Manual for Physics Sessional

Course no. PHY 1106

(For the Program of B.Sc. in EEE, IPE and ME)

Department of Arts and Sciences

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List of Experiments:

1. To determine the modulus of rigidity of the material of a wire by the method of oscillations (Dynamic method).

2. To determine the wavelength of a monochromatic light by a spectrometer using a plane diffraction grating. Hence to calculate the dispersive power of the grating.

3. To determine the radius of curvature of a plano-convex lens by Newton's rings.

4. To determine the refractive index of a liquid by pin method using plane mirror & convex lens.

5. To determine the value of acceleration due to gravity (g) by means of a Compound pendulum.

6. To determine the specific heat of a liquid by the method of cooling.

7. To determine the value of the mechanical equivalent of heat (J) by electrical method.

8. To determine the thermal conductivity of a bad conductor by Lee's and Charlton's method.

9. To determine the spring constant and effective mass of a given spiral spring.

Reference Books:

1. **Practical Physics** *by* Dr. Giasuddin Ahmed and Md. Shahabuddin
2. **Physics-I & II** *by* R. Resnick, D. Halliday
3. **Practical Physics** *by* RK Shukla, Anchal Srivastava

Experiment no 1:

Name of the Experiment: Determination of the modulus of rigidity of the material of a wire by the method of oscillations (Dynamic Method).

Theory:

A cylindrical body is supported by a vertical wire of length l and radius r as shown in Fig. 1.1. The axis of the wire passes through its center of gravity. If the body is twisted through an angle and released, it will execute torsional oscillations about a vertical axis. Therefore, the motion is simple harmonic. If at any instant the angle of twist is θ, the moment of the torsional couple exerted by the wire will be

$$\frac{\eta\pi r^4}{2l}\theta = C\theta,$$

where $C = \frac{\eta\pi r^4}{2l}$ is a constant and η is the modulus of rigidity of the material of the wire.

Therefore, the time period for torsional oscillations is,

$$T = 2\pi\sqrt{\frac{I}{C}}.$$

where I is the moment of inertia of the cylindrical body which is given by $I = \frac{1}{2}Ma^2$, here M and a are the mass and radius of the cylinder respectively.

From above two equations, we get

$$T^2 = \frac{4\pi^2 I}{C} = \frac{8\pi I l}{\eta r^4}$$

$$\text{or,}\quad \eta = \frac{8\pi I l}{T^2 r^4}\ \text{dynes/cm}^2$$

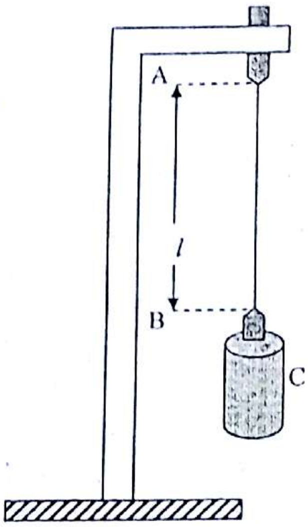


Fig. 1.1: Torsional pendulum

Apparatus:

A uniform wire, A cylindrical bar, Suitable clamp, Stopwatch, Screw gauge, Slide calipers, Meter scale, etc.

Brief Procedure:

1. Find out the value of one smallest division of the main scale and the total number of divisions of the vernier scale of the slide calipers and calculate vernier constant ($V.C$).
2. Find out the value of one smallest division of the linear scale, value of pitch (the distance along the linear scale traveled by circular scale when it completes one rotation) and the total number of divisions of the circular scale of the screw gauge and calculate least count ($L.C$).
3. Measure the radius, a of the cylinder by using the slide calipers.
4. Measure the mass, M of the cylinder. Calculate moment of inertia.
5. Measure the radius, r of the wire by using the screw gauge.
6. Measure the length, l of the wire between the point of suspension and the point at which the wire is attached to the cylinder with a meter scale.
7. Twist the cylinder from its equilibrium position through a small angle and release so that it begins to oscillate. Measure the time for 30 complete oscillations with a stop watch. Find out the time period of oscillation.

8. Calculate the value of the modulus of rigidity (η) of the material of the given wire.

Experimental Data:

Vernier Constant ($V.C.$) of the slide calipers,

$$V.\,C. = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}}$$

Least Count (L.C.) of the Screw Gauge

$$L.\,C. = \frac{\text{Pitch}}{\text{Total number of divisions in the circular scale}}$$

Table-1: Table for the radius of the cylinder

No. of obs.	Main scale reading, x (cm)	Vernier scale division, d	Vernier constant, V_C (cm)	Vernier scale reading, $y = V_c \times d$ (cm)	Diameter, x + y (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius, $a = \frac{D}{2}$ (cm)
1									
2									
3									
4									
5									

Table-2: Table for the radius of the wire

No. of obs.	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y = d \times L_c$ (cm)	Diameter, x + y (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius, $r = \frac{D}{2}$ (cm)
1									
2									
3									
4									
5									

Table-3: Table for the time period

No. of obs.	Time for 30 oscillations, t (sec)	Time period, $T = \frac{t}{30}$ (sec)	Mean T (sec)
1			
2			
3			
4			
5			

Length of the wire, l: (i) cm (ii) cm (iii) cm

Average length of the wire, l = cm

Calculations:

Moment of Inertia of the cylinder, $I = \frac{1}{2} Ma^2$ g-cm^2

Modulus of rigidity of the wire, $\eta = \frac{8\pi I l}{T^2 r^4}$ dynes/cm^2

Error Calculation:

Standard value of the modulus of rigidity of the material of the wire (steel) =

8.4×10^{11} dynes cm^{-2}.

$$\text{Percentage error} = \frac{\textit{Standard value} \sim \textit{Experimental value}}{\textit{Standard value}} \times 100\ \%$$

Result:

Discussions:

Experiment no 2:

Name of the Experiment: Determination of the wavelength of a monochromatic light by a spectrometer using a plane diffraction grating and calculation of the dispersive power of the grating.

Theory:

Diffraction grating is an array of a large number of parallel slits, all with the same width and spaced equal distances between the centers. When a monochromatic light of wavelength λ sent from collimator falls normally on a diffraction grating placed on a spectrometer table (Fig. 2.1), a series of diffracted images will be seen on both sides of the direct image.

If θ be the deviation of light for n^{th} order image and $(a+b)$ be the grating element then from the equation of diffraction,

$$(a + b) \sin \theta = n\lambda \qquad (1)$$

Thus, the wavelength of a monochromatic light is

$$\lambda = \frac{\sin \theta}{nN} \qquad (2)$$

where $N = \frac{1}{(a+b)}$ is the number of lines or rulings per cm of the grating surface also known as grating constant.

Knowing the values of n, N and θ, wavelength λ of the monochromatic light can be found.

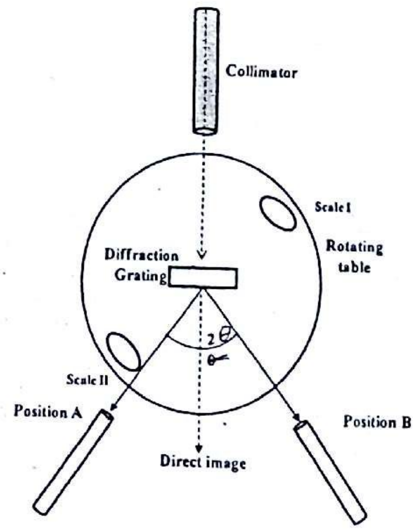


Fig. 2.1: Diffraction grating and spectrometer arrangement

Differentiating equation (2) with respect to λ we have

$$\frac{d\theta}{d\lambda} = \frac{nN}{cos\theta}$$

This equation gives the angular dispersive power of the grating, *i.e.* it's the capacity of the grating to disperse different wavelengths.

Apparatus:

Spectrometer, Plane diffraction grating, sodium lamp set, etc.

Brief Procedure:

1. Record the grating constant.
2. Determine the vernier constant (mentioned in Exp. 1) of the scale of spectrometer.
3. Mount the grating on the spectrometer table with the grating ruling parallel to the collimator slit and plane of grating perpendicular to the collimator axis. Do not move it throughout the experiment.
4. Focus the eyepiece on the cross-wires illuminated by the light from the slit by sliding the eyepiece lens in and out until the cross-wires appear sharpest.
5. Turn the telescope to one side of central position (Say left side, A) until an image of first order diffraction appears on the cross-wires and then record the readings from both scales I & II.
6. Similarly find the image of first order diffraction on the other side (e.g. right side, B) of central position and record the readings as before.
7. Calculate the differences ($A \sim B$) between scale I and scale II readings and determine the angle of diffraction.
8. Calculate the wavelength of the monochromatic light and dispersive power of the diffraction grating using the given equations.

Experimental data:

Grating constant, $N = \frac{lines}{inch} = \frac{lines}{cm}$

Vernier constant of the spectrometer,

$$V.C. = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}}$$

Table-1: Table for the angle of diffraction

Order number (n)	Scale number	Reading for the angle of diffraction, θ												Mean θ (degree)
		Left side					Right side							
		Main scale reading, x (degree)	Vernier scale division, d	Vernier constant, V_c (degree)	Vernier scale reading, $y=d\times V_c$ (degree)	Total, A = x+y (degree)	Main scale reading, x (degree)	Vernier scale division, d	Vernier constant, V_c (degree)	Vernier scale reading, $y=d\times V_c$ (degree)	Total, B = x+y (degree)	$2\theta = A \sim B$ (degree)	θ (degree)	
1	I													
	II													

Calculation:

Wavelength of the monochromatic light,

$$\lambda = \frac{\sin\theta}{nN} = \qquad \text{cm} = \qquad \text{Å}$$

Dispersive power of the grating

$$\frac{d\theta}{d\lambda} = \frac{nN}{\cos\theta} = \qquad \text{cm}^{-1}$$

Error Calculation:

Standard value of the wavelength of sodium light is 5890 Å.

$$\text{Percentage error} = \frac{\textit{Standard value} \sim \textit{Experimental value}}{\textit{Standard value}} \times 100\ \%$$

Results:

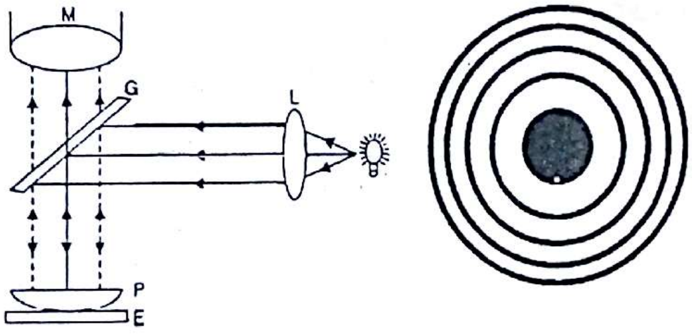
Discussions:

Experiment no 3:

Name of the Experiment: ***Determination of the radius of curvature of a plano-convex lens by Newton's rings.***

Theory:

The phenomenon of Newton's rings is an interference pattern caused by the reflection and transmission of light between a spherical surface and an adjacent flat surface which form a air thin film. When viewed with monochromatic light as shown in Fig. 3.1a, it appears as a series of concentric, alternating bright and dark rings as shown in Fig. 3.1b centered at the point of contact between the two surfaces.



(a) (b)

Fig.3.1: (a) Experimental setup of Newton's rings. (b) Pattern of the rings

Now the diameters of the n^{th} bright or dark rings are

$$D_n^2 = 2(2n+1)\lambda R \quad \text{(Bright Rings)}$$

$$D_n^2 = 4n\lambda R, \quad \text{(Dark Rings)}$$

where R is the radius of curvature of the lens and λ is the wavelength of the monochromatic light.

Similarly, the diameters of the $(n+p)^{th}$ bright or dark rings are

$$D_{n+p}^2 = 2[2(n+p)+1]\lambda R \quad \text{(Bright Rings)}$$

$$D_{n+p}^2 = 4(n+p)\lambda R \quad \text{(Dark Rings)}$$

Subtracting D_n^2 from D_{n+p}^2, we have

$$D_{n+p}^2 - D_n^2 = 4p\lambda R, \text{ for either bright or dark rings,}$$

$$\text{or, } R = \frac{D^2_{n+p} - D^2_n}{4p\lambda}$$

The above equation is employed to compute the radius of curvature R of a lens.

Apparatus:

Travelling microscope, Plano-convex lens, Sodium lamp set, etc.

Brief Procedure:

1. Determine the least count (mentioned in Exp. 1) of the micrometer screw of the travelling microscope.
2. Set the intersecting point of the cross-wires of the eye piece at the middle of the central dark spot.

3. Slide the cross-wires to 12^{th} dark ring on the left side of the central dark spot.
4. Set the vertical line of the cross-wire tangentially to 10^{th} dark ring and note the readings of the linear scale and circular divisions.
5. Set the cross-wire in the same manner to the 9^{th}, 8^{th},.........., 1st rings by sliding the microscope in the same direction.
6. Cross the central dark spot by sliding the cross-wires and note the scale readings by setting the cross-wire to the right side of the 1^{st} ring.
7. Now move the cross-wires in the same direction and record the scale readings in the same manner for successive dark rings up to the 10^{th} ring on the right side.
8. Draw a best fit straight line through origin on a graph paper with square of the diameter as ordinate and number of the ring as abscissa. Calculate the slope of the line.
9. Calculate the radius of curvature of the plano-convex lens by using the given equation.

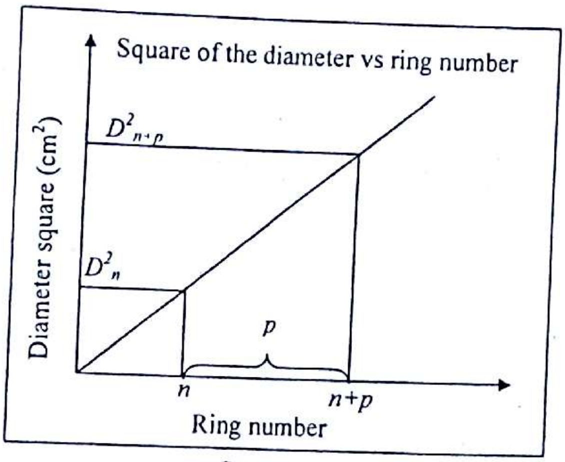
Experimental Data:

Least Count ($L.C.$) of the micrometer scale

$$L.\ C. = \frac{Pitch}{Total\ number\ of\ divisions\ in\ the\ circular\ scale}$$

Table: Table for the diameter of the rings

Ring no.	Readings of the microscope										Diameter, D = L~R (cm)	D^2 (cm^2)
	Left Side (L)					Right Side (R)						
	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y=d\times L_c$ (cm)	Total, x+y (cm)	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Circular scale reading, $y=d\times L_c$ (cm)	Total, x+y (cm)		
1												
2												
3												
4												
6												
7												
8												
9												
10												



Graph 1

Calculation:

$$\text{From graph 1, slope} = \frac{D^2_{n+p} - D_n^2}{(n+p)-n}$$

$$R = \frac{Slope}{4\lambda}$$

Result:

Discussions:

Experiment no 4:

Name of the Experiment: Determination of the refractive index of a liquid by pin method using plane mirror and convex lens.

Theory:

A plano-concave liquid lens can be formed by the combination of a convex lens, a few drops of liquid and a plane mirror. If F be the focal length of combined lenses (convergent lens), then we have the relation

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}, \ldots \ldots (1)$$

where f_1 and f_2 are the focal lengths of the convex lens and the liquid lens, respectively. Correcting for the sign of f_2 which is negative, we get

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

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

$$\text{or, } f_2=\frac{Ff_1}{F-f_1} \ldots \ldots \ldots (2)$$

The focal length of the plano-concave liquid lens is also given by relation

$$\frac{1}{f_2}=(\mu-1)\left(\frac{1}{r}-\frac{1}{r'}\right)$$

where r', r are the radii lower and upper surfaces of liquid lens respectively and μ is the refractive index of the liquid. Being a plane $r=\infty$

$$\frac{1}{f_2}=(\mu-1)\frac{1}{r}$$

According to sign convention, both r and f_2 are negative. Thus,

$$\mu=1+\frac{r}{f_2} \ldots \ldots \ldots (3)$$

The value of μ can be found by using relations (2) and (3).

Since, the upper surface of this liquid lens has the same radius of curvature of the convex lens it can be determined by using a spherometer.

Apparatus:

Convex lens, Plane mirror, Pin/pointer, Spherometer, Slide calipers, Stand & Clamp, Experimental liquid, etc.

Brief Procedure:

1. Calculate the least count (mentioned in Exp. 1) of the spherometer.
2. Place the spherometer on the plane mirror and slowly turn the screw so that the tips of the central leg and the other three legs just touch the surface of the mirror. Note the readings of the main scale and circular divisions of the spherometer.
3. Now put a convex lens on the mirror and place the spherometer on the surface of the lens. Note the readings in the same manner of step 2. Then take the difference of A and B to calculate the height (h) of the central leg with respect to the tips of outer legs.
4. Slightly press the spherometer upon a piece of paper so that the three legs leave three dots on the paper. Measure the distances (a_1, a_2, a_3) between these dots by a scale and calculate the mean distance, a.

5. Calculate the radius of curvature of the lens by using the relation, $r = \frac{a^2}{6h} + \frac{h}{2}$
6. Calculate the vernier constant of the slide calipers.
7. Measure the thickness of the lens by using slide calipers.
8. Place a mirror on the base/table with its reflecting face upwards and put the lens on the mirror. Clamp a pin horizontally on a vertical stand.
9. Find the position of the pin by moving it up or down so that there is no parallax between the image of the tip of the pin and the tip of the pin itself.
10. Measure the distance between the pin and face of the lens at its middle by a meter scale.
11. Calculate the focal length of the convex lens.
12. Pour few drops of liquid between the convex lens and the plane mirror.
13. Repeat steps 9 and 10 and obtain the focal length of the combination of the lenses.
14. Calculate the focal length of the liquid lens.
15. Using the given formula, calculate the refractive index.

Experimental Data:

Vernier constant ($V.\ C.$) of the slide calipers

$$V.\ C. = \frac{The\ value\ of\ one\ smallest\ division\ of\ the\ main\ scale}{Total\ number\ of\ divisions\ in\ the\ vernier\ scale}$$

Least Count ($L.C.$) of the spherometer

$$L.\ C. = \frac{Pitch}{Total\ number\ of\ divisions\ in\ the\ circular\ scale}$$

Table-1: Table for the measurement of h

Reading on	No. of obs.	Linear scale reading, x (cm)	Circular scale Division, d	Least count, L_c (cm)	Circular scale reading, $y = L_c \times d$ (cm)	Total, $x + y$ (cm)	Mean (cm)	$h = B \sim A$ (cm)
Plane mirror, A	1							
	2							
	3							
	4							
	5							
Lens surface, B	1							
	2							
	3							
	4							
	5							

Measurement of 'a' *i.e.*, the average distance among the legs of the spherometer:

Mean value of $a = \frac{a_1 + a_2 + a_3}{3} =$ cm

Radius of curvature of the spherical surface, $r = \frac{a^2}{6h} + \frac{h}{2} =$ cm

Table-2: Table for the thickness of the lens

No. of obs.	Linear scale reading, x (cm)	Vernier scale division, β	Vernier constant, V_C (cm)	Vernier scale reading, $y = \beta \times L_c$ (cm)	Thickness, $t = x + y$ (cm)	Mean thickness, t (cm)	Instrumental error $\pm e$ (cm)	Corrected thickness, $t-(\pm e)$ (cm)
1								
2								
3								
4								
5								

Table -3: Table for the focal lengths

No. of obs.	Distance between the pin and the face of the lens (without the liquid), h_1 (cm)	Focal length of the convex lens, $f_1 = h_1 + \frac{t}{3}$ (cm)	Mean f_1 (cm)	Distance between the pin and the face of the lens (with the liquid), h_2 (cm)	Focal length of the combination, $F = h_2 + \frac{t}{3}$ (cm)	Mean F (cm)	Focal length of the liquid lens, $f_2 = \frac{Ff_1}{F - f_1}$ (cm)
1							
2							
3							
4							

Calculation:

$$\mu = 1 + \frac{r}{f_2}$$

Error Calculation:

Standard value of the refractive index of water is 1.33

$$\text{Percentage error} = \frac{\textit{Standard value} \sim \textit{Experimental value}}{\textit{Standard value}} \times 100\ \%$$

Result:

Discussions:

Experiment no 5:

Name of the Experiment: Determination of the value of the acceleration due to gravity (g) by means of a compound pendulum.

Theory:

A compound pendulum is a rigid body of arbitrary shape which is capable of oscillating about a horizontal axis passing through it. For small angles of swinging, its motion is simple harmonic with a period given by

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

where I is the pendulum's rotational inertia about the pivot, m is the pendulum's mass, and h is the distance between the pivot and the pendulum's centre of gravity as shown in Fig. 5.1.

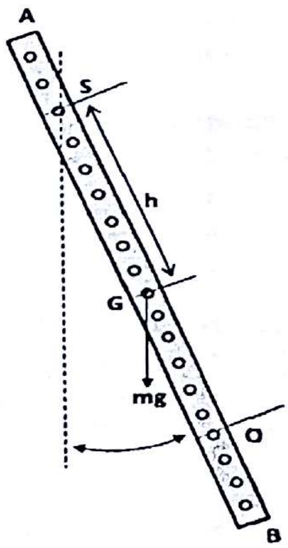


Fig. 5.1: Compound Pendulum

A compound pendulum that oscillates from a suspension point (S) with period T (as shown in Fig. 5.1) can be compared with a simple pendulum of length L with the same period T. L is called the equivalent length of the compound pendulum. The point along the compound pendulum at a distance L from the suspension point is called the oscillation point (Fig. 5.1). In a compound pendulum these two points are interchangeable.

Now using the time period expression of a simple pendulum,

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

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

The acceleration due to gravity (g) at the place of the experiment can be measured by finding L and T graphically.

Apparatus:

A bar pendulum, Stop watch, Meter Scale, etc

Brief Procedure:

1. Label the ends of the compound pendulum bar as A and B.
2. Locate the centre of gravity (G) of the bar.
3. Measure the distance of holes (1, 2, 3,… and 9) from G for both sides.
4. Insert a metal wedge in the 1st hole at end A and place the wedge on the clamp so that the bar can oscillate freely.
5. Oscillate the bar horizontally. Be careful not to make the amplitude of oscillation too large. (Should be less than 5°). Note the time for 20 complete oscillations. Calculate the time period.
6. Do this process at different holes (2, 3, …..and 9).
7. Repeat steps 3, 4 and 5 for end B.
8. Draw a graph with distance as abscissa and time period as ordinate with the origin at the centre of gravity which is put at the middle of the graph paper along the abscissa. Put the length measured towards the end A to the left and that measured toward the end B to the right of the origin (see Graph 1). Draw a line parallel to the abscissa in such a way that it intersects at four points of the two curves as shown in Graph 1. Label these points as P, Q, R and S, respectively.
9. Find out the equivalent length of the pendulum, L and time period, T from the graph.
10. Calculate the value of acceleration due to gravity using the given equation.

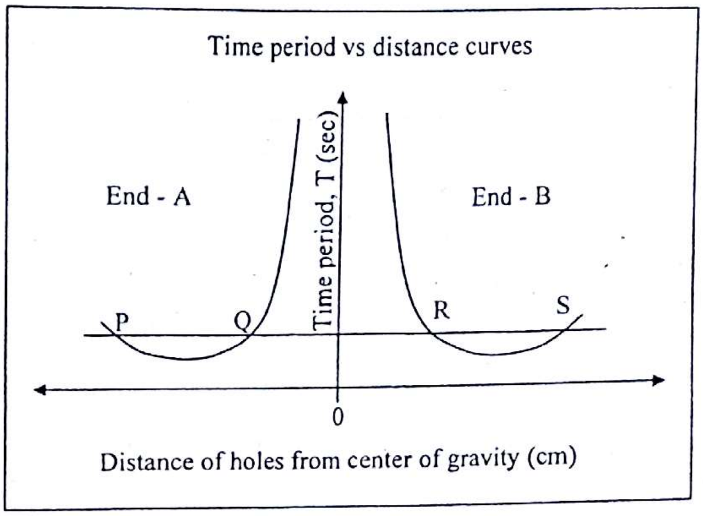
Experimental Data:

Table-1: Table for the time period for end-A

	Hole no.	Distance of the hole from center of gravity (cm.)	Time for 20 oscillations, (sec.)		Mean time, t (sec.)	Time period $T = \frac{t}{20}$ (sec.)
End-A	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					

Table-2: Table for the time period for end-B

	Hole no.	Distance of the hole from center of gravity (cm.)	Time for 20 oscillations, (sec.)		Mean time, t (sec.)	Time period $T = \frac{t}{20}$ (sec.)
End-B	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					



Graph I

Calculations:

From graph 1: Length, $PR =$ cm and length, $QS =$ cm

Equivalent length to the Simple Pendulum, $L = \dfrac{PR + QS}{2}$

Time period, $T =$ sec

The value of acceleration due to gravity, $g = 4\pi^2 \dfrac{L}{T^2} =$ cm/s^2

Error Calculation:

Standard value of the acceleration due to gravity = 981 cm/s^2

$$\text{Percentage error} = \frac{\textit{Standard value} \sim \textit{Experimental value}}{\textit{Standard value}} \times 100\ \%$$

Result:

Discussions:

Experiment no 6:

Name of the Experiment: Determination of the specific heat of a liquid by the method of cooling

Theory:

Newton's law of cooling can be used to determine the specific heat of a liquid by observing the time taken by the liquid in cooling from one temperature to another.

Suppose a liquid of mass M_1 and specific heat S_1 is enclosed within a calorimeter of mass m and specific heat s. The thermal capacity of the system is (M_1S_1+ms). If the temperature of the liquid falls from θ_1 to θ_2 in t_1, then the average rate of loss of heat is

$$(M_1S_1 + ms)\frac{(\theta_1 - \theta_2)}{t_1}$$

If now the first liquid be replaced by an equal volume of second liquid of known specific heat (say water) under similar conditions and if the time taken by the second liquid to cool through the same range of temperature from θ_1 to θ_2 be t_2, then the average rate of loss of heat is

$$(M_2S_2 + ms)\frac{(\theta_1 - \theta_2)}{t_2},$$

where M_2 and S_2 are the mass and specific heat of the second liquid, respectively.

Since the conditions are similar, these two rates are equal

$$(M_1S_1 + ms)\frac{(\theta_1 - \theta_2)}{t_1} = (M_2S_2 + ms)\frac{(\theta_1 - \theta_2)}{t_2}$$

or,

$$S_1 = \frac{M_2S_2t_1 + ms(t_1 - t_2)}{M_1t_2}$$

Apparatus:

Double walled enclosure, Calorimeter, Thermometer, Heater, Stop watch, etc.

Brief Procedure:

1. Clean and dry the calorimeter and measure the mass (m) of the calorimeter and stirrer using a balance.
2. Pour water up to two-third volume of the calorimeter. Measure the total mass (m'') of the calorimeter, water and stirrer. Calculate the mass (M_2) of water.
3. Put the calorimeter on the heater and hold the thermometer bulb in the middle of the water and raise the temperature around 62 °C. Keep the calorimeter into the double walled enclosure with the help of a tongs. Close the lid and fix the thermometer with holder so that its bulb is in the middle of the water.
4. Start the stop watch when the temperature just falls to 60 °C. Note this temperature in the table. Go on recording the temperature of water up to 20-25 minutes at an interval of every one minute. Gently stir the water during the whole process.
5. Pour out the water from the calorimeter and wipe it dry. Take experimental liquid in the calorimeter as the same volume of water. Repeat steps 2, 3 and 4 for liquid.
6. On a graph paper, plot curves (both for water and liquid) by taking temperature as ordinate and time as abscissa (see Graph 1). Calculate t_1 and t_2 from the graph.
7. Using the given formula, determine the specific heat of the given liquid.

Experimental data:

Table: Time–temperature record for water and liquid

No. of obs.	Time (min)	Temperature of water (°C)	Temperature of liquid (°C)
1	00		
2	01		
3	02		
4	03		
5	04		
6	05		
7	06		
8	07		
9	08		
10	09		
..	..		
..	..		
..	..		
26	25		

Mass of the calorimeter + stirrer, m = g

Mass of the calorimeter + stirrer + liquid, m' = g

Mass of the liquid, $M_1 = m' - m$ = g

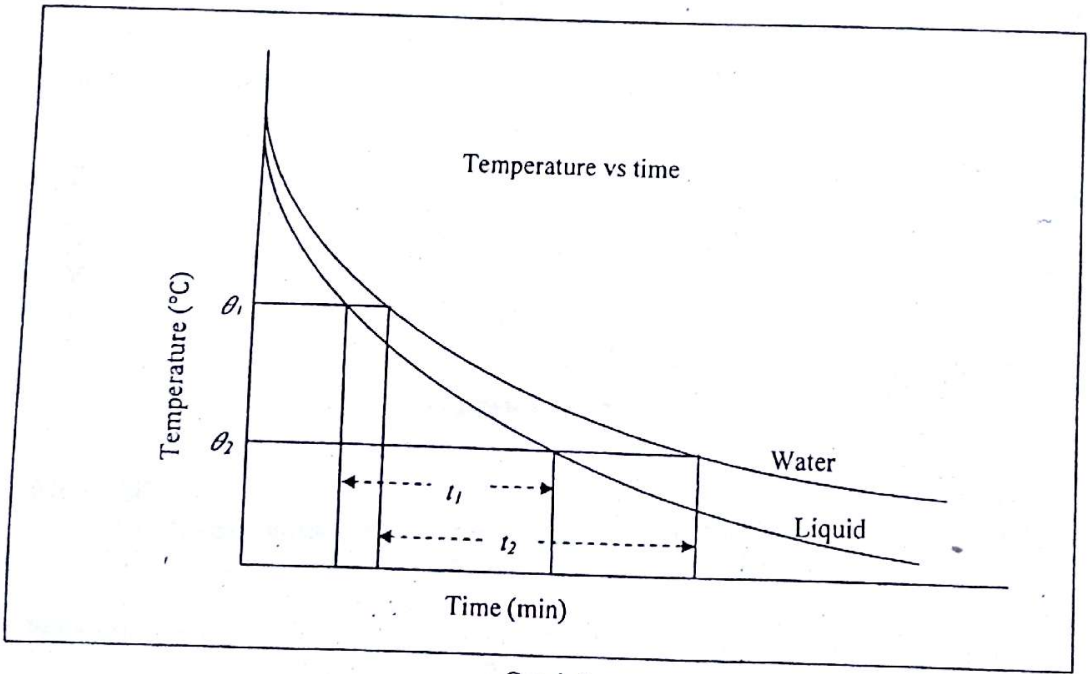
Mass of the calorimeter + stirrer + water, m'' = g

Mass of the water, $M_2 = m'' - m$ = g

Specific heat of the water, S_2 = 1.00 Cal g^{-1} °C^{-1}

Specific heat of the material of the calorimeter (Aluminum), s = 0.2096 Cal g^{-1} °C^{-1}

(Copper), s = 0.0909 Cal g^{-1} °C^{-1}



Graph 1

Calculations:

Time taken by water to cool from $\theta_1 =$ °C to $\theta_2 =$ °C as obtained from the graph 1, $t_2 =$ min

Time taken by the liquid to cool from $\theta_1 =$ °C to $\theta_2 =$ °C as obtained from the graph 1, $t_1 =$ min

Specific heat of the liquid,

$$S_1 = \frac{M_2 S_2 t_1 + ms(t_1 - t_2)}{M_1 t_2}$$

Error Calculation:

Standard value of the specific heat of turpentine is 0.42 Cal g^{-1} °C^{-1}.

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 7:

Name of the Experiment: **Determination of the value of the mechanical equivalent of heat (J) by electrical method.**

Theory:

The mechanical equivalent of heat J is the amount of electrical energy required to generate one calorie of heat. If E volt be the potential difference across a conducting coil (Fig. 7.1) and i ampere be the current flowing through the coil for t seconds, then the electrical energy in the coil is Eit. If this energy is converted into heat H (calories) then the mechanical equivalent of heat J is

$$J = \frac{Eit}{H} \text{ Joules/Calorie} \quad (1)$$

If H is measured by means of a calorimeter with its contents where the temperature raises from θ_1°C to θ_2°C then

$$H = (Ms + W)(\theta_2 - \theta_1), \quad (2)$$

where M is the mass of the water in the calorimeter, s is the specific heat of water and W is the water equivalent of the calorimeter and stirrer. W can be calculated from the mass and specific heat of the calorimeter and stirrer.

From equations (1) and (2), we get

$$J = \frac{Eit}{(Ms + W)(\theta_2 - \theta_1)} \text{ Joules/Calories}$$

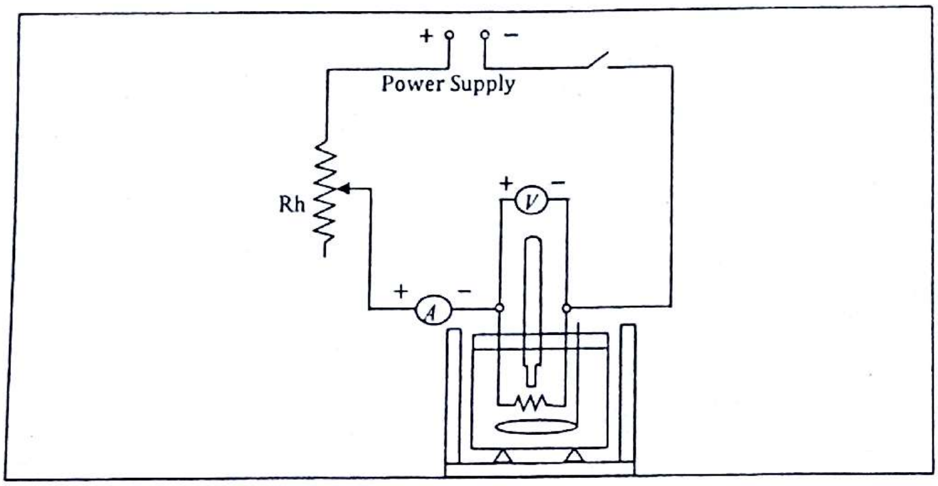


Fig. 7.1: Experimental setup for measuring the mechanical equivalent of heat

Apparatus:

Joule's calorimeter set, Ammeter, Voltmeter, Stop-watch, Thermometer, Balance, Power Supply, Rheostat, Key, etc.

Brief Procedure:

1. Measure the mass (m_1) of the calorimeter and stirrer using a balance.

2. Pour water into the calorimeter which is just sufficient to dip the heating coil and the bulb of the thermometer. Then measure the total mass (m_2) of the calorimeter, stirrer and water. Calculate the mass (M) of water.
3. Place the heating coil into the calorimeter. Keep the calorimeter with heating coil into its insulating box. Fix the thermometer with holder so that its bulb is in the middle of the water but never touching the coil and the calorimeter.
4. Complete the circuit as shown in Fig. 7.1. Switch on the circuit temporarily and adjust the control knob of the power supply until the current is about 2 amperes. Then switch off the circuit and stir the water until a steady temperature is shown by the thermometer. Record this temperature as initial temperature.
5. Switch on the circuit and start the stop watch simultaneously. Then start recording the temperature, current and voltage in the table at an interval of every 1 minute. Keeping the current supply and stop watch on, record these values for 10 minutes. Then switch off the circuit but allow the stop watch to run on and record the temperature for further 10 minutes in the same manner. Stir the water gently during the whole process.
6. Find the maximum and final temperatures. Use them to calculate the radiation correction.
7. Calculate the water equivalent of the calorimeter.
8. Using the given formula, determine the value of the mechanical equivalent of heat.

Experimental data:

Mass of the calorimeter + stirrer, m_1 = g
Mass of the calorimeter + stirrer + water, m_2 = g
Mass of the water, $M = m_2 - m_1$ = g
Specific heat of the water, $s = 1$ Cal $g^{-1}\,°C^{-1}$
Specific heat of the material of the calorimeter (Aluminum), $s_1 = 0.2096$ Cal $g^{-1}\,°C^{-1}$
(Copper), $s_1 = 0.0909$ Cal $g^{-1}\,°C^{-1}$

Table 1: Table for current, voltage and temperature

No of observations	Times (min)	Current, i (amp.)	Voltage, E (Volt)	Temperature, T (°C)
1	00			
2	01			
3	02			
4	03			
5	04			
6	05			
7	06			
8	07			
9	08			
10	09			
11	10			
Current Stopped				
12	11	0	0	
13	12	0	0	
14	13	0	0	
15	14	0	0	
...	...	0	0	
...	...	0	0	
21	20	0	0	

Calculations:

Water equivalent of the calorimeter, $W = m_1 s_1 =$	g
Initial temperature of the calorimeter + contents, $\theta_i =$	°C
Maximum temperature of the calorimeter + contents, $\theta_m =$	°C
Final temperature of the calorimeter + contents, $\theta_f =$	°C
Rise of temperature, $\theta = (\theta_m - \theta_i)$	°C
Radiation correction, $\theta_r = (\theta_m - \theta_f)/2 =$	°C
Corrected rise of temperature $(\theta_2 - \theta_1) = (\theta + \theta_r) =$	°C
Time during which the current is passed, $t =$	sec
Mean current during the interval t, $i =$	amp.
Mean voltage during the interval t, $E =$	volt

Mechanical equivalent of heat,

$$J = \frac{Eit}{(Ms + W)(\theta_2 - \theta_1)} \text{ Joules/Calories}$$

Error Calculation:

Standard value of the mechanical equivalent of heat, J is 4.2 Joules/Calories

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 8:

Name of the Experiment: Determination of the thermal conductivity of a bad conductor by Lee's and Charlton's method.

Theory:

Consider a thin layer of slab of a bad conductor, S (such as glass or ebonite). A and B are the thick discs of brass or copper, one on either side of S. B is a steam chamber from which heat passes to S and A (Fig. 8.1). When steam is passed through B, A is warmed up by the heat conducted through S. After some time, a steady state will be reached when the rate of flow of heat through S equals the heat lost from A by radiation and conduction.

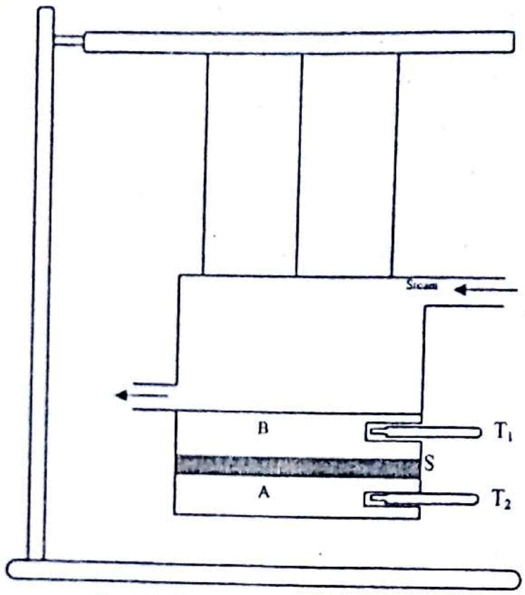


Fig. 8.1 : Lee's and Charlton's apparatus

If θ_1 and θ_2 be the temperatures of B and A in steady state, respectively, then the quantity of heat conducted per second through the slab S is

$$Q_1 = \frac{Ka(\theta_1-\theta_2)}{d},$$

where K is the thermal conductivity of the slab S and a and d are the area of cross-section and thickness of S, respectively.

If $\frac{d\theta}{dt}$ be the rate of cooling of disc A, the heat lost (radiated) per second is

$$Q_2 = ms\,\frac{d\theta}{dt},$$

where m and s be the mass and specific heat of A.

In the steady state, $Q_1=Q_2$.

or, $$\frac{Ka(\theta_1-\theta_2)}{d} = ms\,\frac{d\theta}{dt}$$

or, $$K = \frac{ms\frac{d\theta}{dt}d}{a(\theta_1-\theta_2)}$$

Apparatus:

Lee's and Charlton's apparatus, Slide calipers, Screw gauge, Thermometers, etc.

Brief Procedure:

1. Measure the diameter of the bad conductor slab by using slide calipers.
2. Measure the thickness of the bad conductor slab by using screw gauge.
3. Start heating the boiler apart from the bad conductor slab.
4. Put the slab between A and B.
5. When the steam starts to come from the outlet, start taking data from both the thermometers T_1 and T_2 after at an interval of every 5 minutes until they show steady readings (θ_1 and θ_2). Steady readings mean that they remain constant for at least 3 consecutive intervals, i. e. for 15 minutes.
6. After reaching the steady temperature θ_2 in thermometer T_2, remove B and then heat A with the slab still on the top of it up to (θ_2+10) °C.

7. Remove A with the slab still on top of it from the heater and allow it to cool. Note the temperature at an interval of every half minute until the temperature falls to $(\theta_2\text{-}10)$ ℃.
8. Plot a graph of temperature vs. time from cooling data. Draw a tangent at steady temperature (θ_2). Calculate the slope of the tangent.
9. Determine the thermal conductivity of the bad conductor using the given formula.

Experimental Data:

Vernier Constant ($V.C.$) of the slide calipers

$$V.C. = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}}$$

Least Count ($L.C.$) of the Screw Gauge

$$L.C. = \frac{\text{Pitch}}{\text{Total number of divisions in the circular scale}}$$

Table-1: Table for the radius of the disc S

No. of obs.	Main scale reading, x (cm)	Vernier scale division, φ	Vernier constant, V_c (cm)	Vernier scale reading, $y = V_c \times \varphi$ (cm)	Diameter, $D = x + y$ (cm)	Mean diameter, D (cm)	Instru-mental error ±e (cm)	Corrected diameter, D−(±e) (cm)	Radius, $r = D/2$ (cm)
1									
2									
3									
4									

Table-2: Table for the thickness of the disc S

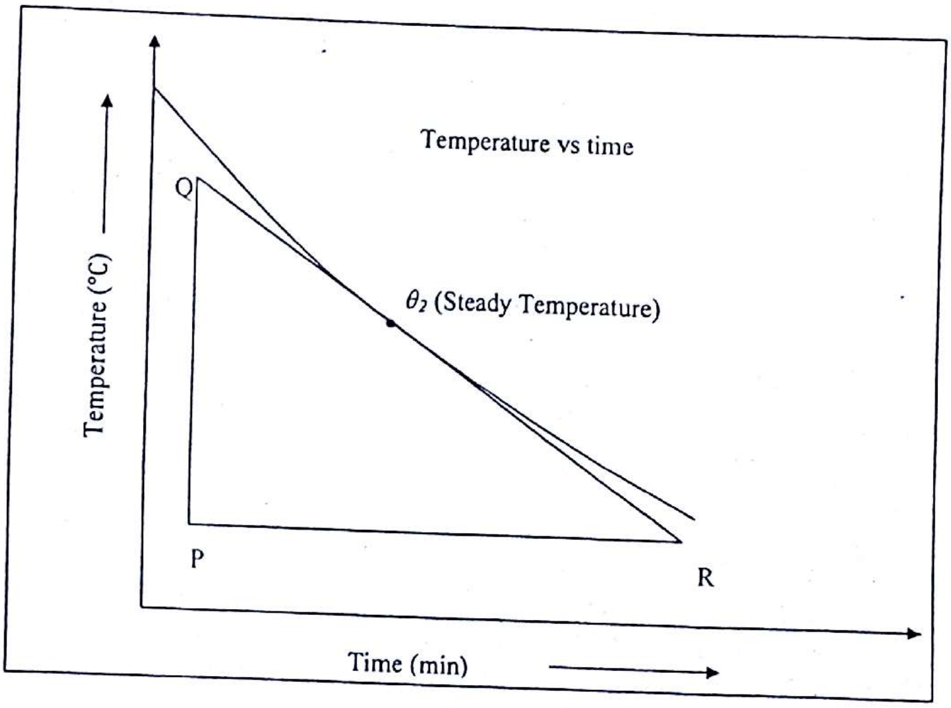
No. of obs.	Linear scale reading, x (cm)	Circular scale division, β	Least count, L_c (cm)	Circular scale reading, $y = \beta \times L_c$ (cm)	Thickness, $d = x + y$ (cm)	Mean thickness, d (cm)	Instrumental error ±e (cm)	Corrected thickness, d−(±e) (cm)
1								
2								
3								
4								

Table-3: Time- temperature records of B and A.

No. of observation	Time (minutes)	Temperature, θ_1 (°C)	Temperature, θ_2 (°C)
1	0		
2	5		
3	10		
4	15		
..	..		
..	..		
..	..		
..	..		
..	..	$\theta_1 =$	$\theta_2 =$

Table-4: Time-temperature record of A during its cooling.

No. of obs.	Time, t (minutes)	Temperature, (°C)
1	0	θ_2+10
2	0.5	
3	1	
4	1.5	
....	....	
....	....	
....	....	
....	....	θ_2-10



Graph 1

Calculations:

Mass of the disc A, m = g

Specific heat of the material of A, s = 0.0909 Cal g^{-1} °C^{-1}

Radius of the specimen disc S, r = cm

Area of cross-section, $\alpha = \pi r^2$ = cm^2

From the graph 1, the slope of the tangent at θ_2 = °C,

$$\frac{d\theta}{dt} = \frac{PQ}{PR} \text{ °C min}^{-1} = \frac{PQ}{PR \times 60} \text{ °C s}^{-1}$$

Thermal conductivity,

$$K = \frac{ms\frac{d\theta}{dt}d}{\alpha(\theta_1 - \theta_2)}$$

Error Calculation:

The thermal conductivity of ebonite is 4.2×10^{-4} cal cm^{-1} s^{-1} °C^{-1}.

$$\text{Percentage error} = \frac{Standard\ value \sim Experimental\ value}{Standard\ value} \times 100\ \%$$

Result:

Discussions:

Experiment no 9:

Name of the Experiment: **Determination of the spring constant and effective mass of a given spiral spring.**

Theory:

When a spiral spring clamped vertically at upper end P (Fig. 9.1) and subjected to applied load, m_o at its lower end, then the extension l becomes proportional to the applied force i.e.

$$F = k\,l$$

$$m_o g = k\,l$$

or,

$$k = \frac{m_o g}{l} \quad \ldots\ldots\ldots\ldots\ (1),$$

where k is a constant of proportionality called spring constant.

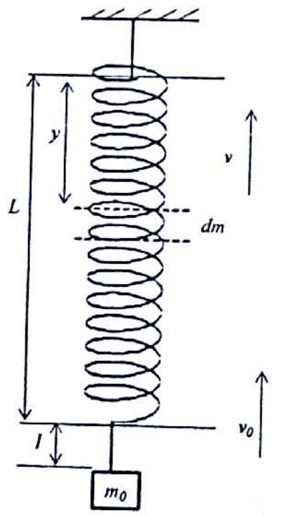


Fig.9.1: Spring-mass system

The theoretical period of a system composed of a mass M oscillating at the end of a mass less spring of force constant k is given by,

$$T = 2\pi\sqrt{\frac{M}{k}}$$

Since no spring is mass less, it would be more correct to use the equation

$$T = 2\pi\sqrt{\frac{m_0 + m_s}{k}},$$

where m_0 is the load and m_s is the mass of the spring.

For a spring of length L oscillating vertically (as shown in Fig. 9.1), the value of m_s can be derived from kinetic energy (E_k) consideration as

$$E_k = \int_0^L \frac{1}{2} v^2 dm,$$

where v is the velocity of the infinitesimal mass dm.

Now, assuming homogeneous stretching and uniform mass distribution, $dm = \frac{m_s}{L} dy$.

Let m_0 and dm are moving with velocities v_0 and v, respectively, where $v < v_0$.

Considering the velocity as the linear function of the position y measured from a fixed point P, v can be represented by

$$v = \frac{v_0}{L} y$$

From the above equations,

$$E_k = \int_0^L \frac{1}{2} \left(\frac{v_0}{L}\right)^2 y^2 \frac{m_s}{L} dy = \frac{1}{2} \frac{v_0^2}{L^3} m_s \int_0^L y^2 dy$$

$$E_k = \frac{1}{2} \frac{m_s}{3} v_0^2 = \frac{1}{2} m' v_0^2,$$

where $m' = \frac{1}{3} m_s$, is the effective mass of the spring.

Apparatus:

A spiral spring, Load, Electronic balance, Stopwatch and meter scale, etc.

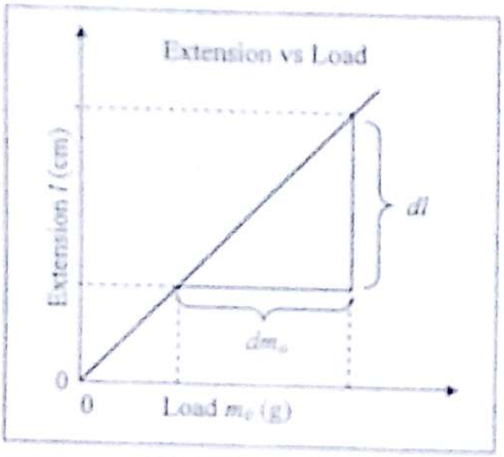
Brief Procedure:

1. Measure the mass (m_s) of the spring with a balance.
2. Clamp the spring vertically by a hook attached to a rigid frame.
3. Measure the length of the spring with a meter scale.
4. Add 100 gm load (m_0) to the free end of the spring. Measure the length of the spring with load. Calculate the extension of the spring.
5. Oscillate the spring with 100 gm load along the vertical axis and record the time for 20 complete oscillations. Then calculate the time period.
6. Repeat steps 4 and 5 for 8 to 10 sets of loads.
7. Draw a best fit straight line through origin with load as abscissa and extension as ordinate (Graph 1). Determine the slope of the line and calculate the spring constant k.
8. Plot another graph with m_0 (abscissa) against T^2 (ordinate) as shown in Graph 2. Find out the effective mass (m') by taking the point of intercept of the resulting lines on m_0 axis.

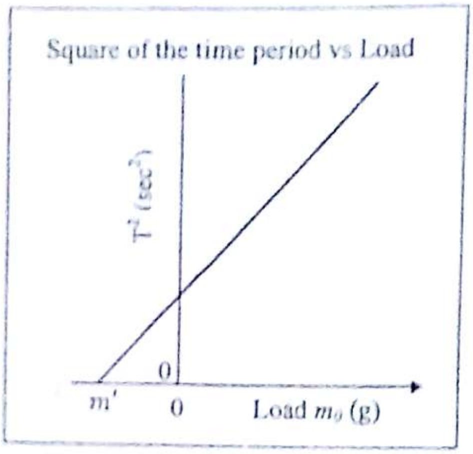
Experimental Data:

Table-1: Table for determining extensions and time periods

No. of obs	Loads, m_0 (gm)	Length of the Spring without load, L_1 (cm)	Length of the Spring with load, L_2 (cm)	Extension $l = L_2 - L_1$ (cm)	Time for 20 vibrations (sec)		Mean Time, t (sec)	Time Period, $T = t/20$ (sec)	T^2 (sec^2)
1	100								
2	200								
3	300								
4	400								
5	500								
6	600								
7	700								
8	800								
9	900								
10	1000								



Graph-1



Graph-2

Calculations:

From graph-1; Slope $= \frac{dl}{dm_o} = \frac{l}{m_o} =$ cm/g

Spring constant, $k = g\frac{m_o}{l} = 981 \times \frac{1}{Slope}$ *dynes/cm*

From graph-2, the effective mass of the spring, $m' =$ g

Error Calculation:

Standard value of the effective mass of the spring $= \frac{m_s}{3}$.

$$\text{Percentage error} = \frac{Standard\ value - Experimental\ value}{Standard\ value} \times 100\ \%$$

Results:

Discussions: