Compilation of Exciting Experiences in Experimental Physics

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[Material to invoke diverse thinking]
With rich tributes to RIE, Mysore

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About 21 exercises

It is a great experience to see, understand and apply the basics of physics through experiments done at RIE, Mysore.

Every Institute provides a few unique areas wherein it had put lot of efforts to excel. Hence visits to each laboratory enables one to understand atleast a few novel concepts and their proper exploration. If one is able to compile the experiences gained, its dissemination has to produce sweet fruits.

RIE, Mysore is an institute where rich experimental environment exists and which has seen contributions from great physics teacher educators since 1964.

Institutes which allow interaction with a large intersection of the teaching community, it has to happen.

I am thankful to all colleagues of Physics Section whose inspiration helped me compile exciting experiences in experiments that run through basics.

I am thankful to Prof.G.Ravindra, Principal, RIE, Mysore for providing me with such an opportunity. I would be glad if someone takes up the matter seriously in order to improve and add more feathers worth trial.

Mysore
30.4.2004 **M N Bapat**

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Experiment 1

Aim : To determine the solar constant and temperature of the Sun.

Apparatus : A shallow dish about 15 to 20 cm dia and 2 to 5 cm deep, the inside of which is coated with black paint, a stick, thermometer, meter scale, a few sheets of paper.

Theory : The solar constant is the amount of radiation received at earth's surface per second per unit area of earth's surface perpendicular to sunrays which is about 1400 W m^{-2}. The solar constant S is given by

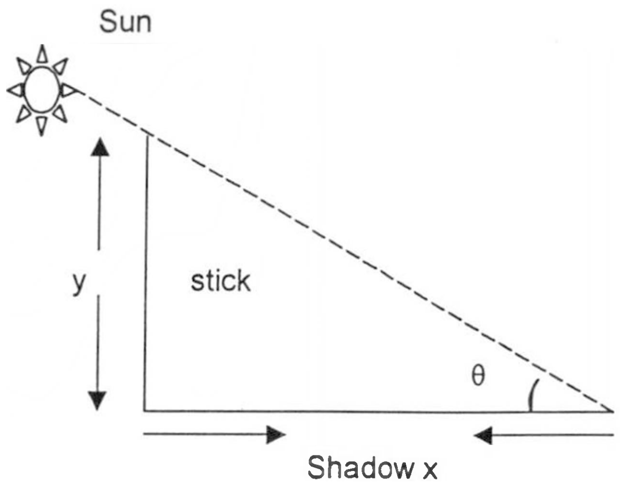


Fig. a

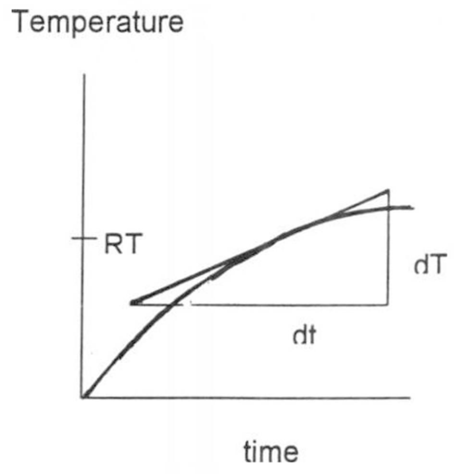


Fig. b

$$SA \sin\theta = w\,(JK^{-1})\,\frac{dT}{dt}(Ks^{-1})$$

$$= w\,(J\,s^{-1}) \qquad \text{(i)}$$

where A = Area of cross section of the dish

$\theta = \tan^{-1}\left(\frac{y}{x}\right)$ [Fig. a]

x = Mean length of the shadow of the stick

y = length of the stick

w = total thermal capacity of the system = $(m_gC_g + m_wC_w)$

and

$\frac{dT}{dt}$ = rate of rise of temperature in degree Celsius at room temperature.

(Slope of the temperature versus time graph at room temperature, Fig. b)

Procedure :

Q. How to find heat received by the dish filled with water ?

1. Weigh the dish and find its thermal capacity, measure the area of cross section of the dish.
2. Pour cool water (cooler than the surrounding temperature) to a depth of 2 to 3 cm and find the total heat capacity of (dish + water). (Why the water should be cooler?)

Q. How to reduce interference of wind on heating of the set up ?

3. Place* the thermometer in the dish and cover the dish with a clean glass plate. The thermometer should be immersed fully in water.

Q. How to account for inclination of sunrays ?

4. Place a stick vertically near the set up and mark the tip of its shadow just before the commencement of heating of water by sunlight and at the end of heating. Note the mean length x of the shadow. (Fig. a)

Q. What is the rate of heating ?

5. Place the dish in sunlight over a few sheets of newspaper (for insulation). Note the time t for every 1°C rise of temperature continuously. Plot a temperature-time graph (Fig. b) and find the slope of the tangent drawn at the point corresponding to room temperature (temperature on Y axis, time on X-axis).

S can be calculated by substituting different values in (i). The temperature of the surface of the sun may be found as follows :

The energy emitted by the sun per unit area per second is $E = \sigma T^4$ where

σ = Stefan's Constant.

$$E \times (4 \pi R_s^2) = S \times 4\pi r^2 \quad \text{or } E = S \left(\frac{r}{R_S}\right)^2 \qquad \ldots \text{(ii)}$$

* Lay the thermometer if cover glass plate does not have a hole to insert the thermometer.

Substitute $E = \sigma T^4$ and S obtained from (i) to find T (Kelvin).

r = radius of the earth's orbit 149.6×10^6 km.

R_s = radius of sun = 6.96×10^5 km.

Comment on the results obtained :

(i) Does cover glass plate affect observations ?

(ii) Does the sun send out same radiation all the time of the day on the earth's surface?

(iii) Should water be blackened ?

(iv) What will happen if the stick is not perfectly vertical ?

(v) Between time and temperature, which parameter affects accuracy most?

(vi) What will happen if we use a metal dish ?

(vii) What will happen if sun is partially or fully covered by clouds ?

(viii) With different sources of errors, experimental values should be higher or lower ?

(ix) Have you noticed that warming up to room temperature is quicker than further warming ? What kind of precaution should then be taken ?

Data Given :

C_g = sp. heat of glass = 500 J kg^{-1} K^{-1}

C_w = sp. heat of water = 4200 J kg^{-1} K^{-1}

σ = Stefan's constant = 5.67×10^{-8} Wm^{-2} K^{-4}

Objectives achieved :

The student

(i) will be able to appreciate that inclination of surface to radiation alters heat received. Hence during different hours heat received is different.

(ii) Appreciates application of Stefan's law.

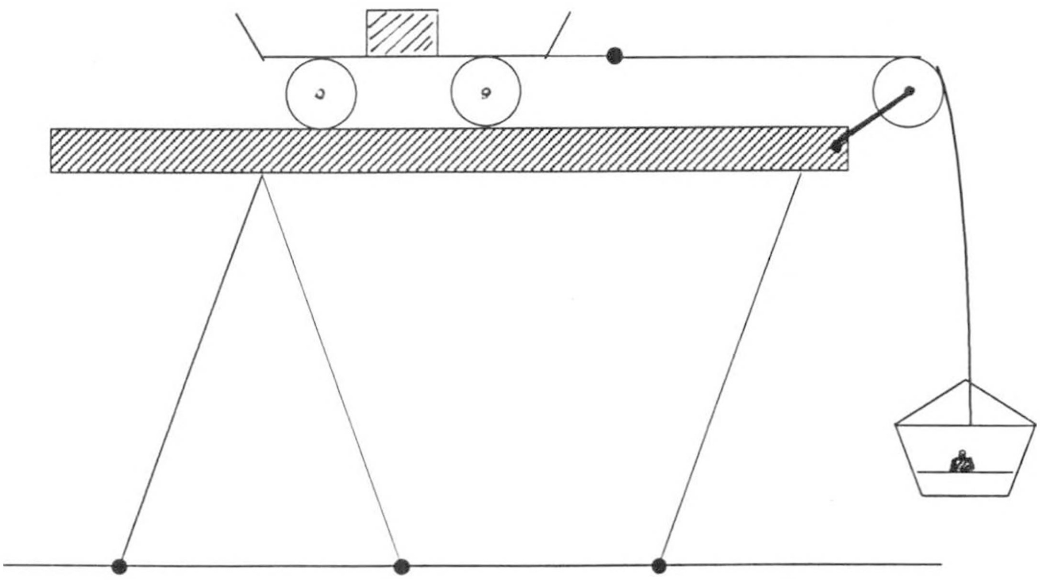
(iii) Understands the procedure of finding rate of heating at room temperature and hence at any other temperature also.

Experiment 2

Aim : To study the relationship between acceleration of a body and unbalanced force acting on it.

Apparatus : One dynamic cart/ toy car, pulley, scale pan, thread, weight box, bumper, stopwatch.

Theory : For a body of mass m moving with a constant acceleration **a** under the action of an unbalanced force **F,** the distance travelled in time t is given by $S = ut + \frac{1}{2}at^2$ where u is the initial velocity. If u = 0, $S = \frac{1}{2}at^2$ and $a = \frac{2S}{t^2}$, t is the time taken, starting from rest, for the body to travel a distance S.



Procedure :

1. Arrange a cart at a distance of 1.0 m from the bumper as shown in the figure. Load the cart with weights of 50 g, 20 g, 10 g, etc. to make up the total mass of the system (cart + weight) to nearest hundred gram.

2. Let us first compensate for the frictional forces i.e. given a gentle push the cart should move with constant velocity as judged by our eyes. (What does the constant motion signify?). For this put small weights in the scale pan and observe the motion of the cart by giving a gentle push. Repeat this till the cart moves with constant speed i.e. unbalanced force on the system is zero. Once this is done note down the mass of the system. The mass of the system is equal to the mass of the cart plus the weights kept on the cart plus the mass of the scale pan including the weights put in. This mass is to be kept throughout the experiment.

Q. *Now transfer a 20 g weight from the cart to the scale pan. Is the equilibrium of the cart disturbed ? Why ? How does the cart move now ?*

3. The system is subjected to an unbalanced force of 20 g weight. Release the cart and note the time 't' taken to travel 1.0 m distance (upto the bumper) using a stopwatch. (What should be the minimum height of the table?)

Repeat the experiment 5 times and select best 3 values of t to find the acceleration ....a = $\frac{2S}{t^2}$.

(Why to take the best 3 values ?)

Q. *How will you change the quantum of unbalanced force ?*

4. Transfer another 10 g from the cart to the scale pan. (The mass of the system is not changed). The unbalanced force now is 30 g weight. As before, find the acceleration a.
5. Repeat the experiment for unbalanced forces of 40 g, 50 g and 60 g by transferring additional masses from the cart to the scale pan. Tabulate your observations.

Observations :

Mass of the cart = ...kg

Mass of the system = ...kg

Distance S = 1m (why not any other ?)

Sl. No.	Unbalanced force (g)	Time taken in to cover 1 m (s)					Mean of best three t(s)	Acceleration $a=\frac{2S}{t^2}=\frac{2}{t^2}$
		1	2	3	4	5		

Plot a graph between unbalanced force (X-axis) and acceleration (Y-axis). What is the nature of the graph ?

Comments on the Result :

(i) Does your result lead to Newton's second law of motion ?

(ii) Suppose the constant velocity as judged by our eyes has ±10% error, how will it affect the result ?

(iii) How will you ascertain that cart moves along the direction of the force? (Hint. Draw a straight line).

(iv) When you remove the load from the cart the opposing rolling frictional force reduces. How will you overcome this error ?

(v) If you add the weight to the scale pan from weight box and not from cart, what kind of error you may come across ? When do you think the error would be negligible ?

(vi) What will happen if the plank on which cart rolls is not horizontal? Or the string pulling it is not horizontal ?

Additional Activity :

1. Draw free body diagram for cart and scale pan when
   (i) velocity is constant
   (ii) acceleration is constant
2. Outline a procedure to find the mass of the cart.
3. What maximum error in constant velocity can be tolerated if your result needs to be correct within $\pm 10\%$?
4. Arrange the string pulling the cart at an angle θ to the direction of displacement. Does $mg \cos \theta$ agree with unbalanced force ?

Objectives achieved :

Student will know that

1. unbalanced force acts on the whole mass of the system and not on the cart alone.
2. when weights from out of the system is added to the pan, mass of the system increases.

Experiment 3

Aim: To study simple harmonic motion of a liquid column

Apparatus: Long transparent U tube, liquid, stop clock

Theory: When liquid level is pressed down in one of the limbs by x, there is a rise in level by x in the other limb. Thus there is a net difference in liquid levels of 2x between two limbs which exerts a force $\pi r^2 L\rho .g$ on the mass $\pi r^2 L \rho$ of the liquid, whence

$$\pi r^2 L\rho\, a + \pi r^2 2x\, \rho\, g = 0$$

$$\text{or } a = -\frac{2g}{L}x$$

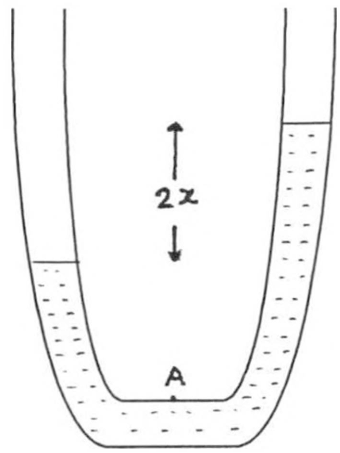
Since the acceleration is proportional to the displacement, the motion of liquid column is simple harmonic. The time period of the oscillation is given by

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

In the above derivation it is assumed that $x << L$. (Why?)

Procedure **:**

Take a transparent U-tube and fill it with a Liquid, say water. Depress the water level in one side by blowing air. The level of the water on each side starts to oscillate. The oscillations are simple harmonic. The time period of oscillation is measured for given values of L, where L is the total length of the water column in the tube.



Part I :

Change L by filling water in steps of at least 20 cm. after measuring time period successively. It can be set in the beginning itself : Identify a fixed point such as A and draw marks on both sides, B,C,D,E,...... etc. corresponding to lengths 1.00 m , 1.10 m, 1.20m, 1.30m,......etc. Measure the time period T for different values of L and tabulate the data as shown.

Sl. No.	Length of the water Column L (m)	$\sqrt{L}$	No. of oscilla-tions (n)	t, Time (s)			Mean t (s)	Time period T=t/n(s)
				Trial 1	Trial 2	Trial 3		
1.								
2.								
3.								
4.								
5.								

Plot t versus $\sqrt{L}$.

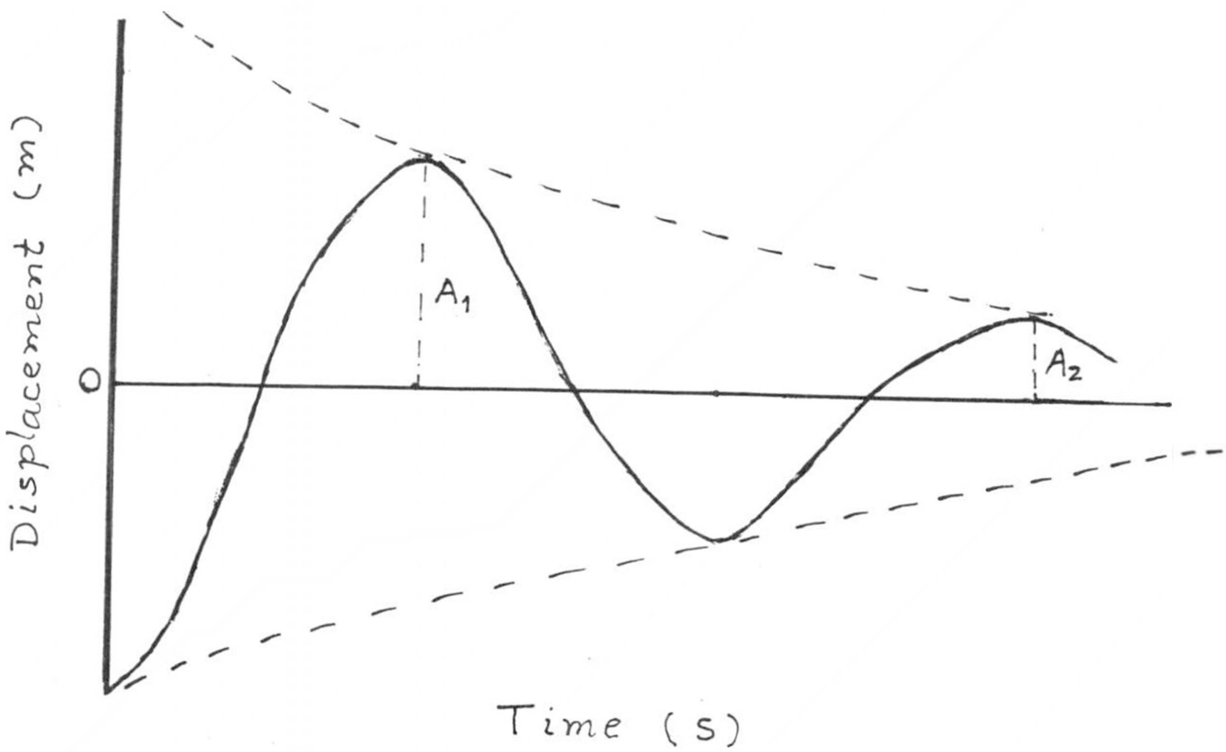
Calculate the slope of the above graph and hence calculate the value of g.

1. Does the time period depend on the values of x?
2. Why do we take L a very large length?
3. Does the result vary if size of the bore of the tube is changed? How? Discuss.
4. What changes do you expect if the liquid is sticky?
5. Should time period depend on the nature of the liquid?

Part II :

For one value of L, the length of the water column, note down the maximum displacements of the water level (both up and down) for the successive oscillations (the amplitude of oscillations goes on decreasing due damping). With the help of these reading and the time period T, show graphically the damped harmonic motion plotted against time (see the figure).

1. What is the locus of successive amplitudes on one side?
2. What are the reasons for this decrease in amplitude?



Comments on the result :

1. Why do oscillation amplitude die out quickly?
2. If you start with different initial values of x, do you get graph of similar nature?

Additional activity :

For same L use different liquids and find ratio of A_1 to A_2. Is it same for all liquids? What additional parameter can you thus calculate ?

Pour liquid to start oscillations. What parameter you are changing? Find the repercussions.

Objectives achieved :

Students will learn that

1. oscillations need external agency to initiate.
2. depending on the nature of oscillating material, oscillations die out.
3. Time-displacement graph is a sine curve with successively decreasing amplitudes.
4. With smaller inertia life of oscillations is also small.

Experiment 4

Aim: To study the Oscillations of a loaded spring.

Apparatus: Spring / elastic / rubber, arrangement for hanging the spring, hanger with weights, meter scale, indicator pin, stopwatch.

Theory: A flat spiral spring is ideally a wire (wound in the form of a regular helix) of circular cross section. When a small force is applied along its axis of symmetry (perpendicular to the plane of the spirals) its length changes.

Consider a flat spiral length of L and radius R suspended from a rigid support. When a mass M is suspended from its lower end, an elongation of l is caused to it. The force Mg imparts a turning moment = MgR to every section of the spring to cause a twist of θ per unit length of the spring. The restoring torsional couple is then equal to $\pi\eta r^4$, where η is coefficient of rigidity of the material of the wire and r is its radius.

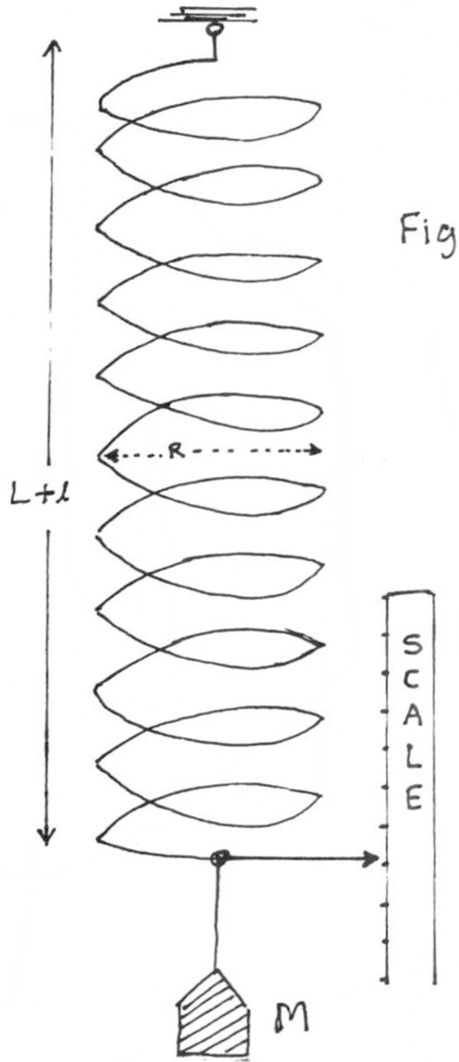


Fig (a)

So $Mg\,R + \pi\eta r^4\,\theta/2 = 0$ ....(i)

Since θ is twist per unit length, $R\theta$ represents extension of spring per unit length.

So total extension

$$l = LR\,\theta \Rightarrow \theta = \frac{l}{LR} \qquad \text{(i)}$$

Substituting θ in equation (i) we get

$$Mg = -\frac{\pi \eta r^4 l}{2LR^2} \qquad \text{(ii)}$$

If this mass M is pushed or pulled vertically through a small distance x and then released, vertical oscillations are produced. Then if a is acceleration of the mass

$$Ma = -\frac{\pi \eta r^4 l}{2LR^2} \cdot x$$

$$\text{Or } a = -\mu x \qquad \text{(iii)}$$

where $\mu = \dfrac{\pi \eta r^4 l}{2MLR^2}$.

Time period of oscillation is given by $T = \dfrac{2\pi}{\sqrt{\mu}}$ which from equation (ii) gives

$$T = 2\pi \sqrt{\frac{l}{g}} \qquad \text{(iv)}$$

If mass of the spring m cannot be neglected then it can be shown that

$$T = 2\pi \sqrt{\frac{M+m}{Mg} \cdot l}$$

***Procedure* :**

1. Fix the Upper end of the spring to the rigid support and attach a weight by hanger at its lower end. Attach also an indicator pin at the lower end as shown in the Figure (a), such that it lies horizontal and moves over the graduations of the scale when spring is stretched or compressed.

A suitable dead weight is loaded to the spring to make it taut and the position of the pointer on the scale is noted (zero reading).

Q. How to find force constant of the spring ?

2. Increase load on the spring by adding equal weights to the hanger and find corresponding extensions.

   Q. Should you verify that extensions corresponding to different additional weights are same whether you add weights or remove weights from the hanger ?

   See the corresponding extensions of the spring when the load of the spring is decreased.

   Q. Do the two observations match? If not why?

3. Take mean extension for a step of definite weights and plot a graph between load and extension of the spring.

   Q. Would the extension be same for springs of different lengths or for different mode of winding or for their different diameters though the material of the spring is same?

Find out the slope $\Delta W/\Delta l$ (Fig.b). Verify that this ratio is constant for a material when $\Delta l \rightarrow 0$ and within elastic limits (i.e. l is small). This gives Force constant.

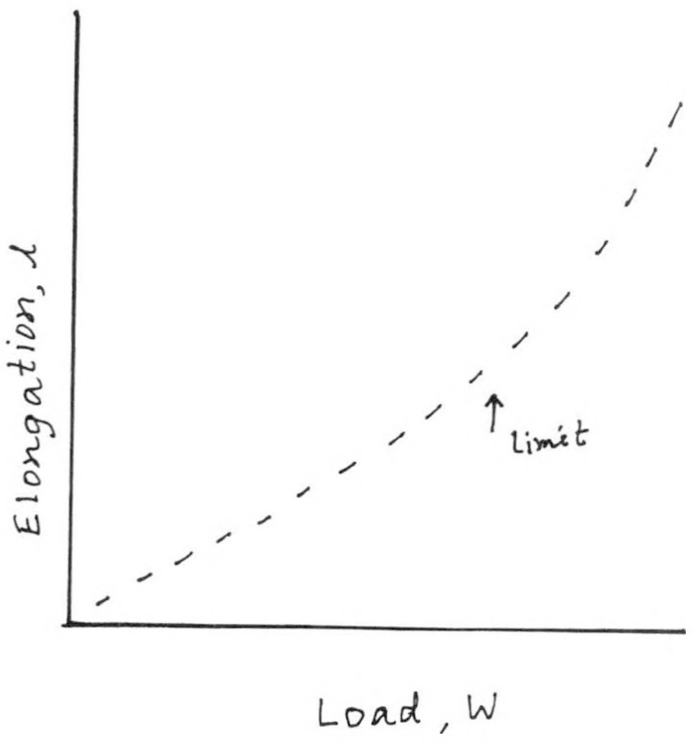


Fig. b

Trial	Load attached g	No. of Oscillations (n)	Time required, t (s) 1 2 3 4	Time period $T = \frac{t}{n}$ (s)	$\frac{M + \frac{m}{3}}{T^2}$
1.					
2.					
3.					
4.					
5.					

Q. Can we find out value of g?

4. g is given by $\frac{4\pi^2}{\mu}$ (slope of $M+\frac{m}{3}$ versus T^2 graph.) Find the value of g.
5. Did the Oscillations of the spring die fast? How would you select the thickness of spring wire?
6. What kind of error do you expect if oscillations of spring are not vertical?

***Comments on the result*:**

1. Do you get a straight line graph for load versus extension? What factors would affect its nature?
2. Which region of the graph W vs l you feel is most reliable and why?
3. Were you troubled by elastic limits?
4. Do you expect that there is a definite period of relaxation for the spring?

Q. How to find period of oscillations?

5. Attach a load M to the spring and pulling the hanger down a little set it into vertical oscillations. Using a stop watch note the time for a convenient number of oscillations and thereby find its time period.

6. Load the spring with a few more sets of weights and find the time period. Find out time periods. Do these values agree? Why?

Tabulate your observations:

I. For Force constant

Trial	Load	Location of points		Mean extension	Load Mean extension
		Load increasing	Load decreasing		
1 2 3 4 5					

II. For period of Oscillations

Mass of the spring m = …….. g

7. How does weight of the spring affect the oscillations?
8. Do you find uniform extension/compression in the spring throughout its length? Why?
9. Do you think buoyancy of air affects oscillations of the spring? If so can you do this experiment in different media? What additional property you are likely to discover?
10. What should be the ideal shape of the load attached to the spring?
11. Can you eliminate mass of the spring by noting time period for two loads and manipulating? What can be the advantage?

Caution – Be aware of statements in additional activity (iv).

Additional Activity:

i) Invert the spring and arrange for placing load over it so that instead of extension spring gets compressed. Undertake all activities suggested for loaded spring.

ii) Place the spring horizontally on a smooth plank. Attach a mass to its loose end. Compress it with a little extra force and observe oscillation. You have eliminated 'g'. Have you? What factors would now govern amplitude and time period of Oscillations?

iii) In activity (ii), mark position of unstrained spring. Push the attached mass little (to compress it or elongate it), but very slowly. Then release the mass gently and allow it to stop at some place mark the new position. What parameter can you investigate into? Do similar activity by further loading the mass, what should happen? Investigate by doing the experiment.

iv) Equation for time period is similar to that for a simple pendulum. In the spring system we can increase l by adding mass to the pan. Hence we can change the time period to a convenient desired value. Find out time periods for different extensions of the spring.

Experiment 5

Aim : *To study collision of two hard spheres*

I. Conservation of Momentum and Energy (One Dimension)

Apparatus : Two steel balls of same mass and same size, grooved ruler, plumb line , drawing board, tracing paper.

Theory: When two spheres collide with each other, they share the momentum. The transfer of momentum is such that the total momentum of the two before collision is equal to the total momentum of the two after collision.

The velocities of the spheres can be measured by making use of the fact that objects projected with different horizontal velocities from the edge of a table take the same time to fall to the floor. Neglecting air resistance, the horizontal component of their velocities remain unchanged so the distance they traverse horizontally before striking the floor is proportional to their horizontal velocity.

Adjustment :

(i) Adjust the height of the screw so that its tip is at the same level as the ramp and also along the same line as the groove on the ramp (Fig. 1)

(ii) Adjust the distance between the edge of the ramp and centre of the set screw to be 3r where r is the radius of the hard spheres.

(iii) Mark point O corresponding to the tip of plumb line. This should represent the point where the hard sphere would have hit if it was released from the location of the set screw.

Procedure

1. To give an initial velocity to one of the spheres, roll it from a height down the grooved ruler. Note the point at which it strikes the drawing board, to which a carbon paper below a tracing paper is pinned. Release the same ball from the same point several times and note the distribution of points on the tracing paper. Measure the distance from the plumb line to this point.

   Q. *To what accuracy the impressions are at the same place ?*
   What does this represent ?

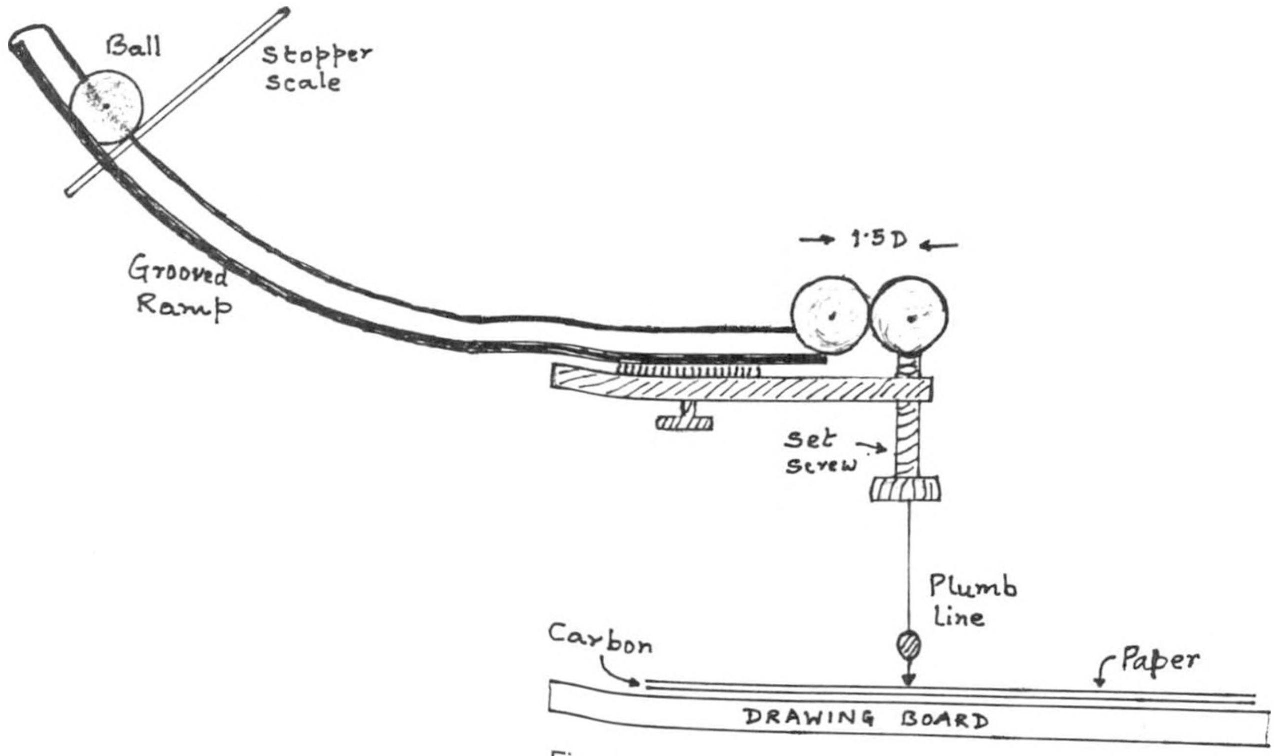


Fig. 1

2. Balance the target ball T on the set screw (just above plumb line). Place the bullet sphere B at the same location on the ramp with the help of a small scale. Release the bullet ball from the same height as

earlier and observe the locations of hit of the balls after collision. Do it 10 to 15 times.

Q. *Why do you get distribution of points on the tracing paper?*

Draw boundary for closely spaced points of impact. Find the location of the centre of distribution.

Q. *To what degree the initial velocity is always same ?*

Observe the motion of the bullet after collision.

Q. *Does it move forward, backward or sidewards ? Explain why ?*
Find the range of horizontal leap from O. (Fig.2)
What is range R basically measure of ? What quantity would it represent if masses of spheres is same ? What would R^2 represent ?

Draw on the paper the vectors representing the velocities of the balls after and before collision.

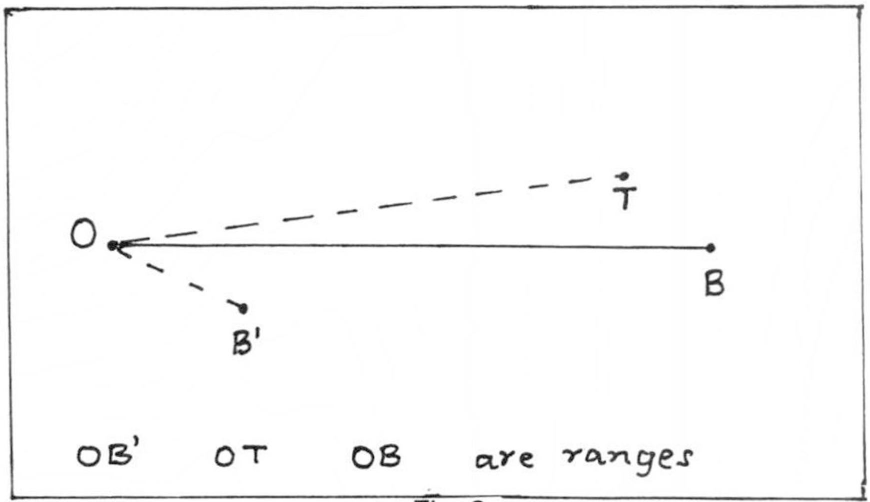


Fig. 2

What is momentum ? What physical quantities are being measured to calculate momentum ? What physical quantity is transferred to target ball by the bullet ball? What is the initial momentum of B ? What is momentum of T after collision ? What is final momentum of B ? How have you measured these ? Verify the law of conservation of momentum (Fig. 2).

Calculate the sum of the squares of the ranges of the balls before and after collision. What do you infer by comparing the two ? Does the difference have an explanation ?

Repeat the whole process by releasing the bullet ball from different heights on the grooved ruler. Why you do not need stop watch ? What additional information would you get if a stop watch is provided to you ?

II. Conservation of Momentum and Energy (Two Dimensions)

Adjustment :

Rotate the set screw so that distance between the ramp edge and the centre of the set screw is less than 3r say 2.5 r (Fig. 3).

Procedure :

Keep the target sphere on the set screw. Place the bullet sphere at a suitable location on the ramp with the help of a small scale. Release bullet and record the observations.

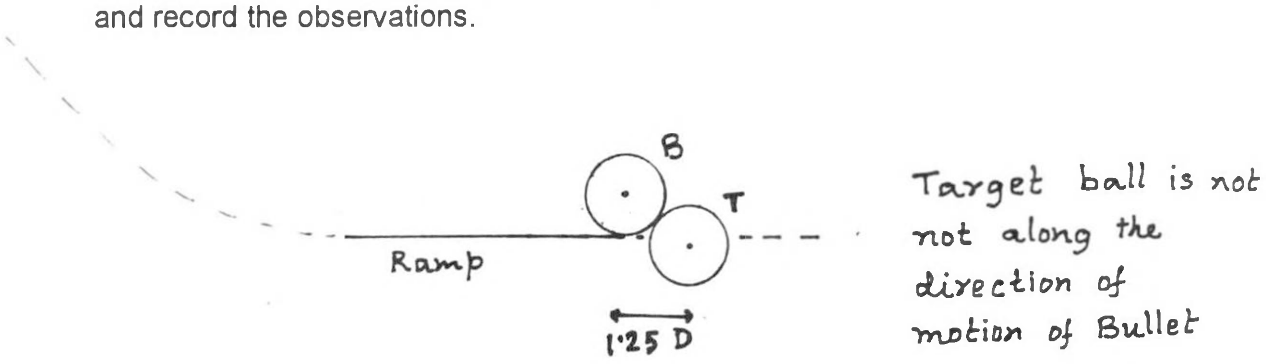


Fig. 3

Observations :

1. Does the bullet ball follow same path as that it followed when target ball was not on the set screw ?
2. Does the target ball move in same direction as the bullet ball after collision ?

3. How do we measure the initial and final momenta now ?

4. Draw parallelogram taking plumb line as one of the corners and distances of target ball and bullet balls as two vectors. Find resultant. Does the resultant compare with the initial momentum? (Fig. 4)

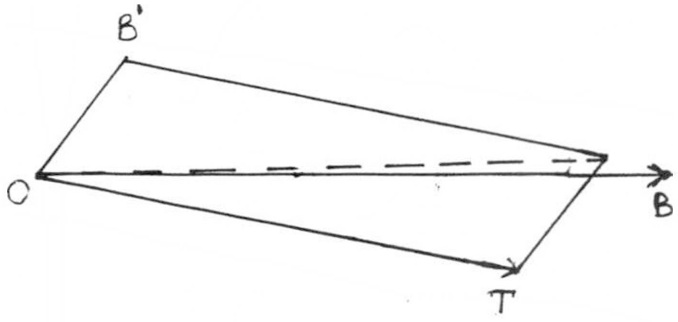


Fig.4

5. Calculate $V_B^2 + V_T^2$ after collision and compare it with V_B^2, before collision. Do these compare ? What law of conservation does it hint at?

Comments on the Result :

(i) Offer explanation for the discrepancies observed.

(ii) List out sources of error and methods to eliminate or minimize them.

(iii) Why do you call it two dimensional collision ?

(iv) What should be the angle between the path of target and bullet balls after collision ?

Additional Activities:

1. Experiment can be performed by using light target sphere. What new information is now obtained ? How will you represent momentum in this case? Find relation between range and velocity. Should you measure masses of spheres ?
2. Why cannot you do this experiment using lighter sphere as bullet ?

Experiment 6

Aim : To sketch the lines of magnetic induction of a long straight conductor carrying current.

Apparatus : A long copper wire bent into a rectangle and set in a vertical plane, dc supply, rheostat, ammeter, plotting compass and a plug key.

Background: Whenever a current passes through a conductor, lines of magnetic induction B surround it. The actual shape of the field lines depend on the strength of the current, environment about the conductor and orientation of the conductor with respect to earth's field lines.

Procedure :

1. Connect the conductor in series with the dc power supply (6V), ammeter 0 – 3A and plug key as shown in Fig. 1.

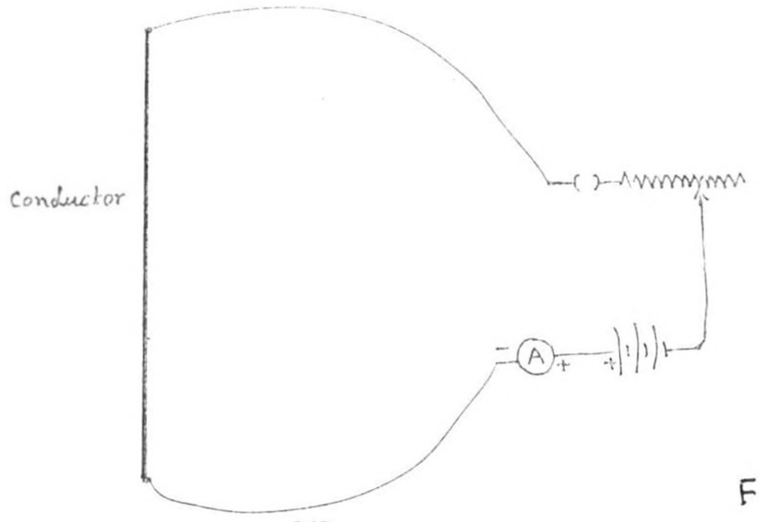


Fig. 1

2. Take a sheet of paper (30 cm × 30 cm) make a hole in the centre and cut the paper from hole to one of the sides of the paper. Insert it into the wire and fix it on the table as shown in Fig.2 and mark North direction on it.

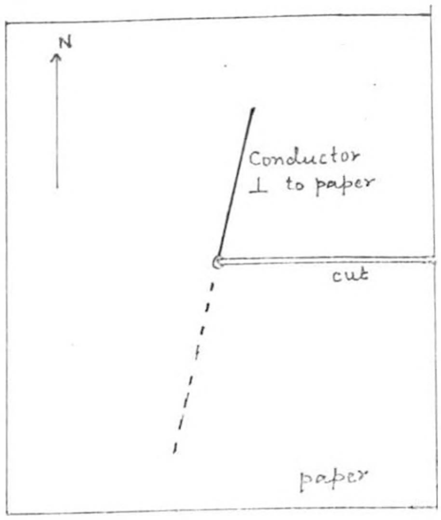


Fig. 2

3. Pass a steady current (*why steady*?) of ~2A through the conductor and plot the lines of magnetic induction. Note effective current will be nI if conductor consists of n wires carrying a current of 2A each. Hence have the part AB of the wire n times wound (see Fig. 3 for details).

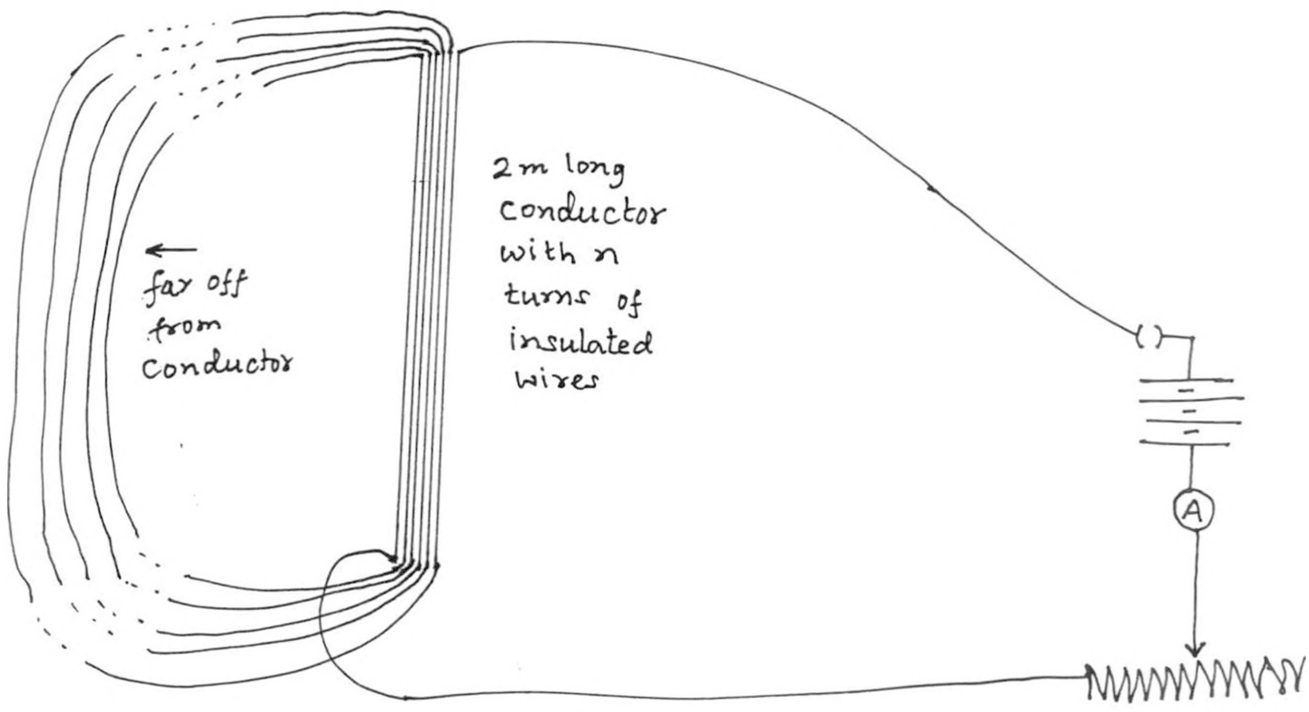


Fig. 3

Observations :

1. What is the nature of the lines near the conductor ?
2. Lines are short and closed at one end while broad on the other end (Fig. 4). What can be the reason ?

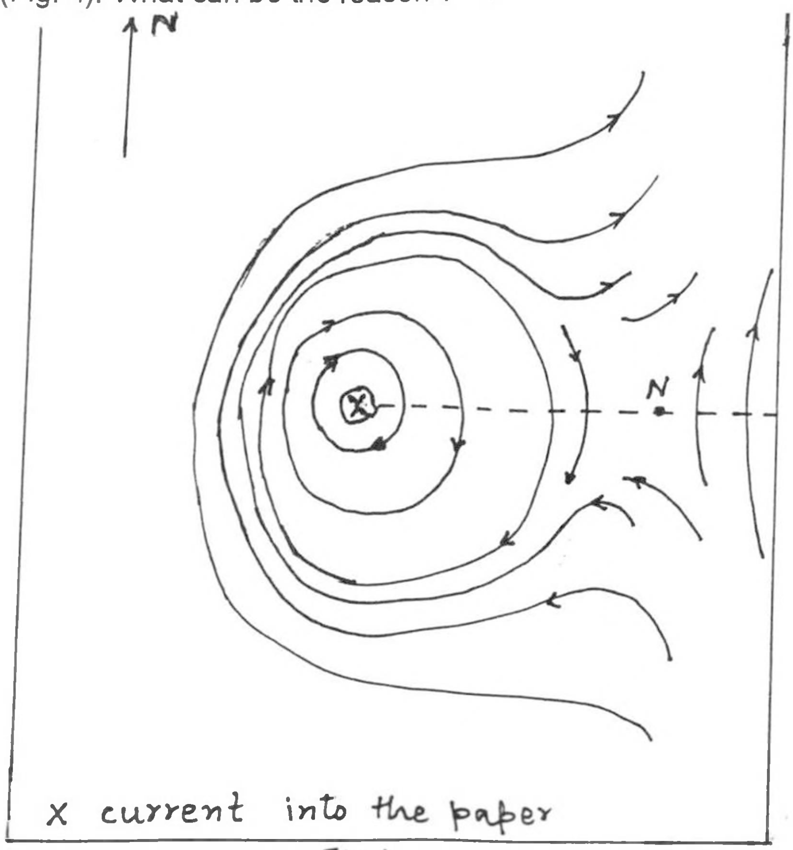


Fig. 4

3. Locate the neutral point N. Does the distance of neutral point depend on the strength of the current ?

4. Change in direction of the current causes change in the direction of neutral point. It is possible to find the locus of neutral point when steady current is changed from +3A to –3A in steps of 0.2 A ? Where is the neutral point for zero current ?

Comments on the Result :

1. Does the location of neutral point follow $d = \frac{\mu_o I}{2\pi H}$?
2. If you have magnetic materials around the wire (or current carrying conductors), what is the effect on the lines of induction ?

3. Did you bother to place paper perfectly horizontal and conductor perfectly vertical ? What kind of error may creep in if you are not very careful ?
4. Would you suggest to use centimeter graph paper in place of a white paper sheet? In what respect is it useful ?
5. If you use wire bent in rectangular shape and plot the lines of induction for both of them together you find that in the region between the two wires, the lines of induction have same direction. What type of conclusion you may draw with respect to attraction or repulsion?
6. How do your performance change if you take plotting compass of smaller diameter ?
7. In what respect earth's magnetic field affect your observations? What conclusions you are likely to draw ?
8. Earth's field lines are parallel and along North whereas resultant lines of induction you obtain are curved. Can you use law of parallelogram of forces to find the field at a point due to current carrying conductor? (Hint B : H tan θ).

Additional Activity:

1. Modify the device to place the conductor in horizontal plane and a drawing board (with hole at the centre to pass the conductor through) in the vertical plane perpendicular to the length of the wire and estimate V component of earth. Will the same compass needle work?
2. Calculate B due to conductor at different distances and plot a graph between B and reciprocal of distance. What result do you get ?
3. Take two closeby wires and pass current through them in same direction. What additional information do you get ?

Experiment 7

Aim: To study conservation of linear momentum in the centre of mass system.

Apparatus : Horizontal frictionless plank (preferably glass sheet with stoppers), bumpers at the edges, meter scale, explosion mechanism.

Procedure :

1. Take two carts (or toy cars) identical in all respect and place them on the horizontal plank. See if they roll away in one or the other direction. If so, adjust the level of the plank.
2. Place the carts end to end with a cracker or a balloon in between at the centre of the plank (Fig.1). What is the momentum of the system in this condition?

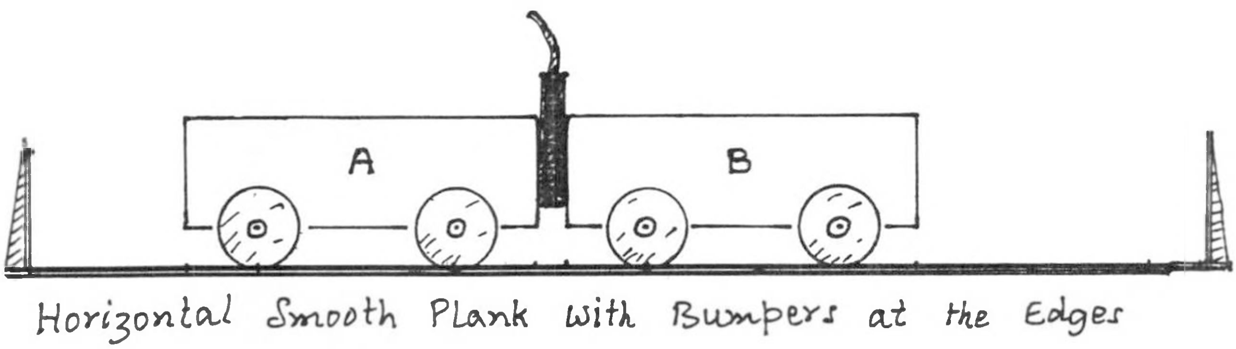


Fig. 1

3. Bring out explosion in the case of a cracker or inflate the balloon in between the two carts so that the two carts move in opposite direction. Note that inflating the balloon should not hinder the free movement of the carts. Can you suggest any other mechanism to set the carts in motion ?

4. How do you measure velocities of the two carts ? (Hint: If time taken by the carts to hit the bumper are same as heard by your ears. Then the distance traveled gives idea of velocity.)
5. Load one of the carts with 200g. and repeat the explosion and find the distances the carts move in equal intervals of time. (No stop watch is given. The carts should hit bumper simultaneously). Do you need to displace carts from the centre of the plank ?
6. Repeat experiment by loading the cart with other weights. Do you find that loaded cart moves shorter distance ? Tabulate, load-distance moved data for fixed time intervals.

Table for asserting momentum

Distance moved by unloaded cart, D_o (m)	Load on the other cart, W (g)	Distance moved by loaded cart, D_L (m)	Value of $D_L + W.\ D_L$
	0		
	100		
	200		
	300		

Does the value $D_L + W.\ D_L$ compare with D_o ?

7. What is the momentum of the carts after explosion ? Find out when masses of carts were same it was easy to calculate. But when one of the carts is loaded, it has become difficult. Why ?

Comments on the Result :

1. What are the limitations in taking distance moved as velocity ?
2. What factors would determine difference in ($D_L - WD_L$) and D_o ?

Objectives Achieved :

Student will understand that

1. distance traveled in a convenient unit of time represents velocity.
2. conservation of momentum says if $m_1 \neq m_2$, then $v_1 \neq v_2$.

Experiment 8

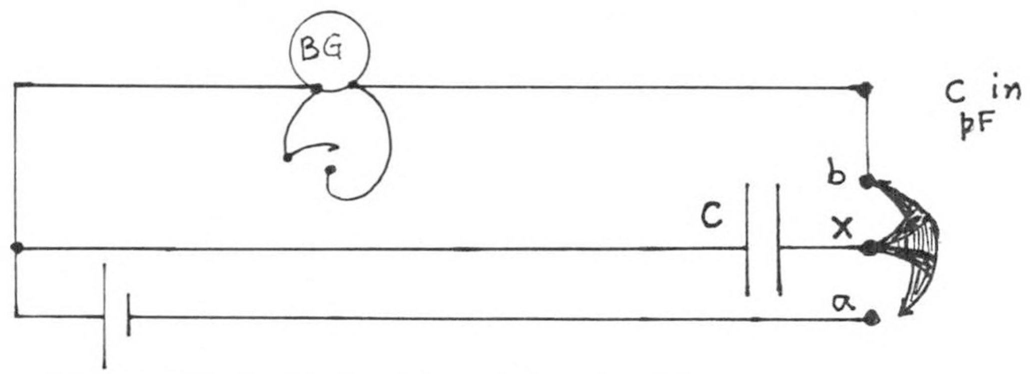
Aim : Estimation of value of ϵ_o.

Apparatus: 5-6 picofarad range capacitors, battery, ballastic galvanometer, keys, 2-plane glass plates (30 cm × 30 cm), aluminium sheets, crocodile clips.

Background: ϵ_o appears in the formulas for electric force, capacity, etc. The capacity of a parallel plate capacitor is given by $\frac{\epsilon_o A}{d}$ when no medium between the capacitor plates exists. For all practical purposes instead of vacuum, we take ϵ_o for air as a medium between the two capacitor plates. Hence if capacity of such a capacitor with known dimensions is measured ϵ_o can be estimated.

Procedure :

1. Connect circuit for charging and discharging of a capacitor as shown.



If end 'a' is connected, to X capacitor gets charged.

Q. What should be the charging time ?

2. Discharge the capacity by throwing switch towards b. Note the deflection. Repeat the procedure for a few number of times. Find the range of deflection obtained for first capacity say θ_{i1} to θ_{i2}.

Q. *Why you do not get same deflection ? Would mean deflection be enough ?*

3. Change capacitors one by one and find ranges of deflections for each of the capacity.

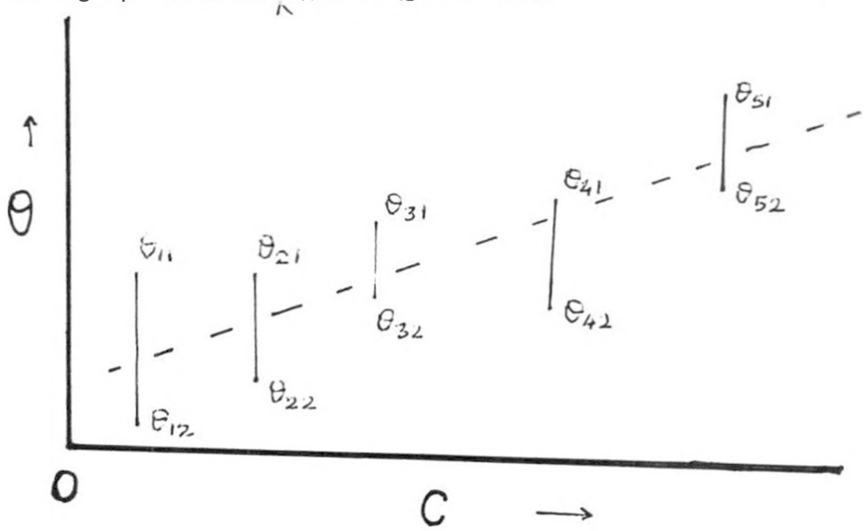
   See whether consistency is observed in C and θ.

   Tabulate the observations.

Sl. No.	**Capacity in pF**	**Least deflection θ_{i1}**	**Maximum deflection θ_{i2}**	**Mean deflection θ_{i3}**

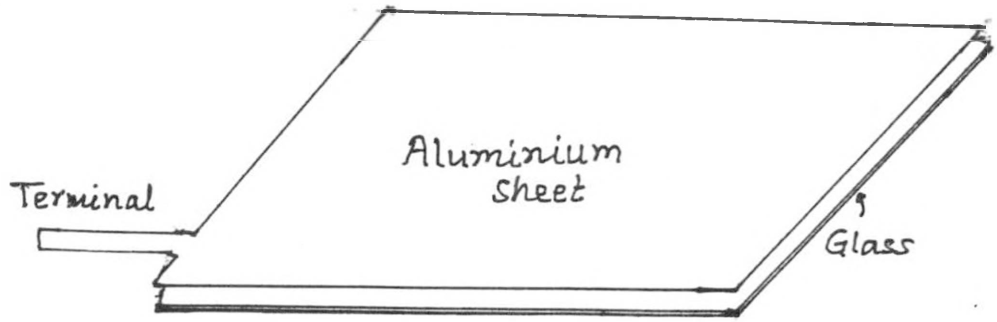
i runs from 1 to say 6.

Plot a graph between C and θ_{i1} and θ_{i2} as shown.



Q. *Would you like to find most probable behaviour by joining the observed pattern by a straight line ?*

4. Paste aluminium sheet on to a glass plate as smooth as possible. Take out terminals by protruding a streak of sheet on one side as suggested below. Make another plate of the capacitor similarly.



Place one plate on a horizontal table so that aluminium sheet faces up. Put 4-5 insulating beads of same size (preferably 1 mm diameter) on the plate so that when another plate is placed (with aluminium sheet facing each other) over it there is no physical contact between the two plates forming a parallel plate capacitor.

Q. *How will you ascertain no physical contact ?*

Replace this capacitor in the circuit and find the range of deflections you get.

5. See where does this deflection fits in the graph (if necessary extend the curve) and so estimate its capacity. What would be the contribution of insulating beads to the capacity? To see the effect of beads, spread a few beads in the space and find the capacity. Plot a graph if necessary between capacity and number of beads in between.

   Q. *How can you minimize the effect of the beads? Would you prefer bigger capacitor plates. (Remember there would be a bulging of the sheet) ? How would you account for stray capacity ?*

6. Multiply the capacity thus obtained by d/A.

   Q. *Are you closer to the value of ϵ_0 reported in the literature ?*
   What can be the causes of difference ?

7. Find the value of ϵ_0 for a different value of d.

   If you decrease d, you cannot be sure of reliable separation and if you increase d, deflection produced is less.

Q. *What are your suggestions for optimization ?*

Note : You can see spot of galvanometer moving slowly if you hold wires coming from X and b.

8. Remove the beads and place the plates one over the other.

   Q. *Can you expect to form the capacitor now?*

   But if you repeat the procedure of charge and discharge, you get deflection.

   Q. *How would you account for it?*

   (Hint: Do not charge the so called capacitor but look for deflection. You get a deflection, why ?

Comments on the Result :

1. When d is small, deviation from perfect plane plates has lot of influence. Why that is so ?
2. Pasting aluminium sheet onto a glass plate may not lead to evenness of surface, still you should not prefer two thick aluminium or any other metal sheets (except iron/steel). *Why* ?
3. Why do you need calibration curve suggested in steps 1 to 3 in procedure ?

   What does this calibration suggest ? Do the capacitors have rated capacity ?
4. Why do you take capacities for calibration in picofarad range ?
5. Would you propose guard ring type arrangement to overcome stray capacity ?
6. You are not finding ϵ_0 strictly. How much reliability one can expect ?
7. Find % variation in ϵ_0 theoretically and compare with your value.

Objectives achieved :

Student learns that

1. A quantity whatsoever small can be estimated when planned justifiably.

   The experiment gives first hand appreciation for ϵ_0 .

Experiment 9

Aim : To estimate contact potential.

Apparatus : Two plates of dissimilar metals, cell, ballastic galvanometer, high resistance / water column , milli voltmeter.

Theory: When pieces of two dissimilar materials are brought into contact, a potential difference develops across the two. This potential difference is characteristic of the given two materials. Volta listed a series of metals and showed that potential difference between any two pair of metals in contact is the sum of potential differences between intervening materials in the series. Millikan expressed this 'intrinsic' contact potential difference between two metals as

$$V_{AB} = (W_A - W_B) / e$$

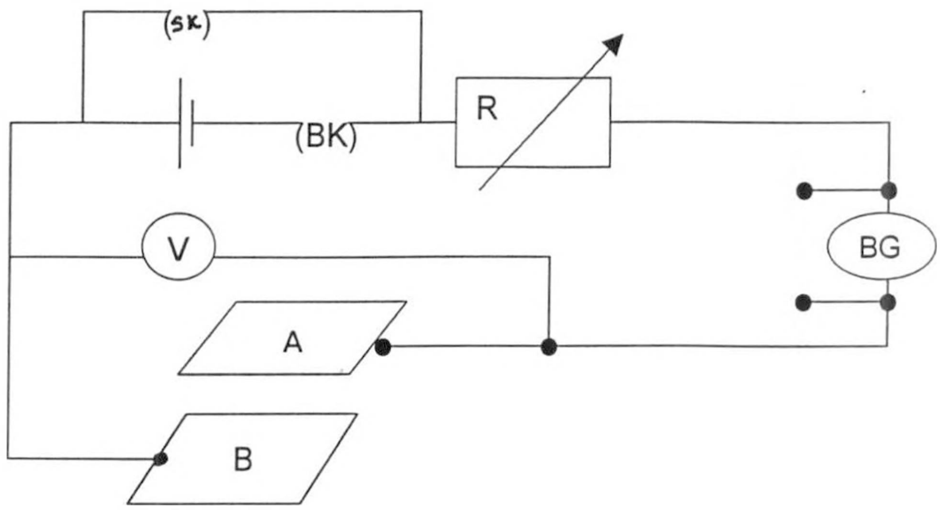
where W represents work function of the given material. Intrinsic word is added when we discuss cases with all adsorbed gases removed.

The contact potential so developed ranges from a few millivolts to a fraction of volt. Hence when one deals with large potential differences, contact potential hardly affects the results.

When material in contact is liquid we sometimes call such potential as polarizing emf or back emf.

Procedure :

1. Connect the terminals securely to the two plates to be brought in contact, and complete the circuit as shown



2. Bring the plates A and B in contact.

   Does the BG show current on by passing the battery by closing SK?

   Press AB to closeness by pushing plate A down with an insulating pad.

   Does the current gets affected? Is it a steady current?

3. Open key SK and close BK. Adjust R to have minimum deflection.

   Do you get current in the same direction? If so can you claim that plate B was at higher potential with respect to A in step 2 ?

4. Modify the circuit such that the deflection in BG in step 2 and step 3 is in opposite direction.

   Why cannot you perform the experiment otherwise? Explore the possibility?

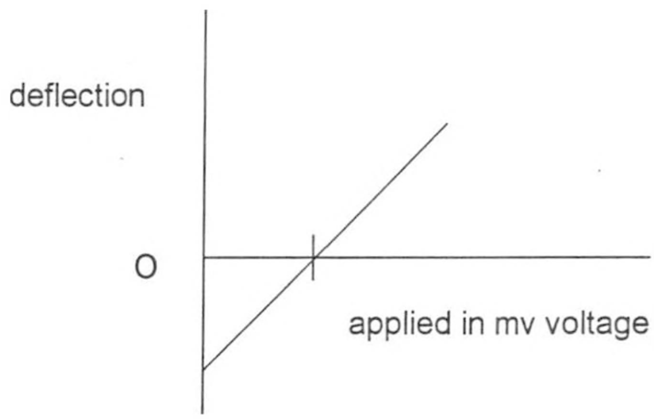
5. Note galvanometer deflections for different potential differences across the plates and plot a graph.

   Does the graph show linearity? Why do your need very low potential difference? Do you expect same results with voltages and currents in higher ranges?

6. Find the potential difference applied, that corresponds to contact potential.

Comments on the result :

1. Do you get same value for contact potential difference irrespective of the size of the plates?
2. What is the effect of closeness of the plates?
3. Extrapolation of graph gives current in opposite direction for zero of applied voltage what is its significance?



Does the current maintains it steady value at zero applied potential?

4. How far the zero deflection point on the graph reliable?
5. Should contact potential differences always oppose the external source if not would you get stable value of the deflection?

Objectives achieved :

Student learns that when two materials of different nature are brought into contact there is a flow of charge from one to another which leads to a contact potential difference. But it cannot drive current in external circuit continuously. Hence emf sources are so designed that current by it is available for a longer period.

Experiment 10

Aim : To estimate power factor for a circuit.

Apparatus : Joule's Calorimeter, DC power supply, ammeter and voltmeter, AC power supply (transformer), ammeter and voltmeter, inductor, thermometer.

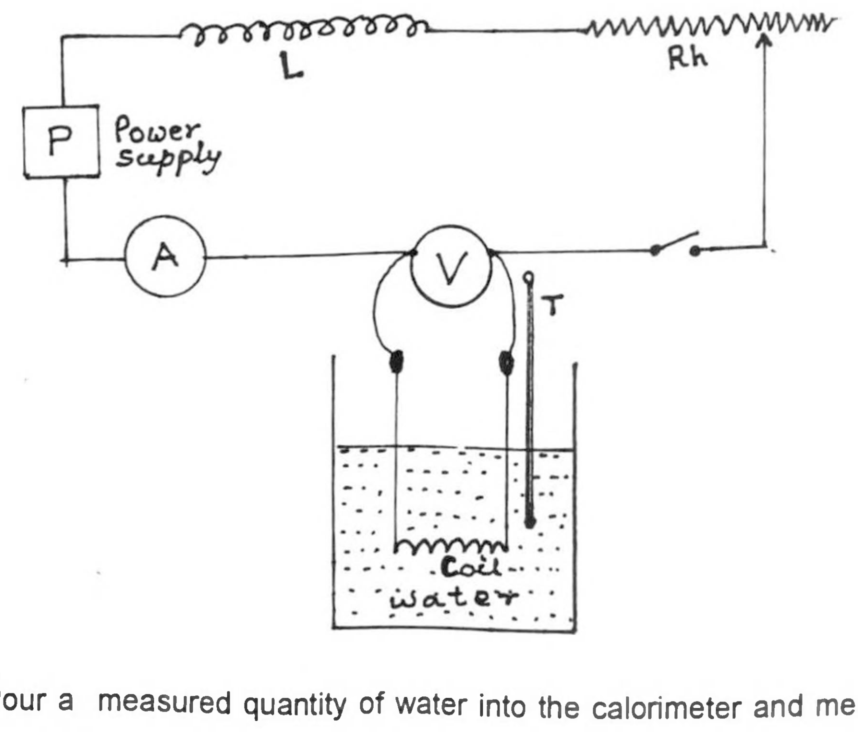
Theory : Power factor of an AC circuit is defined as

$$\text{Cos } \phi = \frac{VI}{V_{\sim}I_{\sim}}$$

where ~ denote rms values of the quantity.

Procedure :

1. Connect the circuit as shown.



2. Pour a measured quantity of water into the calorimeter and measure its initial temperature.

3. Pass dv current for about 10 minutes. Measure steady voltage across Joule's heating coil, steady current through it and final temperature. Calculate heat taken up by the calorimeter and water.

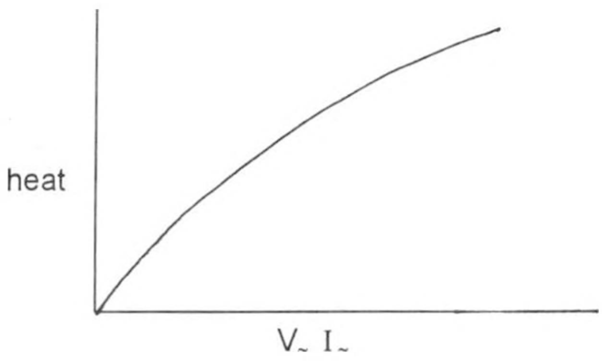
   Should you stir the water during heating? What are the other precautions?

4. Replace water and dc components of the circuit by fresh water and ac components respectively. Set up a current and voltage and note rise in temperature in 10 minutes.

5. Repeat procedure 4 for 3 more different values of current.

   Should you ensure same quantity of water and same initial temperature?

6. Calculate heat taken up by calorimeter and water in each case. Plot a graph between heat taken and $V_{\sim}\ I_{\sim}$.



7. Locate a point on the curve which corresponds to heat consumed in dc heating and find corresponding equivalent value of $V_{\sim}\ I_{\sim}$

   To what extent the presumption that heat generated correspond to $V_{\sim}I_{\sim}$, rms values, is correct?

8. Divide $V\,I$ from procedure 3, by $V_{\sim}I_{\sim}$ value obtained from graph.

   Do you get a value close to one?

9. Repeat the experiment with a different value of L.

   What is the use of inductor in the circuit? Should you use an inductor of different value to get a different power factor?

   Why do not you use capacitor in this circuit?

10. Try to replace Joule's heating element with a coiled coil resistance wire. *Why* ?

Comments on the result :

1. Do you need to take large quantity of water in the calorimeter?
2. How much rise in temperature one should go far?
3. Have you accounted for radiation losses?
4. What are the effects of inductive components around?
5. What are the factors influencing most to the results?
6. Does the power factor obtained agrees with R/Z value ? Where Z is impedance of the circuit.

Objectives achieved :

Student will be able to

1. Differentiate between ac heating and dc heating.
2. use of AC components cause change in power factor.
3. If power factor is less energy is not available in useful power which is undesirable. Hence for a given potential difference a large current is needed to supply desired power. This is the reason why we need to improve power factor in ac operations.
4. A capacitor is connected across the inductive load to improve power factor.

Simple but exciting Activities

Activity 1 : To observe diffraction at a circular aperture

Take a small mirror strip. Scratch its polish at the middle by a sharp needle so that a small circular aperture is formed.

See through this aperture, from reflecting side, the light coming out from a sodium lamp. Tilt the mirror strip, if necessary, so that light falls on the aperture normally. You will be able to see sharp circular fringe pattern resembling Newton's rings.

Discuss why diffraction pattern is not observed if light is seen from side the mirror is silvered.

To further the activity a slit can be formed similarly.

Activity 2 : To observe diffraction by a single slit

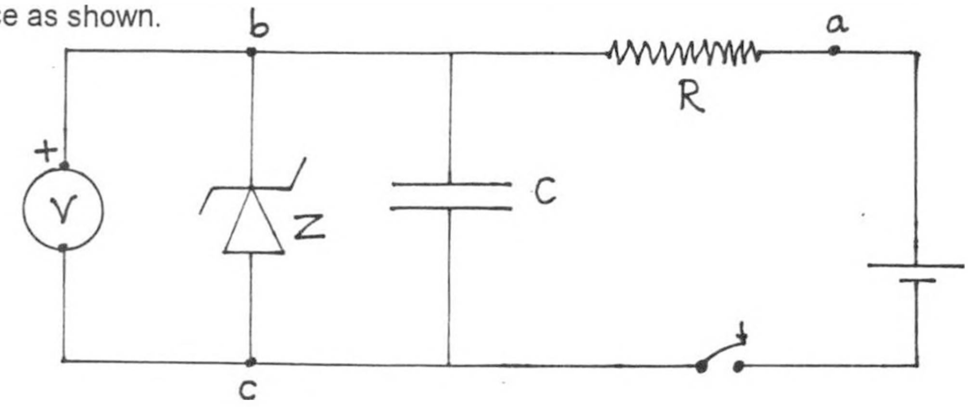
Take two fresh sharp edged blades and place them on a glass slide (plate) side by side such that the sharp edges form a narrow rectangular slit. Fix them by cellotape.

See sodium light through this slit you can observe parallel straight fringe pattern. In the day light on looking through it, alternate white and black fringes are visible. Like in Activity 1, it is difficult to observe fringes from the other side.

Note with practice these fringes can be seen just by holding the sharp edges of the blades closeby and looking through it.

Activity 3 : To observe Zener action of a Zener diode

Connect zener diode with capacitor and resistor to a variable voltage dc source as shown.



When dc voltage is increased successively, the voltmeter shows increase in voltage across capacitor. At zener break down voltage the voltmeter shows almost a stable value.

Capacitor can be replaced by another load R' (an electrical gadget) but current through the zener is defined mostly by resistor R and not R'. Why ?

Note

(i) R causes delay in establishing potential difference across the capacitor. Hence allow the p.d. to stabilize.

(ii) With increase in p.d. beyond break down (avoid such adventure. Why?) there is a slight increase in p.d. across capacitor. What kind of information would it give ?

(iii) If neon lamp (tester bulb) is used, it flicks as ionization potential is reached. Explain why does so happen ? (Use 0 – 90 V source).

(iv) Remove capacitor and increase voltage across circuits in equal steps of voltage. Record p.d. across zener (points bc) and circuit (points ac). Plot a graph between voltage across zener (y-axis) and circuit (x-axis). Find the location of inflexion point with the help of mirror. This point corresponds to zener break down voltage. Why ? [Hint: Initially when p.d. is increased, whole voltage drop is across zener]. In what respect this procedure is better than that described in usual texts ?

Activity 4 : To find the Cauchy's constants

Cauchy's formula is

$$n \approx A + \frac{B}{\lambda^2} \quad \ldots\ldots\ldots \qquad \text{(i)}$$

with A >>B.

If refractive indices for blue and red are found out

$$n_b - n_r \approx B\left(\frac{1}{\lambda_b^2} - \frac{1}{\lambda_r^2}\right) \quad \ldots\ldots \qquad \text{(ii)}$$

This value of B substituted in (i) gives value of A.

Note $\frac{B}{\lambda^2}$ is correction term whose value has to be very small and λ^2 is also very small. This indicates the precision needed in estimation of B. So sharper the lines better is the result.

Alternatively, n is calculated for each λ and a graph is plotted between n and log λ. The value of n corresponds to A when graph is extrapolated for λ tending to infinity.

The value of A obtained from the two methods in general do not agree. Why is it so?

For very large λ refractive index is almost constant. Does it indicate to the structural dependence of n ?

Activity 5 : Demonstration of Inertia

There can be thousands of ways to show that Newton's first law holds good. Let us have one common observation. Place a dish full of water on the horizontal smooth table top. The quantity of water should be such that addition of even a few drops will cause its spilling.

Undertake the activity to the class. "Can anybody move the dish without spilling its water?" When water spills at what place it initiates ?

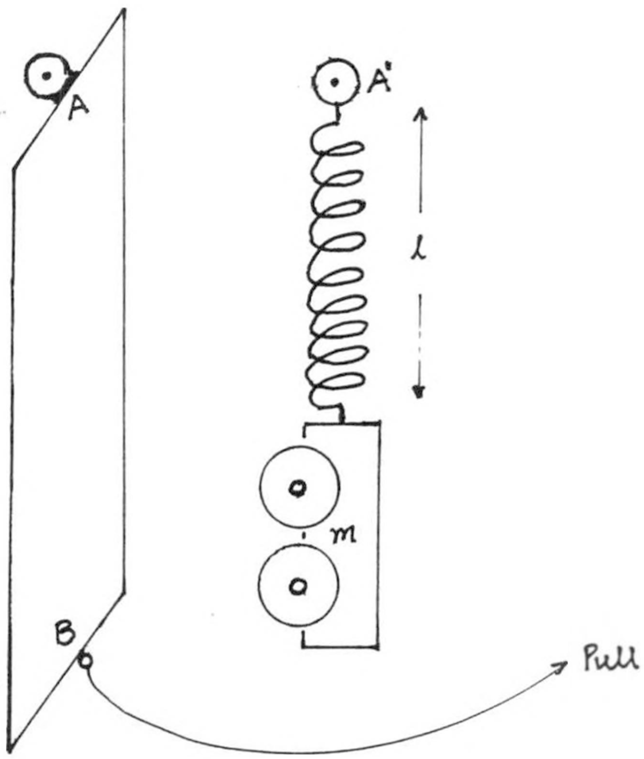
For better understanding now fill the dish more than half and move it gently on the table top. Observe the level of water. Can you ascribe it to inertia ?

How do you make fruits fall by pelting a stone at its stem. Does the stone cut the stem ? How do you make fruits fall from the tree when the trunk of the tree is shaken briskly ? How can these be attributed to inertia ? What kind of inertia it is in above two cases ?

Can you devise an experiment to show criteria of gases? Do air cushion trains use the principle of inertia ? How ?

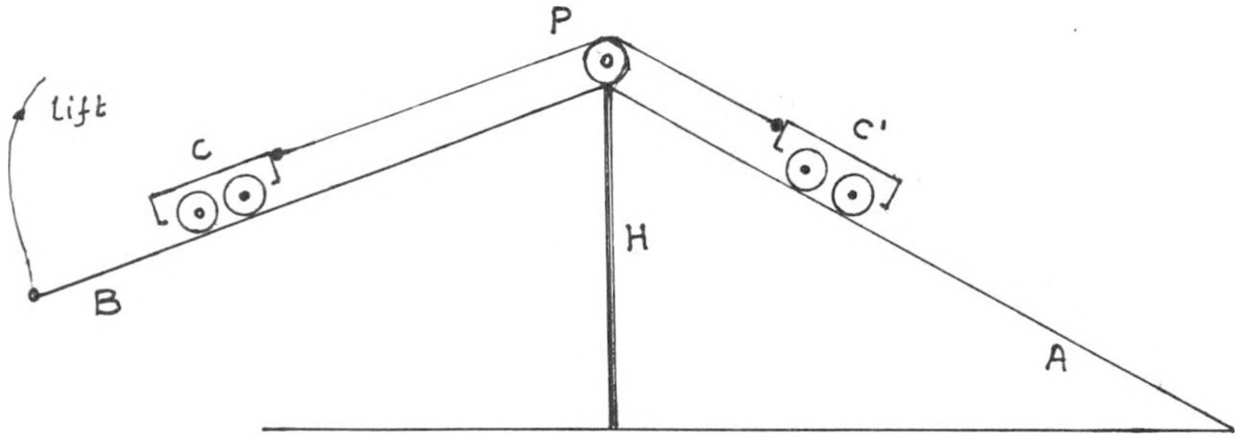
Activity 6 : To show that work done on a system causes increase in potential energy.

Let A and A' be rigid supports with pulleys which allow rotation in vertical plane. Hang a heavy toy car (500 g) to a flat spiral spring of length 20 – 25 cm which in turn is attached to a rigid support A. A smooth plank is hung at A as shown by the side of car, so that wheels of the car can sit on it. Measure *l*. Next push end B of the plank so that car wheels sit on the plank. In pushing the plank up at B, work is done. This work is stored in the spring as potential energy of the spring as it contracts.



If you know the spring constant see if mg $(h_2 - h_1)$ agrees with ½ k $(l_2^2 - l_1^2)$. Otherwise plot a graph between $(h_2 - h_1)$ and $(l_2^2 - l_1^2)$. What does the slope give? Note that weight of the plank is not affecting the spring. Here 'h' indicates vertical height of the car.

Same experiment can be performed in an alternative way. Tie two identical cars to an elastic thread and place them on inclined planes as shown. H is rigid support for smooth planes A and B hinged at P along with a pulley. Measure the length of the elastic thread under stretched condition. Now lift plane B from one end in steps.

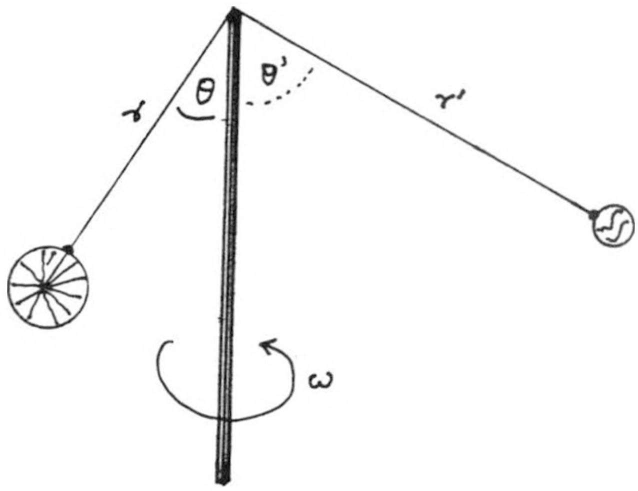


What do you observe ? Does car C is pushed down ? Does car C goes towards P? What happens to length of the thread? Can you do this experiment with non-stretchable thread? Where does work done in lifting go? Prove that for cars of equal masses, stability is attained only when angles the planes make with horizontal are same (friction is neglected). For cars of different weights, there is only one condition

$mg \sin \theta_1 = Mg \sin \theta_2$

Activity 7 : To show that r is more important for I than m

Tie two balls by threads of length r each to a stick vertically held, as shown.



Rotate the stick. For certain ω, the balls also rotate but at a distance of $r\sin\theta$ from the axis of rotation. On increasing the angular velocity further by $d\omega$ the distance from the axis becomes

$r \sin(\theta + d\theta)$

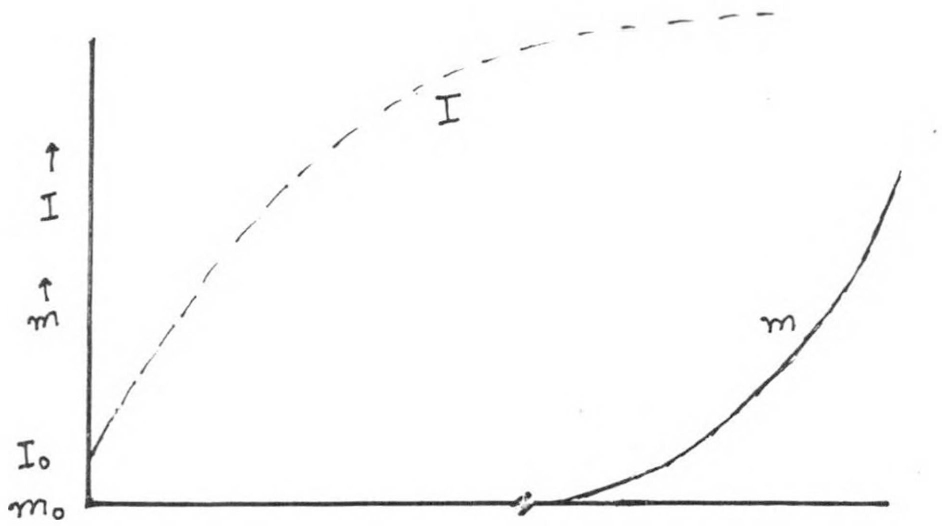
As, ω is increased successively in steps, distance increases in proportion to

$\sin(\theta + d\theta) = \sin\theta \,.\, \delta\theta$ and **I** increases in proportion to $\sin^2(\theta + d\theta)$.

From the property of sine function **I** increases rapidly for initial increase in ω and then slowly. Ultimately it stabilizes to a value proportional to r^2.

Note that if balls are of unequal size/mass and/or tied with threads of different lengths, the angle θ will also be different.

In contrast to it, in linear motion m hardly increase with increase in velocity in the domain of velocities v << c but goes on increasing with v at great velocities. If we represent graphically it would look like



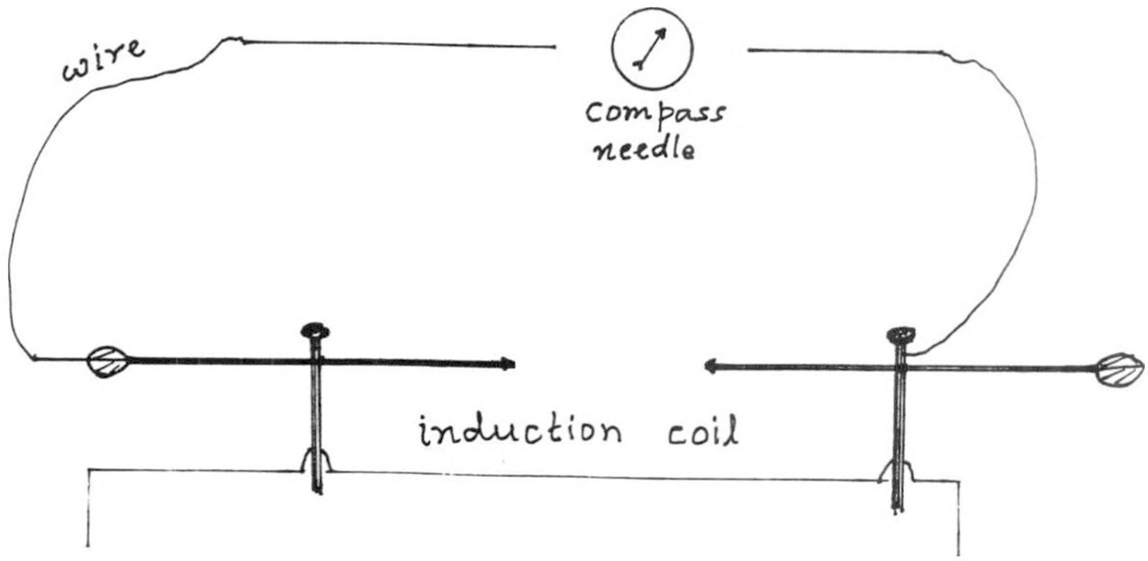
Note : In the discussion, we have assumed that centrifugal force causes increase in r which is true for gases and liquids and valid for not so rigid solids also.

Activity 8 : To show displacement current

Maxwell modified Ampere's law by inclusion of displacement current. He suggested that when a capacitor is charged, the field establishes within the capacitor plates. During the charging thus a time varying displacement current passes between the capacitor plates. This current produces same magnetic effects as the normal current. Thus the passage of displacement current can be indirectly inferred by associated magnetic effects.

Take an induction coil and connect one long wire each to its output terminals so that spark can be obtained at a farther convenient distance from the induction coil as shown. Arrange the loose ends AB along east west so that when magnetic needle is placed between them it is perpendicular to the line joining AB.

The distance between A and B should be such that no spark can initiate.



Now apply the input 10V – 2A to the induction coil and excite it, the needle will experience a jerk to one side. Next change the polarity, you can notice the jerk on the needle in opposite direction. Clearly the magnetic needle is affected by some current.

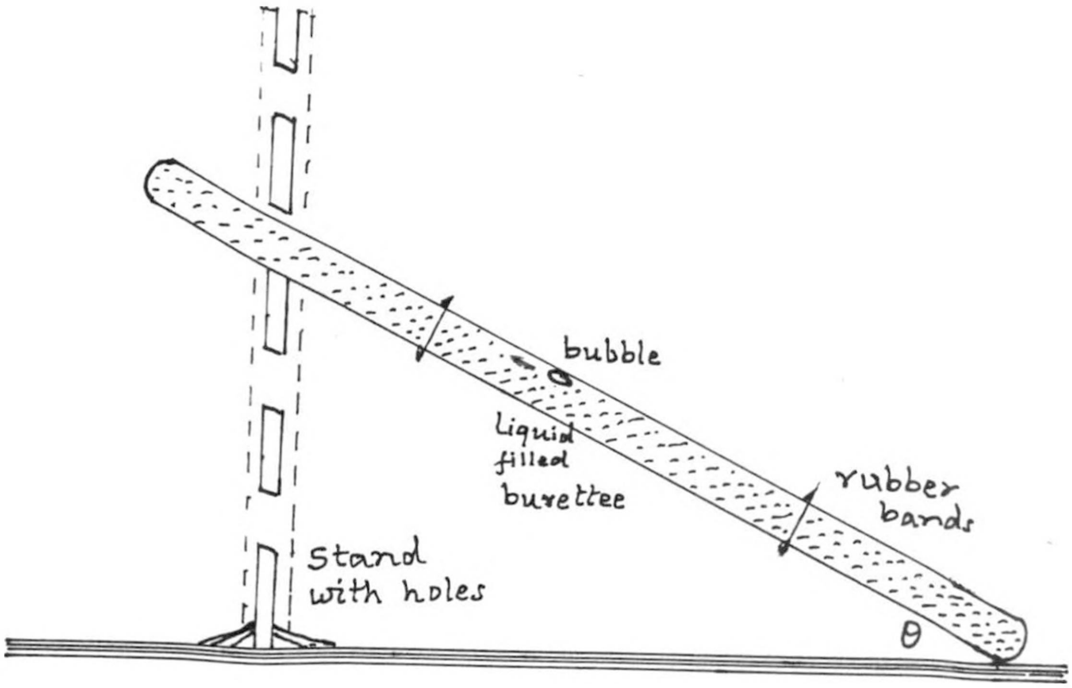
How would you ensure that the deflection in compass is not due to a steady current ? [Hint: Allow a continuous spark to pass through the gap by reducing distance AB and place the compass needle near it].

How would you discard the contribution of ionic current in the gap between A and B ? [Hint ; (i) Deflection in such cases would be negligible, (ii) If you increase the distance between A and B ionization current should be affected very much.].

How would you account for some steady deflection in the needle ? [Hint: The p.d. developed across an induction coil is not pure dc. A small component of ac can be assumed to be superposed on dc. Hence time varying displacement current is always there. But due to inertia of the needle it points to a direction in which average large displacement current would have influence].

Activity 9 : Study of the motion of an air-bubble

Seal both ends of a burette with a trapped air-bubble within the liquid filled in it. Mark a 10 cm distance along the burette using thread or rubber band. Keep the burette in an inclined position as shown below.



As the air bubble moves up along the tube, note the time taken to travel the distance of 10 cms. Calculate the speed of the air bubble. Repeat the same exercise for various distances 20, 30, 40, 50 cms. (atleast 5 distances) for the same inclination of tube. Tabulate your observations and draw a graph between time and distance. From the graph determine the speed of the air-bubble and compare with the calculated value.

Repeat the experiment now for only one distance, say 30 or 40 cms, by changing the inclination of the burette (Do at least for 3 inclinations).

Do you need to bring the bubble to the bottom end every time ?

Tabulate the result.

Height h(cm)	Inclination θ°	Distance moved by air bubble	Time taken (s)					Mean of best three	Velocity cm/s
			1	2	3	4	5	t (s)	

Average velocity =

Velocity from graph =

Inference :

i) Do you propose that motion of air bubble represents uniform motion ?

ii) To what extent you may expect Stoke's law to hold good ?

iii) What is the effect of size of the bubble on its motion ?

iv) What kinds of liquids you can safely use in burette ?

v) How would the length of the burette affect the result ?

vi) Unlike in Stoke's law, here bubble drags along the wall of the tube. What effects it would have ?

vii) Can this experiment be tried at different ambient temperatures ?

viii) How will you measure critical velocity ?

ix) What is the effect of bore of the burette/transparent tube on the motion of the bubble ?

x) Can you demonstrate this experiment in a capillary tube? What are the constraints ?

Objectives achieved

Gravitational force that causes motion of the bubble is opposed by viscous force, uniform motion is achieved when the two ideally get balanced.

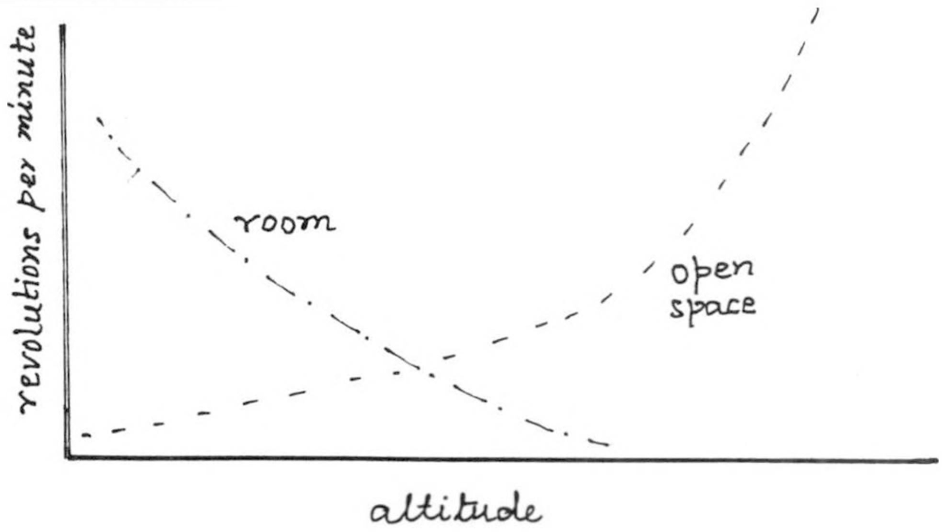
Activity 10 : To measure gradient of wind with altitude

Take a cup - anemometer capable of whirling about a vertical shaft.

Count its revolutions per minute at different heights out in the field.

Take the anemometer now into a room with windows open but ventilators closed and measure the wind speed. Next take observations in a room with windows open and ventilators also open. Plot graph between revolutions per minute and altitude in different cases.

What should you ensure is – there should ideally be no change in atmospheric conditions.



Do you find that in open the wind velocity goes on increasing with altitude? Why ? Should the case be same for wind velocity inside a closed room ? What is the effect of ventilators on your observations ? Would you ascertain it further by taking observations in a room with exhaust fan on ?

What would be the grounds on which you can suggest that room should have cross ventilation, or ventilators ?

In what respect normal fans of the room alter the situation ?

Should you perform this experiment in an ac room ?

Why do not you prefer such an experiment with test wind mill set up (capable of rotating in vertical plane) ?

Activity 11 : To estimate wavelength spread of a monochromatic source/color filter.

The condition for constructive interference is that the path difference between two monochromatic coherent waves of nearly same amplitude should be $n\lambda$ where n is some integer.

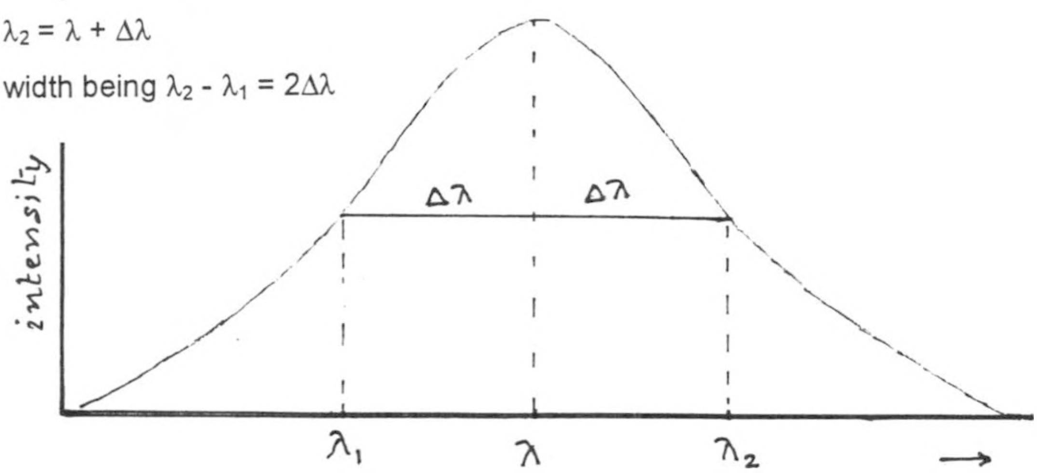
But no physical source does have perfectly monochromaticity. Let us assume that the source emits light of the range of $\Delta\lambda$ about λ.

Further, assume that light distribution about λ is Gaussian as shown

$\lambda_1 = \lambda - \Delta\lambda$

and $\lambda_2 = \lambda + \Delta\lambda$

The width being $\lambda_2 - \lambda_1 = 2\Delta\lambda$



We can always find a number n such that paths $n\lambda$ and $(n \pm ½)\ (\lambda \mp \Delta\lambda)$ are equal so that together they interfere destructively. Consider one simple case

i.e. $n\lambda = (n + ½)(\lambda - \Delta\lambda)$

or $n\lambda = n\lambda + \lambda/2 - \Delta\lambda\,(n + ½)$

or $$\Delta\lambda = \frac{\lambda}{(2n+1)}$$

or the range of wavelengths from $\lambda = \lambda - \Delta\lambda$ to $\lambda + \Delta\lambda$ is given by

$$2\Delta\lambda = \frac{2\lambda}{2n+1} \approx \frac{\lambda}{n} \quad [\ when\ n >> 1\ ]$$

Thus the number of fringes that can be observed clearly is $n < \frac{\lambda}{\Delta \lambda}$.

Note that amplitude of wave at λ is large but it is nullified by two waves of wavelengths $\lambda - \Delta\lambda$ and $\lambda + \Delta\lambda$ both of which are in opposite phases.

This number n then decides the number of fringes that can be observed in an interference pattern.

To count this number use Young's double slit experiment lighted by LED, or incandescent lamp having a color filter.

The number 'n' can be counted in air wedge and Newton's ring pattern also.

Question to ponder

1. Can you count the number of fringes obtained in Newton's rings formed under sodium light ?

   [Hint: If size of lens is properly chosen and microscope of proper magnification used one may count ideally several hundred fringes.]
2. Why do you get sharp but less number of fringes when lens of smaller curvature is used ?
3. What special precautions are needed for finding the range of wavelengths emitted by a laser torch ?
4. How will you account for emissions at wavelengths less than λ_1 and greater than λ_2 ? [Hint: This gives fringe line width at constructive interference].