Laboratory Manual

Course code: PHY 1102
Course title: Physics Practical

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List of Experiments:

1.	To determine the spring constant and effective mass of a given spiral spring.
2.	To determine the value of acceleration due to gravity (g) by means of a compound pendulum.
3.	To find the variation of the frequency of a tuning fork with the length of a sonometer under given tension and hence to determine the unknown frequency of a tuning fork.
4.	To determine the specific heat of a liquid by the method of cooling.
5.	To determine the Latent heat of fusion of ice with radiation correction.
6.	To determine the radius of curvature of a convex lens by Newton's rings.

Reference Books:

1. **Practical Physics,** Dr. Giasuddin Ahmed and Md. Shahabuddin
2. **Physics-I & II,** R. Resnick, D. Halliday

Experiment no 1: **Date:**

Name of the Experiment: Determination of 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,

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

where k is a constant of proportionality called spring constant.

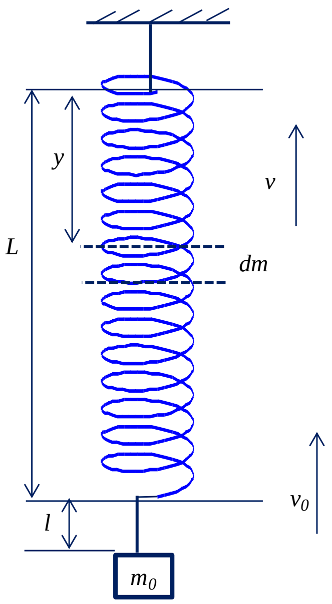


Fig.9.1: Spring-mass system

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 massless, 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.

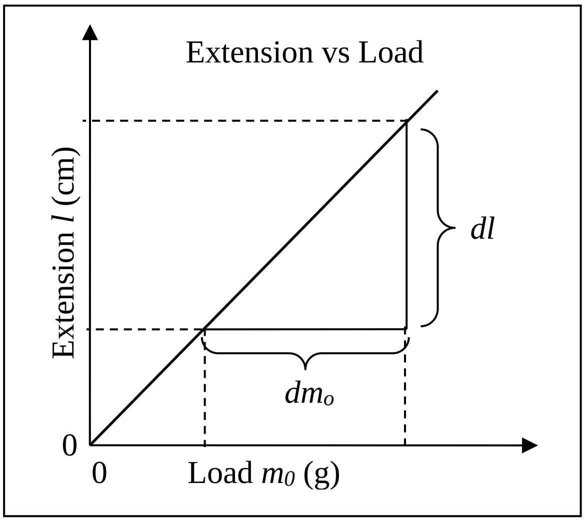
Brief Procedure:

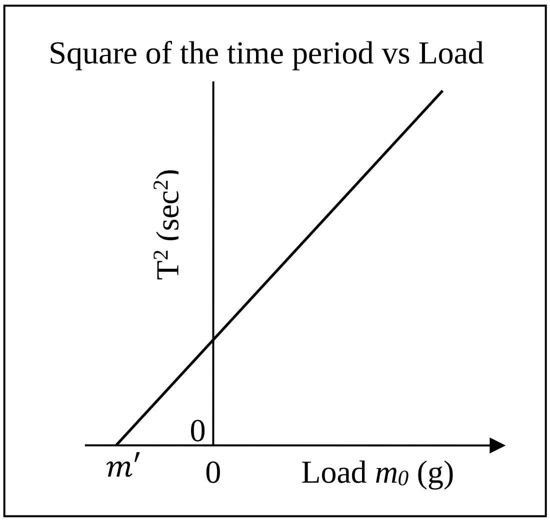
1. Measure the mass (m_s) of the spring with a balance.
2. Clamp the spring vertically by a hook attached to a rigid frame.
3. Measure the length of the spring with a meter scale.
4. Add 100 gm load (m_0) to the free end of the spring. Measure the length of the spring with load. Calculate the extension 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 T^2 (ordinate) against m_0 (abscissa) 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-1Graph-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 $= \frac{m_S}{3} =$ g

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

Results:

Discussions:

Experiment no 2: **Date:**

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.

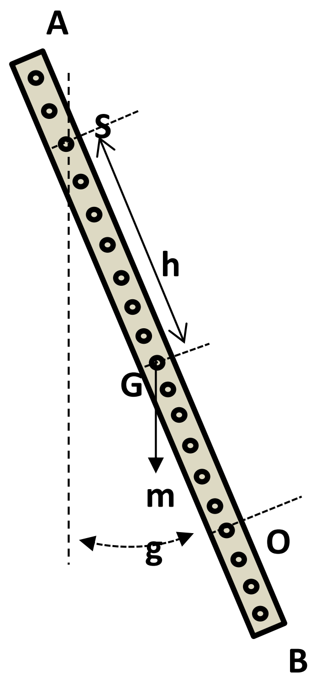


Fig. 5.1: Compound Pendulum

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, Metal wedge, 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* (value of the period at point *O*) from the graph.
10. Calculate the value of acceleration due to gravity using the given equation.

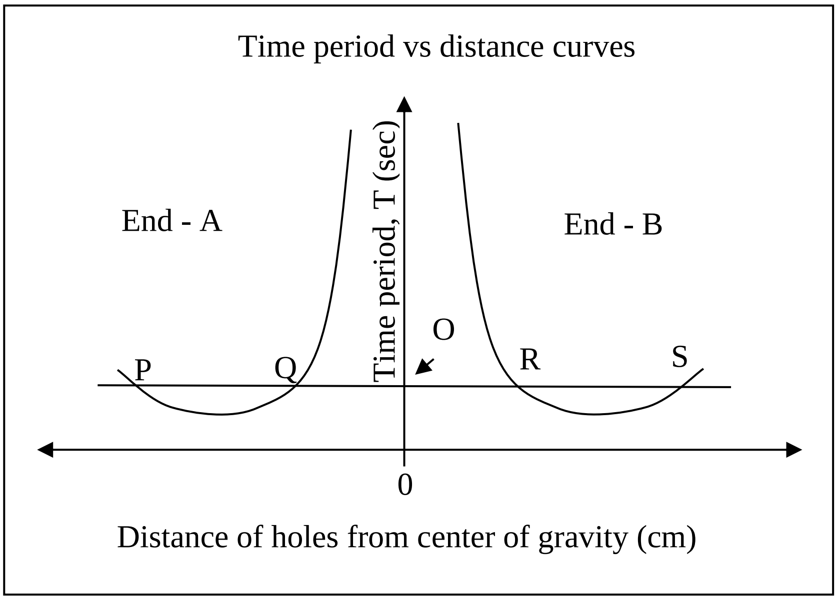
Experimental Data:

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

<u>Calculations:</u>

From graph 1: Length, $PR = (PO+OR) =$ cm
Length, $QS = (QO+OS) =$ cm

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

Time period, $T =$ sec

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

Error Calculation:

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

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

<u>Result:</u>

<u>Discussions:</u>

Experiment no 3: **Date:**

Name of the experiment: To find the variation of the frequency of a tuning fork with the length of a sonometer under given tension and hence to determine the unknown frequency of a tuning fork.

Theory: If a tuning fork be in resonance with stretched string vibrating in its fundamental form, then the frequency n of the fork is given by

$n = \frac{1}{2l}\sqrt{\frac{t}{m}}$ where l is the length of the string between two fixed points, t is the tension used to stretched the string and m is the mass per unit length of the string.

Apparatus: Sonometer, tuning fork of known frequency, tuning fork of unknown frequency, weight box, etc.

Experimental data:

Stretching weight of the wire, M =

Table: To measure the resonating length

<table>
<tr><th>No of obs.</th><th>Frequency n</th><th>Resonating Length</th><th>Mean Resonating Length (l)</th><th>$\frac{1}{l}$</th><th>nl = constant</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3"></td><td></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td rowspan="3">2</td><td rowspan="3"></td><td></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
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<tr><td></td></tr>
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<tr><td rowspan="3">4</td><td rowspan="3"></td><td></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
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<tr><td></td></tr>
<tr><td rowspan="3">5</td><td rowspan="3"></td><td></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td rowspan="3">6</td><td rowspan="3"></td><td></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td></td></tr>
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</table>

Results:

Discussion:

Experiment no 4: **Date:**

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 time 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, Stopwatch, 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 ^{o}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 stopwatch 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 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.

<u>Experimental data:</u>

Table: Time–temperature record for water and liquid

No. of obs.	Time (min)	Temperature of water (℃)	Temperature of liquid (℃)
1	00		
2	01		
3	02		
4	03		
5	04		
6	05		
7	06		
8	07		
9	08		
10	09		
11	10		
12	11		
13	12		
14	13		
15	14		
16	15		
17	16		
18	17		
19	18		
20	19		
21	20		
22	21		
23	22		
24	23		
25	24		
26	25		

Mass of the calorimeter + stirrer, m = g

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

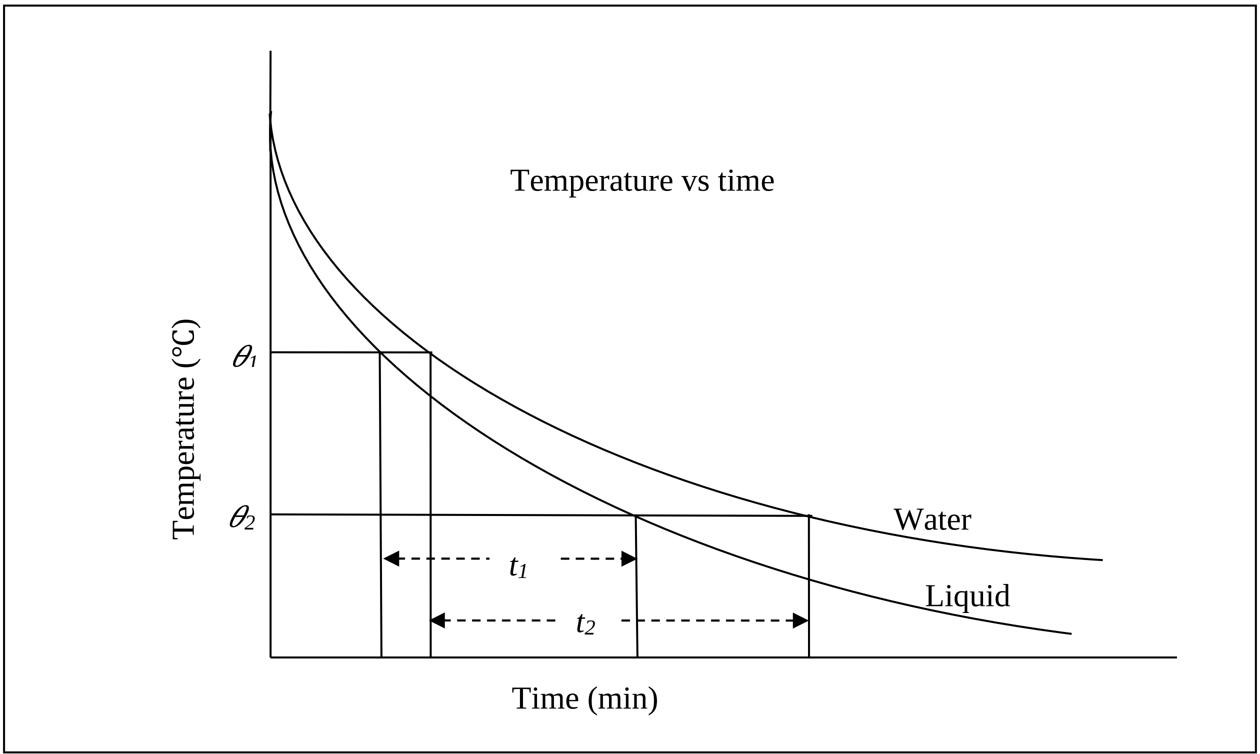
Mass of the liquid, $M_1 = m' - m =$ g

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: Variation of temperature with time

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}.

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

Result:

Discussions:

Experiment no 5: **Date:**

Name of the Experiment: Determination of Latent heat of fusion of ice with radiation correction.

Theory: Latent heat of fusion of ice is defined as the quantity of heat required to melt one gram of ice at 0 ℃ into water at 0 ℃. Let an amount of ice of mass *M* be added to a mass m of water contained in a calorimeter of mass w and specific heat s. Let t_1℃ be the temperature of the calorimeter and its content before the addition of ice and t_2℃ be the final temperature, after making due allowance for the gain of heat from the surrounding, of the mixture after addition and complete melting of ice. Then the heat lost by the calorimeter and water is

$$m(t_1 - t_2) + ws(t_1 - t_2).$$

The heat required to melt the ice is ML where L is the latent heat of fusion of and the heat required to raise the temperature of the water, formed as a result of melting of ice, from 0 ℃ to t_2 ℃ is Mt_2. Therefore, the total heat gained in the experiment is

$$ML + Mt_2 = M(L + t_2)$$

According to the law of colorimetry heat gained is equal to heat lost. So,

$$M(L + t_2) = (m + ws)(t_1 - t_2)$$

or,

$$L = \frac{(m + ws)(t_1 - t_2) - Mt_2}{M}$$

Apparatus: Calorimeter with stirrer, thermometer, blotting paper, stopwatch, ice, balance, etc.

Experimental data:

Mass of calorimeter + stirrer, w =	gm
Specific heat of the calorimeter material, s =	Cal g^{-1}℃$^{-1}$
Mass of calorimeter + stirrer + water, w_1 =	gm
Mass of water, $m = w_1 - w$ =	gm
Mass of calorimeter + stirrer + water + molten ice, w_2 =	gm
Mass of ice added, $M = w_2 - w_1$ =	gm
Initial temperature of water, t_1 =	℃
Final temperature of the mixture, t_2 =	℃

Table: Time–temperature record for ice-water mixture

No. of obs.	Time (min)	Temperature of ice-water mixture (℃)
1	00	
2	01	
3	02	
4	03	
5	04	
6	05	
7	06	
8	07	
9	08	
10	09	
11	10	
12	11	
13	12	
14	13	
15	14	
16	15	
17	16	
18	17	
19	18	
20	19	
21	20	
22	21	
23	22	
24	23	
25	24	
26	25	

Calculations:

Latent heat of fusion of ice is

$$L = \frac{(m + ws)(t_1 - t_2) - Mt_2}{M}$$

Error Calculation:

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

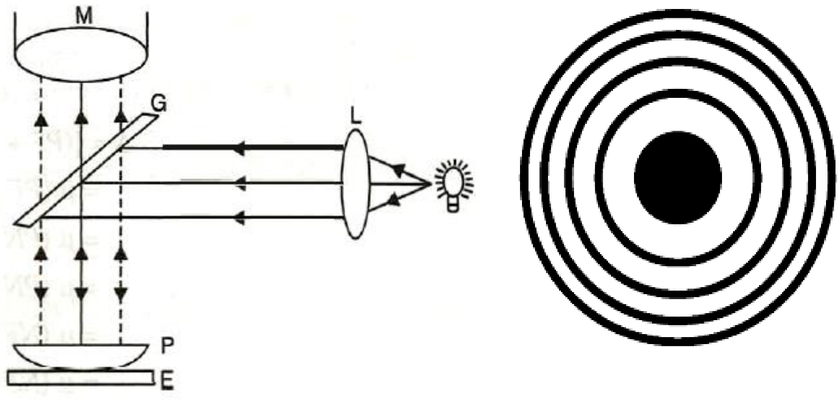
Result:

Discussions:

Experiment no 6: **Date:**

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. 6.1a, it appears as a series of concentric, alternating bright and dark rings as shown in Fig. 6.1b cantered at the point of contact between the two surfaces.



(a) (b)

Fig.6.1: (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

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

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

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 (*L. C.*) (mentioned in experiment no. 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 12th dark ring on the left side of the central dark spot.
4. Set the vertical line of the cross-wire tangentially to 10th dark ring and note the readings of the linear scale and circular divisions.
5. Set the cross-wire in the same manner to the 9th, 8th,………., 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 1st 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 10th 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.

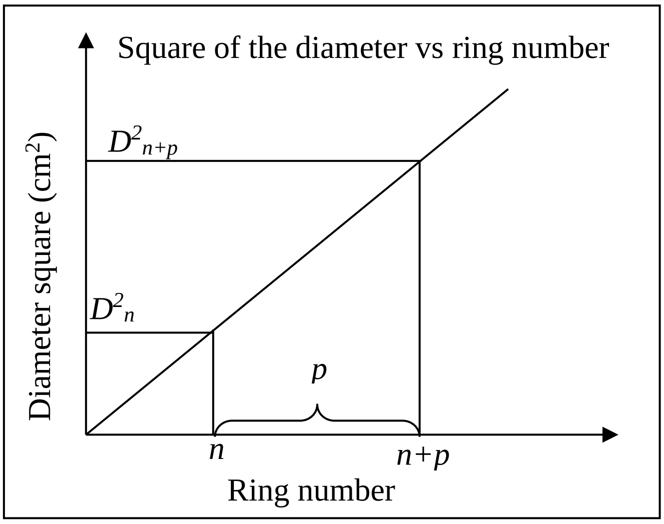
Experimental Data:

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, $D = L \sim R$ (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												
5												
6												
7												
8												
9												
10												



Graph 1

Calculation:

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

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

Result:

Discussions: