15 $\frac{m}{B_h}$ is determined.

To find mB_h using box type vibration magnetometer: The magnetic meridian is drawn on the table using a compass box. This can be done as follows. The compass box is placed on the table and is rotated till the aluminum pointer reads 0-0. Then put chalk marks on the table against the 90-90 markings. The direction of the magnetic meridian is obtained by joining the chalk marks. The box type vibration magnetometer is arranged with its length parallel to the magnetic meridian. The given bar magnet is then suspended horizontally and parallel to the magnetic meridian with its north pole pointing geographic north. The suspended magnet is set into oscillation by bringing another magnet near to it. The time taken for 10 oscillations is determined twice and the mean period of oscillation 'T' is found out.

Mass of the magnet is determined using a common balance. The length and breadth of the magnet are measured using a vernier calipers. Using eqns.1, 2, 4, 5, 6 and 7 m and B_h are calculated.

- The suspended magnet is set into oscillation by bringing another magnet near the north pole or south pole of it in the perpendicular direction and is taken away.
- Remember that the earth's magnetic field is from geographic south to geographic north. Geographic south is magnetically north and geographic north is magnetically south. That is why a freely suspended magnet aligns itself in the magnetic meridian.

Observation and tabulation

To find mass 'M' of the magnet

Load in the pans of the balance		Turning points		Resting point	Sensibility	Correct weight
left	Right (gm)	Left (3)	Right (2)		$S = \frac{0.01}{R_1 \sim R_2}$	$M=W+S(R_1-R_0)$ gm
Nil	Nil			$R_0 = \ldots$		
Magnet	W			$R_1 = \ldots$		
	W + 0.01			$R_2 = \ldots$		

Mass of the magnet, M = ………. gm = ………. kg

To determine the length and breadth of the magnet using vernier calipers

Value of one main scale division (1 m s d) = ………. cm

Number of divisions on the vernier scale, x = ……….

Least count, L. C = $\frac{\text{Value of one main scale division}}{\text{Number of divisions on the vernier scale}} = \frac{1 \text{ m s d}}{x}$ = ……. cm

Trial No.	M S R cm	V S R	L = M S R + V S R×L C cm	Mean length L cm

Length of the magnet L = …….. cm = ……… m

Half the length of the magnet, l = L/2 = ……… m

Trial No.	M S R cm	V S R	b = M S R + V S R×L C cm	Mean breadth b cm

Tan A position

Distance 'd' m	Deflections in degree								Mean θ degree	$y = \frac{m}{B_h} = \frac{4\pi}{\mu_0}\frac{\left(d^2 - l^2\right)^2}{2d}\tan\theta$
	1	2	3	4	5	6	7	8		

Mean ………….

Tan B position

Distance 'd' m	Deflections in degree								Mean θ degree	$y = \frac{m}{B_h} = \frac{4\pi}{\mu_0}\left(d^2 + l^2\right)^{3/2}\tan\theta$
	1	2	3	4	5	6	7	8		

Mean ………….

Mean, $y = \frac{m}{B_h}$ = …………

To find mB_h

Time for 10 oscillations				Period T
1	2	3	Mean	

Moment of inertia of the bar magnet, $I = M\left(\frac{L^2+b^2}{12}\right) = \ldots\ldots\ldots = \ldots\ldots\ldots\ldots$

$x = mB_h = \frac{4\pi^2 I}{T^2} = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots$

Moment of the magnet, $m = \sqrt{xy} = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots$ Am^2

Horizontal component of earth's magnetic field, $B_h = \sqrt{\frac{x}{y}} = \ldots\ldots\ldots\ldots$

$= \ldots\ldots\ldots\ldots$ tesla

Result

Dipole moment of the given bar magnet $m = \ldots\ldots\ldots$ $A.m^2$

Horizontal component of earth's magnetic field, $B_h = \ldots\ldots\ldots\ldots$ T

*Standard data

Permeability of the free space, $\mu_0 = 4\pi\times10^{-7}\ NA^{-2}$

Horizontal component of earth's magnetic field $B_h = 0.38\times10^{-4}$ T

Exp.No.1.18

Searle's Vibration magnetometer-moment and ratio of moments

Aim: To determine the moment of a given bar magnet and compare the moments of two magnets using Searle' vibration magnetometer.

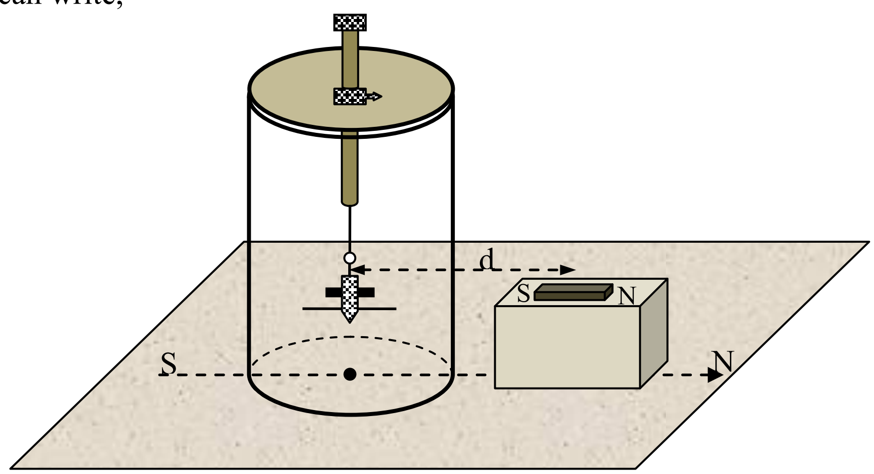
Apparatus: The Searle's vibration magnetometer, given bar magnets, compass box, stop watch, scale, etc.

The Searle's vibration magnetometer consists of a cylindrical glass vessel in which a brass cylinder, on which a magnetic needle and an aluminum pointer are fixed, is suspended by means of a torsionless silk thread as shown in the figure below.

Theory: The oscillations of a magnet of moment 'm' suspended in a magnetic field of strength B is simple harmonic. It can be shown that the time period of oscillation is,

$$T = 2\pi\sqrt{\frac{I}{mB}} \qquad (1)$$

where I is moment of inertia of the suspended magnet. (In this case I is the moment of inertia of the system consisting the brass cylinder, magnetic needle and aluminum pointer). If 'n' is the corresponding frequency, we can write,



$$\frac{1}{n} = 2\pi\sqrt{\frac{I}{mB}}$$

Or, $n^2 \propto B$ (2)

Let n_0 be the frequency of oscillation of the suspended system in the earth's field alone. Then

$$n_0^2 \propto B_h \qquad (3)$$

If a magnet of moment M is placed at a distance 'd' from the suspended magnetic needle such that the net field is given by, $B = B_M + B_h$, the corresponding frequency of oscillation 'n' is given by,

$$n^2 \propto B_M + B_h \qquad (4)$$

Dividing eqn.4 by eqn.3,

$$\frac{n^2}{n_0^2} = \frac{B_M + B_h}{B_h} = \frac{B_M}{B_h} + 1$$

$$\frac{B_M}{B_h} = \frac{n^2}{n_0^2} - 1 = \frac{n^2 - n_0^2}{n_0^2}$$

$$\therefore \quad B_M = B_h\left(\frac{n^2 - n_0^2}{n_0^2}\right) \qquad (5)$$

Since B_M is the axial field due to the bar magnet, we can write,

$$\frac{\mu_0}{4\pi}\frac{2Md}{\left(d^2-l^2\right)^2} = B_h\left(\frac{n^2-n_0^2}{n_0^2}\right)$$

$$\therefore \text{ Moment of the magnet, } M = \frac{4\pi}{\mu_0}\frac{\left(d^2-l^2\right)^2}{2d}\left(\frac{n^2-n_0^2}{n_0^2}\right)B_h \tag{6}$$

Let M_1 and M_2 be the magnetic moments of two magnets and n_1 and n_2 the corresponding frequencies, then the ratio of their magnetic moments is given by,

$$\frac{M_1}{M_2} = \frac{\frac{4\pi}{\mu_0}\frac{\left(d_1^2-l_1^2\right)^2}{2d_1}\left(\frac{n_1^2-n_0^2}{n_0^2}\right)B_h}{\frac{4\pi}{\mu_0}\frac{\left(d_2^2-l_2^2\right)^2}{2d_2}\left(\frac{n_2^2-n_0^2}{n_0^2}\right)B_h} = \frac{\left(d_1^2-l_1^2\right)^2}{\left(d_2^2-l_2^2\right)^2}\left(\frac{d_2}{d_1}\right)\left(\frac{n_1^2-n_0^2}{n_2^2-n_0^2}\right) \tag{7}$$

If the magnets are placed at the same distances, we can write,

$$\frac{M_1}{M_2} = \frac{\left(d^2-l_1^2\right)^2}{\left(d^2-l_2^2\right)^2}\left(\frac{n_1^2-n_0^2}{n_2^2-n_0^2}\right) \tag{8}$$

Procedure: The magnetic meridian is drawn on the table using a compass box as mentioned in exp.No.17. A chalk mark is made on this line. The Searle's vibration magnetometer is placed just over this mark and its compass needle is adjusted to be parallel to the magnetic meridian. The magnetic needle is made to oscillate by bringing a magnet near the vibration magnetometer and is taken away. The time for 10 oscillations of the magnetic needle in the earth's field alone is determined for three times and the average frequency is calculated. Then the given magnet whose moment is to be determined is placed at a distance 'd from the centre of Searle's vibration magnetometer on one of the sides (southern side or northern side) with its north pole pointing geographic north. The magnetic needle of the magnetometer is now set into oscillation by bringing another magnet near it and is taken away. The time for 10 oscillations is determined three times and the average frequency is calculated. The experiment is repeated by placing the magnet on the other side at the same distance. The entire experiment is repeated for at least three distances. Moment of the magnet is calculated using eqn.6.

To compare the ratio of the magnetic moments the entire experiment is repeated for second magnet keeping at the same distances as in the case of the first magnet and the average frequency is calculated. The ratio of the magnetic moments is calculated using eqn.8.

- Magnet should be placed at a height such that the axis of the bar magnet and the axis of the magnetic needle of the vibration magnetometer coincide.
- Magnet should be placed such that its north pole always points towards the geographic north, since in the derivation of the formula it is assumed that the net magnetic field B is $B_M + B_h$.
- To do this experiment one can arrange a deflection magnetometer in the Tan B position with the compass box is replaced by the Searle's vibration magnetometer.
- The suspended magnet is set into oscillation by bringing another magnet near the north pole or south pole of it in the perpendicular direction and is taken away.

Observation and tabulation

To determine the frequency of oscillation n_0 in the earth's field alone

Time for 10 oscillations t seconds				Frequency
1	2	3	Mean t sec	$n_0 = 10/t$ per sec

To determine the frequencies of oscillation with the two magnets

Distance 'd' m	Magnet 1								Magnet 2							
	Time for 10 oscillations t_1 in sec.						Mean t_1 sec	$n_1 = 10/t_1$	Time for 10 oscillations t_2 in sec.						Mean t_2 sec	$n_2 = 10/t_2$
	Southern side			Northern side					Southern side			Northern side				
	1	2	3	1	2	3			1	2	3	1	2	3		

Length of the first magnet, L_1 = …….. cm = ……… m

Half the length of the first magnet, $l_1 = L_1/2$ = ……… m

Length of the second magnet, L_2 = …….. cm = ……… m

Half the length of the second magnet, $l_2 = L_2/2$ = ……… m

Calculation of the moment

'd' in m	n_1 per sec	$m_1 = \frac{4\pi}{\mu_0}\frac{\left(d^2 - l_1^2\right)^2}{2d}\left(\frac{n_1^2 - n_0^2}{n_0^2}\right)B_h$	Mean m_1 Am^2

Calculation of the ratio of the moments

'd' in m	n_1 per sec	n_2 per sec	$\frac{M_1}{M_2} = \frac{\left(d^2 - l_1^2\right)^2}{\left(d^2 - l_2^2\right)^2}\left(\frac{n_1^2 - n_0^2}{n_2^2 - n_0^2}\right)$	Mean $\frac{M_1}{M_2}$

Result

Moment of the first magnet, M_1 = ……… Am^2

Ratio of the magnetic moments, $\frac{M_1}{M_2}$ = ………

Potentiometer

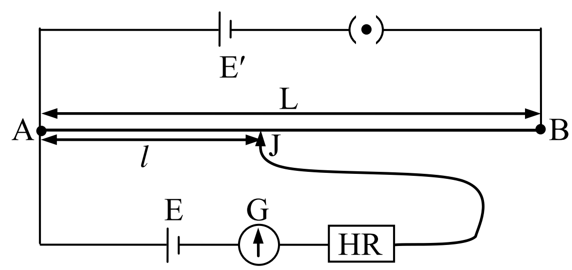
Odd numbered rows from left to right
Even numbered rows from right to left

A potentiometer is a device used for measuring or comparing potential differences. It can also be used to measure any electrical quantity which can be converted into a proportionate DC potential difference.

Potentiometer consists of a uniform wire AB of length 10 m stretched on a wooden board in 10 equal rows as shown in the figure above. For theoretical purpose we show AB as a single line.

Theory of potentiometer

Let a steady current I be passed through the wire AB with the help of a cell of e m f E′. Let ρ be the resistance per unit length of the potentiometer wire and J is a sliding contact. Let AB = L and AJ = l. Then,



Potential difference across AB $= IL\rho$

Potential difference across AJ $= Il\rho$

$$\therefore \quad \frac{\text{PD across AB}}{\text{PD across AJ}} = \frac{IL\rho}{Il\rho} = \frac{L}{l} \qquad (1)$$

$$\therefore \quad \text{PD across AJ} = \left(\frac{\text{PD across AB}}{L}\right)l = \text{PD per unit length} \times \text{length of the wire} \qquad (2)$$

Thus, when a steady current is flowing through the potentiometer wire AB, the PD across any length of the wire is proportional to the length of the wire.

If a DC voltmeter is connected between A and the variable point J it can be seen that the voltmeter registers greater values as the contact maker J moves from A to B.

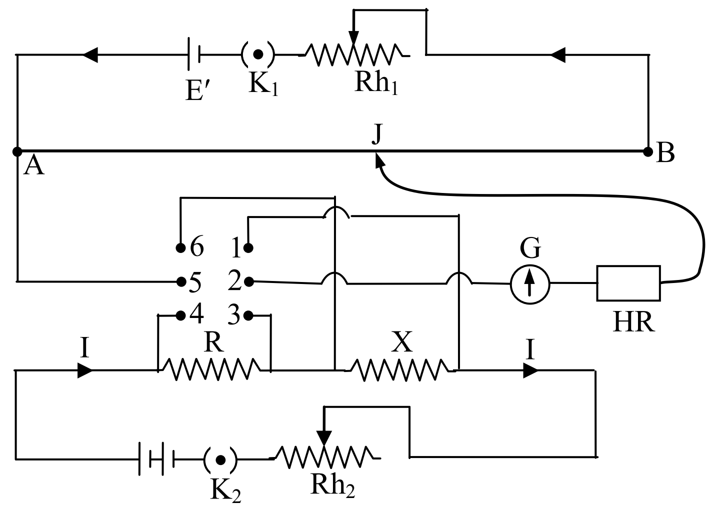
If another cell of e m f equal to PD across AJ is connected between A and J as shown in the figure, no current will flow in the secondary circuit and the galvanometer will show no deflection.

Exp.No.1.19
Potentiometer- Determination of resistance and resistivity

Aim: To determine the resistance of a given wire and hence its resistivity using a potentiometer.

Apparatus: The potentiometer, power supplies, rheostats, standard resistance, resistance wire (unknown resistance), high resistance, galvanometer, six terminal key and ordinary keys etc.

Theory: The steady current flowing through the wire AB by the cell E′ in the primary produces a constant potential difference per unit length. Thus, the potential difference across any length of the wire AJ is proportional to the length AJ. Let I be the steady current flowing through the secondary circuit containing the known resistance R and the unknown resistance X. Let l_R and l_X, respectively, be the balancing lengths corresponding to the voltage across the R and X. Then by the principle of potentiometer,



$$IR \propto l_R \quad (1)$$

$$IX \propto l_X \quad (2)$$

Dividing eqn.2 by eqn.1, we get,

$$\frac{X}{R} = \frac{l_X}{l_R}$$

$$\therefore \quad X = \frac{R l_X}{l_R} \quad (3)$$

Remember, $\frac{IR}{l_R}$ is the potential difference per unit length. The resistivity of the material is defined as follows. The resistance X of the given resistance wire is proportional to its length L and inversely proportional to its area of cross section A. That is,

$$X \propto \frac{L}{A}$$

$$X = \rho\frac{L}{A} \quad (4)$$

The proportionality constant ρ is called the resistivity of the material of the resistance wire.

$$\text{Resistivity, } \rho = \frac{AX}{L} = \frac{\pi r^2 X}{L} \quad (5)$$

where, 'r' is the radius of the resistance wire.

Procedure: Connections are made as shown in the figure. Insert the keys K_1 and K_2. First insert the keys in between 2 and 3 and 4 and 5 of the six terminal key. Check for deflections in the opposite directions when the sliding contact J is pressed near end A and then at the end B. Then insert the keys in between 1 and 2 and 5 and 6 of the six terminal key. Again check for deflections in the opposite directions. After ensuring that the deflections are in the opposite directions for both R and X, apply the P D across R to the potentiometer wire by inserting the keys in between 2 and 3 and 4 and 5 of the six terminal key. Find out the balancing length l_R.

Then unplug the keys in between 2 and 3 and 4 and 5. Then apply the P D across the unknown resistance X by inserting the keys in between 1 and 2 and 5 and 6 of the six terminal key. Find out the balancing length l_X. (Ensure that the rheostats are not adjusted while finding out both the balancing lengths). The experiment is repeated by changing the rheostat adjustment or by changing the standard resistance.

The length of the wire L (in between the terminals) is measured by a scale and its radius 'r' is measured by a screw gauge. Calculate the resistance and resistivity using eqns.3 and 5.

Precautions

- Check the voltages of the cells or power supplies used.
- Clean the ends of the connecting wires.
- Ensure that the wires are not broken. If there is no deflection check the continuity of the circuit with a multimeter.
- Ensure that the secondary voltage applied to the potentiometer (in this case P D across the standard resistance R and P D across the unknown resistance X) should not exceed the P D across A B of the potentiometer wire due to the cell in the primary circuit.
- Ensure that all the positive potential sides are connected to the terminals 4, 5 and 6 and negative sides are connected to the terminals 1, 2 and 3. Remember that the end of the resistance at which current enters it is positive and the end at which current leaves is negative.
- You can check the circuit by a method as follows. Unplug the key K_1 in the primary circuit. By inserting keys in the secondary circuit and the suitable keys in the six terminal key apply the secondary voltage to the potentiometer. Press the sliding contact J at the ends A and B. Make sure that the deflections in the galvanometer are in the same direction. If there is no deflection check the voltage and continuity of secondary circuit. Now insert the key K_1 in the primary circuit and check the deflections at A and B. If the deflections are in the opposite directions connections are correct. Otherwise, check the voltage and continuity of the primary circuit. This checking for opposite deflections must be done separately with P D across X and P D across R separately.
- Ensure that for X and R we get deflections in the opposite directions. If not, either adjust the rheostats or change the standard resistance.
- Ensure that during the determination of final balance point the key of the high resistance is to be inserted.
- Ensure that the radius of the wire is measured at positions where there are no bends. The length of the wire is measured after unwinding the wire completely. Reduce the length needed for connections at the terminals. This is needed to make sure that the length L of the wire is the length in between the terminals.

Observation and tabulation

To find the unknown resistance

Trial No.	Known Resistance R Ω	Balancing lengths		$X = \frac{R l_X}{l_R}$ Ω	Mean X Ω
		l_R in cm	l_X in cm		
1					
2					
3					
4					
5					

Length of the resistance wire, L = …….. cm = ……… m

To find the radius of the wire using a screw gauge

Distance moved by the screw tip for 6 rotations of the head = ……… mm

Pitch of the screw, P = $\dfrac{\text{Distance moved by the screw tip}}{\text{Number of rotations of the head}}$ = ……… mm

Number of divisions on the head scale = ………

Least count (L C) = $\dfrac{\text{Pitch}}{\text{Number of divisions on the head scale}}$ = ……. mm

Zero coincidence = …….. ; Zero error = …….

Zero correction = ……..

Trial No.	P S R 'x' mm	Observed H S R	Corrected H S R 'y'	Diameter of wire $d = x + y \times LC$ mm	Mean d mm
1					
2					
3					
4					
5					

Radius of the wire, r = d/2 = ……… mm = ……… m

Calculation of resistivity

Resistivity, $\rho = \dfrac{\pi r^2 X}{L}$ = ………….. = ………… ohm.m

Result

Resistivity of the material of the resistance wire, ρ = ………. Ω.m

*Standard data

Material	Resistivity Ω.m
Aluminum	0.0262×10^{-6}
Bronze	0.30×10^{-6}
Constantan (Eureka)	0.47×10^{-6}
Copper	0.17×10^{-6}
Manganin	0.45×10^{-6}
Nickel	0.59×10^{-6}
Nichrome	1.10×10^{-6}

Exp.No.1.20

Potentiometer-Calibration of low range voltmeter

Aim: To calibrate the given low range voltmeter.

Apparatus: The potentiometer, power supplies, rheostats, standard resistance, the low range voltmeter, high resistance, galvanometer, six terminal key and ordinary keys etc.

Theory

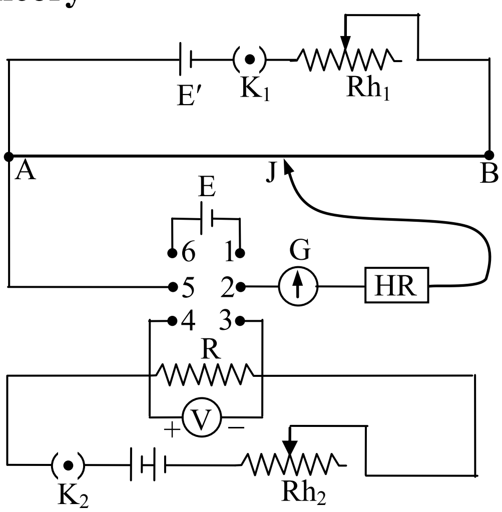


Fig.a: Six terminal key is used

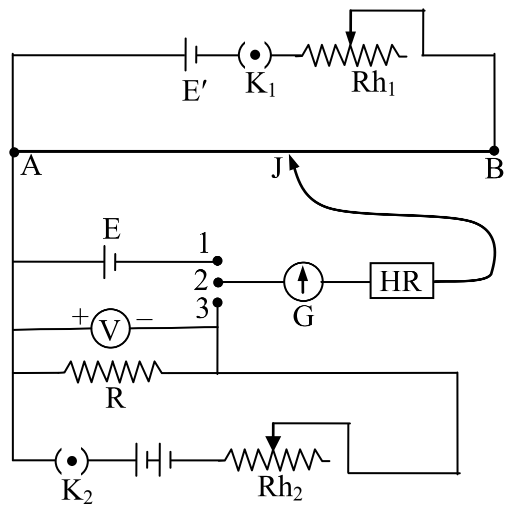


Fig.b: Three terminal key is used

To standardize the potentiometer we use a Daniel cell or a voltage source of 1.08 volt. If L is the balancing length corresponding to this voltage and l is the balancing length for the voltage across a standard resistance,

$$E \propto L \qquad (1)$$

And $$V \propto l \qquad (2)$$

Dividing eqn.2 by 1,

$$\frac{V}{E} = \frac{l}{L}$$

$$\therefore \qquad V = \frac{E}{L} l \qquad (3)$$

Then correction to the voltmeter reading,

$$V - V_0 = \frac{E}{L} l - V_0 \qquad (4)$$

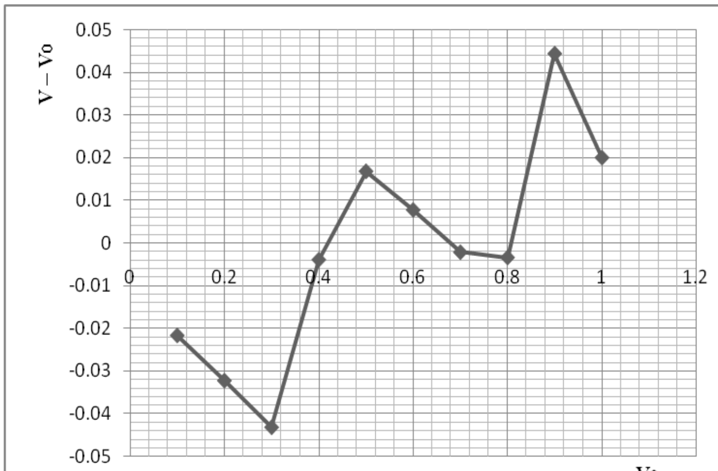


Fig.c

A calibration graph is drawn by taking V_0 along the X axis and the correction $V-V_0$ along the Y axis. The graph may not have regular shape as shown in the fig.c.

Procedure: Connections are made as shown in the fig.a or fig.b. The voltmeter to be calibrated is connected parallel to R. By adjusting rheostat Rh_1 in the primary circuit, a steady current is established in the wire AB. First connect the terminals 1and 2 for fig.b (insert the keys in between 1 and 2 and 5 and 6 for fig.a) and the balancing length L corresponding to the voltage E is determined.

Now disconnect 1 and 2 and connect terminals 2 and 3 for fig.b. (For fig.a remove the keys in between1 and 2 and 5 and 6 and insert in between 2 and 3 and 4 and 5). Adjust rheostat Rh_2 to read the voltmeter a value say V_0. Then the actual voltage developed across R is V. Find out the balancing length l corresponding to this voltage.

The experiment is repeated for various readings of the voltmeter and a calibration graph is drawn by taking V_0 along the X axis and the correction $V-V_0$ along the Y axis as shown in the fig.c.

Observation and tabulation

Standard voltage E = …………volts

Balancing length for standard e m f E = L = ……… cm

Voltmeter reading V_0 volt	Balancing length for PD across R l cm	Calculated voltage $V=\frac{E}{L}l$ volt	Correction $(V-V_0)$ volt
0.1			
0.2			
0.3			
0.4			
0.5			
0.6			
0.7			
0.8			
0.9			
1			

Result

The given low range voltmeter is calibrated and the calibration graph is drawn.

Exp.No.1.21

Carey Foster's Bridge-Determination of resistance &resistivity

Aim: To determine the unknown resistance and hence to find out the resistivity of the material of the resistance wire.

Apparatus: Carey Foster's bridge, given resistance wire, a cell (power supply), standard resistances, a resistance box, key, galvanometer, high resistance, etc.

Theory: The basic principle of Carey Foster's bridge is the Wheatstone's principle. Carey Foster Bridge consists of a uniform wire AB of length 1 m stretched on a wooden board. Five metallic strips are fixed on the wooden board as shown the figure. G_1, G_2, G_3 and G_4 are gaps between the metal strips. Two equal resistances P and Q are connected in the gaps G_2 and G_3 respectively. The unknown resistance X is connected in the gap G_1. A standard resistance R is connected in the gap G_4. A standard cell is connected across the terminals C and F. A galvanometer G is connected between D and the contact maker J that is able to slide along AB.

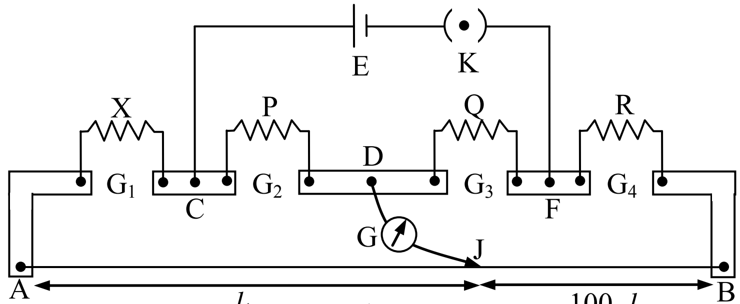


Fig.a

Theory*: The contact maker J is moved along the wire AB until the galvanometer shows no deflection. Then the bridge is said to be balanced. Let l_1 be the balancing length as measured from the end A. Let α and β, respectively, be the end resistances at A and B. Let ρ be the resistance per unit length of the wire AB. The above bridge is equivalent to a Wheatstone's bridge as shown fig.b.

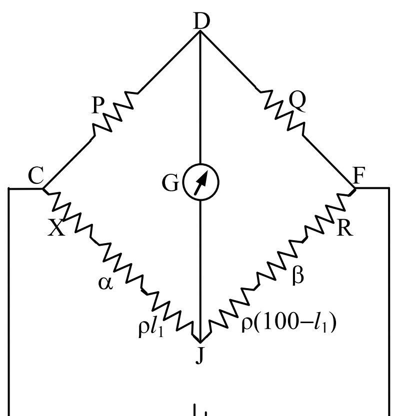


Fig.b

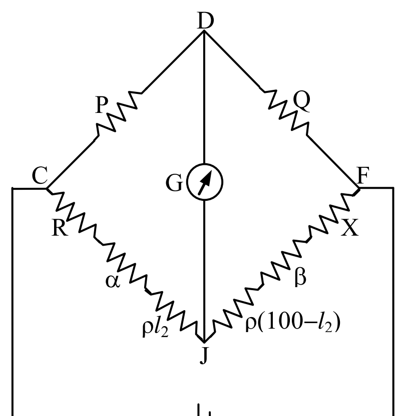


Fig.c

Applying Wheatstone's principle we get,

$$\frac{P}{Q} = \frac{X+\alpha+\rho l_1}{R+\beta+\rho(100-l_1)} \tag{5}$$

The resistances R and X are interchanged and the bridge is again balanced. The balancing length l_2 is measured from the same end A. Then,

$$\frac{P}{Q} = \frac{R+\alpha+\rho l_2}{X+\beta+\rho(100-l_2)} \tag{6}$$

Equating the RHS of eqns.5 and 6 we get,

$$\frac{X+\alpha+\rho l_1}{R+\beta+\rho(100-l_1)} = \frac{R+\alpha+\rho l_2}{X+\beta+\rho(100-l_2)}$$

Adding 1 on both sides, we get,

$$\frac{X+\alpha+\rho l_1}{R+\beta+\rho(100-l_1)} + 1 = \frac{R+\alpha+\rho l_2}{X+\beta+\rho(100-l_2)} + 1$$

$$\frac{X+\alpha+\rho l_1+R+\beta+\rho(100-l_1)}{R+\beta+\rho(100-l_1)} = \frac{R+\alpha+\rho l_2+X+\beta+\rho(100-l_2)}{X+\beta+\rho(100-l_2)}$$

Since the numerators are equal, we can equate the denominators. Thus we get,

$$R+\beta+\rho(100-l_1) = X+\beta+\rho(100-l_2)$$

i.e. $$X - \rho l_2 = R - \rho l_1$$

i.e. $$X = R + \rho(l_2 - l_1) \qquad (7)$$

To find ρ: A thick copper strip is connected in the gap G_1 and a small resistance R' of the order of 0.1 Ω is connected in the gap G_4 and the balancing length l_3 is determined. Now the copper strip and R' are interchanged and the balancing length l_4 is determined. Then from eqn.7, since X = 0 and R = R' in this case, we get,

$$0 = R' + \rho(l_4 - l_3)$$

i.e. $$\rho = \frac{R'}{l_3 - l_4} \qquad (8)$$

Thus, by knowing R and ρ the unknown resistance X can be calculated using eqn.7.

To find the resistivity ρ′: The resistivity of the material is defined as follows. The resistance X of the given resistance wire is proportional to its length L and inversely proportional to its area of cross section A. That is,

$$X \propto \frac{L}{A}$$

$$X = \rho' \frac{L}{A} \qquad (9)$$

The proportionality constant ρ is called the resistivity of the material of the resistance wire.

$$\text{Resistivity, } \rho' = \frac{AX}{L} = \frac{\pi r^2 X}{L} \qquad (10)$$

where, ‘r’ is the radius of the resistance wire.

Procedure

To find ρ

The connections are made as shown in the fig.a. Suitable standard resistances P and Q are connected in the gaps G_2 and G_3. Instead of X connect a thick copper strip in the gap G_1 and a resistance box with fractional resistance in the gap G_4. Take a resistance $R' = 0.2\ \Omega$ in the box. Find the balancing length l_3. It is measured from the end A. Then interchange the copper strip and the resistance box. The balancing length l_4 is determined. It is again measured from the end A. Calculate 'ρ' using eqn.8. The experiment is repeated for $R' = 0.3\ \Omega$, $0.4\ \Omega$, ……….. The average of 'ρ' is calculated.

To find the resistance of the coil

Connections are made as shown in fig.a. The resistance wire is connected in the gap G_1 and a resistance box in the gap G_4. Introduce a suitable resistance R in the box (read precautions) and the balancing length l_1 is determined. It is measured from the end A. Then interchange the resistance wire and the resistance box and the balancing length l_2 is determined. It is again measured from the end A. Repeat the experiment for different values of R. The resistance X is calculated by eqn.7.

Precautions

- Ensure that the resistances X and R are not far different. If they are equal you will get the balance point at the middle of the wire AB. To find approximately equal resistance the contact maker J is kept pressed at the middle of AB and find the resistance needed in R for no deflection in the galvanometer. Then take three readings with R less than and three more readings with R greater than this resistance. Increase or decrease the resistance in steps by 0.5 ohm (or 0.3 Ω).
- When copper strip is used, instead of X, take only the fractional resistance 0.2, 0.3, 0.4, …… Since ρ is the resistance per unit length, sign of $l_3 - l_4$ is not considered.
- The sign of $l_2 - l_1$ is very important. Take positive as positive negative as negative.
- If you are not getting any deflection check the supply voltage and continuity of the circuit with a multimeter.
- Remember the balancing length is always measured from the end A.
- Tight all the plugged keys in all resistance boxes, since the loose keys create unwanted resistance in the circuit.

Observation and tabulation

To find ρ

Sl.No.	Resistance R′ ohms	Balancing length with R′ in		$l_3 \sim l_4$ cm	$\rho = \frac{R'}{l_3 \sim l_4}$ Ω/cm
		Right gap l_3 (cm)	Left gap l_4 (cm)		
1					
2					
3					
4					
5					

Mean ρ = ……… Ω/cm

To find the unknown resistance X

Sl.No.	Resistance R ohms	Balancing length with R in Right gap l_1 (cm)	Left gap l_2 (cm)	$l_2 - l_1$ cm	$X = R + \rho(l_2 - l_1)$ ohm	Mean X ohm
1						
2						
3						
4						
5						
6						

Length of the resistance wire, L = …….. cm = ……… m

To find the radius of the wire using a screw gauge

Distance moved by the screw tip for 6 rotations of the head = ……… mm

Pitch of the screw, P $= \dfrac{\text{Distance moved by the screw tip}}{\text{Number of rotations of the head}}$ = ……… mm

Number of divisions on the head scale = ………

Least count (L C) $= \dfrac{\text{Pitch}}{\text{Number of divisions on the head scale}}$ = ……. mm

Zero coincidence = …….. ; Zero error = ……. ; Zero correction = ……..

Trial No.	P S R 'x' mm	Observed H S R	Corrected H S R 'y'	Diameter of wire $d = x + y \times LC$ mm	Mean d mm
1					
2					
3					
4					
5					

Radius of the wire, r = d/2 = ……… mm = ……… m

Calculation of resistivity

Resistivity, $\rho' = \dfrac{\pi r^2 X}{L}$ = ………….. = ………… ohm.m

Result

Resistance of the given wire, X = ……… ohm

Resistivity of the material of the resistance wire, ρ' = ………. Ω.m

***Standard data** (Refer exp.No.19)

Exp.No.1.22

C++ Program to calculate Standard Deviation (Object oriented programming)

Aim: To write and execute a C++ program (object oriented) to calculate the standard deviation.

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
#define maxnumber 100
class stddev
{
private:
        float x[1000];
        int n,i;
public:
        void getdata()
        {
                cout <<"\nEnter the number of data elements";
                cin>>n;
                for(i=0;i<n;i++)
                {
                        cout<<"\nEnter "<<i+1<<"th"<<" element : ";
                        cin>>x[i];
                }
        }
        float calc()
        {
                float sum=0;
                float sqdev=0;
                float mean,dev,stddev;
                for (i=0;i<n;i++)
```

```
                sum=sum+x[i];
            mean=sum/n;
            for (i=0;i<n;i++)
                sqdev=sqdev+(x[i]-mean)*(x[i]-mean);
            dev=sqrt(sqdev/n);
            return(dev);
        }
};
void main()
{
        char ch;
        stddev s;
        clrscr();
        s.getdata();
        cout<<"\nThe Standard Deviation of Given data= "<<s.calc();
        getch();
}
```

Result

C++ program (object oriented) to calculate the standard deviation is written and is executed.

Exp.No.1.23

C++ Program to solve Quadratic Equation (Object oriented programming)

Aim: To write and execute a C++ program (object oriented) to solve a quadratic equation.

```
#include<iostream.h>
#include<conio.h>
#include<math.h>
#include<stdio.h>
float a1,b1,c1;
class quad
{
        public:
                float a,b,c;// coefficients
                void getcoefficients();//Function to get coefficients
                void equal();// Function for equal roots
                void imaginary(); //Function for imaginary roots
                void real();//Function for unequal real roots
}q;     // q as object
// Definition of member functions
void quad::getcoefficients()
{
        cout<<"\n Enter the coefficient a:";cin>>a;
        cout<<"\n Enter the coefficient b:";cin>>b;
        cout<<"\n Enter the constant term c:";cin>>c;
}
void quad::equal()
{
        cout<<"Equal roots ="<<–b/(2*a);
}
void quad::imaginary()
```

```
{
    float realpart,imaginarypart;
    realpart=–b/(2*a);
    imaginarypart=sqrt(– (b*b–4*a*c))/(2*a);
    cout<<"\nFirst imaginary root="<<realpart<<"+i"<<imaginarypart;
    cout<<"\nSecond imaginary root="<<realpart<<"–i"<<imaginarypart;
}
void quad::real()
{
    cout<<"\nFirst real root="<<(–b+sqrt(b*b–4*a*c))/(2*a);
    cout<<"\nSecond real root="<<(–b–sqrt(b*b–4*a*c))/(2*a);
}
main()
{
    q.getcoefficients();
    if(q.a==0)
        cout<<"\n linear roots="<<–(q.c)/(q.b);
    else
    {
        float d;
        d=q.b*q.b–(4*q.a*q.c);
        if(d==0)
            q.equal();
        else
            if(d<0)
                q.imaginary();
            else
                q.real();
    }
    getchar();
}
```

Result

C++ program (object oriented) to solve a quadratic equation is written and is executed.

Exp.No.1.24

C++ Program to find the transpose of a matrix (Object oriented programming)

Aim: To write and execute a C++ program (object oriented) to find the transpose of a matrix.

```
#include<iostream.h>
#include<conio.h>
class matrix
{
	private:
		float mx[25][25];
		int row,col,i,j;
	public:
		void input(int row, int col)
		{
			cout<<"\nEnter matrix elements";
			for(i=0;i<row;i++)
			{
				for(j=0;j<col;j++)
				{
					cin>>mx[i][j];
				}
			}
		}
		void display(int row, int col)
		{
			for(i=0;i<row;i++)
			{
				for(j=0;j<col;j++)
				{
					cout<<mx[i][j]<<"\t";
				}
				cout<<"\n";
			}
		}
```

```
                    void transpose(int row, int col)
                    {
                              for(i=0;i<col;i++)
                              {
                                        for(j=0;j<row;j++)
                                        {
                                                  cout<<mx[j][i]<<"\t";
                                        }
                                        cout<<"\n";
                              }
                    }
};
void main()
{
          int m,n;
          char ch;
          matrix mat;

                    clrscr();
                    cout<<"Enter the matrix size m and n :  ";
                    cin>>m>>n;
                    mat.input(m,n);
                    cout<<"\nThe given matrix is:\n";
                    mat.display(m,n);
                    cout<<"\nThe Transpose of the given matrix is\n";
                    mat.transpose(m,n);
                    getch();
 }
```

Result

C++ program (object oriented) to find the transpose of a matrix is written and is executed.