BSCPH- 104

B. Sc. I YEAR

Practical Physics


DEPARTMENT OF PHYSICS

SCHOOL OF SCIENCES

UTTARAKHAND OPEN UNIVERSITY

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Course Title and Code	**: Electricity and Magnetism (BSCPH 104)**
ISBN	**:**
Copyright	**: Uttarakhand Open University**
Edition	**: 2017**
Published By	**: Uttarakhand Open University, Haldwani, Nainital- 263139**
Printed By	**: Uttarayan Prakashan , Haldwani.**

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Course 1: Practical Physics
Course code: BSCPH104
Credit: 3

Experiment No. 1

Object: To determine the restoring force per unit extension of a spiral spring by statistical and dynamical methods and also to determine the mass of the spring.

Apparatus Used: A spiral spring, 10 gm. weights- 5 No., a scale pan, a pointer and a stop watch

Formula Used:

(1) Statistical Method:

The restoring force per unit extension (K) of the spring is given by-

$$K = \frac{Mg}{l}$$

where, M = mass kept in the pan at the lower end of the spring

g = acceleration due to gravity

l = extension created in the spring

(2) Dynamical Method:

(a) The restoring force per unit extension (K) of the spring is given by-

$$K = \frac{4\pi^2(M_1 - M_2)}{(T_1^2 - T_2^2)}$$

where M_1 and M_2 = masses kept in the pan at the lower end of the spring successively

T_1 and T_2 = time periods of the spring corresponding to masses M_1 and M_2 respectively

(b) The mass 'm' of the spring is given by-

$$m = 3\left[\frac{M_1T_2^2 - M_2T_1^2}{T_1^2 - T_2^2}\right]$$

where the symbols have their usual meanings.

About apparatus:

Let us know about the apparatus. The given figure 1 shows a mass spring system. A spiral spring whose restoring force per unit extension is to be determined is suspended from a rigid support as shown in the figure. At the lower end of the spring, a small scale-pan is fastened. A small horizontal pointer is also attached to the scale pan. A scale is also set in front of the spring in such a way that when spring vibrates up and down, the pointer freely moves over the scale.

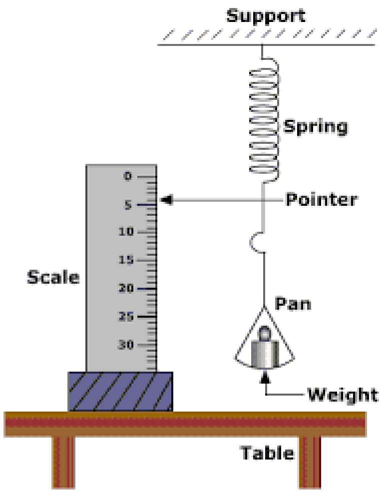


Figure 1: Mass spring system

Procedure:

Let us perform the experiment to determine the restoring force per unit extension of a spiral spring and mass of the spring. We shall perform the two methods in the following way-

(1) Statistical Method:

(i) Without no load in the scale-pan, note down the zero reading of the pointer on the scale.

(ii) Now place gently 10 gm. load (weight) in the pan. Stretch the spring slightly and the pointer moves down on the scale. In this steady position, note down the reading of the pointer. The difference of the two readings is the extension of the spring for the load in the pan.

(iii) Let us increase the load in the pan in equal steps until maximum permissible load is reached and note down the corresponding pointer readings on the scale.

(iv) The experiment is repeated with decreasing weights (loads).

(2) Dynamical Method:

(i) Put gently a load M_1 (say 10gm.) in the pan. Now let us displace the pan vertically downward through a small distance and release it. You will see that the spring starts to perform simple harmonic oscillations.

(ii) With the help of stop watch, note down the time of a number of oscillations (say 10). Now get the time period or the time for one oscillation T_1 by dividing the total time by the total number of oscillations.

(iii) Increase the load in the pan to M_2 (say 20 gm.). As described above, find out the time period T_2 for this load.

(iv) Now repeat the experiment with different values of load.

Observations:

Statistical Experiment:

Table 1: The measurement of extension of the spring

S.No.	Load(weight) in the pan (gm.)	Reading of pointer on the scale (meter)			Extension for 30 gm. (meter)	Mean extension (meter)
		Load increasing	Load decreasing	Mean		
1	10				(3)-(1)=	
2	20					
3	30				(4)-(2)=......	
4	40					
5	50				(5)-(3)=.......	

Dynamical Experiment:

Table 2: The measurement of periods T_1 and T_2 for loads M_1 and M_2

Least count of stop-watch = ...sec.

S.No.	Load in pan (gm.)		No. of oscillations	Time taken with load		Time period (sec)	
	M_1	M_2		M_1 sec	M_2 sec	T_1	T_2
1	10	20					
2	30	40					
3	50	60					
4	70	80					
5	90	100					

Calculations:

Statistical Experiment:

The restoring force per unit extension of the spring is given by-

$K = \frac{Mg}{l}$ = ... Newton/meter

Let us draw a graph between the load and scale readings by taking the load as abscissa and the corresponding scale readings as ordinates. You will see that the graph comes out to be a straight line as shown in figure 2.

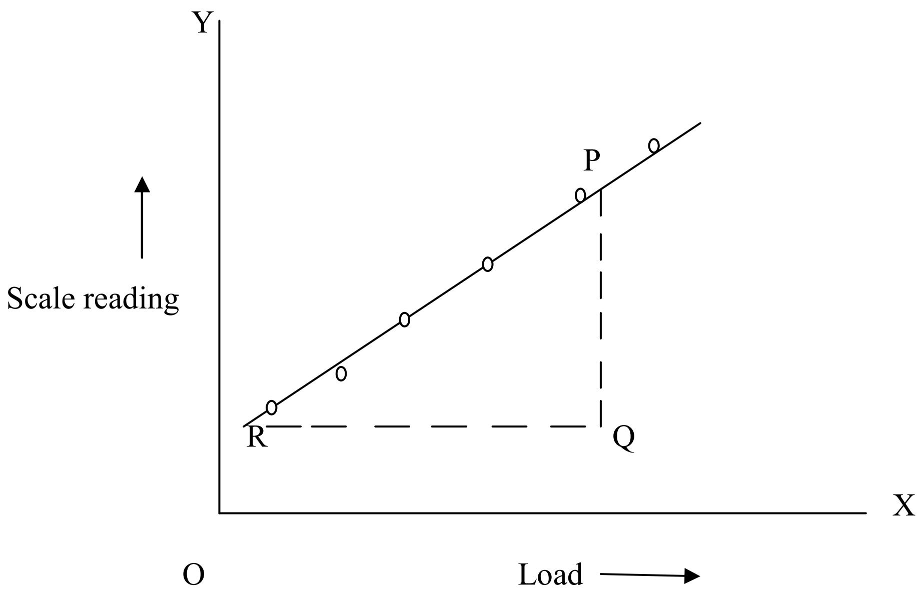


Figure 2

From the graph, we measure PQ and QR. Now the restoring force per unit extension is given by-

$K = \frac{RQ}{PQ} \times g =$ .... Newton/meter

Dynamical Experiment:

Restoring force per unit extension of the spring- $K = \frac{4\pi^2(M_1 - M_2)}{(T_1^2 - T_2^2)} =$ .... Newton/meter

Similarly, you should calculate K for other sets and then obtain the mean value.

Mass of the spring-

$$m = 3\left[\frac{M_1T_2^2 - M_2T_1^2}{T_1^2 - T_2^2}\right] = \text{.................} \quad \text{Kg.}$$

Similarly, you can calculate m for other sets and then obtain the mean value.

Result:

The restoring force per unit extension of the spring = ... Newton/meter

The mass of the spring =................ Kg.

Precautions and Sources of Errors:

(i) Statistical Method:

(1) The axis of the spring must be vertical.

(2) The spring should not be stretched beyond elastic limits.

(3) The pointer should move freely on the scale.

(4) Load (weight) should be placed gently in the scale pan.
(5) The scale should be set vertical. It should be arranged in such a way that it should give almost the maximum extension allowable.
(6) Readings should be taken very carefully from the front side.

(ii) Dynamical Method:

(1) The spring should oscillate vertically.
(2) The amplitude of oscillations should be small.
(3) Time periods T_1 and T_2 should be measured very accurately.

Objectives: After performing this experiment, you should be able to-

- Understand mass-spring system
- Understand statistical and dynamical methods
- Understand and calculate restoring force per unit extension of a spiral spring

VIVA-VOCE:

Question 1. What is a spiral spring?

Answer. A long metallic wire in the shape of a regular helix of given radius is called a spiral spring.

Question 2. What is effective mass of a spring?

Answer. In calculations, we have a quantity (M + m/3) where M is the mass suspended and m, the mass of the spring. The factor m/3 is called the effective mass of the spring.

Question 3. What do you mean by restoring force per unit extension of a spring?

Answer. The restoring force per unit extension of a spring is defined as the elastic reaction produced in the spring per unit extension which tends to restore it back to its initial conditions.

Question 4. What is the unit of restoring force per unit extension of a spring?

Answer. The unit of restoring force per unit extension of a spring is Newton/meter.

Question 5. How does the restoring force change with length and radius of spiral spring?

Answer. This is inversely proportional to the total length of wire and inversely proportional to the square of radius of coil.

Question 6. How the knowledge of restoring force per unit extension is of practical value?

Answer. By the knowledge of restoring force per unit extension, we can calculate the correct mass and size of the spring when it is subjected to a particular force.

Experiment No. 2

Object: To study the oscillations of a spring

Apparatus Used: Mounting arrangement, a pan, springs, a stop watch, weights of 10 gm- 5 Nos.

Formula Used:

(1) For experimental verification of formula for a spring

$$\frac{T_1}{T_2} = \sqrt{\frac{m_1 g}{m_2 g}} \times \sqrt{\frac{K_{x'_0}}{K_{x_0}}}$$

where T_1 = Time period of a spring when subjected to a load m_1g

T_2 = Time period of the same spring when subjected to load m_2g

K_{x0} = Force constant of spring corresponding to equilibrium extension x_0

$K_{x'0}$ = Force constant of spring corresponding to equilibrium extension x'_0

where x_0 and x'_0 are the equilibrium extensions corresponding to loads m_1g and m_2g.

(2) The total potential energy U (Joule) of the system is given by-

$$U = U_b - mg.x$$

where U_b = Potential energy of the spring

x = Displacement from the equilibrium position due to a load mg

-mg.x = Gravitional energy of mass m which is commonly taken as negative

Procedure:

(i) Let us set up the experimental arrangement as shown in figure 1 in such a way that when a load is subjected to the spring, the pointer moves freely on meter scale. Now remove the load and note down the pointer's reading on meter scale when spring is stationary.

(ii) Put a weight of 10 gm. On the spring pan. Now the spring is stretched. Note down the pointer reading on the meter scale.

(iii) Continue the above process of loading the spring in steps of 10 gm. And note the extension with the elastic limit.

(iv) Record the reading of the pointer by removing the weights in steps. Observe that if the previous readings are almost repeated then the elastic limit has not exceeded. For a particular weight, the mean of two corresponding readings gives the extension for that weight (load).

(v) Again put 10 gm. in the pan and wait till the pointer is at a stop. Now pull down the pan slightly and release it. The pan starts oscillating vertically with amplitude decreasing quickly. Record the time of few oscillations with the help of sensitive stop watch. Now calculate the time for one oscillation i.e. time period. Similarly, repeat the experiment for other weights (loads) to obtain the corresponding time periods.

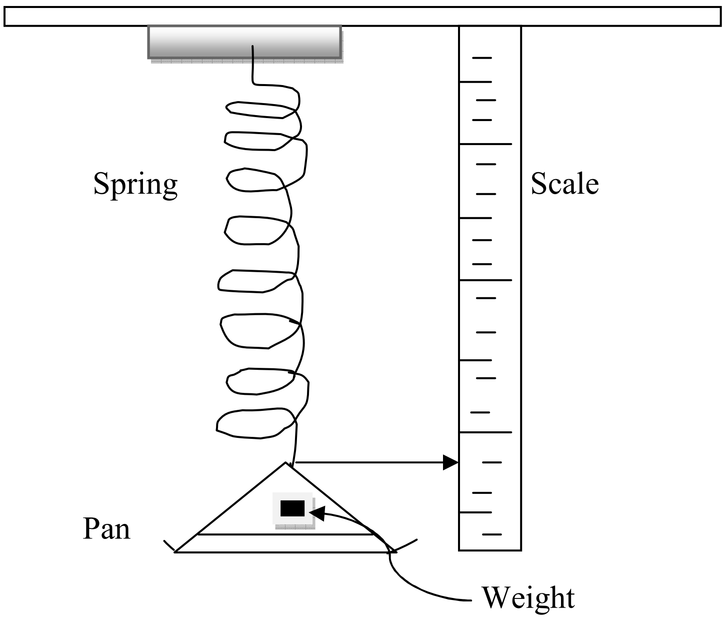


Figure 1

(vi) Let us draw a graph between load and corresponding extension as shown in figure 2. Consider different points on the curve and draw tangents at these points. Obtain the values of Δm and Δx for different tangents. Now calculate the force constant using the following formula-

$$K_{x_0} = g\left(\frac{\Delta m}{\Delta x}\right)_{x_0}$$

Record the extensions from graph and corresponding force constants in the table.

(vii) Now calculate the time periods by using the formulae-

$T_1 = 2\pi\sqrt{\frac{m_1}{K_{x_0}}}$ and $T_2 = 2\pi\sqrt{\frac{m_2}{K_{x_0'}}}$

Compare the experimental time periods with calculated time periods.

(viii) From load extension graph [Figure 2], let us consider the area enclosed between the curve and the extension axis for different loads (weights) increasing in regular steps. The area enclosed are shown in figure 3. The area gives U_b corresponding to a particular extension.

(ix) Now calculate U_m for mass = 20 gm. and get the value of U by the following formula-

$U = U_b + U_m$

(x) Draw a graph in extension and the corresponding energies i.e, U_b, U_m and U . The graph is shown in the figure 4.

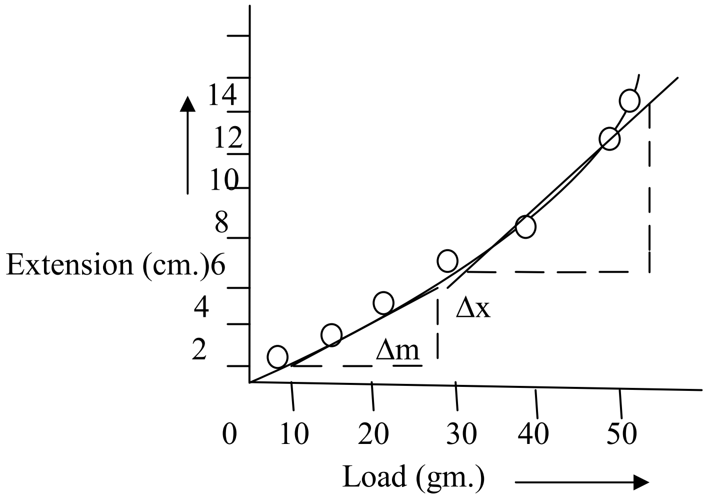


Figure 2

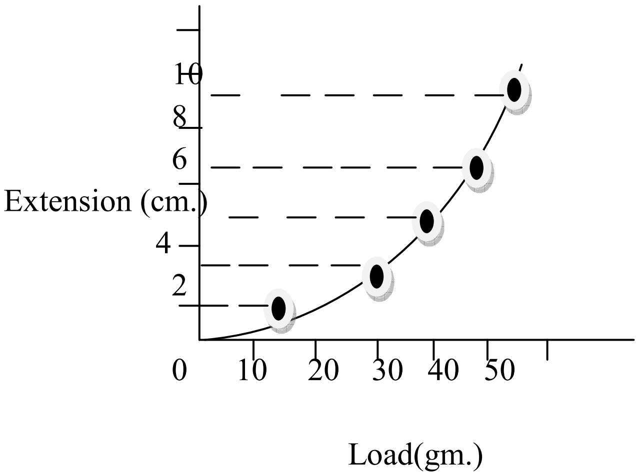


Figure 3

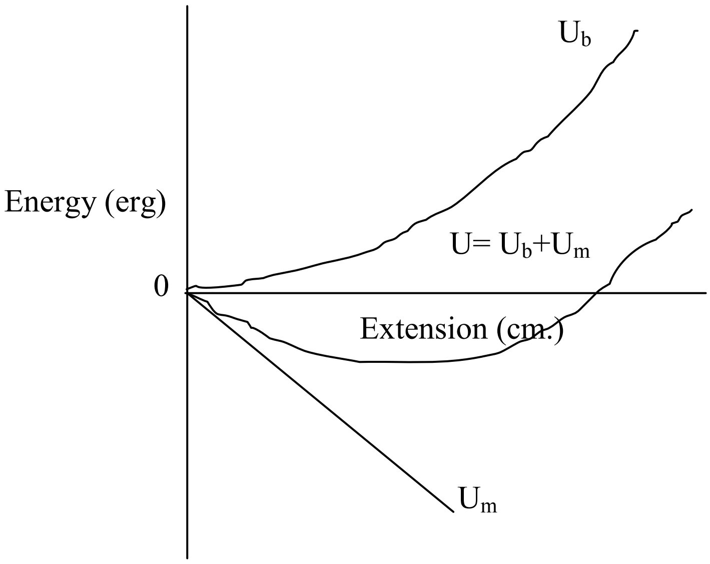


Figure 4

Observations and Calculations:

Table 1: For load extension graph

S.No.	Mass suspended (gm.)	Reading of pointer with load		Mean (a+b)/2 (Meter)	Extension of spring meter
		Increasing a (meter)	Decreasing b (meter)		
1	0				
2	10				
3	20				
4	30				
5	40				
6	50				

Original length of the spring = …………cm

Table 2: For oscillations of the spring

S.No.	Mass suspended (gm.)	No. of oscillations	Time (sec)	Time period (sec) (Observed)	Equilibrium extension from graphs	K from a graph (N/Meter)	Period (Calculated)
1	10						
2	30						
3	50						

Table 3: Computation of U_b, U_m vs extension ; m = 20 gm.

S.No.	U_b (Joule)	U_m for	

Results:

(1) The force constant of rubber band is a function of extension a in the limit of elasticity. It is observed that the force constant is independent of extension a within the limit of elasticity.

(2) From Table 2, it is observed that the calculated time periods are the same as experimentally observed time periods.

(3) U_b, U_m and U versus extension are drawn in the graphs of Figure 4.

Precautions and Sources of Errors:

(1) The spring should not be loaded beyond of the load required for exceeding the limit of elasticity.
(2) The time period should be recorded with sensitive stop watch.
(3) The experiment should also be performed by decreasing loads.
(4) The experiment should be performed with a number of springs.
(5) Amplitude of oscillations should be small.
(6) For graphs, smooth curves should be drawn.

Objectives: After performing this experiment, you should be able to-

- Understand oscillations
- Understand force constant of spring
- Understand potential energy

VIVA-VOCE:

Question 1. What is a spiral spring?

Answer. A long metallic wire in the shape of a regular helix of given radius is called a spiral spring.

Question 3. What do you mean by restoring force per unit extension of a spring?

Answer. The restoring force per unit extension of a spring is defined as the elastic reaction produced in the spring per unit extension which tends to restore it back to its initial conditions.

Question 4. What is the unit of restoring force per unit extension of a spring?

Answer. The unit of restoring force per unit extension of a spring is Newton/meter.

Question 5. How does the restoring force change with length and radius of spiral spring?

Answer. This is inversely proportional to the total length of wire and inversely proportional to the square of radius of coil.

Question 6. How the knowledge of restoring force per unit extension is of practical value?

Answer. By the knowledge of restoring force per unit extension, we can calculate the correct mass and size of the spring when it is subjected to a particular force.

Question 7: What is the unit of potential energy?

Answer: The unit of potential energy is erg or joule.

Experiment No. 3

Object: To determine the coefficient of damping, relaxation time and quality factor of a damped simple harmonic motion using a simple pendulum.

Apparatus Used: A long simple pendulum with brass bob and two extra bobs one of aluminium and the other of wood of the same mass or of the same diameter as that of brass, one meter scale and a stop watch.

Formula Used:

The coefficient of damping K is given by-

$$K = \frac{2.3036\Delta \log_{10} A_n}{\Delta t} \qquad \text{..... (1)}$$

where A_n is the amplitude of nth damped simple harmonic motion at any time t.

The relaxation time τ is the time in which the energy of oscillation reduces to 1/e of the original value and is given by-

$$\tau = \frac{1}{2K} \qquad \text{..... (2)}$$

The quality factor of simple harmonic motion is 2π times the ration of energy stored to the energy lost per cycle and is given by-

$$Q = \frac{2\pi}{T}\tau \qquad \text{..... (3)}$$

About apparatus:

Let us know about the apparatus. An ideal simple pendulum consists of a heavy point mass suspended from a rigid support by means of a weightless, flexible and inextensible string. In actual practice a bob is used which is suspended by a long thread from a rigid support near the wall as shown in figure 1. To note the amplitude of the oscillations, a marked scale is attached on the wall just opposite to the bob. When the bob is allowed to oscillate, its amplitude slowly decreases and after sometime it comes to rest. Such type of the motion is called damped simple harmonic motion and slow decay of the amplitude is called damping.

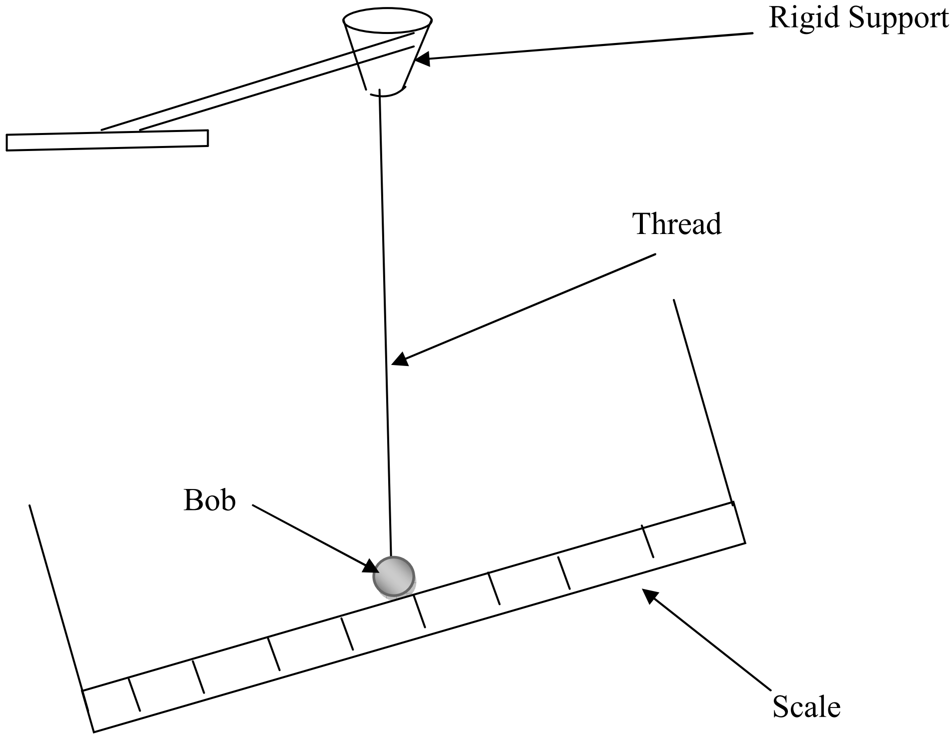


Figure 1

Procedure:

(i) Let us set up the arrangement as shown in figure 1 with length of the thread about 3 meter long.

(ii) Now give the pendulum a displacement of about 60-70 cm. and leave it. Allow the first 6-8 oscillations to pass and ensure that the thread and bob would not touch the wall.

(iii) When the amplitude of oscillation is approximately 40-50 cm. note down this amplitude A_0 and start counting the number of oscillations. Then note down the amplitude A_n at equal intervals of say 5 oscillations. Here you have to remember that a stop watch is not required. The counting of the oscillations should continue till the amplitude becomes about 10 cm.

(iv) Again allow the pendulum to oscillate simple harmonically i.e. with small amplitude and note the time taken of about 10-15 oscillations with a stopwatch. Divide the whole time by the number of oscillations to calculate the time period T. You should take atleast three sets and calculate the mean period of the pendulum.

(v) Now repeat the whole experiment with bobs of aluminium and wood which are either of the same mass or of the same diameter as brass bob.

Observations:

Table 1: The observation of A_n against n

S.No.	No. of oscillations (n)	Amplitude A_n for			$Log_{10}A_n$ for		
		Brass bob	Aluminium bob	Wooden bob	Brass bob	Aluminium bob	Wooden bob
1	0						
2	5						
3	10						
4	15						
5	20						
	90						
	95						
	100						

Table 2: The observations of time period of the bobs

Least count of the stop watch = ... sec.

S.No.	Number of oscillations (n)	Time taken								
		Brass bob			Aluminium bob			Wooden bob		
		Total time (sec)	Time period T_1 (sec)	Mean T_1(sec)	Total time (sec)	Time period T_2 (sec)	Mean T_2(sec)	Total time (sec)	Time period T_3 (sec)	Mean T_3(sec)
1	10									
2	15									
3	20									
4	25									
5	30									

Calculations:

Let us plot a graph between number of oscillations ‘n’ on the X-axis and corresponding values of $\log_{10}A_n$ on the Y-axis for brass bob.

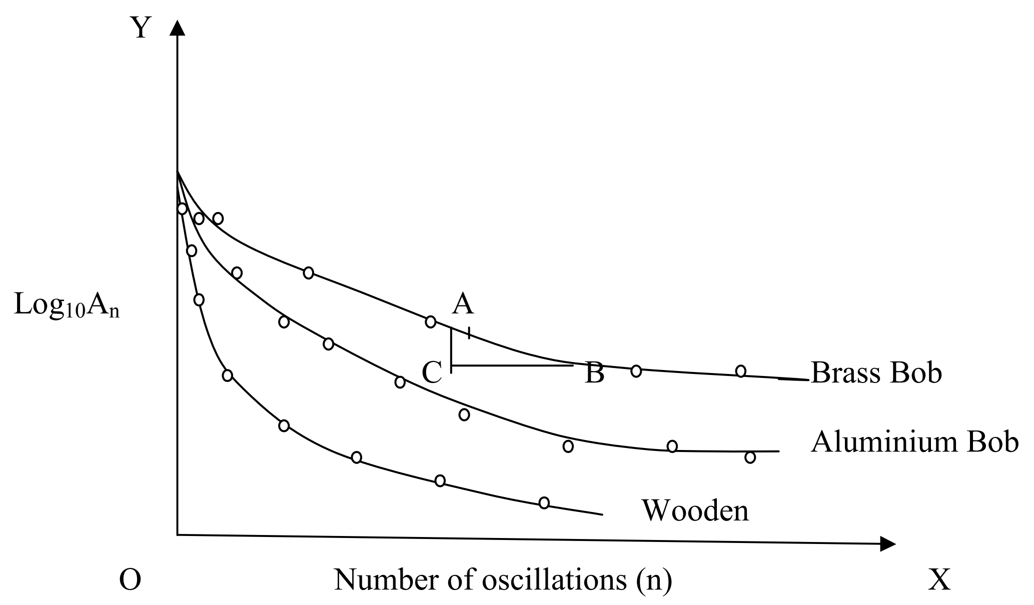


Figure 2

You will see that the graph plotted comes out nearly a straight line as shown in figure 2. From the graph, find the slope $\frac{\Delta \log_{10} A_n}{\Delta n}$. Now divide this slope by time period T_1 of the pendulum to calculate $\frac{\Delta \log_{10} A_n}{\Delta t_1}$ because $\Delta t_1 = T_1 \times \Delta n$. In the same way, plot graphs for aluminium and wooden bobs and calculate the corresponding values of $\frac{\Delta \log_{10} A_n}{\Delta t_2}$ and $\frac{\Delta \log_{10} A_n}{\Delta 3}$. Now, follow the following procedure to calculate the coefficient of damping(K), relaxation time(τ) and quality factor(Q)-

For the simple pendulum with brass bob-

Slope of the curve $\frac{\Delta \log_{10} A_n}{\Delta n} = \frac{\mathrm{AC}}{\mathrm{CB}} = -$ .... per oscillation

Therefore, $\frac{\Delta \log_{10} A_n}{\Delta t_1} = \frac{\Delta \log_{10} A_n}{\mathrm{T_1 \times \Delta n}} = \frac{\mathrm{AC}}{\mathrm{T_1 \times CB}} = -$ .... per sec

The damping coefficient, $K = -\ 2.3026 \times \frac{\mathrm{AC}}{\mathrm{T_1 \times CB}} = +$ .... per sec

The relaxation time, $\tau = \frac{1}{2\mathrm{K}} =$ .... sec

The quality factor, $Q = \frac{2\pi}{\mathrm{T}} \tau =$ ....

Do similar calculations for aluminium and wooden bobs.

Results: The values of different constants are given below-

S.No.	Simple pendulum with	Constants		
		Coefficient of damping (K)	Relaxation time (τ)	Quality factor(Q)
1.	Brass Bob			
2.	Aluminium Bob			
3.	Wooden Bob			

Precautions and Sources of Errors:

(1) The length of the pendulum should be sufficiently large.
(2) The pendulum should not touch the scale.
(3) The readings should be taken carefully.

Objectives: After performing this experiment, you should be able to-

- understand simple pendulum
- understand damping, relaxation time and quality factor
- calculate coefficient of damping, relaxation time and quality factor

VIVA-VOCE:

Question 1. What is a simple pendulum?

Answer. If a heavy point-mass is suspended by a weightless, inextensible and perfectly flexible string from a rigid support, then this arrangement is called a simple pendulum.

Question 2. What do you mean by periodic and oscillatory motion?

Answer. When a body repeats its motion continuously on a definite path in a definite interval of time then its motion is called periodic motion and the interval of time is known as time period. If a body in periodic motion moves along the same path to and fro about a definite point (equilibrium position), then the motion of the body is called vibratory motion or oscillatory motion.

Question 3. What do you understand by free, damped and forced oscillations?

Answer. When an object oscillates with its natural frequency, its oscillations are said to be free. If there is no external frictional forces, then the amplitude of free oscillations remains constant. In the presence of frictional forces (like air), the amplitude of oscillations goes on decreasing. Such oscillations are called damped oscillations. If a constant external periodic force is applied in such a way that the amplitude of vibrations remains constant, then such oscillations are called as forced oscillations.

Question 4. What is meant by relaxation time?

Answer. The relaxation time is defined as the time in which the energy of oscillation reduced to 1/e of the original value.

Question 5. What do you mean by quality factor?

Answer. Quality factor is defined as 2π times the ratio of the energy stored to the average energy lost per cycle.

Question 6. On what factor or factors, the relaxation time depend?

Answer. The relaxation time depends upon the coefficient of damping.

Experiment No. 4

Object: To determine Young's modulus, modulus of rigidity and Poisson's ratio of the material of a given wire by Searle's dynamical method.

Apparatus Used: Two identical bars, given wire, stop watch, screw gauge, vernier callipers, meter scale, physical balance, candle and match box

Formula Used: The Young's modulus of the material of the wire is given by-

$$Y = \frac{8\pi Il}{T_1^2 r^4} \qquad .....(1)$$

Modulus of rigidity is given by-

$$\eta = \frac{8\pi Il}{T_2^2 r^4} \qquad .....(2)$$

Poisson's ratio is given as-

$$\sigma = \frac{T_2^2}{2T_1^2} - 1 \qquad .....(3)$$

Here, I = Moment of inertia of the bar about a vertical axis through its centre of gravity

l = Length of the given wire between the two clamping screws

r = Radius of the wire

T_1 = Time period when the two bars execute simple harmonic motion together

T_2 = Time period for the torsional oscillations of a bar

About apparatus:

In this experiment, two identical rods PQ and RS of square or circular cross section connected together at their middle points by the specimen wire, are suspended by two silk fibres from a rigid support such that the plane passing through these rods and wire is horizontal as shown in figure.

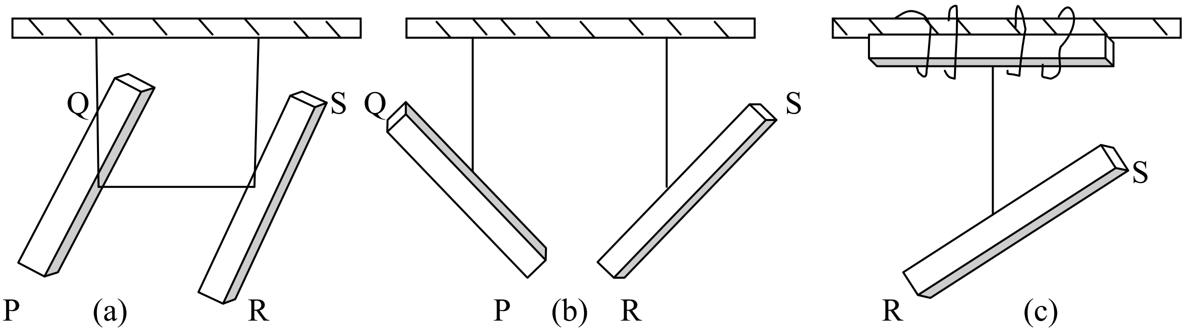


Figure 1

Procedure:

(i) Take the weight of both bars with the help of physical balance and find the mass 'M' of each bar.

(ii) Measure the breadth 'b' of the cross bar with the help of vernier callipers.(If the rod is of circular cross-section then measure its diameter 'D' with vernier callipers).

(iii) Take the measurement of length 'L' of the bar with the help of meter scale.

(iv) Now attach the experimental wire to the middle points of the bar and suspend the bars from a rigid support with the help of equal threads such that the system is in a horizontal plane [as shown in figure 1a].

(v) Take the two bars close together (through a small angle) with the help of a small loop of the thread [as shown in figure 1b].

(vi) Now burn the thread with the help of stick of match box and note the time period T_1 in this case.

(vii) Clamp one bar rigidly in a horizontal position so that the other hangs by the wire [as shown in figure 1c]. Rotate the free bar through a small angle and note the time period T_2 for this case also.

(viii) Measure the length 'l' of the wire between the two bars with the help of meter scale.

(ix) Measure the diameter of the experimental wire at a large number of points in mutually perpendicular directions by a screw gauge and find the radius 'r' of the wire.

Observations:

Table 1: Determination of T_1 and T_2

Least count of the stop watch = ... sec.

S.No.	No. of oscillations (n)	Time T_1			Time period T_1 (= a/n) (sec.)	Mean T_1 (sec.)	Time T_2			Time period (=b/n) (sec.)	Mean T_2 (sec.)
		Min.	Sec	Total sec. (a)			Min.	Sec.	Total sec (b)		
1	5										
2	10										
3	15										
4	20										
5	25										

Mass of either of the rod PQ or CD, M = ... gm. = ...Kg.

Length of the either bar L= ..... cm.

Table 2: Measurement of the breadth of the given bar

Least count of the vernier callipers = $\frac{\text{value of one division of main scale in cm}}{\text{total number of divisions on vernier scale}}$ = ... cm.

Zero error of vernier callipers = ± .... cm.

S.No.	Reading along any direction			Reading along a perpendicular direction			Uncorrected breadth b = (X+Y)/2 cm.	Mean corrected breadth b cm.
	M.S. reading	V.S. reading	Total X- cm	M.S. reading	V.S. reading	Total Y- cm.		
1								
2								
3								

b = ... cm. = ... meter

If the bars are of circular cross section then the above table may be used to determine the diameter D of the rod.

Length ‘l’ of the wire = ... cm.

Table 3: Measurement of the diameter of the given wire

Least count of screw gauge = $\frac{\text{value of one division of main scale in cm}}{\text{total number of divisions on vernier scale}}$ = ... cm

Zero error of screw gauge = ± ..... cm

S.No.	Reading along any direction			Reading along a perpendicular direction			Uncorrected diameter (X+Y)/2 (cm.)	Mean uncorrected diameter (cm.)
	M.S. reading	V.S. reading	Total X- (cm)	M.S. reading	V.S. reading	Total Y- (cm.)		
1								
2								
3								

Mean corrected diameter d = Mean uncorrected diameter ± zero error = ... cm.

Mean radius r = d/2 = ... cm.

Calculations:

$I = \frac{M(L^2+b^2)}{12}$ = ... Kg.×m^2 [for square cross-section bar]

$I = M\left(\frac{L^2}{12} + \frac{D^2}{16}\right)$ = ... Kg.× m^2 [for circular bar]

The Young's modulus of the material of the wire Y = $\frac{8\pi Il}{T_1^2 r^4}$ = ... Newton/meter^2

Modulus of rigidity η = $\frac{8\pi Il}{T_2^2 r^4}$ = ... Newton/meter^2

Poisson's ratio σ = $\frac{T_2^2}{2T_1^2} - 1$ = ...

Result:

Y = ... Newton/meter^2

η = ... Newton/meter^2

σ = ...

Standard Result:

Y = ... Newton/meter^2

η = ... Newton/meter^2

σ = ...

Percentage error:

Y = ... %

η = ... %

σ = ... %

Precautions and Sources of Errors:

(1) The length of the two threads should be same.
(2) The radius of the wire should be measured very accurately.
(3) The two bars should be identical.
(4) The amplitude of oscillations should be kept small.
(5) Bars should oscillate in a horizontal plane.

Objectives: After performing this experiment, you should be able to-

- understand Searle's dynamical method
- understand Young's modulus, modulus of rigidity and Poisson's ratio
- calculate Young's modulus, modulus of rigidity and Poisson's ratio

---

VIVA-VOCE:

Question 1. Should the moment of inertia of the two bars be exactly equal?

Answer. Yes. If the two bars are of different moment of inertia, then their mean value should be used.

Question 2. How are Y and η involved in Searle's dynamical method ?

Answer. The wire is kept horizontally between two bars. When the bars are allowed to vibrate, the experimental wire bent into an arc. Thus the outer filaments are elongated while inner ones are contracted. In this way, Y comes into play. When one bar oscillates like a torsional pendulum, the experimental wire is twisted and η comes into play.

Question 3. What is the nature of vibrations in two parts of Searle's dynamical method?

Answer. In the first part, the vibrations are simple oscillations while in second part, the vibrations are torsional vibrations.

Question 4. What is meant by Poisson's ratio?

Answer. Within the elastic limits, the ratio of the lateral strain to the longitudinal strain is called Poisson's ratio.

Question 5. Which type of bar do you prefer to use in this experiment- heavier or lighter?

Answer. We shall prefer heavier bars because they have large moment of inertia. This increases the time period.

Question 6. Can you use thin wires in place of threads?

Answer. No, we can't use thin wires in place of threads because during oscillations of two bars, the wires will also be twisted and their torsional reaction will affect the result.

Question 7: What are various relationship between elastic constants?

Answer: $Y = 2\eta\,(1 + \sigma)$, $Y = 3K\,(1\text{-}2\sigma)$, $\sigma = \frac{3K-2\eta}{6K+2\eta}$, $Y = \frac{9\eta\, K}{\eta\, +3K}$

Experiment No. 5

Object: To determine the moment of inertia of an irregular body about an axis passing through its centre of gravity and perpendicular to its plane by dynamical method.

Apparatus Used: Inertia table, irregular body whose moment opf inertia is to be determined, regular body whose moment of inertia can be calculated by measuring its dimensions and mass, stop watch, sprit level, physical balance with weight box and vernier callipers

Formula Used: The moment of inertia I_1 of the irregular body is determined with the help of the following formula-

$$I_1 = I_2 \times \frac{T_1^2 - T_0^2}{T_2^2 - T_0^2}$$

Where I_2 = Moment of inertia of the regular body

T_0 = Time period of inertia table alone

T_1 = Time period with the irregular body on the inertia table

T_2 = Time period with the regular body on the inertia table

If the regular body is a disc then $I_2 = \left(\frac{1}{2}\right) MR^2$

Where M = Mass of the disc, R = Radius of the disc

About apparatus:

The following figure shows the inertia table. One end of a wire is attached to the middle of the cross bar while the other end carries a circular table. The inertia table is kept horizontal by means of three balancing weights m_1, m_2 and m_3 placed in the concentric groove cut on the upper surface using a sprit level. The base of the inertia table is made horizontal with the help of screws S_1, S_2 and S_3 using spirit level. There is a mirror attached to the wire to count the number of oscillations with the help of lamp and scale arrangement. The cross bar is supported by the pillar PP fixed to a heavy base.

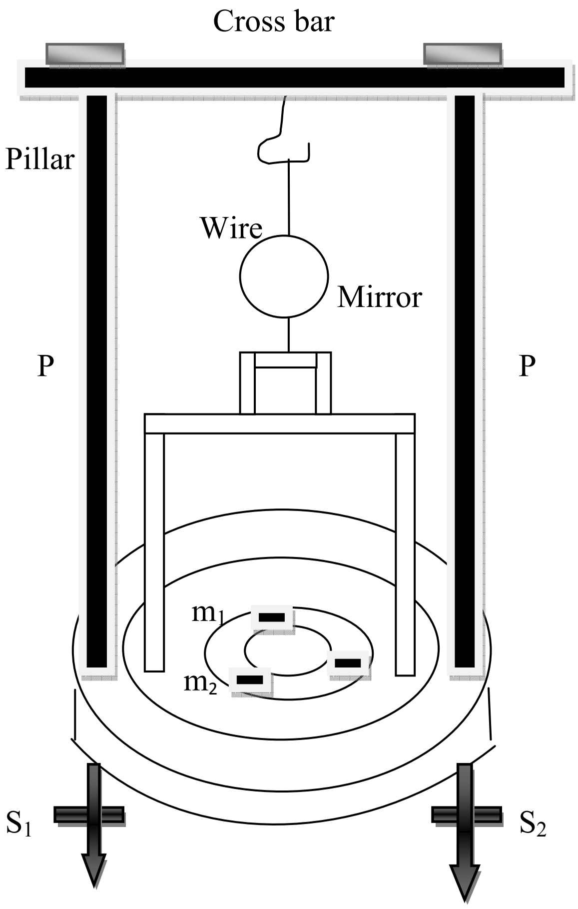


Figure 1

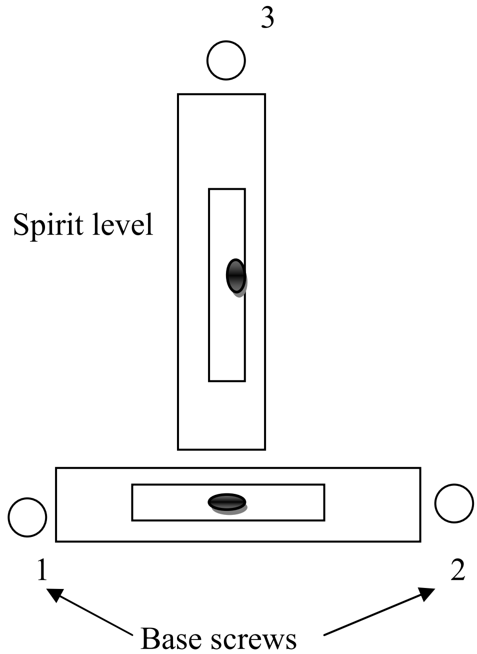


Figure 2

Procedure:

(i) First of all, make the base of inertia table horizontal by using the following procedure-

Put the spirit level along a line joining the screw1 and screw 2 as shown in figure 2. With the help of levelling screw 1 and screw 2, bring the bubble in spirit level in the middle. Again put the spirit level in a perpendicular direction and make the bubble to be in the middle by adjusting the third screw. In the second position, levelling screw 1 and screw 2 should not be touched. You will observe that now the base of inertia table is horizontal.

(ii) Put the small weights in the concentric groove and make the inertia table horizontal using the spirit level.

(iii) Now rotate the disc slightly in its own plane and release it in such a way that it rotates about the wire as axis executing oscillations. Find the time taken by 5, 10, 15, 20 and 25 oscillations and thereby T_0.

(iv) Put the irregular body on the inertia table and find T_1.

(v) Now remove the irregular body and place the regular body on inertia table whose moment of inertia is known by its dimensions. Thus find T_2.

(vi) Weigh up the regular body (i.e. disc) and note down the mass M.

(vii) Find the diameter of the disc with the help of vernier callipers.

Observations:

Mass of the disc = ...Kg

Table 1: Measurement of diameter of the given disc

Least count of vernier callipers = $\frac{\text{value of one division of main scale in cm}}{\text{total number of divisions on vernier scale}}$ = ... cm.

Zero error of vernier callipers = ± .... cm.

S.No.	Reading along any direction			Reading along a perpendicular direction			Uncorrected diameter (X+Y)/2 cm.	Mean uncorrected diameter cm.
	M.S. reading	V.S. reading	Total X- cm	M.S. reading	V.S. reading	Total Y- cm.		
1								
2								
3								

Mean corrected diameter D = Mean uncorrected diameter ± zero error = ... cm.

Mean radius R = D/2 = ... cm.

Table 2: Determination of T_0, T_1 and T_2

S.No.	No. of oscillations	Time taken by														
		Inertia Table alone			Time period T_0	Mean period T_0	Inertia Table + Irregular body			Time period T_1 sec.	Mean T_1 sec.	Inertia Table + disc			Time period T_2 sec.	Mean T_2 sec
		Min.	Sec.	Total sec			Min.	Sec.	Total			Min.	Sec.	Total sec		
1	5															
2	10															
3	15															
4	20															
5	25															

Calculations:

$I_1 = I_2 \times \frac{T_1^2 - T_0^2}{T_2^2 - T_0^2} = \frac{1}{2} MR^2 \times \frac{T_1^2 - T_0^2}{T_2^2 - T_0^2}$ = ...Kg m^2

Result:

Moment of inertia of the irregular body = ... Kg m^2

Precautions and Sources of Errors:

(1) The base and inertia table should always be set horizontal.
(2) There should not be up and down as well as to and fro motion of the inertia table.
(3) The inertia table should be rotated by a few degrees only.
(4) There should not be any kink in the wire.
(5) The periodic time should be noted very carefully.

Objectives: After performing this experiment, you should be able to-

- understand moment of inertia
- understand centre of gravity
- calculate moment of inertia of a irregular body

VIVA-VOCE:

Question 1. Explain inertia.

Answer. According to Newton's first law of motion, a body continues in its state of rest or uniform motion in a straight line in the same direction unless some external force is applied to it. This property of the body by virtue of which the body opposes any change in their present state is called inertia. It depends upon the mass of the body.

Question 2. What is moment of inertia of a particle?

Answer. The moment of inertia of a particle about an axis is given by the product of the mass of the particle and the square of the distance of the particle from the axis of rotation i.e. $I = mr^2$

Question 3. Define moment of inertia of a rigid body.

Answer. The moment of inertia of a rigid body about a given axis is the sum of the products of the masses of its particles by the square of their respective distances from the axis of rotation i.e. $I = \sum mr^2$

Question 4. What is the unit of moment of inertia?

Answer. The unit of moment of inertia is Kg-m^2.

Question 5. Define moment of inertia in terms of torque.

Answer. We know that $\tau = I \times \alpha$

Or $I = \tau/\alpha$

If $\alpha = 1$ then $I = \tau$

i.e. the moment of inertia of a body about an axis is equal to the torque required to produce unit angular acceleration in the body about that axis.

Question 6. Define moment of inertia in terms of rotational kinetic energy.

Answer. We know that rotational kinetic energy $K = (1/2)\, I\omega^2$

Or $I = 2K/\omega^2$

If $\omega = 1$ then $I = 2K$ i.e. the moment of inertia of a body rotating aboput an axis with unit angular velocity equals twice the kinetic energy of rotation about that axis.

Question 7: Explain radius of gyration.

Answer: The radius of gyration of a body about an axis of rotation is defined as the distance of a point from the axis of rotation at which, if whole mass of the body is assumed to be concentrated, its moment of inertia about the given axis would be the same as with its actual distribution of mass.

If M is the mass of the body, its moment of inertia is I then radius of gyration is given as –

$$k = \sqrt{\frac{I}{M}}$$

Question 8: How do you oscillate the inertia table?

Answer: The inertia table is rotated slightly by hand in its own plane and then left to itself. The inertia table performs torsional oscillations.

Question 9: What type of oscillations the table execute?

Answer: The inertia table executes simple harmonic oscillations in horizontal plane.

Question 10: What type of wire would you choose for your experiment?

Answer: We should choose a thin and long suspension wire so that periodic time may be large.

Question 11: Can you change the position of balancing weights any time during the experiment?

Answer: No, we cannot change the position of balancing weights any time during the experiment.

Experiment No. 6

1. Object:

To find out the moment of inertia of a flywheel.

2. Apparatus Used:

A fly wheel, a few different masses, hanger, a strong and thin string, a stop watch, a meter rod, a vernier calliper.

3. Formula Used:

Moment of inertia of fly wheel is given by

$$I = \frac{2mgh - mr^2\omega^2\omega}{\omega^2(1 + \ n_1/n_2)}$$

Where m = mass which allow to fall

h = height through which the mass is fallen

ω= angular velocity = $\frac{4\pi n_2}{t}$

t = time to make n_2 revolution.

n_1 = No. Of revolutions the wheel makes during the decent of mass

n_2= No. Of revolutions made by wheel after the string detached from the axle

Figure 1

4. Theory:

4.1 Movement of Inertia:

The movement of inertia of a body is defined as the sum of products of masses distributed at different points and square of distances of mass point and axis where the body is being rotated.

If a body of total mass M is to be made of larg number of point masses $m_1, m_2, m_3, ...$ distributed at distances $r_1, r_2, r_3, ...$ from the axis of rotation then the movement of inertia is defined as

$I = m_1r_1^2 + m_2r_2^2 + …….. + m_nr_n^2 = \sum mr^2$

4.2 Radius of Gyration:

The radius of gyration is defined as

A body of mass M rotates about an axis and mass M is supposed to be made of small mass $m_1, m_2, m_3, ...$ and $r_1, r_2, r_3, ...$ are distances from the axis. If the moment of inertia of the body is I then the radius of gyration (K) is defined as a distance from axis of rotation to a point where the whole mass of the body may be concentrated, and product of total mass and square of this distance gives the same movement of inertia.

$I = \sum mr^2 = mK^2$ Where K is the radiation of gyration.

4.3 Some examples of movement of inertia (MI) of different shapes:

1. **Movement of Inertia of a circular ring:** If a circular ring of mass M and radius R is considered then the movement of inertia (I) is given as:
   $I = MR^2$
2. **Movement of Inertia of a circular Disc:** if a circular disc has mass M and radius R the movement of inertia (I) about the axis passing through centre of gravity (CG) and perpendicular to the disc is given as:
   $$I = \frac{1}{2}MR^2$$
3. **Movement of Inertia of a rectangular lamina:** A lamina is a rectangular bar. If the length of lamina is a and width is b then the movement of inertia (I) of the lamina about the axis passing through the centre of gravity (CG) and perpendicular to the bar is given by:
   $$I = \frac{1}{12}(a^2 + b^2)$$
4. **Movement of Inertia of a sphere:** The movement of inertia of a sphere of radius r about its diameter is given as:
   $$I = \frac{2}{5}Mr^2$$

4.4 Movement of Inertia of a fly wheel:

A fly wheel is a heavy circular disc fitted with a strong axle this wheel is designed in such a way that the mass distribution is mostly at the corners so that it provides maximum moment of inertia. The axle is mounted on the ball bearing on two ends of fixed support.In the experiment a small mass m is attached to the axle of the wheel by a string which is wrapped several times around the axle, one end of the string is attached with a hook which can easily be attached or detached from the axle. A suitable length of the string is to be chosen from the axle to the ground. The end of string is attached with a hanger on which suitable manes may be attached.

In this experiment, the potential energy of mass m is converted into its translation kinetic energy and rotational kinetic energy of flywheel and some of the energy is lost in overcoming frictional force. The conservation of energy equation at the instant when the mass touches the ground can be written as,

P.E. of mass = K.E. of mass m + K.E. of wheel + work done to overcome the friction

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}Im\omega^2 + n_1F$$
(1)

Here v (= rω) is the velocity of mass and ω is the angular velocity of flywheel at the instant when the mass touches the ground. Here F is the frictional energy lost per unit rotation of the flywheel and it is assumed to be steady. n_1 is the number of rotations completed by the flywheel, when the mass attached string has left the axle.

Even after the string has left the axle, the fly wheel continue to rotate and its angular velocity would decrease gradually and come to a rest when all is rotational kinetic energy of wheel is used to overcome the friction (frictional energy). If n_2 is the number of rotation made by the flywheel after the string has left the axle then

$$n_2F = \frac{1}{2}I\omega^2$$

$$F = \frac{1}{2n_2}I\omega^2 \tag{2}$$

By substituting eq. 2 for F in eq. 1, we get the expression for moment of inertia as,

$$mgh = \frac{1}{2}mr^2\omega^2 + \frac{1}{2}Im\omega^2 + n_1\frac{1}{2n_2}I\omega^2$$

$$I = \frac{2mgh - mr^2\omega^2}{\omega^2(1+{n_1}/{n_2})} \tag{3}$$

Let t be the time taken by the flywheel to come to rest after the detachment of the mass. During this time interval, the angular velocity varies from ω to 0. So, the average angular velocity ω/2 is,

$$\frac{\omega}{2} = \frac{2\pi n_2}{t}$$

$$\omega = \frac{4\pi n_2}{t} \tag{4}$$

5. Procedure:

1. Setup the experiment as shown in Fig. 1 by taking a string of appropriate length and mass m.
2. Allow the string to unwind releasing the mass.
3. Count the number of rotation of the flywheel n_1 when the mass touches the ground.
4. Switch on the stopwatch when the moment the mass touches the ground and again count the number of rotation of flywheel, n_2 before it comes to rest. Stop the watch when the rotation ceases and note down the reading t.
5. Repeat the measurement for at least three times with the same string and mass such that n_1 , n_2 and t are closely comparable. Take their average value.
6. Repeat the measurement for another mass.
7. Measure the radius of axle using a vernier calipers and the length of the string using a scale.
8. Calculate the moment of inertia and maximum angular velocity ω using eq. 3 and 4.

6. Observations:

Vernier Constant = ------------------

Diameter of the Axle D_1 = _________

D_2 = _________

D_3 = _________

Mean diameter of the axle $D = \frac{D_1 + D_2 + D_3}{3}$

Radius of axel r = D/2 = __________

6.1 Observation table:

S. No.	MASS (in gm)	NO. OF REVOLUTION n_1			NO. OF REVOLUTION n_2			Time (t)		
		1st reading	2nd Reading	Mean n_1	1st reading	2nd Reading	Mean n_2	1st reading	2nd Reading	Mean t
1.	100									
2.	200									
3.	300									

Average angular velocity ω_1 _________

ω_2 _________

ω_3 _________

Movement of inertia of the fly wheel for

For mass m_1 : I_1 = _________

For mass m_2 : I_2 = _________

For Mass m_3 : I_3 = _________

Mean of I = _________

RESULT

Movement of inertia of a fly wheel = __________ Kg m^2

PRECAUTIONS

1. There should be a possible friction in the wheel. The tied to the end of the cord should be of such a value that it is able to overcome friction at the beginning and thus automatically stats falling.

2. The length of the string should less than the height of the axle of the fly wheel from the floor.
3. The string should be thin and should be wound evenly.

4. The stop watch should be started just when the string is detached.

Experiment No. 7

Object: To study the variation T (time period) and l (distances of the knife-edges form the centre of gravity) for a compound pendulum, plot a graph then determine acceleration due to gravity g, radius of gyration K and the moment of inertia I of the bar in the laboratory.

Apparatus Used:

Compound pendulum, a wedge, a spirit level, a telescope, a stop-watch, a meter rod, a spring balance and a graph paper.

Formula Used: Acceleration due to gravity is given by

$$g = \frac{4\pi^2 L}{T^2}$$

Radius of gyration K=$\sqrt{l_1 l_2}$

Where L is equivalent length of compound pendulum and calculated with the help of graph and T is corresponding time period.

Theory:

Simple pendulum: Before understanding a compound pendulum, we should review about a Simple pendulum. It consists of a heavy particle suspended by a weightless, inextensible and perfectly flexible string fixed from a point. The pendulum oscillates without friction about fixed point. In practice, it is not possible to have such an ideal pendulum because neither we can get a single material particle nor a weightless and inextensible string. But we can consider a simple pendulum consists of a small heavy sphere, suspended from a fixed support by a very fin e flexible cotton thread as ideal pendulum. By using such a device, we can study the behavior of a pendulum and easily determine acceleration due to gravity of a simple pendulum. If the amplitude is small, the time period t of a simple pendulum of length l is given by

$$t = 2\pi\sqrt{\frac{l}{g}}$$

A simple pendulum whose time period in two seconds is called a second's pendulum.

Compound pendulum and bar pendulum: A compound pendulum or a bar pendulum is slightly different than a simple pendulum. Since an ideal simple pendulum cannot be realized in actual practice. Therefore, we use compound pendulum so that we can find better result and most of the defects are removed by using a compound pendulum. A compound pendulum consists of a rigid body or a rigid bar which can oscillate freely about a horizontal axis passing through it.

Bar pendulum is a special type of a compound pendulum as shown in figure 15. 1. It consists of uniform metal bar having holes drilled along its length symmetrically on either side of the centre of gravity. Two knife edges are placed symmetrically with respect to the center of gravity C.G. as at A and B. The time period is determined about each hole by placing the two knife edges symmetrically. The distance of each of the knife edges (i.e. the point of suspension) form the center of gravity is measured in each case.

Time period of a compound pendulum:

Consider a rigid body i.e. a bar pendulum of mass m capable of oscillating freely about a horizontal axis passing through it perpendicular to its plane.

Let O be the center of suspension of the body and G its center of gravity in the position of rest. When the body is slightly displace through a small angle θ, the centre of gravity is shifted to the position G and its weight mg acts vertically downward at G.

If the pendulum is now released a restoring couple acts on it and brings it back to the initial position. But due to inertia it starts oscillating about the mean positions.

The moment of the restoring couple of torque

$$\tau = -mg \times GA = -mg\ l\ sin\theta = -mgl\theta$$

Since the angle θ through which the pendulum is displace is small so that sin $\theta = \theta$

This restoring couple provides an angular acceleration α in the pendulum. If I is the moment of inertia of the rigid body (bar pendulum) about an axis through its center of suspension restoring couple (torque) is given by

$$\tau = I\alpha = I\frac{d^2\theta}{dt^2}$$

Comparing equation (i) and (ii), we have

$$I\frac{d^2\theta}{dt^2} = -mgl\theta$$

$$\frac{d^2\theta}{dt^2} = -\frac{mgl\theta}{I}$$

$$\frac{d^2\theta}{dt^2} \propto \theta$$

This is the condition for simple harmonic motion. As the angular acceleration is proportional to angular displacement, the motion of the pendulum is simple harmonic and its time period T is given by

$$T = 2\pi\sqrt{\frac{Angular\ displacement}{Angular\ acceleration}} = 2\pi\sqrt{\frac{\theta}{\frac{mgl\theta}{I}}} = 2\pi\sqrt{\frac{I}{mgl}}$$

If I_{cg} is the moment of inertia of the body (or compound pendulum) about an axis passing through center of gravity (C.G.) and I is the moment of inertia of the body about a new axis Z' parallel to the given axis then according to the theorem of parallel axis, we have

$$I = I_{cg} + ml^2$$

Where l is the parallel distance about two axis as shown in figure.

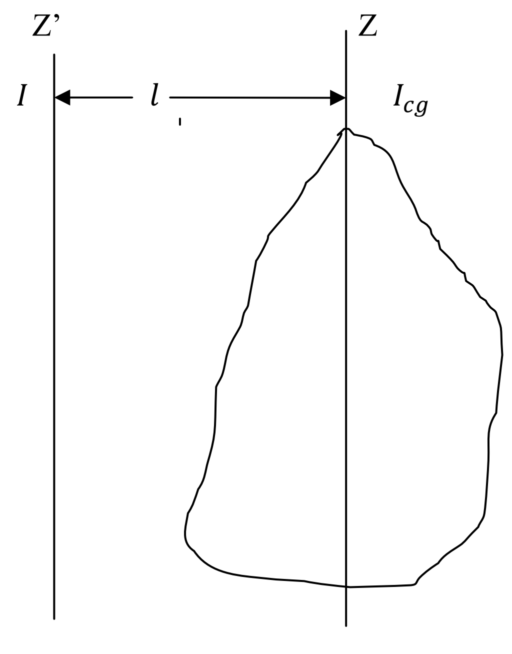


Figure 1

Now, moment of inertia center of gravity $I_{cg} = mk^2$, $where\ k\ is\ the\ radius\ of\ gyration.$

$$I = mk^2 + ml^2 = m(k^2 + l^2)$$

Substituting the value of I in relation of time period, we get

$$T = 2\pi\sqrt{\frac{mK^2 + ml^2}{mgl}} = 2\pi\sqrt{\frac{k^2 + l^2}{lg}}$$

In case of simple pendulum time period T is given as

$$T = 2\pi\sqrt{\frac{L}{g}}$$

On comparing above two relations, length $L = \frac{k^2}{l} + l$ which is called equivalent length.

Thus relation shows that the time period of a compound pendulum is the same as that of a simple pendulum of length $L = \frac{k^2}{l} + l.$ Since k^2 is always a positive quantity, the length of an equivalent simple pendulum is always greater than l.

Centre of suspension: As stated above, the point O through which the horizontal axis about which the pendulum vibrates, passes is called the center of suspension. If l_l is the distance of O from the center of gravity G, then

Time period $T = 2\pi\sqrt{\frac{k^2+l_1{}^2}{l_1 g}}$

Centre of Oscillation: A point C on the other side of center of gravity G and at a distance $l_2 = \frac{k^2}{l_1 g}$ from it is called the centre of oscillation.

$$OC = OG + GC = l_1 + \frac{k^2}{l_1 g} = l_1 + l_2 = L$$

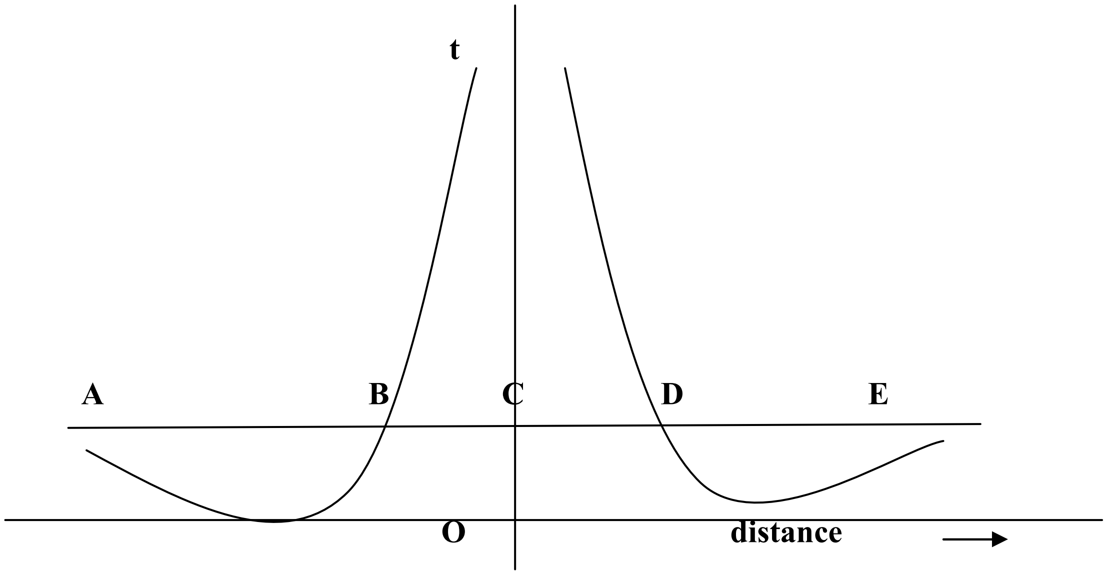
If pendulum is suspended at center of oscillation then time period

Time period $T = 2\pi\sqrt{\frac{k^2+l_2{}^2}{l_2 g}} = 2\pi\sqrt{\frac{k^2+\left(\frac{k^2}{l_1 g}\right)^2}{\left(\frac{k^2}{l_1 g}\right)}} = 2\pi\sqrt{\frac{k^2+l_1{}^2}{l_1 g}}$

Thus the time period of the compound pendulum about a horizontal axis through C is the same as about O. Thus the point C at a distance equal to the length of an equivalent simple pendulum from the point of suspension O on the straight line passing through the center of gravity G is called the center of oscillation. Mathematically, the time period is same for both center of suspension and the center of oscillation therefore the center of suspension and the center of oscillation are interchangeable. The time period of a compound pendulum is minimum when the distance of the point of suspension from C.G. is equal to the radius of gyration.

Procedure:

1. A graph is plotted between the distance of the knife-edges from the center of gravity taken along the x-axis and the corresponding time period t taken along the Y-axis for a bar pendulum, then the shape of the graph is as shown in figure 15.4.
2. If a horizontal line ABCDE is drawn, it cuts the graph in points A. B and D, E about which the time period is the same. The points A and D or B and E lie on opposite sides of the center of gravity at unequal distances such that the time period about these points is the same. Hence one of these corresponds to the center of suspension and the other to the centre of oscillation. The distance AD or BE gives the length of the equivalent simple pendulum L. If t is the corresponding time period, and $l_1 and\ l_2$ are the distances of the point of suspension and the point of oscillation from the centre of gravity, M is the mass of the bar pendulum then



Observation:

1. The reading for distance and time period is to be taken as shown in table.

No. of Hole	Side A			Side B		
	Total time for 20 oscillations	**Time period T=t/20**	**Distance from CG in cm**	**Total time for 20 oscillations**	**Time period T=t/20**	**Distance from CG in cm**
1						
2						
3						
4						

5						
6						

2. Plot the graph Take the Y-axis in the middle of the graph paper. Represent the distance from the C.G. along the x-axis and the time period along the y-axis.
3. Plot the distance on the side A to the right and the distance on the side B to the left of the origin.
4. Draw a smooth curves on either side of the Y-axis passing through the plotted points taking care that the two curves are exactly symmetrical as shown in fig. 14.5.

Calculation:

From graph

For line ABCDE

T=

L_1=

L_2=

$$L = L_{1+}L_2$$

Radius of gyration K=$\sqrt{l_1 l_2}$

And Moment of inertia I=Mk^2

Precaution:

1. Mark one end of the Bar pendulum as A and the other as B.
2. Suspend the pendulum from the knife-edge on the side A so that the knie-edge is perpendicular to the edge of the slot and the pendulum is hanging parallel to the wall.
3. Measure the distance between the C.G. and the inner edge of the knife-edge.
4. Now suspend it on the knife-edge on the side B and repeat the observations.
5. Repeat the observations with the knife-edges in the 2^{nd}, 3^{rd} 4^{th} etc. holes on either side of the center of gravity.
6. See that the knife edges are always placed symmetrically with respect to C.G.
7. The knife-edges should be horizontal and the bar pendulum parallel to the wall.
8. Amplitude should be small.
9. The two knife-edges should always lie symmetrically with respect to the C.G.
10. The distance should be measure from the knife-edges.
11. The graph drawn should be a free hand curve.

Sources of error:

1. Slight error is introduced due to (i) resistance of air, (ii) curvature of knife-edges. (iii) yielding of support and (iv) finite amplitude.

2. The stop watch may not be very accurate.

3. The time period should be noted after the pendulum has made a few vibration and the vibrations have become regular.

4. The two knife-edges should always lie symmetrically with respect to the c.g.

5. The distance should be measured from the knife –edges.

6. The graph drawn should be a free-hand curve.

Experiment No. 8

Object:

To determine the value of acceleration due to gravity with the help of a Keter's pendulum.

Apparatus Used:

Kater's pendulum, a wedge, a stop-watch, a meter rod and a graph paper.

Formula Used:

Acceleration due to gravity is given by

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}}$$

Where T_1 = Time period with knife edge K_1

T_2 = Time period with knife edge K_2

l_1= distance of knife edge K_1 from C.G.

l_2 = distance of knife edge K_2 from C.G.

Theory:

Kater's pendulum is a physical pendulum consists of a steel rod of nearly 1.2m capable to oscillate about two adjustable knife edges at two sides. The two knife edges K_1 and K_2 faced toward each other in such a way that pendulum can be suspended and set swinging by resting either knife edge on a flat, level surface. The rod can be made to oscillate by using K_1 and K_2 points as centre of suspension. One metal weight W and another wooden weight W' are kept symmetrically at two ends of the steel rod as shown in figure. The wooden weight W' is the same size and shape as the metal weight W so that it provides nearly equal air resistance to swinging as possible in either suspension. Another smaller metal weight w is also kept between the two knife edges which can be slide along the length of rod and clamped at any position. The position of smaller weight w is to be adjusted such a way that the time period of the pendulum about both the knife edges K_1 and K_2 is same or nearly same. As we know center of suspensions and center of oscillation are interchangeable therefore the time period about edges K_1 and K_2 will be same if K_1 and K_2 are center of suspensions and center of oscillation. In this condition the equivalent length L of the Keter pendulum will be distance between K_1 and K_2.

The time period of Keter pendulum

$$T = 2\pi\sqrt{\frac{L}{g}} \tag{1}$$

In the experiment the time periods about the both edges K_1 and K_2 are to be adjusted by moving the weights W and W' or small weight w along the rod and we find out the position at which time period about edges K_1 and K_2 are same. However, it is very difficult to find out the position of weight w when the time period is to be same, therefore we find the position of weight when the time periods are nearly same and apply the formula for time g.

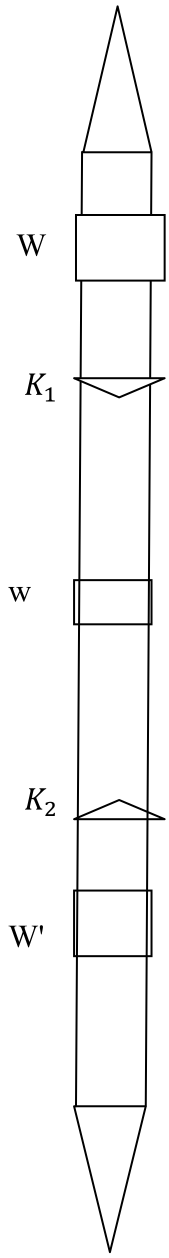


Figure 16.1 Keter's Pendulum

If T_1 and T_2 are time periods about knife edge K_1 and K_2 respectively, and l_1 is distances of knife edge K_1 from C.G. and l_2 is distance of knife edge K_2 from C.G. then the time periods can be given as

$$T_1 = 2\pi\sqrt{\frac{k^2+{l_1}^2}{l_1 g}} \quad (2)$$

and $$T_2 = 2\pi\sqrt{\frac{k^2+{l_2}^2}{l_2 g}} \quad (3)$$

using above relations

$${T_1}^2 l_1 = \frac{4\pi^2}{g}\left(K^2 + {l_1}^2\right) \quad (4)$$

$${T_2}^2 l_2 = \frac{4\pi^2}{g}\left(K^2 + {l_2}^2\right) \quad (5)$$

Subtracting equation (5) from (4)

$$g = \frac{8\pi^2}{\frac{T_1^2+T_2^2}{l_1+l_2}+\frac{T_1^2-T_2^2}{l_1-l_2}} \quad (6)$$

If If T_1 and T_2 are same (If $T_1 = T_2 = T$) the above equation (6) becomes

$$g = \frac{4\pi^2\ (l_1 + l_2)}{T^2}$$

Procedure:

3. Hang the pendulum from knife edge $K_1$and find out the time period for 20 oscillations (t_1). Hang the pendulum from knife edge K_2 and find out the time period for 20 oscillations (t_2).
4. Find $|t_1 - t_2|$
5. Now move W to 12 cm from A and K_1 is again at 2cm from W. Also move W' 12 cm from B and K_2 is again at 2cm from W'.
6. Repeat step 3 and 4.
7. Note that $|t_1 - t_2|$ for 12 cm position is less than $|t_1 - t_2|$ for 10 cm position.
8. Now keeping moving (W, K_1) and (W' , K_2) inwards by 2 cm till $|t_1 - t_2|$ becomes more than previous position.
9. Go back to previous. And find out he position for which $|t_1 - t_2|$ is minimum. Find for the t_1 and t_2 for 50 oscillations. Then find out T_1 and T_2 .
10. Find C.G. by balancing the keter pendulum on wedge. Mark the C.G. by using pencil.
11. Find out l_1 and l_2.

Observation Table:

Distance from the Edge	K_1		K_2		$\lvert t_1 - t_2 \rvert$
	Time period for 20 Oscillations (t_1)		Time period for 20 Oscillations (t_2)		
10					
12					
14					
16					
18					
--					
--					

Calculation:

For minimum $\lvert t_1 - t_2 \rvert$

Time period for 50 oscillations from K_1 side $t_1 =$ sec

Time period for 50 oscillations from K_2 side $t_2 =$ sec.

$T_1 = {}^{t_1}/_{50} =$ sec. and $T_2 = {}^{t_2}/_{50} =$ sec.

$l_1 =$ cm and $l_2 =$ cm

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}}$$

Result:

The values of acceleration due to gravity g is……………….. cm/sec^2

Precaution:

6. Mark one end of the Keter's pendulum as A and the other as B.
7. Suspend the pendulum from the knife-edge on the side A so that the edge is perpendicular to the support and the pendulum is hanging parallel to the wall.
8. Measure the distance from the knife-edge.

6. See that the knife edges are always placed symmetrically with respect to C.G.

7. Amplitude should be small.

Sources of error:

1. Slight error is introduced due to (i) resistance of air, (ii) curvature of knife-edges. (iii) yielding of support and (iv) finite amplitude.

2. The stop watch may not be very accurate.

3. The two knife-edges should always lie symmetrically with respect to the c.g.

5. The distance should be measured from the knife –edges.

Experiment No. 9

Object: To convert Weston galvanometer into an ammeter of 1 amp/3 amp/ 100 μ amp range.

Apparatus Used: Weston galvanometer-1, accumulator-1, high resistance box-1, voltmeter-1, one ammeter of the same range as given for conversion, plug key-1, a rheostat, resistance wire and apparatus for determining the galvanometer resistance by Kelvin method (if the resistance of galvanometer is not given).

Formula Used:

The current sensitivity or figure of merit is given by-

$$C_s = \frac{E}{n(R+G)} \qquad .....(1)$$

Where E = e.m.f. of the battery, R = resistance introduced (from Resistance Box, R.B.) in the circuit of galvanometer, n= deflection in galvanometer on introducing R in galvanometer circuit and G = galvanometer resistance.

We can calculate the maximum current passing through the galvanometer for full scale deflection using the following formula-

$$I_g = C_s N \qquad .....(2)$$

Where N is the total number of divisions on the scale of the galvanometer on one side of the zero of scale.

Now, we can calculate the shunt resistance S required to convert the galvanometer into an ammeter by the following formula-

$$S = \frac{I_g}{I - I_g} G \qquad .....(3)$$

Where I_g = the maximum current passing through the galvanometer for full scale deflection,

I = range of the ammeter in which the galvanometer is to be converted (1 amp/3 amp/ 100 μ amp)

The length 'l' of the shunt wire can be calculated by the following formula-

$$l = \frac{S}{\rho} \qquad .....(4)$$

where S = shunt resistance as calculated by equation (3)

ρ = resistance per unit length of shunt wire

The length 'l' of the shunt wire can be calculated by using the formula, $l = \frac{\pi r^2 S}{k}$ .....(5)

Where r is the radius of the wire used that can be find out using screw gauge and k the specific resistance of the material of the wire. The value of k can be taken from the table of constants.

About apparatus:

To measure the strength of the current flowing in the circuit, an ammeter is used in series. In series, the whole current passes through the ammeter. The ammeter should have negligible resistance in order that it may not change the current in the circuit. An ideal ammeter has zero resistance. To convert a galvanometer into an ammeter of given range, we must determine experimentally the resistance of the galvanometer coil, the current sensitivity and the shunt in the following way-

Let C_s, N, I_g, I and S be the current sensitivity of the galvanometer, total number of divisions on the scale, the maximum current that passes through the galvanometer for the full scale deflection, range of the ammeter in which the galvanometer is to be converted and S the value of shunt required, then $I_g = C_s N$

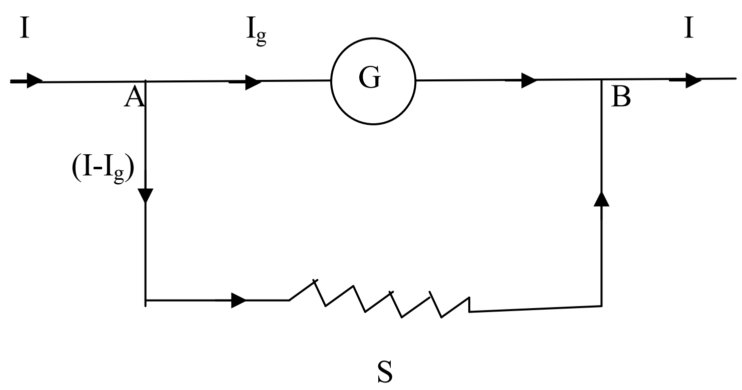


Figure 1

Considering figure 1, the potential difference between points A and A is-

$$V_A - V_B = (I - I_g) \times S = I_g \times G$$

Or
$$S = \frac{I_g}{I - I_g} G$$

Where G is the galvanometer resistance. Knowing the value of the shunt, galvanometer can be converted into an ammeter of the given range I.

Procedure:

Determination of galvanometer resistance (G):

If the value of galvanometer resistance is not given then it can be determined with the help of Kelvin's method.

Determination of the current sensitivity of the galvanometer (C_S)

(i) Set up the electrical circuit as shown in the following figure 2.

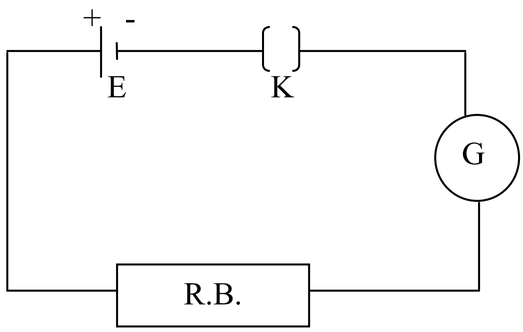


Figure 2

(ii) Using voltmeter, measure the e.m.f. E of the accumulator (battery). Note down the initial reading of the galvanometer carefully and adjust the resistance box (R.B.) to a high value.

(iii) Close the key K in the circuit and adjust the resistance box to get approximately the full scale deflection. Let R be the resistance in the resistance box to obtain n divisions deflection in galvanometer taking into account the zero reading.

(iv) Now, calculate the current sensitivity (or figure of merit) C_s using the formula-

$$C_s = \frac{E}{n(R+G)}$$

(v) Again calculate $I_g = C_sN$, where N is the total number of divisions on one side of the scale of galvanometer.

Determination of shunt resistance (S) and length of the shunt wire (l)

Shunt resistance $S = \frac{I_g}{I-I_g}G$, where I is the range of the ammeter in which the given galvanometer is to be converted.

Length of the shunt wire $l = \frac{S}{\rho}$, where ρ is the resistance per unit length of the wire used for shunt

Or $l = \frac{\pi r^2 S}{k}$, where r is the radius of the wire used that can be find out using screw gauge and k the specific resistance of the material of the wire. The value of k can be taken from the table of constants. For copper, $k = 1.78 \times 10^{-6}$ ohm.

Calibration of the converted galvanometer

Now let us calibrate the converted galvanometer as follows-

(i) Set up the electrical circuit as shown in figure 3.

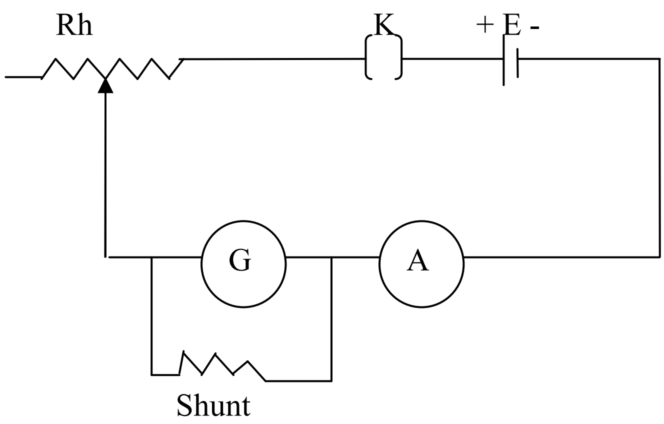


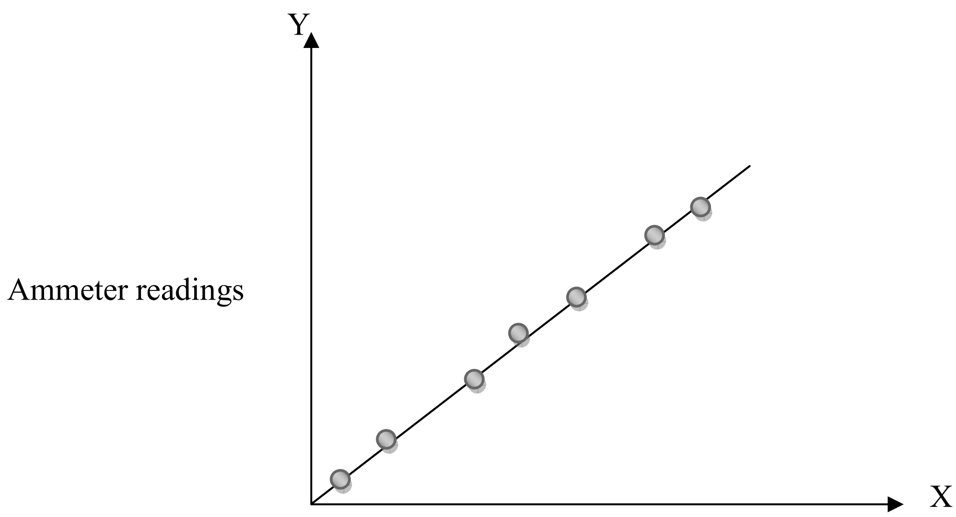
Figure 3

(ii) For a particular setting of Rh, close the key K and note down the ammeter and galvanometer readings.

(iii) Now convert the galvanometer reading into amperes and find the difference between the readings of the two instruments.

(iv) Now, change the value of Rh and repeat the above procedure till the entire range of the converted galvanometer is covered.

(v) Plot a graph taking converted galvanometer readings as abscissa and corresponding ammeter readings as ordinates. The graph is shown in figure 4.



Converted galvanometer reading

Figure 4

Observations:

Determination of galvanometer resistance (G)

If the value of galvanometer resistance is not given then it can be determined with the help of Kelvin's method. Note down the observations for Kelvin's method for the determination of galvanometer resistance.

Galvanometer resistance G = ...ohm

Determination of I_g

E.M.F. of the battery E = ...volt

No. of divisions on one side of zero of scale on the galvanometer N = ...

S.No.	Resistance introduced in resistance box R (ohms)	Deflection in galvanometer n	Current sensitivity C_s	$I_g = C_sN$ (amp)	Mean I_g (amp.)
1					
2					
3					

Calibration of shunted galvanometer

S.No.	Reading of shunted galvanometer		Ammeter reading I' (amp)	Error (I-I') amp
	In division	In ampere I		
1				
2				
3				
4				
5				
6				
7				

Calculations:

The current sensitivity or figure of merit $C_s = \frac{E}{n(R+G)}$ = ...

The maximum current passing through the galvanometer for full scale deflection $I_g = C_sN$

= .... amp

Shunt resistance $S = \frac{I_g}{I - I_g} G$ = ...ohm

Length of shunted wire $l = \frac{\pi r^2 S}{k}$ = ...cm

Result:

The length of the shunt wire of SWG ....required to convert the given galvanometer into an ammeter of range of .... amp. = ...cm.

Precautions and Sources of Errors:

(1) The battery/accumulator used should be fully charged.
(2) All connections should tight.
(3) The initial readings of galvanometer and ammeter should be at zero mark.
(4) While connecting the shunt exact length should be connected in parallel to the galvanometer.
(5) All the readings should take carefully.

Objectives: After performing this experiment, you should be able to-

- understand current sensitivity or figure of merit
- understand about shunt
- calculate length of shunted wire

VIVA-VOCE:

Question 1. What is an ammeter?

Answer. An ammeter is an instrument designed to read current flowing in an electrical circuit. It is connected in series with circuit.

Question 2. What will happen if the ammeter is connected in parallel to the circuit?

Answer. It will measure only the fraction or part of the current flowing through it and not the total current.

Question 3. The resistance of an ammeter is kept low, why?

Answer. If the resistance of an ammeter is kept high, it will change the value of the current in the circuit.

Question 4. How is the resistance of an ammeter made low?

Answer. It is done by connecting a low resistance (shunt) in parallel with galvanometer.

Question 5. A galvanometer as such cannot be used as an ammeter, why?

Answer. A galvanometer as such cannot be used as an ammeter due to the following reasons-

(i) The resistance of the galvanometer coil is appreciable.
(ii) It can measure only a limited current corresponding to the maximum deflection on the scale.

Question 6. How do you convert a galvanometer into an ammeter?

Answer. According to the range of the ammeter, we find the resistance of shunt, then from resistance we find the length of shunt to be connected in parallel with the galvanometer.

Question 7. Can you change the range of ammeter? If yes, how?

Answer. Yes, we can change the range of ammeter by changing the resistance of shunt.

Experiment No. 10

Object: To convert Weston galvanometer into a voltmeter of 50 volt/ 3 volt range.

Apparatus Used: Weston galvanometer-1, accumulator-1, high resistance box-1, one voltmeter of the same range as given for conversion, plug key-1, a rheostat and apparatus for determining the galvanometer resistance by Kelvin method (if the resistance of galvanometer is not given).

Formula Used: The current sensitivity or figure of merit is given by-

$$C_s = \frac{E}{n(R+G)} \qquad .....(1)$$

Where E = e.m.f. of the battery, R = resistance introduced (from Resistance Box, R.B.) in the circuit of galvanometer, n= deflection in galvanometer on introducing R in galvanometer circuit and G = galvanometer resistance.

We can calculate the maximum current passing through the galvanometer for full scale deflection using the following formula-

$$I_g = C_s N \qquad .....(2)$$

where N is the total number of divisions on the scale of the galvanometer on one side of the zero of scale.

To convert the galvanometer into a voltmeter of a given range, the series resistance R required for it is given by-

$$R = \frac{V}{I_g} - G \qquad .....(3)$$

About apparatus:

A voltmeter is used to measure the potential difference between two points in an electrical circuit. It is always connected in parallel to the branch across which the potential is to be measured. It must have a high resistance so that it may not draw appreciable current otherwise the current in the circuit will decline, resulting in the fall of potential difference to be measured. Thus ideal voltmeter should have infinite resistance. A moving coil galvanometer cannot be used as a voltmeter because its resistance is not very high. Its resistance is made high by placing a high resistance in series with the galvanometer. The high resistance can be planned as follows-

Let G, I_g and V be the galvanometer resistance, maximum current in the galvanometer for full scale deflection (Figure1).

Applying Ohm's law in figure 1, we can write-

$$I_g(R+G) = V$$

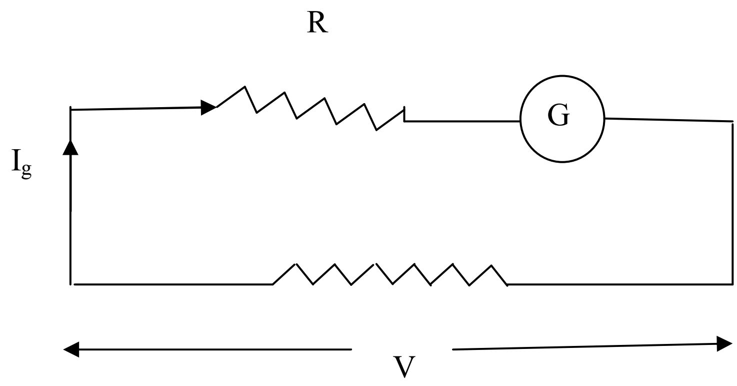


Figure 1

$$I_g R + I_g G = V \quad \text{or} \quad I_g R = V - I_g G$$

Or $$R = \frac{V}{I_g} - G$$

Using above equation, resistance R can be calculated.

Procedure:

Determination of galvanometer resistance (G):

If the value of galvanometer resistance is not given then it can be determined with the help of Kelvin's method.

Determination of the current sensitivity of the galvanometer (C_S)

(i) Set up the electrical circuit as shown in the following figure 2.

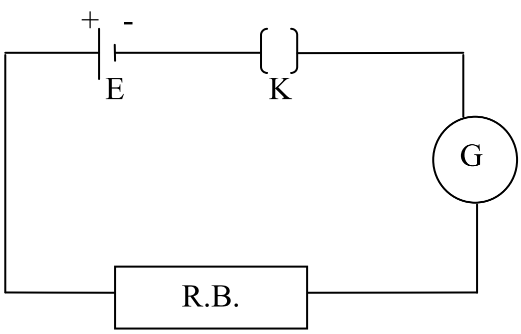


Figure 2

(ii) Using voltmeter, measure the e.m.f. E of the accumulator (battery). Note down the initial reading of the galvanometer carefully and adjust the resistance box (R.B.) to a high value.

(iii) Close the key K in the circuit and adjust the resistance box to get approximately the full scale deflection. Let R be the resistance in the resistance box to obtain n divisions deflection in galvanometer taking into account the zero reading.

(iv) Now, calculate the current sensitivity (or figure of merit) C_s using the formula-

$$C_s = \frac{E}{n(R+G)}$$

(v) Again calculate $I_g = C_s N$, where N is the total number of divisions on one side of the scale of galvanometer.

Determination of series resistance

Using formula, $R = \frac{V}{I_g} - G$, we can calculate the series resistance R required to change the galvanometer into voltmeter of the given range of V volt that is, if we want to convert galvanometer into a voltmeter of range 50 volt then V = 50 volt.

Calibration of the converted galvanometer

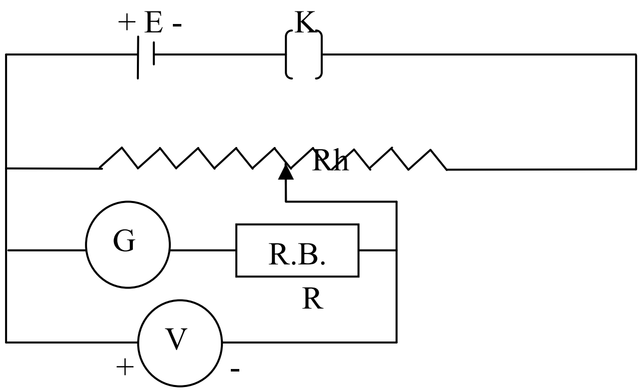


Figure 3

(i) Let us set up the electrical connections as shown in figure (2). The two base terminals of a rheostat Rh are connected in series with a battery E and key K. The galvanometer together with its series resistance (introduce a resistance box) is connected in parallel to the rheostat Rh . Between the same points, a voltmeter is also connected.

(ii) Now we shift the position of the sliding contact on the rheostat and take a number of readings in galvanometer and voltmeter respectively. We convert the galvanometer reading in volt and calculate the error between the two readings.

(iii) We plot a graph between converted galvanometer reading in volt and corresponding reading in voltmeter. You will see that the graph is a straight line as shown in figure 4.

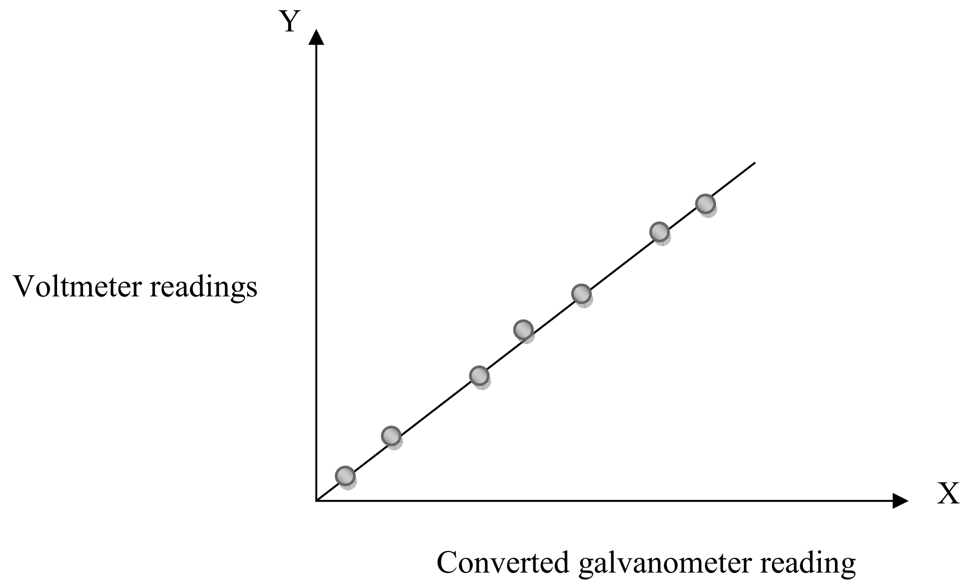


Figure 4

Observations:

Determination of galvanometer resistance (G)

If the value of galvanometer resistance is not given then it can be determined with the help of Kelvin's method. Note down the observations for Kelvin's method for the determination of galvanometer resistance.

Galvanometer resistance G = ...ohm

Determination of I_g

E.M.F. of the battery E = ...volt

No. of divisions on one side of zero of scale on the galvanometer N = ...

S.No.	Resistance introduced in resistance box R (ohms)	Deflection in galvanometer n	Current sensitivity C_s	$I_g = C_sN$ (amp)	Mean I_g (amp.)
1					
2					
3					

Calibration of shunted galvanometer

S.No.	Reading of shunted galvanometer		Ammeter reading I' (amp)	Error (I-I') amp
	In division	In ampere I		
1				
2				
3				
4				
5				
6				
7				

Calculations:

The current sensitivity or figure of merit $C_s = \frac{E}{n(R+G)}$ = ...

The maximum current passing through the galvanometer for full scale deflection $I_g = C_sN$

= .... amp

Series resistance required $R = \frac{V}{I_g} - G =$ ..... ohm

Result:

The resistance required to convert the given galvanometer into voltmeter of range of .... volt is ...... ohms.

Precautions and Sources of Errors:

(1) The battery/accumulator used should be fully charged.
(2) All connections should tight.
(3) The initial readings of galvanometer and ammeter should be at zero mark.
(4) While connecting the shunt exact length should be connected in parallel to the galvanometer.
(5) All the readings should take carefully.

Objectives: After performing this experiment, you should be able to-

- understand current sensitivity or figure of merit
- understand about resistance
- calculate the resistance required.

VIVA-VOCE:

Question 1. What is an voltmeter?

Answer. A voltmeter is an instrument designed to read potential difference between two points directly in volts, when connected across those points. It is connected in parallel.

Question 2. What should be the resistance of a voltmeter? Why?

Answer. The resistance of a voltmeter should be high so that it may not draw appreciable current otherwise the current in the circuit will decline, resulting in the fall of potential difference to be measured.

Question 3. A moving coil galvanometer cannot be used as a voltmeter, why?

Answer. A moving coil galvanometer cannot be used as a voltmeter because its resistance is not very high. Its resistance is made high by placing a high resistance in series with the galvanometer.

Question 4. What is the resistance of an ideal voltmeter?

Answer. The resistance of an ideal voltmeter is infinite.

Question 5. How can you convert a galvanometer into voltmeter?

Answer. As per the range of the voltmeter, we find the value of high resistance that is to be connected in series with galvanometer resistance.

Experiment No. 11

Object: To determine the Young's modulus of the material of a given beam supported on two knife-edges and loaded at the middle point.

Apparatus Used: The given beam, spherometer, 0.5 kg weights-8 Nos., hanger, vernier callipers, meter scale, dry cell (or Leclanche cell), plug key, bulb (or shunted galvanometer)

Formula Used: The Young's modulus (Y) for a beam of rectangular cross-section can be calculated by the following relation-

$$Y = \frac{Mgl^3}{4bd^3\delta}$$

Where M = load suspended from the beam, g = acceleration due to gravity = 9.8 m/sec^2, l = length of the beam between the two knife edges, b = breadth of the beam, d = thickness of the beam, δ = depression of the beam in the middle

About apparatus:

The experimental set up is shown in figure 1. A beam PQ is supported on two knife-edges K_1 and K_2. Suitable loads (weights) can be applied to the beam with the help of a hanger suspended from the middle of the beam. A bulb, key, dry cell and rheostat are connected in series between the central leg of spherometer and the end Q of the beam. The depression of the beam in the middle is measured with the help of spherometer fixed just above the knife edges.

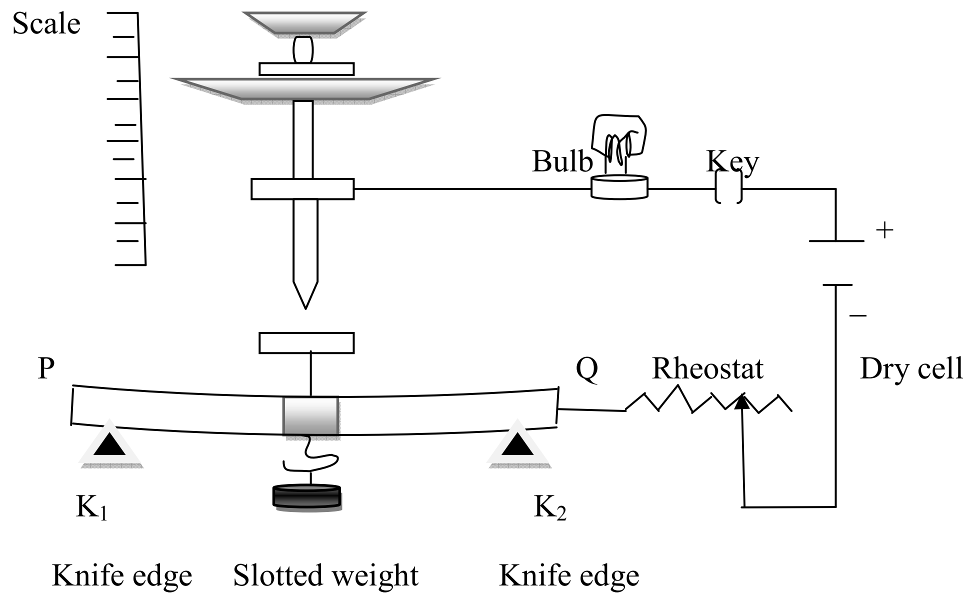


Figure 1

Procedure:

(i) Let us place the beam on the knife edges symmetrically and adjust the hanger in the middle of the beam.

(ii) We measure the distance between the two knife edges with meter scale. This distance is 'l'.

(iii) We measure the breadth of the beam at different points with the help of vernier callipers and take the mean. This gives us breadth 'b' of the beam.

(iv) Now we measure the thickness of the beam at different places with the help of vernier callipers. This is'd'.

(v) When the beam is unloaded, rotate the spherometer, till its central leg just touches the hanger, i.e. the bulb just glows. We note down this reading of the spherometer.

(vi) Let us place a weight(load) of 0.5 kg in the hanger. In this case, the beam bends and the contact is broken. Again the spherometer is rotated till there is just glow in the bulb. We note down this reading. Take the difference between two readings, this difference gives the depression for 0.5 kg. In this way, we go on loading the beam and noting the spherometer reading each time, till the maximum permissible load is applied.

(vii) Now gradually decrease the load step by step and note down the reading of spherometer each time. This time, while decreasing the load, the spherometer is rotated in reverse direction so as to move upwards and the readings are taken when the light in the bulb just disappears.

(viii) Now, we calculate the mean depression (□) of the beam as shown in observation table.

Observations:

Length of the beam between the knife edges, l = ... meter

Measurement of thickness (d) of the bar

Least count of the vernier callipers = ... cm

Zero error of the vernier callipers = ± .... cm

S.No.	Vernier callipers reading			Mean uncorrected d (cm)	Corrected d (cm)
	M.S. reading (cm)	V.S. reading (cm)	Thickness d (cm)		
1					
2					
3					
4					

Thickness of the bar d = ... cm = ...meter

Table for the measurement of depression (□) of the bar

Least count of the spherometre = $\frac{\text{value of one division of main scale in cm}}{\text{Total number of divisions on circular scale}}$ = ... cm.

Zero error of spherometer = ± .... cm.

S.No.	Load (weight) in the hanger (kg.)	Spherometer reading with load increasing			Spherometer reading with load decreasing			Mean reading (a+b)/2 (cm.)	Depression □ for M = 2.0 kg. (cm.)	Mean □ for M= 2.0 kg. (cm)
		M.S. reading (cm.)	C.S. reading (cm.)	Total a (cm)	M.S. reading (cm.)	C.S. reading (cm.)	Total b (cm)			
1	0							.......(i)	(v)-(i) = ...	
2	0.5							........(ii)		
3	1.0							......(iii)	(vi)-(ii)=	
4	1.5							......(iv)		....
5	2.0							.......(v)	(vii)-(iii) =....	
6	2.5							......(vi)		
7	3.0							......(vii)	(viii)-(iv)=.....	
8	3.5							....(viii)		

Depression of the bar for M = 2.0 kg., □ = ... cm.= ....meter

Note: C.S (circular scale) reading = No. of divisions on circular scale in front of main scale × least count of spherometre

Table for breadth (b)

Least count of vernier callipers = ... cm.

Zero error = ± .... cm.

S.No.	Vernier callipers reading			Mean uncorrected breadth (cm.)	Corrected b (cm.)
	M.S. reading (cm.)	V.S. reading (cm.)	Total reading i.e. breadth b (cm.)		
1					
2					
3				....	....
4					
5					

Breadth of the bar b = ... cm.= .... meter

Calculations:

The Young's modulus (Y) for a beam of rectangular cross-section -

$$Y = \frac{Mgl^3}{4bd^3\delta} = \quad \text{........ Newton/meter}^2$$

We substitute the values of M, l, b, d and □ to calculate the value of Y.

Result:

The Young's modulus of the material of the beam is .... Newton/meter^2

Standard Result:

The Young's modulus for........................... is .... Newton/meter^2

Percentage error:

$$\text{Percentage error} = \frac{\text{Standard result} \sim \text{Experimental result}}{\text{Standard result}} \times 100 = \quad \text{........ \%}$$

Precautions and Sources of Errors:

(1) The beam bust be symmetrically kept on the knife edges.
(2) The hanger should be suspended from the centre of gravity of the beam.
(3) The weights (loads) should be kept or removed from the hanger as gently as possible and the reading should be recorded only after waiting for sometime so that the thermal effects produced in the specimen, get ended.
(4) The breadth, depression and thickness should be noted very carefully.
(5) All readings should be taken carefully.

Objectives: After performing this experiment, you should be able to-

- understand Young's modulus
- understand bending of beam
- understand and calculate depression of beam
- compute Young's modulus

VIVA-VOCE:

Question 1. What are elastic body?

Answer. Body which regain its shape or size or both completely as soon as deforming force is removed is called perfectly elastic body.

Question 2. What is elasticity?

Answer. Elasticity is that property of the material of a body by virtue of which the body opposes any change in its shape or size when deforming force is applied to it and recovers its original state as soon as the deforming force is removed.

Question 3. What do you mean by limit of elasticity?

Answer. The maximum deforming force upto which a body retains its property of elasticity is called the limit of elasticity of the material of the body.

Question 4. What is stress?

Answer. Force per unit area of cross-section is known as stress.

Question 5. What is strain?

Answer. The change occurred in the unit size of the body is called strain.

Question 6. What is Hooke's law?

Answer. Hooke's law states that within the limit of elasticity, the stress is proportional to strain i.e. stress/strain = a constant, called modulus of elasticity.

Question 7. What do you understand by Young's modulus?

Answer. The Young's modulus is defined as the ratio of longitudinal stress to the longitudinal strain within the limit of elasticity. It is denoted by Y.

i.e. $Y = \frac{\text{longitudinal stress}}{\text{longitudinal strain}}$

Question 8. What do you mean by a beam?

Answer. A bar of uniform cross section whose length is much greater as compared to thickness is called a beam. A beam may be circular or rectangular.

Question 9. If the length of a beam is changed, what is the effect on Young's modulus?

Answer. The Young's modulus remains the same because it is constant for a given material. It does not change according to length, thickness or breadth.

Question 10. Why have you placed the beam flat(horizontally) on knife edges? Can you keep it with breadth vertical?

Answer. The depression caused by a given load, will be very small in that case.

Experiment No. 12

Object: To determine the electrochemical equivalent of copper and reduction factor of a Helmholtz galvanometer.

Apparatus Used: Copper voltameter, test plate, Helmholtz galvanometer, accumulator, commutator, connection wires, chemical balance and weight box

Formula Used: If we set the plate of the Helmholtz galvanometer coil in the magnetic meridian and electric current i ampere is allowed to flow through it, then-

$$i = \frac{50\sqrt{5}rH}{32\pi N}\tan\theta \qquad .....(1)$$

Here, r = radius of the coil, H = Earth's magnetic field's horizontal component, n = number of turns of either of the coils of Helmholtz galvanometer

If the same electric current is allowed to pass through a copper voltameter connected in series with Helmholtz galvanometer, then from Faraday's law of electrolysis, we have-

$$m = z\, i\, t$$

Here, m = mass of the copper deposited on cathode plate, t = time (sec) for which the current passes, i = magnitude of the electric current, z = electrochemical equivalent of copper ion

From the above relation, we have-

$$z = \frac{m}{it} \qquad .....(2)$$

Putting for i from equation (1) in equation (2), we get-

$$z = \frac{32\, m\, \pi\, n}{50\sqrt{5}rH\, \tan\theta \times t}$$

Thus, using the above relation, we can calculate the electrochemical equivalent of copper ion.

The reduction factor of Helmholtz galvanometer is given as-

$$k = \frac{m}{z\, t\, \tan\theta}$$

Procedure:

(i) First of all, we should clean the cathode plate carefully with sandpaper and weigh it with the help of chemical balance.

(ii) Keep the coils in the magnetic meridian and rotate the compass box to make the pointer read zero-zero.

(iii) Set up electrical connections as shown in following figure (1). Using copper test plate as cathode, allow electric current to pass in the circuit and read and note down the deflection. Now, with the help of commutator reverse the direction of electric current and again read and note down the deflection. Check whether the two deflections are same, if the two deflections are same then the coils are in the magnetic meridian otherwise we should rotate the coils slightly till the two deflections are the same. The pointer should read zero when no electric current is passed.

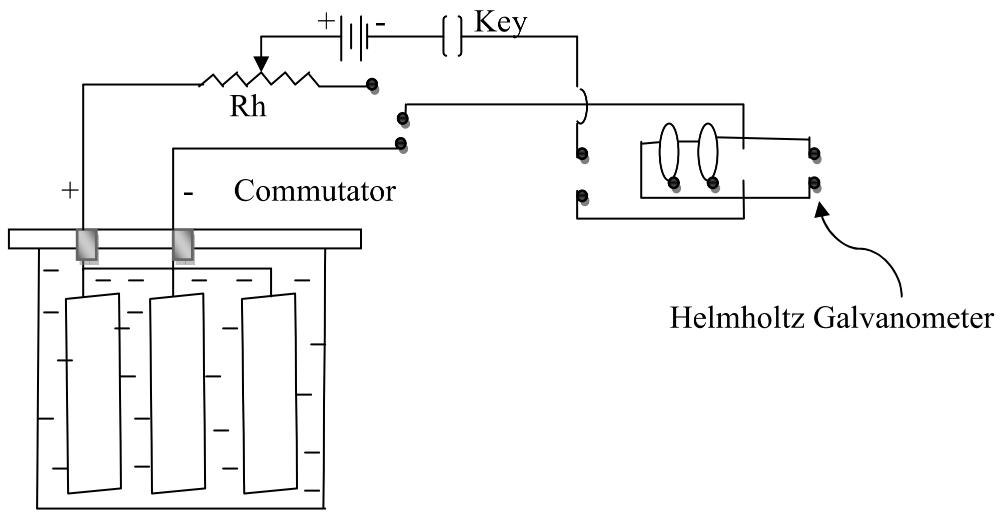


Figure 1

(iv) With the help of rheostat Rh, we adjust the deflection say within 45^o to 50^o.

(v) Now switch off the current and remove the test plate. Now put the previously weighed plate to act as cathode.

(vi) We switch on the electric current and at once start the stop watch. We note down the deflection after a regular interval of 5 minutes and keep it constant with the help of rheostat. After fifteen and twenty minutes, we reverse the current and note the deflection. At the end of other half of time, we switch off the current and note down the reading of stop watch.

(vii) Now we remove the copper plate from voltameter and immerse the plate in water and then press it between the sheets of filter paper to soak the water. Now we dry it with the help of cold air blower and weigh it with chemical balance.

(viii) To measure the diameter of the coil, we measure the circumference and calculate radius by equating to 2π r. We measure both external and internal circumference and calculate the mean of the radius. We take this as r.

Observations:

Value of the magnetic field H = ... oersted

Radius of the coil r = ... cm.

Number of turns in each coil n = ...

Table for the measurement of m and t:

S.No.	Quantities measured	Amount (gm.)	Calculated quantities from observations
1	Mass of the copper plate before deposition of copper	....	Mass of copper deposited m = ... gm
2	Mass of the copper plate after deposition of copper	....	
3	Initial reading of stop watch	....	Total time t taken = ... sec.
4	Find reading of stop watch	....	

Table for the determination of θ:

Time (minutes)	Deflection of pointer for direct current		Deflection of pointer for reverse current		Mean	tan θ
	Left end θ_1	Right end θ_2	Left end θ_3	Right end θ_4		
0	45^0	45^0	45^0	45^0	45^0	....
5						
10						
15						
20						
25						

Calculation:

The electrochemical equivalent of copper ion, $z = \frac{32\, m\, \pi\, n}{50\sqrt{5}rH\, \tan\theta \times t}$ = ... gm./Coulomb

The reduction factor of Helmholtz galvanometer, $k = \frac{m}{z\, t\, \tan\theta}$ = ... amp.

Result: The electro-chemical equivalent of copper = ... gm./Coulomb and the reduction factor of Helmholtz galvanometer = ... amp.

Precautions and Sources of Errors:

(1) The galvanometer coils should be set in magnetic meridian carefully.
(2) The deflection of the galvanometer should be kept constant with the help of rheostat.
(3) The electric current passed in the coils should be of such a value as to produce a deflection of nearly 45^0.
(4) The middle plate should be made cathode.
(5) All readings should be taken carefully.

Objectives: After performing this experiment, you should be able to-

- understand and compute electrochemical equivalent
- understand and compute reduction factor of Helmholtz galvanometer
- understand Helmholtz galvanometer

VIVA-VOCE:

Question 1. What is an electrolyte?

Answer. An electrolyte is a solution which conducts the electricity through it.

Question 2. What is chemical equivalent?

Answer. Chemical equivalent is equal to atomic weight/valency i.e. same as equivalent weight.

Question 3. What is electrochemical equivalent?

Answer. Electrochemical equivalent is the mass of substance liberated by the passage of 1 coulomb of electric charge.

Question 4. What is reduction factor? What is its unit?

Answer. The reduction factor is the current required to produce a deflection of 45^0 in tangent galvanometer. Its unit is ampere.

Question 5. On what factors reduction factor depends?

Answer. The reduction factor depends on the following factors-

(a) Number of turns in the coil
(b) Radius of the coil

Question 6. How does reduction factor depend on number of turns in the coil and radius of the coil?

Answer. Reduction factor decreases with increase in number of turns in the coil and increases by increasing the radius of the coil.

Question 7. Why H_2So_4 is added in the solution?

Answer. Addition of H_2So_4 furnishes additional ions in the solution and thus increases its conductivity.

Experiment No. 13

Object: To study the resonance in series LCR circuit with a source of given frequency (A.C. mains).

Apparatus Used: Inductance of 10 H, resistance of 1 KΩ, variable condenser unit (values in μF), an auto transformer, 4- A.C. voltmeters of suitable ranges.

Formula Used: In series LCR circuit, the current is given as-

$$i = \frac{E}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}}$$

where E = voltage, R = resistance, L = inductance, C = capacitance, ω = frequency of A.C. mains

At resonance, $\omega L = 1/\omega C$ and if i_r be the electric current at resonance then

$$i_r\ \omega L = i_r/\Omega c$$

$$V_L = V_C$$

Combined potential difference across C and L i.e. V_{CL} should be zero but never found such in practice due to choke coil resistance. V_{CL} is minimum at resonance.

Auto Transformer

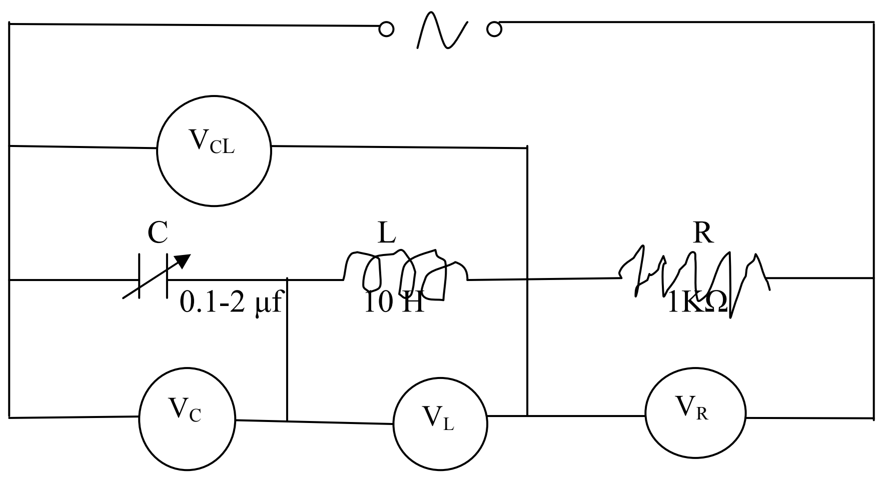


Figure 1

At resonance, impedance is minimum and consequently current is maximum. It means that voltage $V_R = i_r R$ should also be maximum. Thus at resonance-

(1) $V_L = V_C$
(2) V_{CL} is minimum and
(3) V_R is maximum

Procedure:

(i) We make electrical connections as shown in figure 1.

(ii) Keep the value of C equal to 0.1 μf and note down the readings of four voltmeters giving V_C, V_L, V_R and V_{CL} .

(iii) By changing the values of capacity in regular steps of 0.1 μF, we take some sets of observations.

Observations:

Table for the measurement of V_C, V_L, V_R and V_{CL}

S.No.	Capacitance introduced in the circuit C (μF)	Voltage across C, V_C (volt)	Voltage across L, V_L (volt)	Voltage across R, V_R (volt)	Voltage combined across C and L, V_{CL} (volt)
1	0.1				
2	0.2				
3	0.3				
4	0.4				
5	0.5				

Calculations:

Values of V_L, V_C, V_R and V_{CL} are plotted as a function of C in figure 2 and 3.

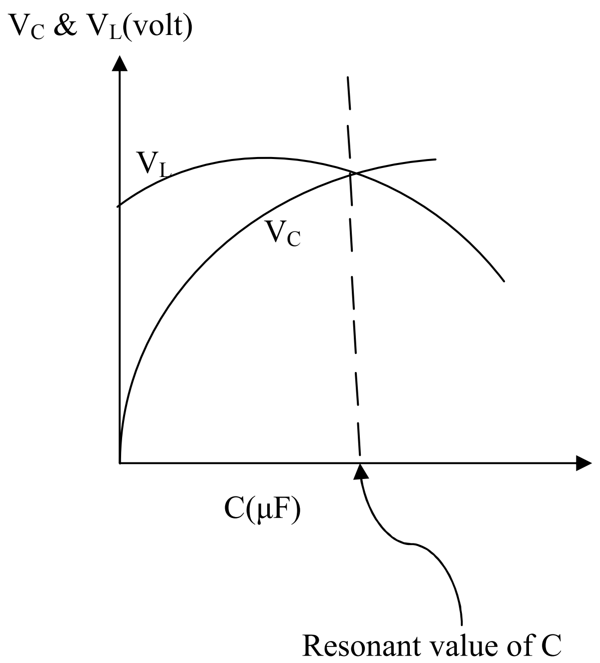


Figure 2

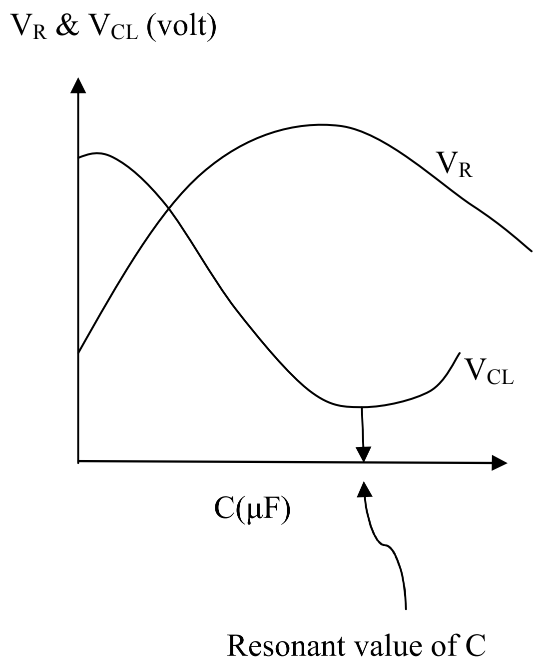


Figure 3

Result: From figure 2, resonant value of capacitance C = ... μF

From figure 3, resonant value of capacitance C = ... μF

We also find that at resonance-

(i) $V_L = V_C$
(ii) V_R is maximum and
(iii) V_{CL} is minimum

Precautions and Sources of Errors:

(1) All the electrical connections should be tight.
(2) Suitable values of capacitance should be chosen.
(3) All readings should be taken carefully.

Objectives: After performing this experiment, you should be able to-

- understand resonance
- understand and compute the resonant value of C

VIVA-VOCE:

Question 1. What is the relation between the frequency of applied voltage and natural frequency of the circuit in a series resonant circuit?

Answer. In a series resonant circuit, the frequency of the applied voltage is equal to the natural frequency of the circuit.

Question 2. What is the another name of a series resonant circuit and why?

Answer. A series resonant circuit gives voltage-amplification. Hence it is also called voltage resonant circuit.

Question 3. When a series LCR A.C. circuit is brought into resonance, the current has a large value, why?

Answer. The current in series LCR A.C. circuit is **-**

$$i = \frac{E}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

At resonance, $\omega L = \frac{1}{\omega C}$; the denominator in the above equation i.e. impedance of the circuit decreases and hence the current increases.

Question 4. In an A.C. resonant circuit, L,C and R are connected in series. What is the expression for the frequency of the oscillatory circuit?

Answer. f = $\frac{1}{2\pi\sqrt{LC}}$, provided R is small.

Question 5. When are the voltage and electric current in LCR series A.C. circuit in phase?

Answer. At resonance

Experiment No. 14

Object: To study the theorem of parallel axes.

Apparatus Used: Maxwell's needle apparatus with solid cylinders only and a stop watch or a light aluminium channel about 1.5 metre in length and 5 cm. in breadth fitted with a clamp at the centre to suspend it horizontally by means of wire, a stop watch , two similar weights, a meter scale

Formula Used: The time period T of the torsional oscillations of the system is given by-

$$T = 2\pi\sqrt{\frac{I_0+2I_s+2m_sx^2}{c}} \qquad .....(1)$$

Where I_0 = Moment of inertia of hollow tube or suspension system , I_s = Moment of inertia of solid cylinder or added weight about an axis passing through their centre of gravity and perpendicular to their lengths, m_s = Mass of each solid cylinder or each added weight, x = Distance of each solid cylinder or each added weight from the axis of suspension, c = Torsional rigidity of suspension wire

Squaring both sides, we get- $T^2 = \frac{4\pi^2}{c}[I_0 + 2I_s + 2m_sx^2]$

$$= \frac{8\pi^2 m_s x^2}{c} + \frac{4\pi^2}{c}(I_0 + 2I_s) \qquad .....(2)$$

The above equation (2), is of the form y = mx + c. Therefore, if we plot a graph between T^2 and x^2, it should be a straight line.

About apparatus:

The Maxwell's needle with two solid cylinders can be used for the purpose of verifying the theorem of parallel axis. The two weights are symmetrically placed in the tube on either side of the axis of rotation and their positions are noted down on the scale engraved by the side of the groove on the hollow brass tube as shown in figure 1. The time period of the torsional oscillations is now determined.

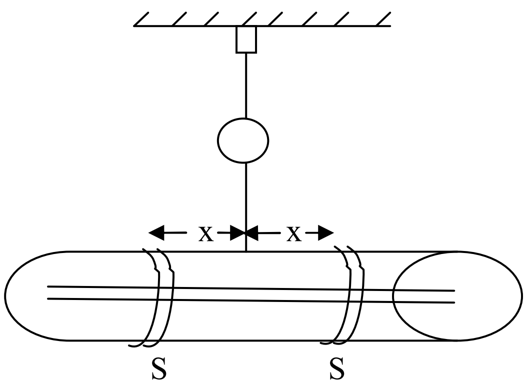


Figure 1

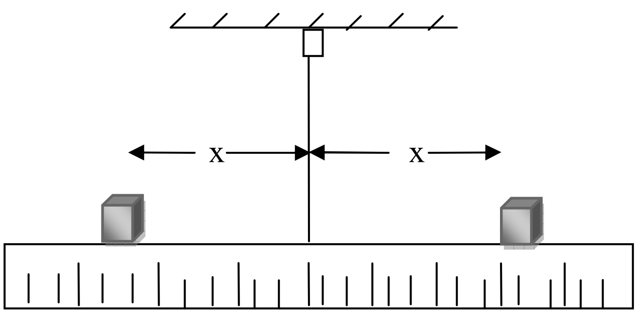


Figure 2

Now the positions of these cylinders are changed in regular steps which cause the variation in distribution of mass. By measuring the time periods in each case, we determine the moment of inertia of the system. In this way, the variation of moment of inertia of the system is studied by the variation in the distribution of mass. For the successful performance of the experiment, the moment of inertia of the suspension system should be much smaller than the moment of inertia of the added weights so that a large difference in the time period may be obtained by varying the position of the added weights. For this purpose, a light aluminium channel of about 1.5 metre in length and 5 cm. in breadth may be used as shown in figure 2.

Procedure:

(i) We place two solid cylinders symmetrically on either side in the hollow tube of Maxwell's needle and note down the distance x of their centre of gravity from the axis of rotation as shown in figure 1.

Or

We place the two equal weights on the aluminium channel symmetrically on either side of axis of rotation and note down the distances x of their centre of gravity from the axis of rotation as shown in figure 2.

(ii) We rotate suspension system slightly in the horizontal plane and then release it gently. The system executes torsional oscillations about the suspension wire.

(iii) With the help of stop watch, we note down the time taken by 20-25 oscillations and then by dividing the total time by the number of oscillations to calculate the time period T.

(iv) Now, we remove both the cylinders or added weights by a known distance say 5 cm. away from the axis of rotation and determine the time period as discussed above.

(v) We take atleast 5 or 6 such observations at various values of x by displacing the weights in regular steps of 5 cm.

(vi) Now we plot a graph between x^2 on X-axis and corresponding values of T^2 on Y-axis. The plotted graph is shown in figure 3.

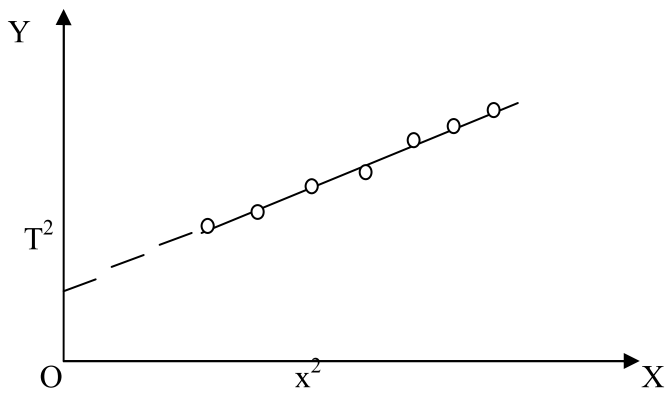


Figure 3

Observations:

Table for the measurement of time period T and the distance x of the weight

S.No.	Distance of the cylinder or added weight from axis of rotation x (meter)	x^2 (meter^2)	Time period				T^2 (sec^2)
			Number of oscillations n	Time taken t (sec)	Time period T (=t/n) sec	Mean time period T (sec)	
1	x_1	x_1^2	20 25 30	....	....	....	....
2	x_2	x_2^2	20 25 30	....	....	......	....
3	x_3	x_3^2	20 25 30	....	....	....	....
4	x_4	x_4^2	20 25 30	....	....	....	....
5	x_5	x_5^2	20 25 30	....	....	....	....

Result: The graph between T^2 and x^2 comes out to be a straight line. Therefore, it verifies that the basic theorem $I = \sum mx^2$ from which theorem of parallel axes follows, is valid.

Precautions and Sources of Errors:

(1) The suspension system should always be horizontal.
(2) The suspension wire should be free from kinks.
(3) The two solid cylinders or added weights should be identical.
(4) Oscillations should be purely rotational.
(5) The suspension wire should not be twisted beyond elastic limits.
(6) Periodic time should be noted very carefully.

Objectives: After performing this experiment, you should be able to-

- understand moment of inertia
- understand theorem of parallel axes

VIVA-VOCE:

Question 1. Which apparatus are you using for the study of theorem of parallel axes?

Answer. We are using Maxwell's needle for the study of theorem of parallel axes.

Question 2. How do you vary the distribution of mass here?

Answer. By changing the positions of two weights symmetrically inside the tube.

Question 3. How can the moment of inertia be changed?

Answer. The moment of inertia of a system can be changed by varying the distribution of mass.

Question 4. How can you verify the theorem of parallel axes with this experiment?

Answer. If we plot a graph between T^2 and x^2, it comes out to be a straight line. This verifies the theorem of parallel axes.

Question 5. What type of motion is performed by the needle?

Answer. The needle performs the simple harmonic motion.

Experiment No. 15

Object: To study the air flow through a capillary and determine the coefficient of viscosity of air by Anderson's method.

Apparatus Used: Compression pump, stop watch, travelling microscope, meter scale and Anderson's apparatus

Formula Used: The coefficient of viscosity of air can be determined by the following formula-

$$\eta = \frac{\pi r^4 h\rho g t/(8lV)}{2.303 log_{10(h_1/h_2)}}$$

where r= radius of capillary tube, l = length of the capillary, h = height of the barometer, ρ = density of mercury (= 13.6 ×10^3 Kg/m^3), g = acceleration due to gravity, V = constant volume of air in the vessel, h_1 and h_2 = difference in the levels of the liquid (in manometer) at t = 0 and t = t.

About Apparatus:

The Anderson's apparatus has been shown in figure 1. It consists of a bulb B in which a glass tube PQ is fused. This tube is connected to a rubber tube and then to a glass tube SK. This forms the manometer. The upper part of glass tube AB carries a reservoir R. The manometer is filled with some oil having small vapour pressure or sometimes with water.

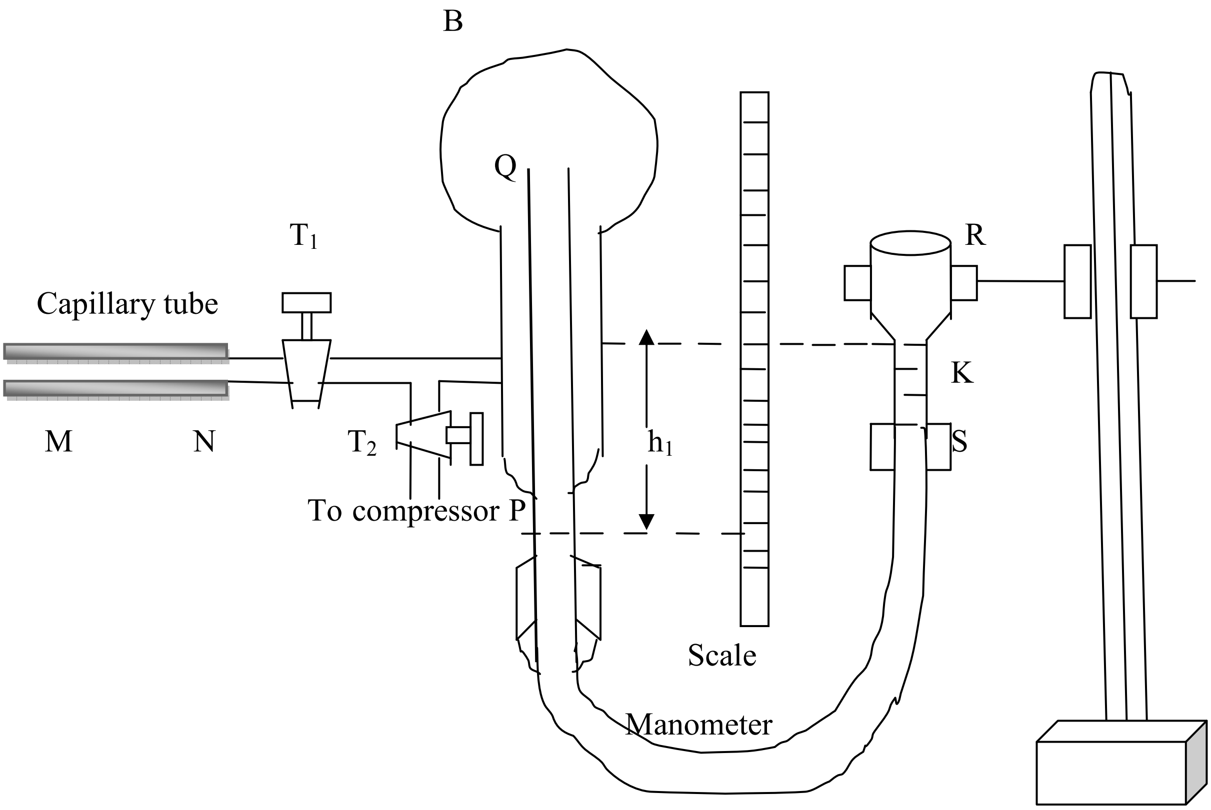


Figure 1

The lower part of the bulb is connected to a horizontal tube provided with two glass stop-cocks T_1 and T_2. A capillary MN is connected to the T joint. The other end of the T-joint is connected to a compressor. The whole apparatus is mounted on a board. The glass tube AB is mounted on a stand so that its position may be adjusted according to the required situation.

Procedure:

(i) First of all we check that whether all the joints are tight. Now we open the stop cocks T_1 and T_2 and adjust the tube SK so that the liquid in the two arms of manometer is the same. We put a mark P at the level of liquid in the tube PQ.

(ii) We close stop-cock T_1, pump the air into vessel through T_2 by a compressor. We close the stop-cock T_2 and adjust the position of the tube SK so that the liquid in tube PQ is at the mark P again. We take the difference h_1 in levels of the liquid in two tubes. Here it should be remembered that any change in the level of liquid indicates leakage in the apparatus.

(iii) We open the stop-cock T_1 and simultaneously start the stop watch. The gas is allowed to flow through capillary tube MN for a known interval of time t and then stop-cock T_1 is closed. We find the difference h_2 in the levels of liquid in the two tubes.

(iv) We repeat procedure (ii) and (iii) at least five times.

(v) We remove the capillary tube from the apparatus. We measure its length. We determine the mean radius with the help of travelling microscope.

Observations:

Table for time t, h_1 and h_2

S.No.	Fixed position of liquid at P (cm.)	Reading of liquid in tube SK level		Time interval t (sec)	h_1(m)	h_2(m)	$\log_{10}(h_1/h_2)$	$t/\log_{10}(h_1/h_2)$
		At t = 0 (m)	At t = t (m)					

Mean $t/\log_{10}(h_1/h_2)$ = ……….

Length of the capillary tube l = ………. m

Volume of the bulb V = …… m^3

Table for the measurement of diameter of capillary tube

Least count of microscope = ... cm

S.No.	Reading along any direction			Reading along a perpendicular direction			Diameter (X+Y)/2 cm.	Mean diameter d (cm.)
	One end reading (cm.)	Second end reading (cm.)	Difference X (cm.)	One end reading (cm.)	Other end reading (cm.)	Difference Y (cm.)		
1								
2								....
3								
4								

Mean radius r = d/2 = ... cm.= .... metre

Calculations: The coefficient of viscosity of air is given by-

$$\eta = \frac{\pi r^4 h\rho g t/(8lV)}{2.303 log_{10(h_1/h_2)}} = \text{...........} \text{ Kg/m-sec}$$

Result: The coefficient of viscosity of air is .... Kg/m-sec

Precautions and Sources of Errors:

(1) The apparatus should be held vertical.
(2) The apparatus should be air tight.
(3) The capillary tube should be of uniform cross-section and be placed horizontally
(4) After pumping air, sometime should be allowed for the air to achieve room temperature.
(5) The volume of the air in the flask should be maintained constant throughout the experiment.

Objectives: After performing this experiment, you should be able to-

- understand coefficient of viscosity
- compute the coefficient of viscosity

VIVA-VOCE:

Question 1. What do you mean by viscosity?

Answer. The property of the fluid by virtue of which it opposes the relative motion between its adjacent layers is known as viscosity.

Question 2. What is the unit of viscosity?

Answer. The unit of viscosity is Kg/m-sec.

Question 3. What is the another unit of viscosity?

Answer. The another unit of viscosity is poise. 1 Kg/m-sec = 10 poise.

Question 4. What is the effect of temperature on viscosity of air?

Answer. The viscosity of air (or gases) increases with rise in temperature.

Experiment No. 16

Object: To determine the mass susceptibility of $NiSO_4$ solution.
Apparatus Used: Electromagnet, search coil, standard solenoid, battery, ammeter, rheostat, key, travelling microscope, commutator, ballistic galvanometer

Formula Used: The magnetic field H between the pole pieces of an electromagnet is given by-

$$H = \frac{8\pi n i r_1^2 n_2 \theta_1}{10 r_2^2 n_1 \theta_2} \qquad .....(1)$$

Where n = Number of turns per unit length in primary of solenoid, n_1 = number of turns in the search coil, n_2 = total number of turns in the secondary of the solenoid, i = electric current in amperes flowing in the primary, r_1 = radius of the secondary of solenoid, r_2 = radius of the search coil, θ_1 = first throw in ballistic galvanometer when search coil is withdrawn from electromagnet, θ_2 = first throw in ballistic galvanometer due to electric current i in the primary of solenoid

The mass susceptibility of solution is given by-

$$\chi_{solution} = \frac{X}{\rho} = \frac{4gh}{H^2} \qquad .....(2)$$

where h = rise of the liquid in uniform bore tube kept inside field, H = field between pole pieces

Procedure:

(i) We set the galvanometer and lamp and scale arrangement such that the spot of light is free to move on both sides of zero of the scale. We make electrical connections as shown in figure 1.

(ii) We allow a suitable electric current to pass in the electromagnet.

(iii) We place the search coil in between the pole pieces of the electromagnet with the face of the coil perpendicular to the magnetic lines of force. In this position, the spot of light should be on the zero of the scale.

(iv) Now we withdraw the search coil rapidly from electromagnet and note down the first throw θ_1.

(v) We repeat the above procedure for different currents in electromagnet.

(vi) Now we pass suitable currents in the primary of the solenoid and with the help of the commutator and find out the corresponding throws θ_2. We find magnetic field values H for currents passed in the electromagnet.

(vii) We prepare $NiSO_4$ solution and fill it in a U-tube of uniform bore. We put this tube in between the pole pieces such that the surface of solution may be in the centre of the space between poles of electromagnet. We take the reading for surface of the solution with the help of travelling microscope.

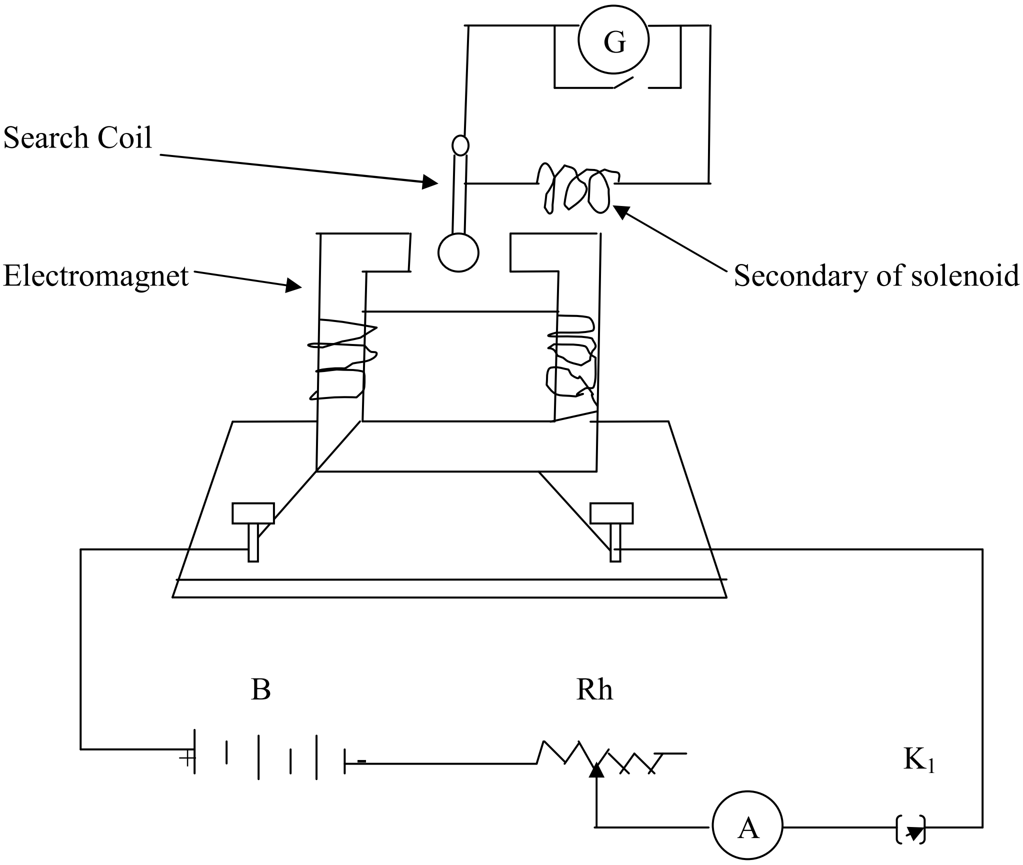


Figure 1

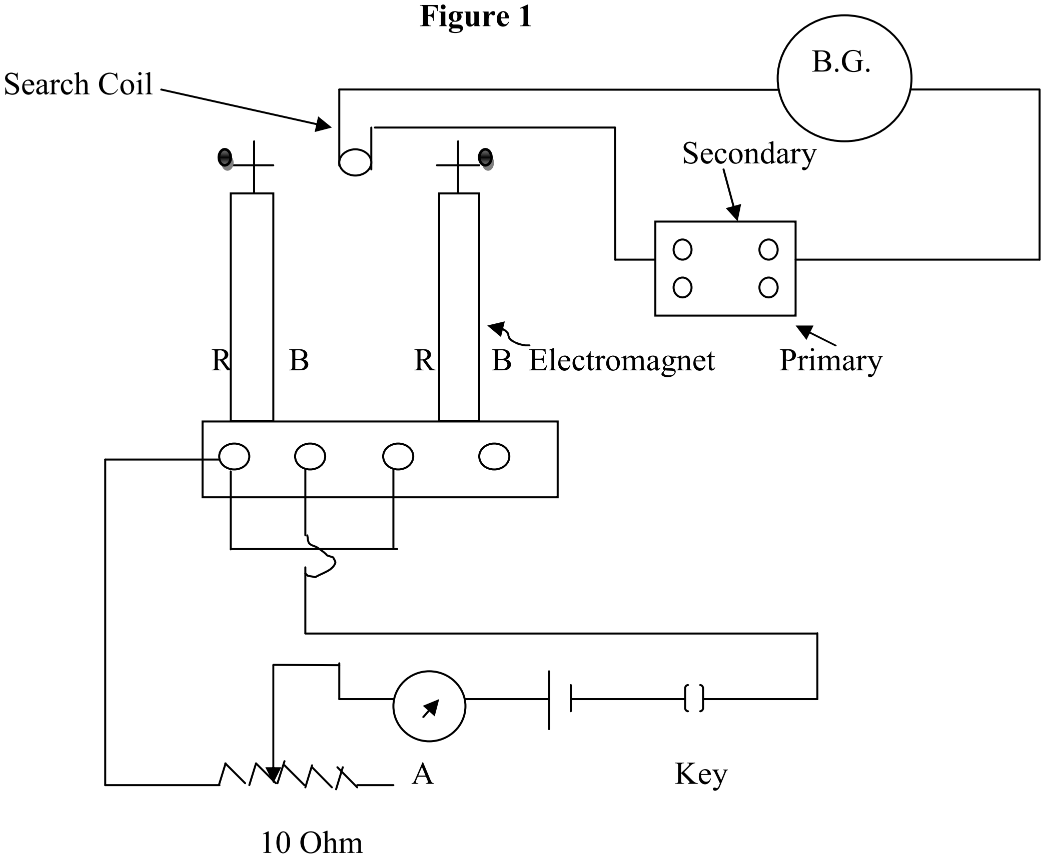


Figure 2

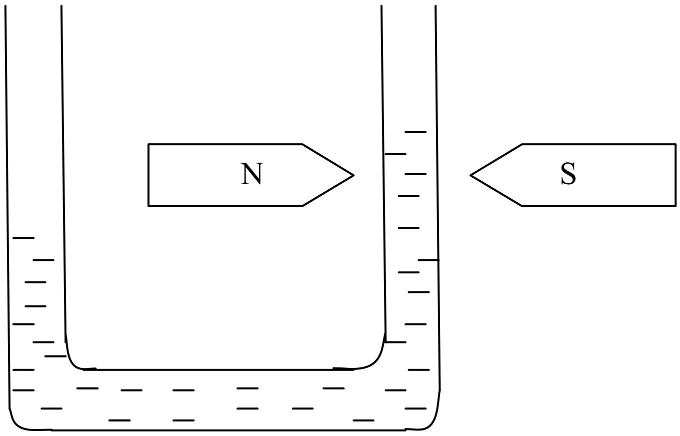


Figure 3

(viii) We send the same currents in electromagnet for which the magnetic fields are calculated. We measure the rise of liquid column in each case.

(ix) We calculate the volume susceptibility of $NiSO_4$ solution.

Observations:

Radius of the search coil r_2 = ... cm.

Radius of the secondary of the solenoid r_1 = ... cm.

Number of turns in the search coil n_1 = ...

Number of turns in the secondary of solenoid n_2 = ...

Number of turns per unit length in the primary of solenoid n = ...

Weight of $NiSO_4$ = ... gm.

Volume of water = ... c.c.

Total volume = ...c.c.

Weight of solution = ...gm.

Density of $NiSO_4$ = ... gm./c.c.

Table for first throw θ_1 when search coil is withdrawn from electromagnet

S.No.	Current passed through the electromagnet I (amp)	Corresponding throw θ_1 (cm.)
1	2	
2	3	
3	4	
4	5	
5	6	
6	7	

Table for first throw θ_2 when current is passed in the primary of solenoid

S.No.	Current in the primary of solenoid i (amp)	Corresponding throw θ_2 (cm.)
1	0.8	
2	0.7	
3	0.6	
4	0.5	
5	0.4	
6	0.3	

Table for the rise of the liquid

Least count of microscope = ... cm.

S.No.	Current in electromagnet I (amp.)	Position of liquid when field is OFF (a) cm.	Position of the liquid when field is ON (b) cm.	h = (b – a) cm.
1				
2				
3				
4				
5				
6				

Calculations:

Let us draw a graph between different currents passed in the primary of the solenoid and the corresponding observed throws. The nature of the graph is shown in figure 4. We find the value of i/θ_2 from the graph.

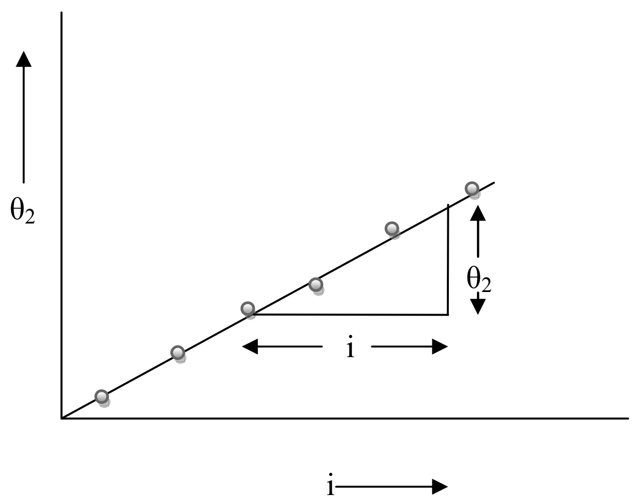


Figure 4

Now we use the formula $H = \frac{8\pi n i r_1^2 n_2 \theta_1}{10 r_2^2 n_1 \theta_2}$, to calculate the value of the magnetic field for different currents passed in the electromagnet.

Value of the field for I = 2 amp. θ_1 = ... cm. is-

$$H = \frac{8\pi n i r_1^2 n_2 \theta_1}{10 r_2^2 n_1 \theta_2} = \text{....... Gauss}$$

Value of the field for I = 3 amp. θ_1 = ... cm. is-

$$H = \frac{8\pi n i r_1^2 n_2 \theta_1}{10 r_2^2 n_1 \theta_2} = \text{....... Gauss}$$

Similarly, we calculate the value of field for 4, 5, 6 and 7 amps.

Now $\chi_{solution} = \frac{X}{\rho} = \frac{4gh}{H^2}$

$$= \frac{4g\,(\text{rise of liquid at 2 amp.})}{(\text{value of magnetic field for 2 amp.})^2} = \text{...............}$$

Similarly, we calculate $\chi_{solution}$ for 3, 4, 5, 6 and 7 amps.

Result: The value of mass susceptibility of $NiSO_4$ solution = ...

Precautions and Sources of Errors:

(1) Tapping key should be used across the galvanometer.
(2) The galvanometer coil should be made properly free.
(3) The distance between the pole pieces should be constant.
(4) The search coil should be kept in the gap of the pole pieces such that its face is parallel to the face of the pole pieces or perpendicular to the magnetic field lines.
(5) The resistance R of the galvanometer circuit should remain the same.
(6) Search coil should be withdrawn quickly from the electromagnet.

Objectives: After performing this experiment, you should be able to-

- understand electromagnet
- understand search coil
- understand mass susceptibility
- compute mass susceptibility

VIVA-VOCE:

Question 1. What is the construction of electromagnet?

Answer. A copper coil is wound over continuous soft iron core in such a way that one end of the core becomes south pole while the other the north pole.

Question 2. What is the construction of search coil?

Answer. Search coil consists few number of turns of thin insulated copper wire. Due to few turns galvanometer deflection remains within the range of scale.

Question 3. Define susceptibility of a substance.

Answer. Susceptibility is defined as the ratio of intensity of magnetisation (I) to the magnetising field (H). Thus, $\chi = \frac{I}{H}$.

Question 4. What is the unit of susceptibility?

Answer. Susceptibility is unit less quantity.

Physical Constants

Universal Gravitational Constant G = 6.67×10^{-11} Newton-m^2/kg^2

Boltzmann Constant $k_B = 1.38 \times 10^{-23}$ Joule/K

Planck's Constant h= 6.63×10^{-34} Joule-sec

Charge on electron e = 1.6×10^{-19} Coulomb

Velocity of light in vacuum c = 3×10^8 m/sec^2

Mass of electron $m_e = 9.1083 \times 10^{-31}$ Kg

Mass of proton $m_p = 1.67399 \times 10^{-27}$ Kg