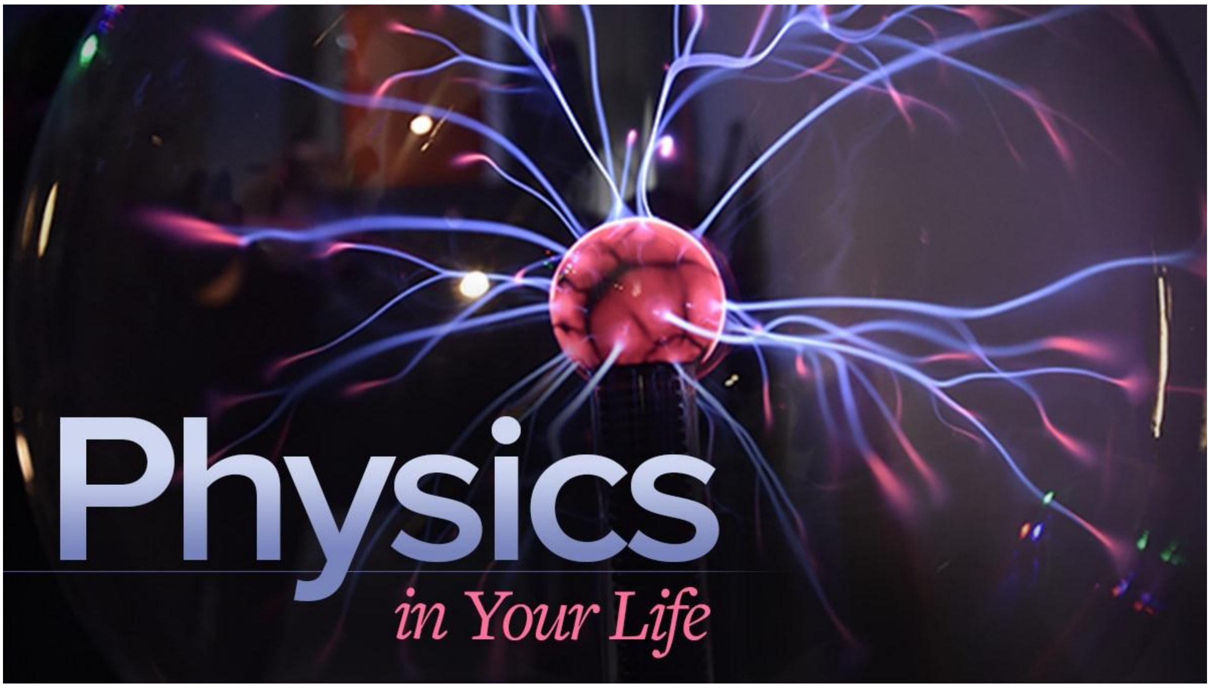
National Institute of Technology Agartala

Department of Physics



BS-MS, BT-MT 2ND SEM LAB MANUAL

GENERAL PHYSICS LAB

Contents:

Aim of the experiment

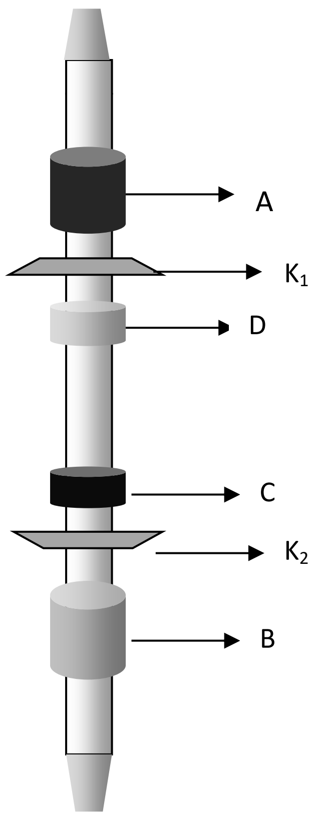
Determination of acceleration due to gravity by Kater's pendulum

Apparatus required.

- A kater's pendulum
- A stop watch
- A meter scale

Kater's pendulum

It consists of a metal rod of about one meter long.The rod is provided with two knife edges K_1 and K_2 which are turned inwards to face each other. Two equal cylinders to face each other. Two equal cylinders A and B, A made of box wood and B made of a metal, are placed beyond the knife edges. Between the knife edges two equal cylinders C and D, smaller in size are also mounted. The cylinder C and D, smaller in size are also mounted. The cylinder C made of boxwood whereas the cylinder D is made of a metal. The cylinders C and D are capable of moving along the rod and their positions on the rod determine the positions on the rod determine the position of the centre of gravity of the system. The knife edges K_1 and K_2 are generally movable and can be fixed at any desired positions. The pendulum is allowed to oscillate about any of the knife edges by placing the corresponding knife edge on a metallic plate which in turn is rigidity fixed on a permanent support.



Theory

On adjusting the different masses, if the periods of oscillation about the two knife edges of a Kater's pendulum are made exactly equal then the distance L between the two knife edges will be length of the equivalent simple pendulum having the same time period. So we get,

$$T = 2\pi\sqrt{\frac{L}{g}}\ , \qquad \text{or} \qquad g = \frac{4\pi^2}{T^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

If l_1 and l_2 be the distances of the knife edges from the cog of the system and K be the radius of gyration about a parallel axis through the cog, the periods T_1 and T_2 about the knife edges will be given by,

$$T_1 = 2\pi\sqrt{\frac{l_1^2+K^2}{l_1 g}} \quad \text{and} \quad T_2 = 2\pi\sqrt{\frac{l_2^2+K^2}{l_2 g}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Where K is the radius of gyration of the pendulum about an axis passing through its C.G

From (ii) we get

$$l_1 g T_1^2 = 4\pi^2\left(l_1^2 + K^2\right) \quad \text{and} \quad l_2 g T_2^2 = 4\pi^2\left(l_2^2 + K^2\right)$$

On subtracting we get

$$g\left(l_1T_1^2 - l_2T_2^2\right) = 4\pi^2\left(l_1^2 - l_2^2\right)$$

$$\frac{4\pi^2}{g} = \frac{l_1T_1^2 - l_2T_2^2}{l_1^2 - l_2^2} = \frac{1}{2}\left[\frac{T_1^2+T_2^2}{l_1+l_2} + \frac{T_1^2-T_2^2}{l_1-l_2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\textbf{(iii)}$$

Equation (iii) is the working formula of the experiment and shows that by measuring l_1 and l_2, the acceleration due to gravity g can be determined.

Procedure

(i) Place one of the knife edges (say K_1) of the pendulum on a rigid support so that the metallic cylinder B is in the downward direction.Allow the pendulum to oscillate through very small amplitude and observe the oscillations.

(ii) Measure the time taken for asmall number of oscillations (say, 5) by means of a precision stopwatch.

(iii) Now, place the pendulum on the second knife-edge i.e K_2, and after allowing it to oscillate. Measure the time taken for the same number of oscillations i.e 5.The times in the two cases may be widely different.

(iv) Shift the position at the cylinder D is one direction and measure again the times for the same number of oscillations before. If the shift at the cylinder D increases the difference in the times of oscillations then shift the position of the cylinder D in the opposite direction.

(v) The shifting of the cylinder D and the repetition of operation 2 are to be continued till the two times are nearly equal.

(vi) Repeat the process now with more number of oscillations about the two knife edge are very nearly equal times.

(vii) Now the position of cylinder C is adjusted .Keeping cylinder D fixed and the times for equal numbers if oscillations about the two knife edges K_1 , K_2 are noted. This is continued till the time for, say 40 oscillations about the two knife edges are almost equal. The exact periods of oscillations T_1, T_2 are measured after this final adjustment.

(viii) Now place the pendulum horizontally on a sharp wedge which is mounted on a horizontal table to locate the c.g of the pendulum. Mark the position of the c.g by a metre scale.

Experimental Data

Table 1

Observation of the times of oscillation and adjustment of the position of the cylinders

No of Obs.	Adjustment by shifting position	No. of oscillation	Total time of oscillation about the	
			Knife edge K_1 (sec)	Knife edge K_2 (sec)

Table 2

Measurement of periods of oscillations T_1 and T_2 after final adjustment

No. of Obs.	Oscillation about the knife edge	Time for 40 oscillations (sec)	Mean (sec)	Time period (sec)
	K_1			
	K_2			

Table-3

Measurement of distances l_1 and l_2

No. of obs.	Distance of K_1 from C.G l_1 (cm)	Mean l_1 (cm)	Distance of K_2 from C.G l_2 (cm)	Mean l_2 (cm)

Calculation

$$\frac{4\pi^2}{g} = \frac{1}{2}\left\{\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}\right\}$$

$\boldsymbol{g} =$ cm/sec

Computation of proportional error

$$\frac{\delta g}{g} = 2\frac{\delta T_1}{T_1} + 2\frac{\delta T_2}{T_2} + \frac{\delta\{l_1 + l_2\}}{l_1 + l_2}$$

Here, $\delta T_1 =$, $\delta T_2 =$, $\delta l_1 =$, $\delta l_2 =$

∴ Percentage of error = $\frac{\delta g}{g} \times 100$

Precautions

- The amplitude of oscillations must be kept very small so that the motion is truly simple harmonic
- The knife edges must be horizontal and parallel to each other so that the oscillations are confined in a vertical plane and the pendulum remains in a stable position

Related questions

1. What is a compound pendulum?
2. What is a simple pendulum? Mention the advantages of a compound over a simple pendulum.
3. Define the terms ‘centre of suspension’ and ‘centre of oscillation’.
4. Why should the knife edges be horizontal?
5. What would happen if the centre of suspension coincides with the C. G?

Aim of the experiment:-

To construct a one ohm coil

Apparatus required:-

i). Carey foster bridge

ii). Two equal resistances (P,Q)

iii). A variable resistance box (R)

iv). A standard one ohm

v). Two thick copper strips

vi). A plug commutator (C)

vii). A table galvanometer

viii). Connecting wires

Circuit diagram

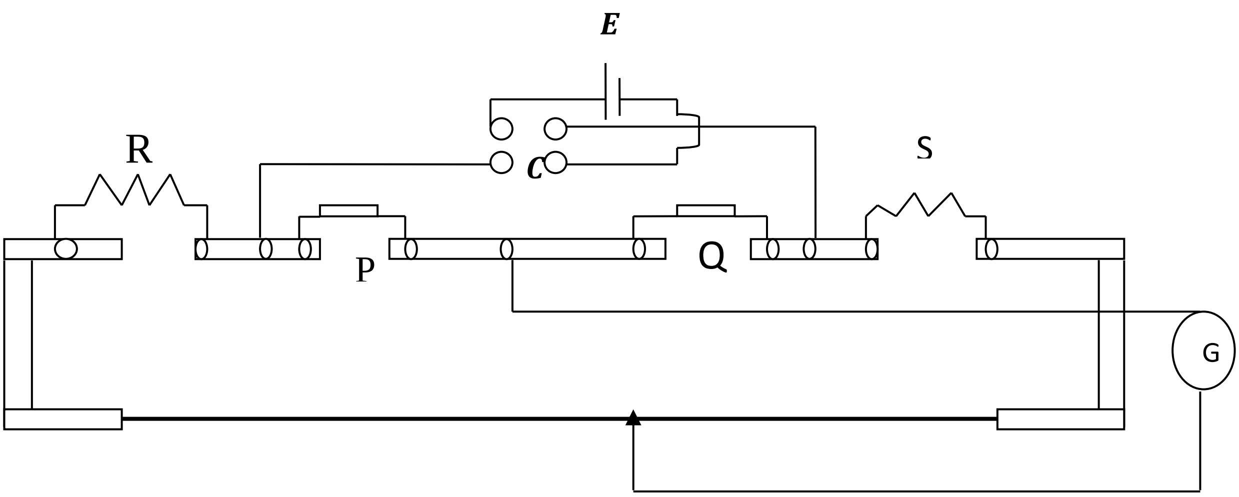


Fig – 1: Circuit diagram of Carey foster bridge

Theory:-

When the bridge is balanced, let the null point l_1 cm from the left end of the bridge wire. If by interchanging R and S, the null point is obtained at l_2 cm from the same end, we have

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

$$\rho = \frac{R}{(l2 - l1)} \text{.......................(i)}$$

Where ρ is the resistance per unit length (in Ω/cm) of the bridge wire.

Let the thick copper strip S be replaced by a know resistance by r, and R be replaced by the given wire of length L. suppose that the resistance of the given wire be R_x and $l_1^{/}$ is the distance of the null point from the left end of the bridge wire obtained with this circuit. Let $l_2^{/}$ be the distance of the null point from the same end of the bridge wire when r and R_x are interchanged.

Then

$$R_x = r + \rho(l_2^{/} - l_1^{/}) \quad \text{.............................(ii)}$$

The length of the wire for one ohm is therefore given by

$$L^{/} = \frac{L}{R_x} \text{...................................(iii)}$$

To compare the prepared one ohm (say,P_1 Ω) with a standard ohm (say S_1 Ω), Eq (ii) is used and the final correct value of the prepared ohm is obtained from

$$P1 = S1 + \rho\,(l_2\text{''} - l_1\text{''}) \text{ ....(iv)}$$

Where $l_2^{//}$ and $l_1^{//}$ are the final positions of the null points from the left end of the bridge wire. In the experiment $l_2^{//}$ and $l_1^{//}$ are made as close as possible.

Procedure:

1. Connect the resistance as shown in fig
2. Connect a fractional resistance box in the position of ‘S’ and close the copper strip in the position ‘R’, this indicates that resistance at R = 0.
3. Now varying the resistance in the resistance box you have to find out the null point and note then position of the null point from the scale. This reading is denoted by ‘l_1’
4. Reverse the direction of current by the commutator and check the reading.
5. Such way take readings of ‘l_1’ for different resistance.
6. Now interchange the copper strip S and resistance box R. put those resistances serially from the resistance box which were you used before and record the null point ‘l_2’ in

the previous manner. In this case the null points will be located between the mid-point and the right end of the bridge wire.

7. Find the value of ρ of the b ridge wire from each set of readings using eq. (i) and obtain the mean ρ.
8. Take the sample wire and bend its two ends over about 1 cm for insertions in the binding screw of the bridge. Measure the length L of the wire between the two bends and record this length.
9. Put the sample wire in the extreme left gap and a resistance box r in the extreme right gap of the bridge. Insert a resistance from the resistance box r so that the null point is obtained near the left end of the bridge wire. Record the null points ($l_1^{/}$) for direct and reverse currents. Increase gradually the value of the resistance r (say in steps of 0.2Ω) from the box and each time record the null points for direct and reverse currents.
10. Interchange the positions of the sample wire and the resistance box r. Repeat steps 9 by inserting the previous values of the resistances from the box r. this time the null points ($l_2^{/}$) will be located near the right end of the bridge wire.
11. Knowing the values of r and the positions of the null points in steps 9 and 10 calculate value of resistance R_x and l by using eq. (ii).
12. Calculate the length $L^{/}$ of the wire required for 1 ohm from R_x and L by using eq. (iii).
13. Cut off a length which is slightly less than $L^{/}$ from the sample wire and solder its two ends to two copper strips.
14. Connect copper strips to the two outer gaps of the bridge so that R =0Ω and S = 0Ω. Obtain the null points for both direct and reverse currents and denote it as $l_{0.}$
15. Connect the wire in place of the copper strip at the left and the standard ohm in place of the right-hand copper strip of the bridge. Obtain the null points for direct and reverse currents. Find the mean value of the null points ($l_1^{/\,/}$)
16. Rub a little the wire by a fine grained sand paper and obtain the null point again. In this case, the difference ($l_1^{/\,/}$- l_0) will be reduced from the previous value. The process of rubbing is repeated several times until the value of ($l_2^{//}$ - l_0) becomes approximately equal to zero.
17. Interchange the positions of the wire and the standard ohm and record the null point reading ($l_2^{//}$). Calculate the correct value of the resistance of the wire by using eq. (iv) with last value of $l_1^{/\,/}$ obtained in step 16.
18. Fold the prepared one ohm wire on itself and wind round a bobbin non-iductively.

Experimental results

Table 1

Determination of ρ of the bridge wire

P = Q = 1Ω

No. of obs	R in the Box S(Ω)	Null point when the copper strip						$\rho = \frac{R}{l_2 - l_1}$	Mean ρ (Ω/cm)
		Right gap			Left gap				
		Direct Current (cm)	Reverse Current (cm)	Mean l_1(cm)	Direct Current (cm)	Reverse Current (cm)	Mean l_2(cm)		

Table 2

Determination of the resistance (R_x) of the sample wire at T= ^{o}C

No. of sets	Resistance in the		Position of null point for			($l_2^{/}$ - $l_1^{/}$) (cm)	R_x= r - ρ($l_2^{/}$ - $l_1^{/}$) (Ω)	Mean R_x (Ω)
	Left gap (Ω)	Right gap (Ω)	Direct current (cm)	Reverse Current (cm)	Mean (cm)			
1	R_x	r_1 =			………… ($l_1^{/}$)			
1	r_1 =	R_x			($l_2^{/}$)			
2	R_x	r_2 =						
2	r_2 =	R_x						
3	R_x	r_3 =						
3	r_3 =	R_x						
4	R_x	r_4 =						
4	r_4 =	R_x						
5	R_x	r_5 =						
5	r_5 =	R_x						

Table 3

Determination of length of the wire corresponding to 1 ohm

Length of the given wire between the bends (cm)	Resistance (R_x) of the wire from table 2 (Ω)	Length required for 1 ohm = L/R_x (cm)

Table 4

Determination of null points (l_0) when R = 0Ω; S = 0Ω; P = Q = 1Ω

Position of null points with		Mean (l_0) (cm)
Direct current (cm)	Reverse current (cm)	

Table 5

Comparison of prepared ohm (P_1 Ω) with the standard ohm (S_1 Ω)

No of obs.	Condition of P_1 Ω	Resistance in the		Position of null point with			$(l_1^{//} - l_0)$ Or $(l_2^{//} - l_1^{//})$ (cm)	Remarks
		Left gap (Ω)	Right gap (Ω)	Direct Current (cm)	Reverse Current (cm)	Mean (cm)		
	Before rubbing							
	After first rubbing							
	After second rubbing							
	…..							
	…..							
	…..							

Error calculation:

From Eq. (iv) we have $P_1 – S_1 = \rho(l_2^{//} - l_1^{//})$

By logarithmic differentiation, we get

$$\frac{\delta(P_1 - S_1)}{P_1 - S_1} = \frac{\delta\rho}{\rho} + \frac{\delta(l_2^{//} - l_1^{//})}{l_2^{//} - l_1^{//}}$$

Again $\rho = \frac{R}{l_2 - l_1}$

Hence, $\frac{\delta\rho}{\rho} = \frac{\delta(l_2 - l_1)}{l_2 - l_1}$

Also, $\delta S_1 = 0$

$\therefore$ $$\frac{\delta P_1}{P_1 - S_1} = \frac{\delta(l_2 - l_1)}{l_2 - l_1} + \frac{\delta(l_2^{//} - l_1^{//})}{l_2^{//} - l_1^{//}} = \frac{2\delta l}{l_2 - l_1} + \frac{2\delta l}{l_2^{//} - l_1^{//}}.$$

The position of null points are measured on an metre scale having a minimum scale reading of 1 mm, i.e., $\delta l = 0.1$ cm. therefore,

$$\frac{\delta P_1}{P_1 - S_1} = \frac{0.2}{l_2 - l_1} + \frac{0.2}{l_2^{//} - l_1^{//}} = 0.2\left(\frac{1}{l_2 - l_1} + \frac{1}{l_2^{//} - l_1^{//}}\right).$$

The percentage error in the prepared one ohm is thus given by

$$\frac{\delta P_1}{P_1} \times 100 = 20 \times \frac{(P_1 - S_1)}{P_1} \times \left(\frac{1}{l_2 - l_1} + \frac{1}{l_2^{//} - l_1^{//}}\right).$$

Use $S_1 = 1\Omega$, and the measured values of P_1, $(l_2 - l_1)$, and $(l_2^{//} - l_1^{//})$ on the right hand side of the above equation to find the percentage error in P_1.

Discussion

1. Before proceeding with the measurements, ensure that there is no loose contact anywhere in the circuit.
2. As the bridge wire is not perfectly uniform, choose R in such that the length ($l_2 - l_1$) between two null points is as large as possible.
3. Also the resistance R_x of the sample wire should be measured by selecting values of r which give greater lengths between the null points $l_1^{/}$ and $l_2^{/}$.
4. Since the rubbing results in an increase of resistance, cutoff a length from the sample wire which is slightly less than the actual length obtained from the measurement.
5. Each time rub the wire slightly and compare. After each rubbing, wait a little before observing the null point to allow dissipation of the heat produced during rubbing.

Related questions:

- What is an international ohm?
- Can a copper wire be used as a bridge wire?
- Why do you perform your experiment with direct as well as with reverse current?
- What are the ‘end corrections ‘ of a metre bridge?
- Can you measure very low or very high resistances with a standard Wheatstone bridge?

Aim of the experiment

Determination of the co-efficient of viscosity of a liquid from its rate of flow through a capillary tube.

Apparatus required

- A metallic tank.
- A manometer.
- A Capillary tube.
- A measuring cylinder.
- A stop watch.
- A thermometer.

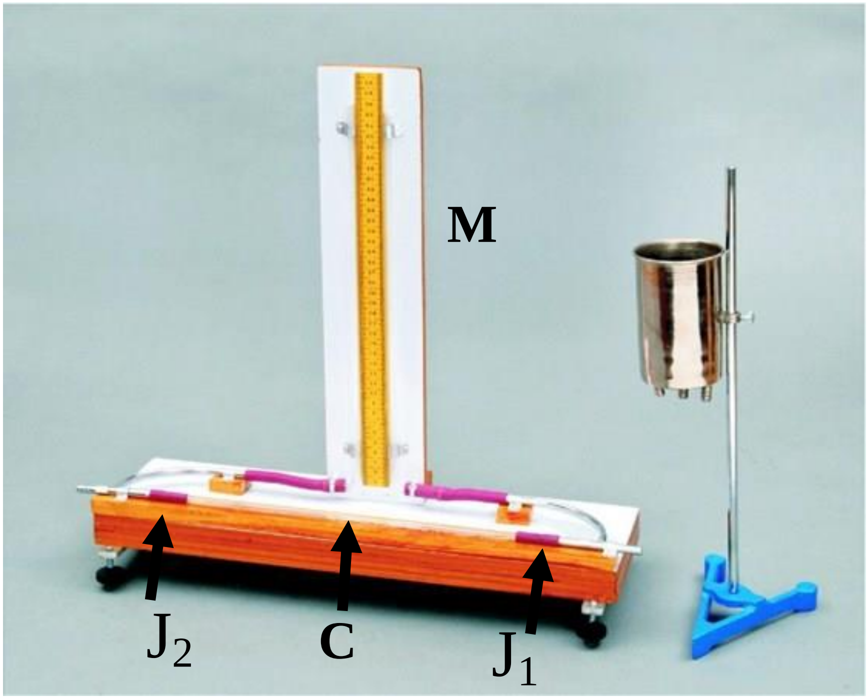


Fig : Experimental set up for determination of co-efficient of viscosity

Theory

If a liquid flows in stream lines through a horizontal capillary tube of internal radius r and length l, then the volume V of this liquid that flows out per second under a steady pressure difference P (= $h\rho g$) between its ends is given by

$$V = \frac{\pi p r^4}{8 l \eta} \quad \text{..(i)}$$

where η is the co-efficient of viscosity of the given liquid.

Thus

$$\eta = \frac{\pi P r^4}{8 l V} \quad \text{..(ii).}$$

Equation (ii) represents the *working formula* of the experiment and η is determined by measuring *P, r, l* and *V*.

Procedure

1. The length of the capillary tube is measured thrice by a scale and its mean value (*l)* is found out.
2. Radius of the capillary tube is supplied.
3. Pressure difference, *P* is given by P = hρg, where ρ is the density of the experimental liquid and *g* is the local acceleration due to gravity. To ensure that the liquid flows in streamlines in the experiment, *h* should be much less than the critical height h_c.

   A rough estimate of h_c can be made in terms of Reynold's number k as follows : The critical velocity marking the transition from the streamline to the turbulent motion of the liquid is given by

$$v_c = \frac{k\eta}{\rho r} \quad \text{..(iii).}$$

   The velocity of the liquid in the capillary tube is a maximum along the axis of the tube ; this maximum value is

$$u_{max} = \frac{h\rho g}{4\eta l} r^2 \quad \text{..(iv).}$$

   As the velocity of the liquid drops off as one moves away from the axis of the tube ; v_c is put to $u_{max}/2$. Then $h = h_c$, and we have from Eq. (iii) and (iv),

$$h_c = \frac{8k\eta^2 l}{\rho^2 g r^3} \quad \text{..(v).}$$

Taking h = 2 (or 3) cm, find the volume V of the outflowing liquid per second by collecting the liquid in a measuring cylinder and dividing the collected volume by the time of collection. Then find a rough value of η from Eq. (ii). Using this value of η, h_c is calculated from Eq. (v), considering k = 1000, the value of Reynold's number for narrow tubes.

The experiment will be performed for different values of *h* much less than h_c (typically below $h_c/2$).

4. The liquid from the metallic tank flows to the junction J_1. From the junction, the liquid goes simultaneously to an arm of manometer M and to a capillary tube C which connects the second junction J_2. The liquid from junction J_2 goes to the second arm of the manometer and to a measuring cylinder through a rubber tube. A pinch-cock could be used in the outlet rubber tube to adjust the liquid flow to the measuring cylinder in a very slow stream or in succession of drops. This condition is possible if the difference in heights h of the liquid in the two arms of the manometer is maintained at a steady low value. The collection of the liquid in the measuring cylinder is started after this steady state condition is achieved.

Two scales are attached with the two arms of the manometer M. Take the readings of the base of the meniscus of the liquid from the attached scales in the two arms of the manometers. Designate the readings by R_1 and R_2, respectively. The difference ($R_1 \sim R_2$) of the two readings gives h, i.e., the pressure difference in terms of the height of the liquid column.

5. The temperature of the collected liquid (T^o C) in the measuring cylinder is noted by a thermometer and the density (ρ) of the liquid is given in physical tables.

6. V may be determined by measuring the volume of the liquid collected in t sec with the help of measuring cylinder and dividing by t.

7. Measure V for several other values of h.

8. Draw a graph by plotting *h* along the x-axis and the corresponding *V* along the y-axis. The graph will be a straight line passing through the origin (0, 0).

9. On the graph choose a point and obtain the corresponding values of *h* and *V*. Calculate the value of *P* from the relation $P = h\rho g$. Compute the co-efficient of viscosity by using equation (ii).

Experimental Data

Table – 1

Measurement of length (*l*) of the capillary tube :

No of Obs.	Measured length (cm)	Mean *l* (cm)

Table – 2

Data for rough estimation of η and h_c

Value of $\boldsymbol{r}$ *(radius of the capillary tube) = ……….. cm*

k = 1000, ρ = …………kg/m^3, g = ………..m/s^2

Difference of liquid levels found by a meter scale h (m)	Volume of liquid collected in a measuring cylinder V' (cm^3)	Time of collection of water t (sec)	$V = \frac{V'}{t} X 10^{-6}$ (m^3/sec)	Value of r (m)	Value of l from table 1 (m)	Value of η from Eq. (ii) (N.s/m^2)	$h_c = \frac{8k\eta^2 l}{\rho^2 g r^3}$ (m)

Table 3

Determination of pressure difference in terms of height h

Density (ρ) of the liquid at ………^{o}C = ……………. gm/cm^3

No of Obs.	Reading of the liquid level in the left arm of the manometer R_1 (cm)	Reading of the liquid level in the right arm of the manometer R_2 (cm)	$\boldsymbol{h} = R_1 \sim R_2$ (cm)

No of Obs.	Reading of the liquid level in the left arm of the manometer R_1 (cm)	Reading of the liquid level in the right arm of the manometer R_2 (cm)	$\boldsymbol{h} = R_1 \sim R_2$ (cm)

Table 4

Determination of the volume of liquid collected per second (*V*)

No of obs.	*h* from Table 3 (cm)	Time (t) of collection (sec)	Volume of liquid collected V' (cm^3)	Mean V' (cm^3)	$V = V'/t$ (cm^3/sec)

No of obs.	h from Table 3 (cm)	Time (t) of collection (sec)	Volume of liquid collected V' (cm^3)	Mean V' (cm^3)	$V = V'/t$ (cm^3/sec)

Table 5

Data for (*h*-*V*) graph

No of Obs.	h (from Table 3) (m)	Corresponding V (from Table 4) (m^3/sec)

Table 6

Determination of coefficient of viscosity η at T^{o}C

T = …………^{o}C, g = ………….. m/s^{2}

h (from graph) (m)	Corresponding V (from graph) (m^3/sec)	Given density of the liquid at T^{o}C, ρ (kg/m^3)	$P = h\rho g$ (Pa)	l (from Table 1) (m)	r^4 (m^4)	$\eta = \frac{\pi P r^4}{8lV}$ (N.s/m^2)

Computation of Percentage Error

We have,

$\eta = \frac{\pi P r^4}{8lV} = \frac{\pi h \rho g r^4 t}{8 l V_t}$, since P = hρg and $= \frac{V_t}{t}$, where V_t represents the volume of the liquid collected in time t. The maximum proportional error in the measurement of η is given by

$$\frac{\delta\eta}{\eta} = \frac{\delta h}{h} + 4\frac{\delta r}{r} + \frac{\delta t}{t} + \frac{\delta V_t}{V_t} + \frac{\delta l}{l}$$

∴ percentage error

$$\frac{\delta\eta}{\eta} x100 =$$

Precautions

- The pressure difference across the ends of the capillary tube is kept at a low value in order that the liquid flows through the tube in streamlines. The straight line nature of the (h-v) graph also indicates that the motion is streamline.
- The accuracy of the result in the experiment can be improved by collecting alarge quantity of the liqid over a large period of time.
- The temperature of the liquid should be noted carefully, for value of it's viscosity changes rapidly with temperature.

Related Questions

- What do you mean by the term 'viscosity' and 'co-efficient' of viscosity of liquid?
- What do you mean by streamline motion and turbulent motion?
- How does the coefficient of viscosity change with temperature?
- On what factors viscosity depends?
- What are the units of co-efficient of viscosity in C. G. S and S. I system?
- What is Reynolds number?

Aim of the Experiment

Measuring Unknown wavelength of laser with a diffraction grating

Apparatus Required

1. Optical Bench
2. LASER Light Source
3. Component Holder
4. Diffraction Grating
5. Meter Scale

Theoretical Discussion

The diffraction of classical weaves refers to the phenomenon where in the waves encounter an obstacle that fragments the wave into components that interfere with one another. It is important to understand the physical processes that give rise to the diffraction phenomenon. Here, we will consider the diffraction of light through a diffraction grating, which is the device that we will be using in laboratory.

Diffraction gratings are used to make very accurate measurements of the wavelength of light. A diffraction grating has may slits, rather than two, and the slits are very closely spaced. By using closely spaced slits, the light is diffracted to large angles and measurements can be made more accurately.

As the light on the grating, the light waves that fall on the slits propagate straight on through. The light that impinges on the slit separation, however, is absorbed or reflected backward. At certain points in the forward direction, the light passing through the slits will be in phase and will constructively interfere. Whenever the difference in path length between the light passing through different slits in an integral number of wavelengths of the incident light, the light from each of these slits will be in phase, and then it will form an image at the specified location.

Theory

If a parallel bean of monochromatic light is incident normally on the face of the plane transmission grating, bright diffraction maxima are observed on the other side of the grating. These diffraction maxima satisfy the grating condition:

$$D \sin\theta_m = m\lambda \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where d = the grating element (= 2.54/N, N being the number of rulings per inch of the grating)

θ_m = the angle of diffraction of the m^{th} maximum.

M = the order of spectrum which can take values 0, $\pm$ 1, $\pm$ 2, $\pm$ 3,……………………

λ = wave length of the incident light

Clearly, the diffraction is symmetrical about $\theta_0 = 0$. By measuring θ_n and knowing N, λ can be calculated.

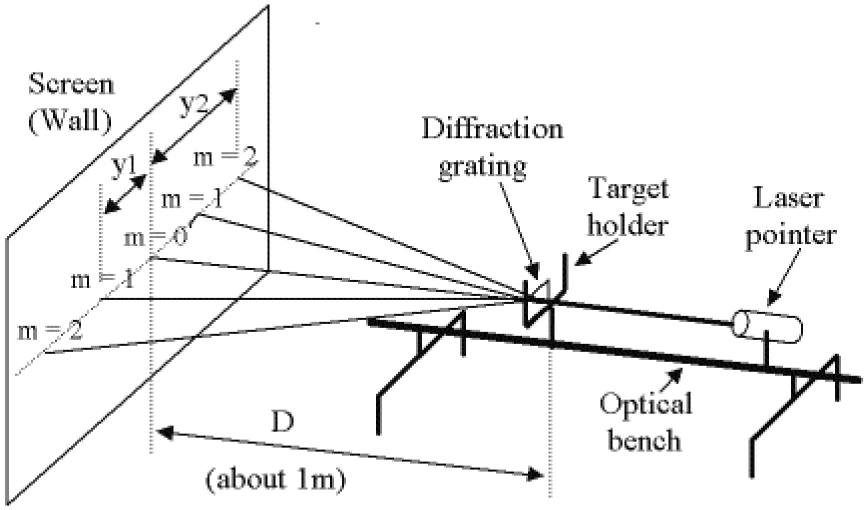


FIG. 1: Experimental set-up for measuring wavelengths with a diffraction grating

Figure 1 shows the set-up for a diffraction grating experiment. If a monochromatic light source shines on the grating, images of the light will appear at a number of angles – θ1, θ2, θ3 and so on. The value of θ_m is given by the grating equation Eq. (1), so that

$$\theta_m = \sin^{-1} (m\lambda/d) \qquad (2)$$

The image created at θ_m is called the m^{th} order image. The 0^{th} order image, i.e., principal maxima, is the light that shines straight through. The image created by this interference pattern appears at an angle of $\theta = 0$ no matter what the wave length or grating spacing is.

<u>Procedure</u>

1. Set up the laser and grating as shown in Figure 1.
2. Turn on the laser and measure the distance L between the diffraction grating and the 0^{th} order image.
3. Measure the distance S_1 between the 1^{st} order images (m = 1) appearing on the left and right sides of the centre line
4. Measure the distance s_2 between the 2^{nd} order images (m = 2) appearing on the left and right sides of the centre line.

It should be clear from simple trigonometric considerations that

$$\Theta_1 = \tan^{-1} (S_1/2L)$$

And……………….. ………..(3)

$$\Theta_2 \tan^{-2} (S_2/2L)$$

5. Knowing the values of θ_m from Eqs. (3), one can extract independent measurements of the laser wavelength, λ can be estimated from the equation,

$$\lambda = d \sin\theta_m/m \text{ ……………………………………………………..(4)}$$

Experimental Data

Measuring unknown wavelength (λ) of a laser with a diffraction grating

Determination of distance between grating plate and principal maximum (0^{th} order) =……………….. m, Supplied, d = 1.016×10^4 nm

Table -1

Order number (m)	Distance (S_m) between images of secondary maxima appearing on the left and right sides of the principal maximum (m)	$\theta_m = \tan^{-1}(S_m/2L)$	$\lambda = d \sin\theta_m/m$ (nm)	Mean λ (nm)

Computation of percentage error

The wave length of the spectral line is determined from the relation:

$$\lambda = \frac{Sin\theta}{nN}$$

Therefore, the maximum proportional error in the determination of λ is

$$\frac{\delta\lambda}{\lambda} = \frac{cos\theta\ \delta\theta}{sin\theta}$$

$$\frac{\delta\lambda}{\lambda} = \frac{\delta\theta}{tan\theta} \text{ ……………………………………….. (A)}$$

2θ measured from the difference between two readings corresponding to two positions of the telescope. Hence δθ is equal to the value of one vernier constant (in radian). Substituting the measured values of θ and the value of δθ in Eqn. (A) and multiplying by 100, the maximum percentage error in λ can be calculated.

Table – 2

Determination of number of rullings per inch (N) of an unknown grating L = ………… M

Order number (m)	**Distance (S_m) between images of secondary maxima appearing on the left and right sides of the principal maximum (m)**	**$\theta_m = \tan^{-1}(S_m/2L)$**	**$d = \frac{m\lambda}{\sin\theta_m}$**	**$N = \frac{2.54 \times 10^7}{d}$**	**Mean N**

Result:…………………………………………

Precautions:

1. The Diffraction Grating is a delicate component. Do not scratch the surface or touch it with your fingers.

2. Optical systems are sensitive and are often fine-tuned. Be very careful with the equipment, as a slight nudge might damage the equipment.

3. Make sure diffraction grating is standing vertically.

4. Ensure turntable is horizontal/flat by using the levelling screws

Related Question:

1. Diffraction grating is sometimes called as super-prism. Why?

2. Compare diffraction grating with prism in possible ways.

3. Diffraction grating can separate the colours of light. How?

4. A diffraction grating having 20000 lines per inch is better than that having 15000 lines per inch. Why?

5. Distinguish between the resolving power and dispersive power of the grating.

Aim of the experiment

Determination of surface tension of a liquid by capillary tube method

Apparatus required

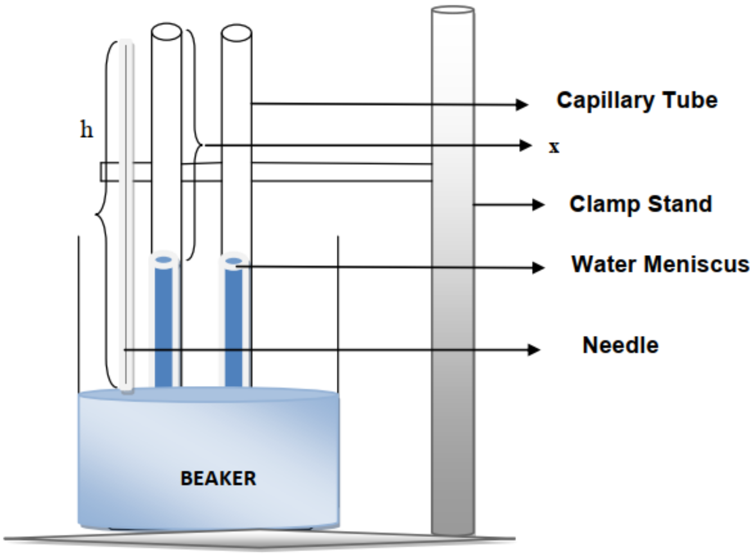
6. Capillary tubes of uniform circular bores
7. Needle
8. Glass beaker
9. Travelling microscope

Theory

If a capillary tube of uniform circular bore is partly introduced in liquid which wets glass and is kept vertical, the liquid rises in the tube. If 'h' be the height of the base of the of the concave meniscus in the tube from the outer level of liquid and r be the internal radius of tube at which the meniscus stands, then the surface tension T of water is given by

$$T = \frac{\rho r g}{2}\left(h + \frac{r}{3}\right)$$

where, ρ is the density of water and g is the acceleration due to gravity.



Procedure

Take two or three capillary tubes of different bores and the bores of these capillary tubes should be as uniform as possible.

- A clean glass beaker is almost completely filled with water.

- The apparatus is arranged as shown in above fig. The capillary tubes are fixed parallel to each other on a strip. A clean needle (also called the *index rod*) with pointed ends *is* also fixed to the strip parallel to the tubes but not close to them so that capillary action between the needle and its adjacent tube may not arise. The strip is kept clamped by a stand so that the tubes remain vertical.
- The position of the stand is adjusted in such a way that the tubes remain vertical with the lower ends immersed in water while the lower end of the needle just touches the water surface.
- Now adjust the microscope so that its horizontal movement becomes parallel to the plane of the capillary tubes. By this adjustment it is ensure that if the liquid meniscus, in one tube is focused then that in the other tube will also remain focused. To make the tubes perfectly vertical, the strip (on which they are fixed) may be rotated slightly in its own plane until the centre of the cross-wire always goes along of the tube as the microscope is raised upwards.
- The microscope is now adjusted so that its horizontal cross-wire becomes tangential to the image of the needle head. The reading (R_1) of the vertical scale and the vernier is noted. Then the microscope is shifted horizontally as well as vertically until horizontal cross-wire becomes tangential to the base of the concave meniscus in the first tube. The reading (R_2) of the vertical scale and vernier is taken. In this way the readings corresponding to the base of the concave meniscus of second, third etc tube noted.

6. Now the difference (x) between the readings of the needle head (R_1) and the base of the concave meniscus (R_2) in each tube is determined $x = (R_1 \sim R_2)$. If 'l' be the length of the needle, the height of the meniscus from the level of liquid in the beaker, is given by

$$h = l \pm x$$

The + or – sign should be taken according as the needle head is below or above the meniscus.

7. Now the strip is clamped such a way that all the tubes are in the horizontal plane. The microscope is then focused on the end of the first tube and the vertical cross-wires are made tangential to the left side of the inner bore which is almost circular and the reading (R_3) of the horizontal scale is taken. Then the microscope is moved horizontally until the same vertical cross-wire becomes tangential to the right side of the inner bore. The reading (R_4) of the horizontal scale is taken. Now by differing this two reading we can find out the diameter of the bore of first tube i.e., diameter (D) = $R_3 \sim R_4$. The radii of all other tubes are determined in same manner. The length l of the needle is measured by placing it vertically and finding the difference of the two readings obtained from the vertical scale, when the microscope is focused properly on the two ends of the needle successively.

8. The specific gravity of liquid at θ°C is found out from a table of physical constant.

Experimental data

Temperature of water during the experiment = $^{\circ}$C

Density of water at ……….. $^{\circ}$C = ……………….gm/cc

Table 1

Vernier constant for the horizontal scale of the microscope

-------- divisions (say, m) of the vernier scale = ---------- divisions (say, n) of the main scale.

Value of 1 smallest main scale divisions (l_1) (cm)	Value of 1 vernier division $l_2 = \frac{n}{m} l_1$ (cm)	Vernier constant v.c.= ($l_1 - l_2$) (cm)

Table 2

Measurement of length (l) of the needle

Reading(in cm) for						$l = R' \sim R''$ (cm)	Mean l (cm)
End 1			End 2				
M.S.R	V.S.R	Total (R')	M.S.R	V.S.R	Total (R'')		

Table 3

Determination of h

Tube no.	Reading (cm)						Difference $x = R_1 \sim R_2$ (cm)	Height of meniscus (cm) $h = l \pm x$
	Needle - head			Meniscus base				
	Main scale	Vernier scale	Total (R_1)	Main scale	Vernier scale	Total (R_2)		

Table 4

Measurement of radius (r) of the tubes

Tube no.	Direction of obs.	Left/lower end of the bore (cm)			Right/upper end of the bore (cm)			Dia. ($R_3 \sim R_4$) (cm)	Mean dia. (cm)	Mean radius r (cm)
		Main scale	Vernier scale	Total	Main scale	Vernier scale	Total			
				$= R_3$			$= R_4$			
				$= R_3$			$= R_4$			
				$= R_3$			$= R_4$			
				$= R_3$			$= R_4$			

Table 5

Determination of surface tension T

Tube no.	**Temp. of water (^oC)**	**Density of water (ρ) (gm/c.c.)**	**h (cm)**	**r (cm)**	**(h + r/3) (cm)**	$T = \frac{\rho r g}{2}\left(h + \frac{r}{3}\right)$ **(dynes/cm)**

Calculation

Diameter of tube no.1 =…………………………………………..cm

Radius of tube no.1 =…………………………………………..cm

Value of h for tube no.1 =………………………………………..cm

Surface tension of water from tube no.1 = ………………………..

Diameter of tube no. 2 = …………………………………. cm

Radius of tube no. 2 = …………………………………….. cm

Value of h for tube no. 2 = ………………………………. cm

Surface tension of water from tube no. 2 = …………………………………..

Therefore mean surface tension of water =…............................

Result

Therefore surface tension of water at a temperature of ………………………^{o}C is………………………. dyne/cm.

Computation of percentage error

$$\frac{\delta T}{T} = \frac{2 \times \delta r}{r} + \frac{\delta l}{l} + \frac{\delta x}{x}$$

Here, δr =………………………….. δl =……………………… δx =…………………….

Percentage of error = $\frac{\delta T}{T} \times 100$

=

Precautions

- The surface tension depends on the radius of the tube at which the liquid meniscus stands. So the tube should be of as uniform bore as possible.
- The tubes should be made perfectly vertical.
- As surface tension is lowered by the presence of a small amount of grease, the beaker and tubes must be clean.
- All the tubes must be fixed parallel to each other and for this purpose a graph paper should be placed below the glass strip and each tube should be fixed coinciding with a line of paper.
- The horizontal line of movement of the microscope should be parallel to the plane of the tubes.

Related questions

(ix) Define-surface tension, angle of contact, cohesive and adhesive forces.
(x) Will all liquids rise in capillary glass tubes?
(xi) What is the effect of temperature and electrification on the surface tension of liquid?

(xii) Does the medium in contact with the liquid surface influence the value of surface tension?

(xiii) Can you name some phenomena on surface tension?

(xiv) How does the surface tension of pure water differ from that of the solution of a salt in water?

(xv) Will the height of liquid in the capillary tube be affected by change of the diameter of the tube?

Aim of the experiment

To Determine the Self-Inductance of a Coil with Anderson's Bridge

Apparatus and accessories required

(a) Anderson's Bridge training board. R_1, R_2, R_3resistance serves as P, Q and R resistance respectively, and a variable resistance s_1 andinductance (L) is connected in unknown arm C and D. A set of capacitors C = C_1, C_2, C_3, C_4, C_5, C_6, C_7 and resistance r in two steps of (i) X 100Ω upto 1KΩ (ii) X 1KΩ upto 10 KΩ are provided on the board. A frequency oscillator, a headphone or galvanometer,Three inductances L_1, L_2 and L_3 are also provided on the board.

Theory and working formula

For low frequencies a practical coil can be represented by a self-inductance in series with a resistance which accounts for the losses in the coil. The self-inductance of a coil can be measured with the help of Anderson's bridge, illustrated in Fig 1.

Let L be the self-inductance of the coil and s be its resistance. A variable resistance s_1 inserted in the arm CD of the bridge in which the coil is placed. In Fig. 1 S (= s + s_1) is the total resistance in the arm CD; P, Q, R are non-inductive resistance; r is a variable non-inductive resistance; C is a standard capacitor; and Dr is a detector (typically a Headphone/ Speaker).

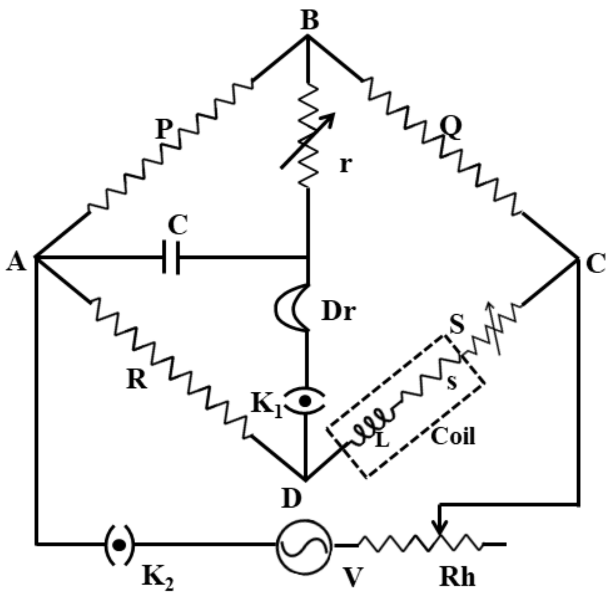


Fig. 9.1: Circuit diagram for Anderson's

At balance i.e., for no flow of current through the detector, we have

$$S = \frac{RQ}{P} \qquad (1)$$

And $$L = CR\left[Q + r\left(1 + \frac{Q}{P}\right)\right] \qquad (2)$$

Equation (1) and (2) are respectively referred as the DC and AC balance condition of the bridge.If P = Q, equation (2) reduces to

$$L = CR(Q + 2r) \qquad (3)$$

The AC balance represented by equation (3) can be achieved only when L >CRQ; otherwise the resistance r will be negative. If c is expressed in farad, R, Q and r are expressed in ohm, then L will be obtained in henry from equation (3)

Procedure

(a) Attainment of DC balance:

1. Setup the circuit as shown in Fig. 2. Here is a galvanometer; K_1 and K_2 are two plug keys; Rh is a rheostat; and B is the dc power source.
2. The resistance P, Q and R of the P.O. box are each taken equal the 100Ω.
3. Complete the battery circuit by closing the key K_2.
4. Vary the resistance $s_1$and close the key K_1 each time to set the balance condition. When the galvanometer deflection changes in the opposite direction for one ohm variation in s_1, insert fractional resistance to achieve exact null of the galvanometer. The total resistance in the arm CD of the bridge will then be $S = 100\ \Omega = (s_1 + s_2)$.

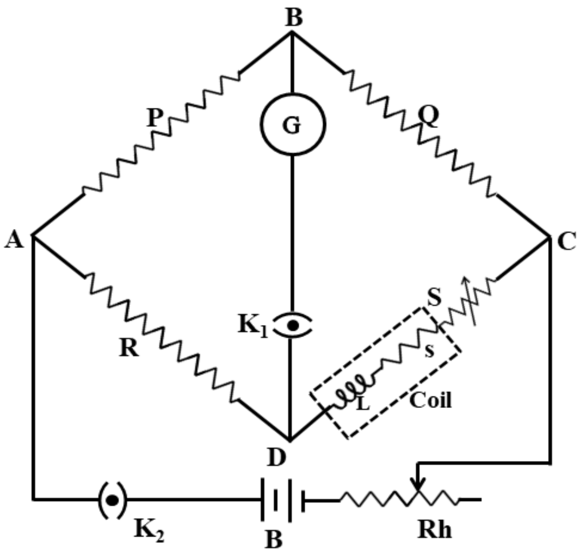


Fig. 9.2: Circuit diagram for attainment of DC balance

Therefore, the coil resistance s will be

$$s = (100 - s_1)\ \Omega$$

By this arrangement, the resistance in all the four arms of the Wheatstone bridge are made equal, e.g. 100Ω. Under the condition the bridge is most sensitive.

(b) Attainment of AC balance:

1. In the circuit of Fig. 2 replace the galvanometer (G) by a headphone/ speaker, and the dc power source by an audio oscillator. Also, insert the standard capacitor C and the resistance r properly to obtain the circuit of Fig. (1). The resistance P, Q, R and S as obtained for dc balance [operation in (a)], are unaltered.
2. Complete the oscillator circuit by closing the key K_2. Adjust the output voltage of the audio oscillator to a suitable value and sets its frequency at above 1 kHz.
3. Close the key $K_1$and vary the resistance r until the sound in the headphone is zero or a minimum. Note the corresponding value of r.
4. Calculate L using equation (2).
5. Repeat step 2 to step 4 for different values of C and calculate the mean value of L.

Experimental Results

Table 1

Data for DC balance

Sl. No.	Resistance in ohm				Galvanometer deflection	Value of s_1 at null point (s_{1n}) (Ω)	Coil resistance $S = 100 - s_{1n}$ (Ω)
	P	Q	R	s_1			

Table 2

Data for DC balance

$P = Q = R = 100\ \Omega$; $S = s + s_1 = 100\ \Omega$ frequency of the ac source = ……….......... Hz

Sl. No.	Capacitance (C) (µF)	Value of r (Ω)	Sound intensity in the speaker	Value of r at null point (Ω)	L (mH)	Mean L (mH)
		… … … … …	large faint minimum faint large			

Calculation of Standard Deviation of L

If x is the deviation of an individual value of L from its arithmetic mean, the standard deviation is given by

$$\text{Standard deviation } \delta = \sqrt{\frac{\Sigma x^2}{\sqrt{n(n-1)}}}$$

where the summation Σ extends over the number of times L is determined. The number is denoted by *n*. standard deviation has the same unit as L.

Thus

δ =

Calculation

Result

……………………………………………………………………………………………..

Precautions

1. Initially the output of frequency oscillator should be kept low and near null point it should be increased.
2. If head phone is used these should be silence in the neighbouring.
3. For greater sensitivity of the bridge resistances in the four arms should be nearly same.
4. Plug type Resistance box or P.O. box should not be used.
5. For obtaining balance point $L > CR_2R_3$.
6. For inductance L1 is of low value C_1, C_2, C_3 capacitors should be used. For inductance L_2 is medium value C_3, C_4, C_5. Capacitors should be used and for L_3 Capacitors C_5, C_6, C_7 should be used to get null point and better results.

Related Questions

1. What do you mean by self-inductance of a coil? What is its SI unit?
Ans. The self-inductance of a coil is the voltage induced in the coil for a unit rate of change of current through it. The SI unit of self-inductance is henry (H).
2. Define 'henry'.
*Ans.*the self-inductance of a coil is 1 henry when a rate of change of current of 1 A/s induced an emf of 1 V in it. As 1 H is a large unit, inductance are usually expressed as mH (= 10^{-3} H).
3. Apart from self-inductance, what other circuit parameter will a coil have?
*Ans.*Apart from the self-inductance, the coil has resistance. It will also have self-capacitance.

Aim of the experiment:

To study the linear motion under virtually frictionless conditions using linear Air Track

.

Apparatus required:

1. Linear Air Track,

2. Timer, Photogate,

3. RJII cables,

4. A base stand with rod,

5. Boss head,

6. Blower with hose pipe,

7. Vehicles, Plug with card,

8. Fork with rubber band,

9. Plug with adhesive tape,

10. Masses etc.

THEORY:

A. Elastic collision – The collision in which both momentum and kinetic energy of the colliding objects are conserved is called elastic collision. The relative velocity is same before and after collision.

Fig.(i)

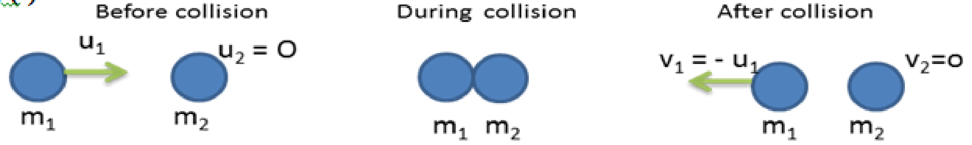
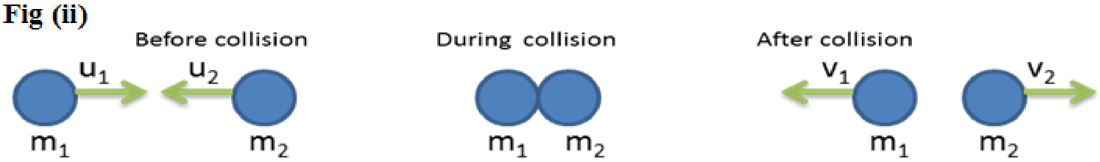
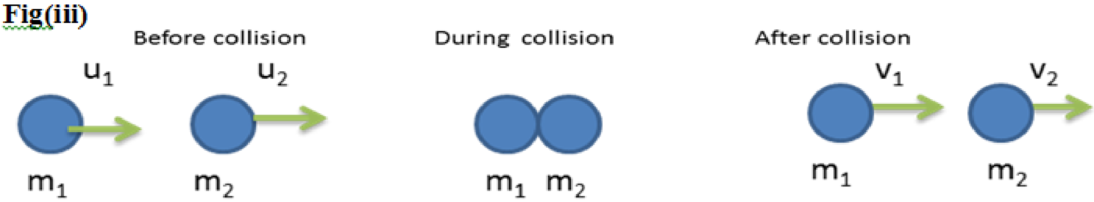


Fig (ii)



Fig(iii)



By conservation of momentum

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ ……….(1)

By conservation of kinetic energy

$1/2m_1u_1^2 + 1/2\ m_2u_2^2 = = 1/2m_1v_1^2 + 1/2\ m_2v_2^2$ ……..(2)

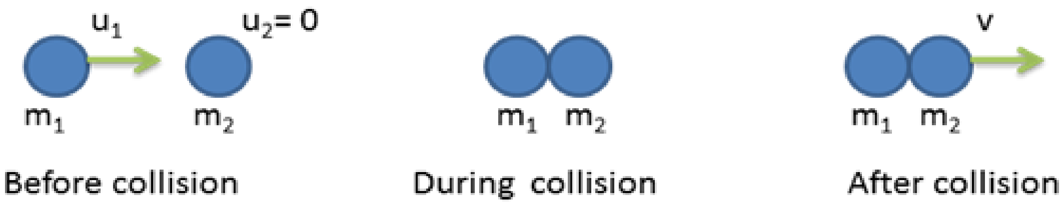
Solving (1) & (2) we can write

$$V_1 = \frac{m_1-m_2}{m_1+m_2}\ u_1\ +\ \frac{2m_2}{m_{1+}\ m_2}\ u_2 \text{ and } V_2\ =\ \frac{m_1-m_2}{m_1+m_2}\ u_2\ +\ \frac{2m_2}{m_{1+}\ m_2}\ u_1$$

B. Inelastic collision: -- The collision in which there is a maximum loss of kinetic energy but momentum is conserved is called inelastic collision. After collision they stick together and move with same velocity.

Fig. (iv)

Fig. (iv)



By conservation of momentum

$m_1u_1 + 0 = (m_1 + m_2)\, v$ Therefore, $v = \frac{m_1u_1}{m_1+m_2}$

By conservation of kinetic energy

$\frac{k_f}{k_i} = \frac{\frac{1}{2}(m_1+m_2)v^2}{\frac{1}{2}m_1u_1^2} = \frac{m_1}{m_1+m_2}$ which is less than one.

If $m_1 = m_2$, then, $\frac{k_f}{k_i} = \frac{1}{2}$

we can find loss of kinetic energy $k_i - k_f = \Delta k = \frac{1}{2}\frac{m_1m_2}{m_1+m_2}u_1^2$

PROCEDURE:

Linear Air Track: --- First, set the track up so that it looks level to the eye. Attach the blower and turn on. Place a vehicle on the track, hold it still and then gently release it. If it begins to move along the track without any help, adjust the single leveling screw until the vehicle remains stationary.

ELASTIC COLLISION

Case: - 1

(a) TIMER – Choose mode: Speed

Select: Collision -1

Connect one photo gate in Gate -1

(b) Keep one vehicle fix in between the photo gates. Press start\stop key. The timer will display "……**……"which means that timer is ready.

(c) Pass the other vehicle through the sensor of photo gate. The vehicle collides elastically with the second vehicle and after collision it moves backward and passes the sensor again [Fig. i]

(d) The timer will show the initial velocity u_1 and final velocity v_1.

Use review key and record these in Table -1. Repeat the process two times more. Find out difference in momentum.

(e) The weight of vehicles can be increased by placing mass on it. Put same mass on both sides. Make two more tables for different masses of vehicles.

CASE-2

(a) Choose mode: Speed,   Select: Collision –2

Connect one photo gate in Gate – 1 and other in Gate -2

(b) Push both the vehicles in opposite direction so that they pass through the photo gates and collide in between the photo gates. After collision they move backward passing through the photo gates. [Fig: - ii].

(c) The timer displays the initial and final velocities of both the vehicles. Use review key and record in Table –2. Repeat the process two times more. Find out difference in momentum.

(d) Increase the weight of the vehicles by putting mass on them and make two more tables.

CASE—3

(a) Choose mode: speed, Select: Collision -2

Connect one photo gate in Gate – 1 and other in Gate -2

(b) Push both the vehicles with different velocities in the same direction so that they pass through the photo gate and collide in between the photo gates. After collision they pass through the second photo gate. Use review key and record the initial and final velocities of the two vehicles in Table -3. Repeat the process two times more. Find difference in momentum.

(c) Increase the weight of the vehicles by putting mass on them and make two more tables.

INELASTIC COLLISION

(a) Choose mode: speed, Select: One Gate

Connect both photo gates in Gate -1

Fix the plugs attached with adhesive tape at the other end of the vehicles. Keep one vehicle without 2-b picket fix in between the photo gates.

(b) Push other vehicle through the sensor of photo gate. After collision they stick together and pass through the second photo gate with same velocity. Record the velocities in Table-4 and repeat the process two times more.

(c) Find out difference in momentum and loss in kinetic energy.

(c)Increase the weight of the vehicles and repeat the process of Table -4. Record the data in Table -5.

(d) Find out difference in momentum and loss in kinetic energy for Table-4 & 5.

EXPERIMENTAL DATA

Table -1

Considering $m_{1=}$ $m_{2=}$ …..gm and target vehicle is fixed i.e $u_2 = 0$

No. of obs.	Initial velocity of m_1 m/sec	Final velocity of m_1 m/sec	Difference in momentum

Table-2

Considering $m_{1=}$ $m_{2=}$ …..gm and vehicles in opposite direction.

Sl. No	Initial velocity of m1 m/sec	Initial velocity of m_2 m/sec	Final velocity of m_1 m/sec	Final velocity of m_2 m/sec	Initial momentum	Final momentum	Diff. in momentum

Table-3

Considering $m_{1=}$ $m_{2=}$ …..gm and vehicles in same direction.

Sl. No	Initial velocity of m_1 m/sec	Initial velocity of m_2 m/sec	Final velocity of m_1 m/sec	Final velocity of m_2 m/sec	Initial momentum	Final momentum	Diff. in momentu m

INELASTIC COLLISION

Table -4

Considering $m_{1=}$ $m_{2=}$ …..gm and velocity of target vehicle is always zero i.e $u_2= 0$

Sl. No.	Initial velocity of m_1 m/sec	Final velocity of $(m_1+ m_2)$ m/sec	Diff in momentum	Loss in kinetic energy

Table -5

Considering $m_{1=}$ ……gm $m_{2=}$ …..gm and velocity of target vehicle is zero i.e $u_2= 0$

Sl. No.	Initial velocity of m_1 m/sec	Final velocity of $(m_1+ m_2)$ m\sec	Diff in momentum	Loss in kinetic energy

CONCLUSION:--

Precautions:

1. There should be no acceleration when vehicles are pushed.

2. The Air Track should be leveled / horizontal.

3. When two horns are used, they should be mounted at 45° to the vehicle, so that the elastic bands are perpendicular to each other.

4. Look carefully at the vehicle end-on. Both sides should be floating at an equal distance above the air track. If not, adjust the pair of leveling screws until the vehicles floats level.

Related Questions:

1. What is an Air Track? What are its uses?

2. What are elastic and inelastic collision? Give example.

3. Are kinetic and momentum conserved in elastic and inelastic collision?

4. What is the purpose of the experiment?

5. What is the purpose of using Blower and Photo gate in the experiment?

Aim of the Experiment

Determination of the frequency of a tuning fork using Melde's Apparatus.

Apparatus required

[1] Electrically maintained tuning fork

[2] Two pointers

[3] Clamp stand with pulley

[4] Weight box

[5] Thread of uniform thickness

[6] A meter scale

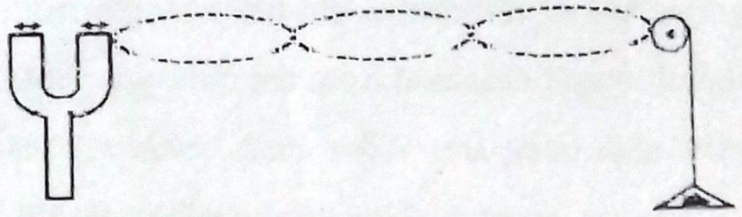


Fig. 1:Schematic diagram of Melde'sexperiment

Theory:

When the prongs of the fork vibrate, transverse waves will proceed along the length of the string and they on reaching the distant end of the string will be reflected back. The superposition of the direct and reflected waves will from stationery waves, in which the extreme fixed ends of the string will always be nodes and in between them there may be one or more number of antinodes depending on the load placed on the scale pan.

When the length and the tension of the string are adjusted to make the frequency (N) of the fork equal to that of the fundamental or any one of the higher tones of the string, resonance will occur between the fork and the particular mode of vibration of the string. At this stage the amplitude of vibration of the string at the antinodes will be the greatest.

The velocity V of transverse waves along a string of linear density m (in gms. Per sem) and stretched by a tension T (in gms-wt) is given by,

$$V = \sqrt{\frac{Tg}{m}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

But the frequency (n) of the vibration of the string is given by,

$$n = \frac{V}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{Tg}{m}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

In transverse arrangement the frequency N of the fork is equal to that of the string (n). Hence

$$N = \frac{1}{\lambda}\sqrt{\frac{Tg}{m}} = \sqrt{\frac{g}{m} \cdot \frac{T}{\lambda^2}} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Knowing m and T/λ^2, the frequency N of the fork can be calculated from equation (3)

Procedure

[1] A silk string (about a meter long) is taken and its length (L) is measured thrice by a meter scale. The mass per unit length m (= w/L) is determined, where the mass (w) of the string is supplied. The mass (Q) of the scale pan is also supplied. The silk string and the scale pan are now set up in the apparatus.

[2] A certain load (M) is placed on the scale pan and the fork is made to vibrate electrically. At this time ill-defined nodes and antinodes are clearly depicted. At this time resonance occurs between the fork and the particular mode of vibration of the string.

[3] Two pointers of adjustable highest are placed below the two extreme well – defined nodes (but not below the nodes at the two ends of the string) and the distance d between them is measured by a scale. The number of loops (k) between the pins is also counted. This operationis performed thrice by independently adjusting the length of the thread and the positions of the pointer. The mean of the three values of d when divided by k gives half the wave length λ. Thus λ=2d/k is obtained for this particular load [Fig 2].

[4] Now steps 2 and 3 repeated for two other increasing loads (by which the number of loops will decrease).

[5] The tension T (in gms.-wt) of the string is given by (M+Q) gms. Wt.

[6] Plot the graph T vs. λ^2.

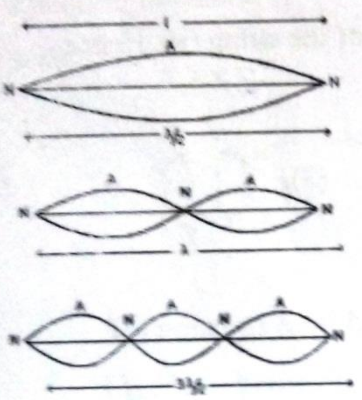


Fig. 2 Formation of loops

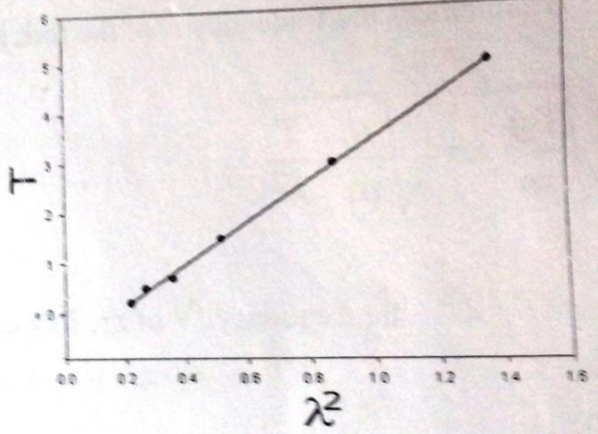


Fig. 3 Plot of Tension versus λ^2

Experimental Data

Mass of the scale pan (Q) =………………..gm

Mass of the thread (w) = …………………..gm

Table No – 1.

Determination of linear density (m) of the string

Length of the thread (L) in cm	Mean L in cm	Mass of the thread (w) in gm	Mass per unit length of the thread, m(=w/L) in gm/cm

Table No – 2

To find the wavelength (λ) in the string

No. of obs.	Load on the pan in gm. (M)	Distance between the pointers in cm	Mean d in cm	No. of loops between the pointers (k)	Wavelength = $\lambda = 2d/k$ in cm.

Table No – 3

To find the frequency (N) of the fork

No. of obs.	Tension of the string T = (M+Q) gms-wt.	Wavelength in cm (λ) [from table 2]	Value of T/λ^2	Mean Value Slope of T/λ^2	Frequency of the fork = N= $\sqrt{\frac{g}{m} \cdot \frac{T}{\lambda^2}}$

Table No – 4

Data for graph T vs. λ^2

T (in gms-wt)	Value of λ^2	Slope of the plot	Frequency of the fork = N = $\sqrt{\frac{g}{m} \cdot \frac{\Delta T}{\Delta \lambda^2}}$

Calculation:

Result:

Precautions:

[1] The vertical portion of the string i.e. the portion of the string between the pulley and the scale pan should be as small as possible. Otherwise the mass of this portion of the string should be added to (M+Q) to get the tension.

[2] The experiment should be begun with a small load (M) on the pan, so that the number of loops may be six. Then the load should be increased in order to decrease the number of loops to 4 and 2, respectively. If T be the load for one loop then the load T_k for k loops is given by $T_k = T/k^2$, when the length of the string is constant. The number of loops (k) can also be increased by increasing the length of the string when the tension is constant. If l be length required for one loop, the length required for k loops would be $l_k = kl$, when the tension is kept constant.

[3] At the nodes at the two ends of the string are not distinct, the pointers should be plaed below the nodes which are next to the nodes at the two ends.

[4] The string should be of as uniform a linear density as possible.

Experiment related question:

[1] What is frequency?

[2] What do you mean by transverse arrangement and longitudinal arrangement?

[3] If the number of the loops in the two arrangements is to be kept same, in what way their tensions will vary?

[4] if the tensions are to be kept same, in what way the number of loops in the two arrangements the will vary?

[5] Why the length of the string between the pulley and the scale pan is kept short?