ORDINARY AND ADVANCED LEVEL EXPERIMENTAL PHYSICS

PUBLISHED BY PACON COMPANY LIMITED

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2016

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1.0. MECHANICS

GUIDE NOTES ON PRACTICALS IN EXPERIMENTAL PHYSICS

1.0. Report Presentation:

The following areas on practical report presentation are important. Every practical report should be guided by these areas.

1.1. **Aim**:

This introduces the report. The experimenter should clearly state the aim the experiment. In some cases the experiment may involve the determination of one or more physical quantities. In other cases the experiment may involve verification of law or testing of a particular principle.

1.2. Data collection

i) Measurable physical quantities have to be recorded properly. Each quantity measured should specifically be written in the report, accompanied by its corresponding units. Example: height of the bob, h = 5 ±0.1 cm.

ii) If several measurements of the same quantity are made, a **TABLE OF RESULTS** has to be neatly drawn, columns or rows may be used for this purpose.

Example

Table of Results:

(a) Columns

Trial	**H (± 0.1) cm**	**t (± 0.2) s, 30 Osc**	**T (s)**	**T^2 (s^2)**
1				
2				
3				
4				
5				
6				

(b) Rows

Trial	**1**	**2**	**3**	**4**	**5**	**6**
H (± 0.1) cm						
t (± 0.2) s, 30 Osc						
T (s)						
T^2 (s^2)						

NOTE:

i) Each column or row is headed by a symbol of the physical quantity to be measured

ii) For each physical quantity, the uncertainty error inherent in the measuring instrument is indicated as

iii) For each physical quantity with added information, the information is specified. For example, t is measured for 30 oscillations (Osc.)_

1.3 Data Analysis

The collected data has to be analysed in order to come up with the required experimental results depending on the stated aim(s). The data analysis may be carried out either by substituting measured values in a physical formula or by graphical techniques or both.

1.3.1 Physical Formula

Example: In an experiment to measure the resistivity ρ of a metallic conductor the measured physical quantities are:

- Resistance, R
- Diameter, d
- Length, L

The resistivity ρ is given by:

$$\rho = \frac{\pi R d^2}{4L}$$

1.3.2 Graphical Techniques:

Examples: In an experiment to determine the acceleration, g , due to gravity; and the height H between a floor and the point of suspension, the periodic time T of a simple pendulum and the height h of the bob above the floor are measured fro several values of h.

T and h are related by the formula :

$$T = 2\pi\sqrt{\frac{H-h}{g}} \quad \text{...(1)}$$

Which can be put in to the form

$$T = \frac{-4\pi^2 h}{g} + \frac{4\pi^2}{g} \quad \text{...(2)}$$

Note equation (2) is in the form of the equation of a straight line y = -mx + c,

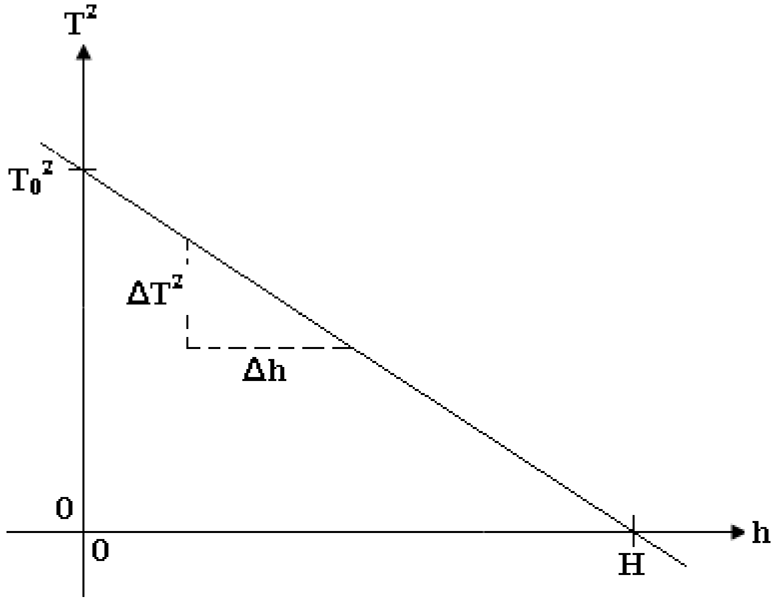
$$y = T^2,\ x = h,\ m = \frac{4\pi^2}{g}, c = \frac{4\pi^2 H}{g}$$

Equation (2) may be sketched by predicting the vertical, T_o^2 and horizontal h_o intercepts; if a graph of T^2 against h is to be drawn; as follows;

$$T^2 \ axis \ \ \text{int}\,ercept\ (vertical)\ when\ h = 0; \therefore T_o^2 = \frac{4\pi^2 H}{g}$$

$$h\ axis\ \text{int}\,ercept\ (horizontal)\ when\ T^2 = 0; \therefore h_0 = H$$

Sketch;



Since intercepts are needed, the axis must start at the origin, (0,0)

1.4.0 Deduction of experimental values

(i) Deducing the value of g. Since m is the slope of the equation, and in this cade it's a negative, then

$$slope = m \ or \ slope = \frac{-4\pi^2}{g}$$

$$or \ \ g = \frac{-4\pi^2}{slope}$$

(ii) Deducing the value of H. Since the h-axis intercept,h_0 is equal to H, the we get its value directly from the intercept

1.4.1 Determination of the slope

By definition, slope is the ration between the vertical change and horizontal change

$$i.e \quad slope = \frac{vertical\ change}{horizontal\ change}$$

in this example,

$$slope = \frac{\Delta T^2}{\Delta h}\ where\ \Delta\ is\ called\ 'delta'\ which\ means\ 'change\ in'$$

Its advisable to take large intervals of the slope .This minimizes the risk of too much approximations, and hence increases the accuracy of the results.

The calculated slope must be accompanied by the corresponding units of the physical quantities plotted.

1.5.0 Graph

The following points should be observed when drawing a graph. The graph should have:

- (i) Title eg $\mathbf{T^2}$ against **h**
- (ii) Axes scales indicated ;e.g Vertical Scale: 1 cm : 0.2 s^2,Horizontal Scale: 1cm : 5.0cm.
- (iii) Axes drawn in sharp pencil and labeled in ink with quantities and units indicated.e.g Vertical axis $\mathbf{T^2(s)}$ **,** Horizontal axis **h** (cm).
- (iv) Correct and clear plotting of points.
- (v) Line/Best line of fit / curve i.e The line or curve drawn should represent an estimated average of all practical graph points
- (vi) No calculations of any kind is allowed on the graph paper.

1.6.0 Errors Discussion:

At the end of each experiment report, error discussion should be presented. In this discussion ,the experimenter points out the physical factors which might have contributed to errors in the final result. For each error contribution mentioned a suggestion of how to minimize it has to be suggested.

COMMON SOURCES OF ERRORS IN MECHANICS AND PROPERTIES OF MATTER EXPERIMENT

Careless errors

1. Parallax in reading the scales of the physical quantities measuring instruments affect the accuracy of the recorded data

   Examples:

   (i) Metre-rule used to measure length

   (ii) Stop watch used to measure time

   Precautions:

   Readings should be taken in perpendicular position to the scale of the measuring instrument.

2. Time reaction in starting and stopping the stop-watch affect the accuracy of the recorded times

   Precautions:

   Improve Care

   A reference mark , e.g a chalk line should be used for observing crossing of oscillating body

3. Approximating reading from the scale of an instrument whose precision is poor (i.e scale not finely subdivided)

   Precautions:

   A finely subdivided scale of the instrument should be used

Random errors

1.Air or wind resistance affect (damp) the oscillations of the system

Precautions:

Minimize air resistance by closing windows and doors. Switch off ceiling fans

2 Frictional forces at the point of suspension damp the oscillations

Precautions:

Ensure rigid (firm) support at the point of suspension

Systematic errors

These arises due to the instrument used eg incorrect calibration of the instrument,zero adjustment etc.

Precaution

Inspect the instrument carefully.

Experiment No. M – 01

The aim of this experiment is to find the acceleration, g due to gravity by means of a simple pendulum.

Proceed as follows:

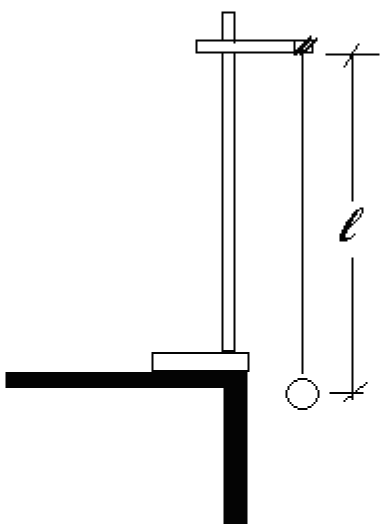


Fig. 1

Tie a thread to the pendulum bob provided.

Hang the pendulum bob so that the length, ℓ of the thread is 100 cm, as shown in Fig.1.

Pull the pendulum bob aside and release it so that it swings to and fro with small amplitude.

Find the time, t for 3 0 oscillations.

Repeat the experiment three times and find the average time, t. Find the period, T of the oscillations.

Record the results in a tabulated form.

Repeat this process for values of ℓ = 80 cm, 60 cm, 40 cm and 20 cm.

(a) Plot a graph of ℓ against T^2

(b) Find the slope of the graph.

(c) Using the relation $T^2 = \dfrac{4\pi^2\ell}{g}$ find the acceleration, g due to gravity.

(d) Mention the sources of errors and their precautions in this experiment.

(e) **Further exercise**: Use the same data to plot a graph of T^2 against ℓ and use it to find the acceleration, g due to gravity. Comment on your result.

Experiment No. M – 02

The aim of this experiment is to deduce a value of an unknown length fixed on a simple pendulum system.

Proceed as follows:

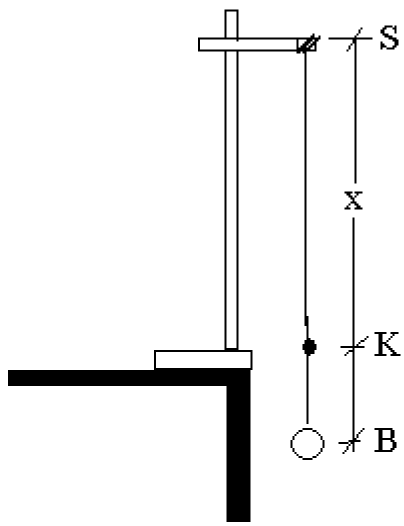


Fig. 2

Tie a knot, K such that KB is much shorter than the pendulum's length, SB.

Suspend the pendulum as shown in Fig. 2

X, is the distance between the point of suspension S and the knot K on the string.

Adjust the string at its point of suspension so that X = 60 cm.

Swing the pendulum and measure the time, t for 20 oscillations of small amplitude.

Calculate the periodic time, T for one oscillation and hence determine, T^2.

Record the values of X, t, T, and T^2 in a tabular form.

Repeat the above procedure for values of X = 40 cm, 30 cm,

20 cm and 10 cm.

(a) Plot a graph of T^2 (y-axis) against X. From the graph:

(i) Determine the values of the slope and the y-intercept of the graph.

(ii) Hence compute the ratio: P = (y-Intercept)/slope

(b) What is the physical significance of P.

(c) Use the value of the slope you have determined in (a) (i) to calculate a value of the acceleration, g due to gravity.

Experiment No. M-03

The aim of this experiment is to determine the acceleration, g due to gravity and an unknown height, H using a simple pendulum.

Proceed as follows:

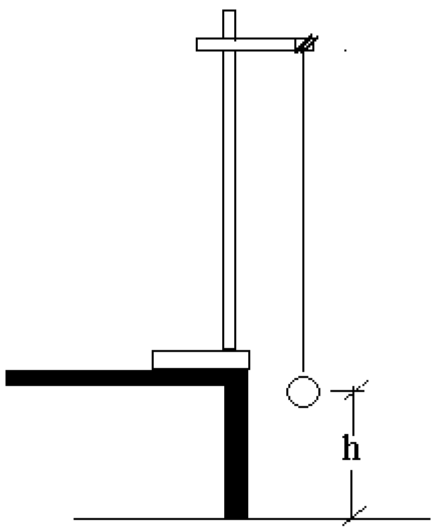


Fig. 3

You are provided with a piece of thread and a pendulum bob.

Tie one end of the thread to the pendulum bob and fix the other end to the point of suspension, S so that the pendulum bob is at the height, h of about 5 cm from the floor as shown in Fig. 3.

Displace the pendulum through a small angle to one side and let it oscillate.

Record the time t for 30 oscillations and hence find the period T for one complete oscillation.

Increase the height, h of the bob above the floor by about 5 cm and repeat the above procedure. Do this for four other values of h, each time increasing h by about 5 cm.

Tabulate your results.

If the period, T is related to the height, h by the relation:

$$T^2 = -\frac{4\pi^2 h}{g} + \frac{4\pi^2 H}{g}$$

(a) Plot a graph of T^2 against h.

(b) From your graph, determine:

(i) The slope and hence the value of the acceleration g, due to gravity.

(ii) A value of H from the h – axis intercept.

(c) What is the physical significance of H?

Further exercise: If you were to plot a graph of h against T^2, what answers would you have for part (b) above?

Experiment No. M – 04

In this experiment you are required to find the relationship between the length, l of a simple pendulum and its period, T (the time for one oscillation).

Proceed as follows:-

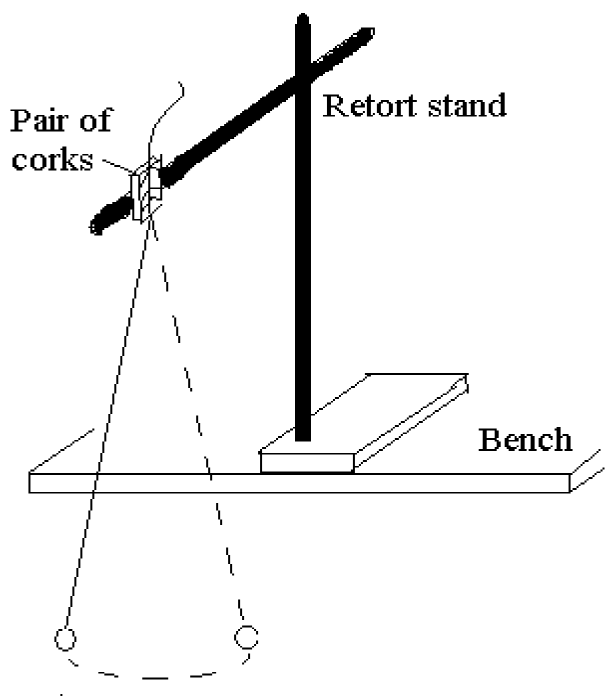


Fig. 4

Suspend a simple pendulum of length 140 cm, as shown in Fig.4.

Displace the pendulum through a small angle so as to make it swing in a vertical plane parallel to the edge of the bench (or table).

Determine the time needed for 20 oscillations of the pendulum.

Now reduce the length of the pendulum by 20 cm and again find the time for 20 oscillations.

Continue reducing the length of the pendulum by 20 cm each time, and obtain a total of six readings.

(Don't repeat any reading of the time taken for 20 oscillations so as to find an average time to be recorded)

Record your readings in a table as shown below:-

Length of pendulum, ℓ(cm)	**$Log_{10}\ell$**	**Time for 20 oscillations (s)**	**Periodic time, T(s)**	**$Log_{10}T$**

Assuming that $T \propto \ell^a$, we have $T = k\ell^a$; and taking logarithms to base ten we obtain:

$Log_{10}T = a \log_{10}\ell + \log_{10}k$

(i) Plot a graph of $\log_{10}T$ (vertical axis) against $\log_{10}\ell$ (horizontal axis). Hence determine the values of "a" and 'k' (each correct to one decimal place).

(ii) From your answer in (i) above, write down the values of 'a' and then, 'k' each in the form b/c where b and c are integers (i.e. whole numbers).

(iii) From the assumption and your answer in (ii) deduce the form of the equation governing the motion of the simple pendulum.

Experiment No. M – 05

The aim of this experiment is to determine the acceleration, g due to gravity at your local area, and a constant T_c for the ruler provided.

Proceed as follows:-

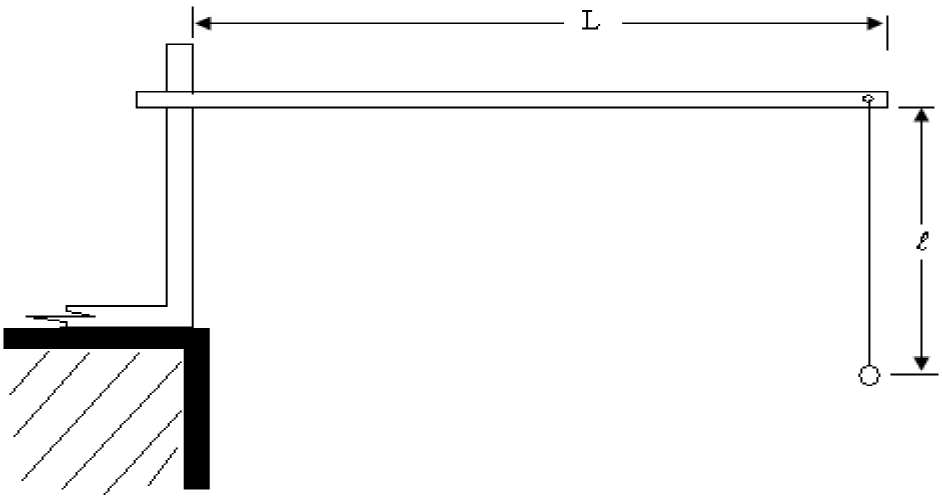


Fig. 5

(a) (i) Using a vice or clamp, fix the metre-rule on one leg of a bench (or stool) as shown in Fig 5. The flat part of the metre-rule should be vertical and the projection L from the fixed end should be 80 cm.

(ii) By means of the string given, suspend the pendulum bob from the hole through the metre-rule as illustrated in Fig. 5.

(b) (i) Starting with ℓ = 80 cm, displace the bob through a small angle along the direction of the length of the ruler and then release it so that it performs small-amplitude oscillations.

Record the time, t for 20 complete oscillations and hence the period, T for one oscillation.

(ii) Without altering L, repeat (b) (i) above for the following values of ℓ

in turn: 70 cm, 60 cm, 50 cm, and 20 cm.

(c) Given that:

$$T^2 = \frac{39.49\ell}{g} + T_C$$

Plot a graph of T^2 against ℓ, and use it to determine:

(i) The acceleration due to gravity, g at your local area, and

(ii) The constant, T_c.

(d) What is the physical significance of the constant T_c in your experiment?

(e) State any sources of errors involved and precautions taken in this experiment.

Experiment No. M - 06

The aim of this experiment is to determine the gravitational field intensity, g using a spiral spring.

Proceed with the experiment as follows:

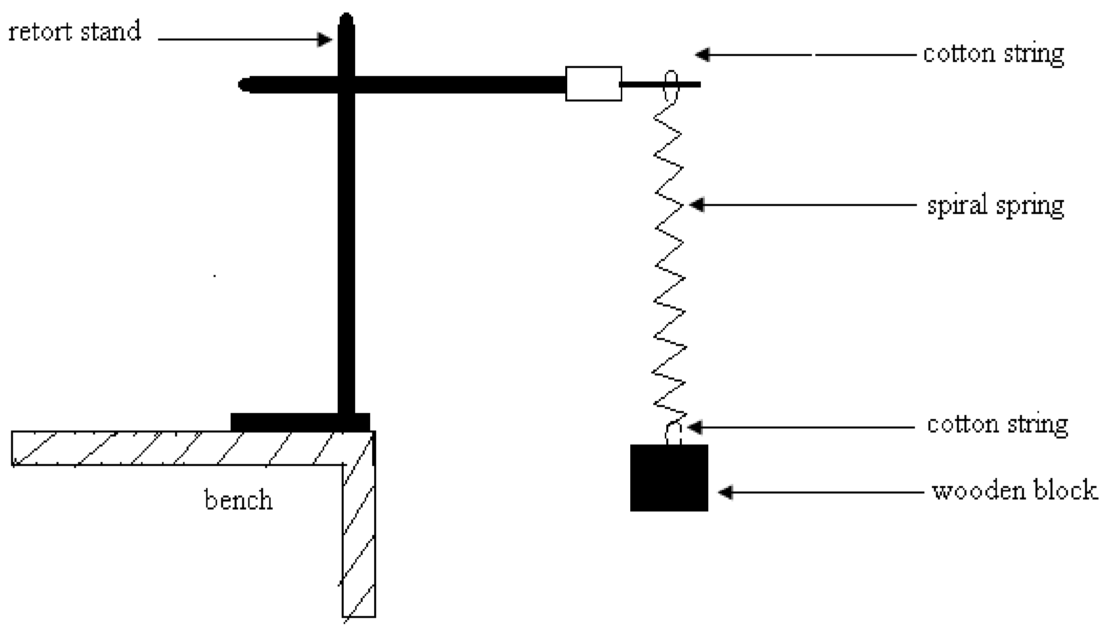


Fig. 6

(a) (i) Set up the apparatus as illustrated in Fig. 6 above so that a 150 g, wooden block hangs vertically from the lower end of the spring.

(ii) Measure the distance h between the floor and the lower end of the spring.

(iii) Now pull the wooden block downwards through a short distance and then release it thus allowing it to perform simple harmonic motion.

(iv) Measure the time t taken by 20 complete oscillations and hence determine the corresponding period, T of the motion.

(v) Calculate the corresponding value of T^2.

(b) Repeat the procedure described in (a) above five times, each time using a different wooden block. The blocks increase in mass by steps of 50 g.

Tabulate your results in a tabular form as shown below:

h (cm)	m (g)	t (s) for 20 oscillations	T (s)	T^2 (s^2)

(i) Plot a graph of h against T^2 (whose values are recorded in (i) and find its gradient.

(ii) Determine the gravitational field intensity, g given that both h and T are related through the equation:

$$h = H - \frac{gT^2}{4\pi^2}$$

Where: H is a constant.

(iii) Determine from the graph a value of H.

(iv) What is the physical significance of H?

Experiment No. M – 07

The aim of this experiment is to determine the spring constant, k and the effective mass, S of the spiral spring provided.

Proceed as follows:

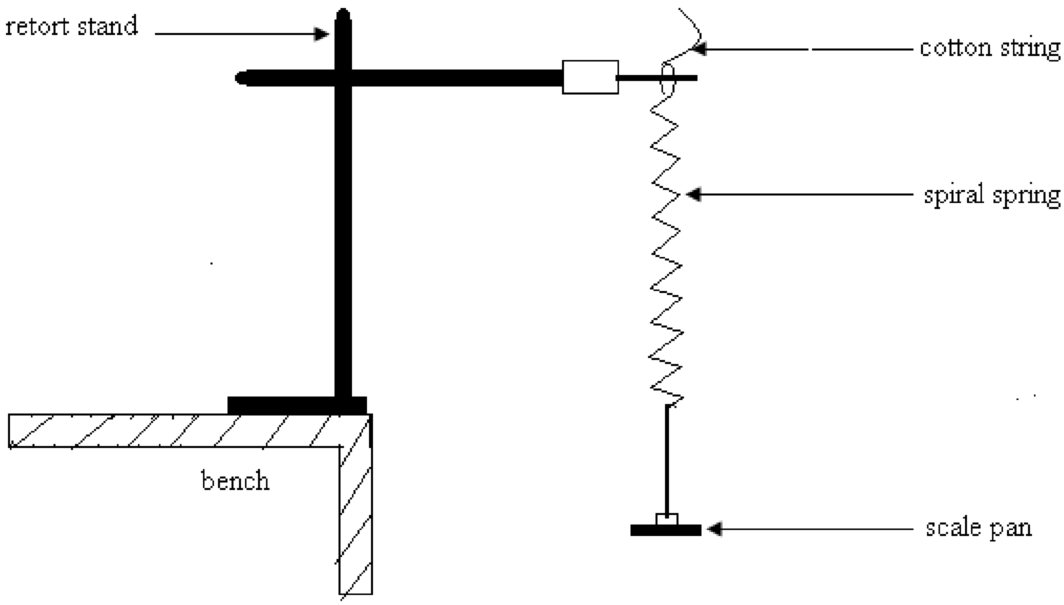


Fig. 7

(a) Suspend the spiral spring with its scale pan from the support A as shown in Fig. 7

(b) Load it with mass, m =100 g. Pull the scale pan slightly below the equilibrium position and release it so that the system executes vertical oscillations of small amplitude.

(c) Record the time for 20 vertical oscillations and determine the period, T.

(d) Repeat this procedure with five other different masses in steps of 50 g.

(e) If the period, T and the spring constant, k are related by an expression of the form:

$$T = \frac{2\pi}{k}\sqrt{(m+S)}$$

(i) Use the given expression to plot a graph of
T^2 against m.

(ii) Use your graph to determine the quantities k and S.

Experiment No. M-08

The aim of this experiment is to determine the earth's gravitational intensity, g and the effective mass s of the spiral spring.

Proceed as follows:

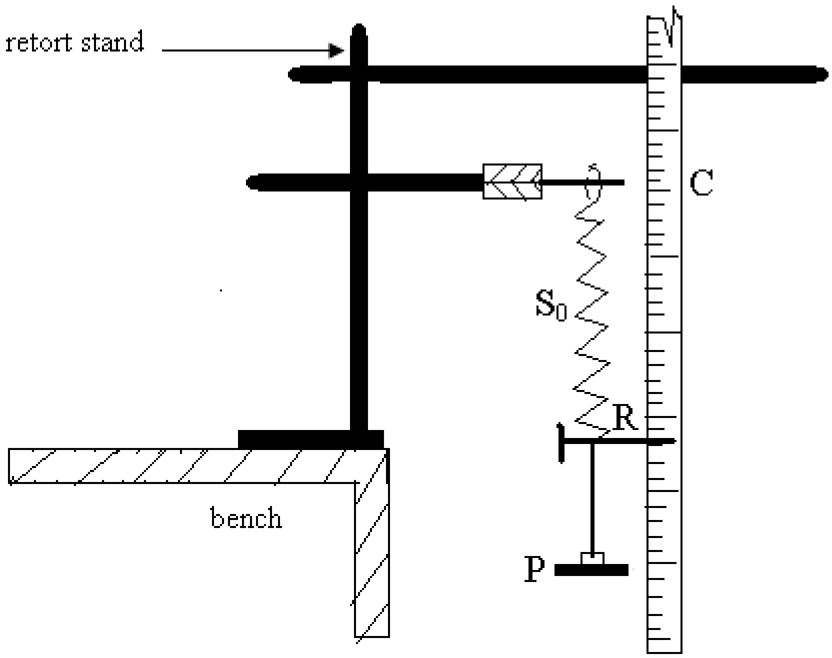


Fig. 8

Suspend the spiral spring, so with its scale pan, P from a rigid support. Attach a light pointer, R to the spring. Set up a fixed vertical metre rule, C besides the spring (Fig. 12). Record the initial reading of the pointer and then add suitable weights, m noting the reading of the pointer each time. Obtain about six readings. Tabulate your results.

If the extension, x of the spring is related to the added weights m by:

$$x = \frac{g}{k}m + \frac{g}{k}S$$

Where k is the elastic constant of the spring, (k=13.0Nm^{-1}) plot a graph of x against m.

Use the given relation and your graph to determine:

(a) A value of g, in Newton's per kilogramme,

(b) A value for S in kilogrammes.

Experiment No. M – 09

The aim of this experiment is to determine the value of the spring constant, k of the helical spring provided.

Proceed as follows:

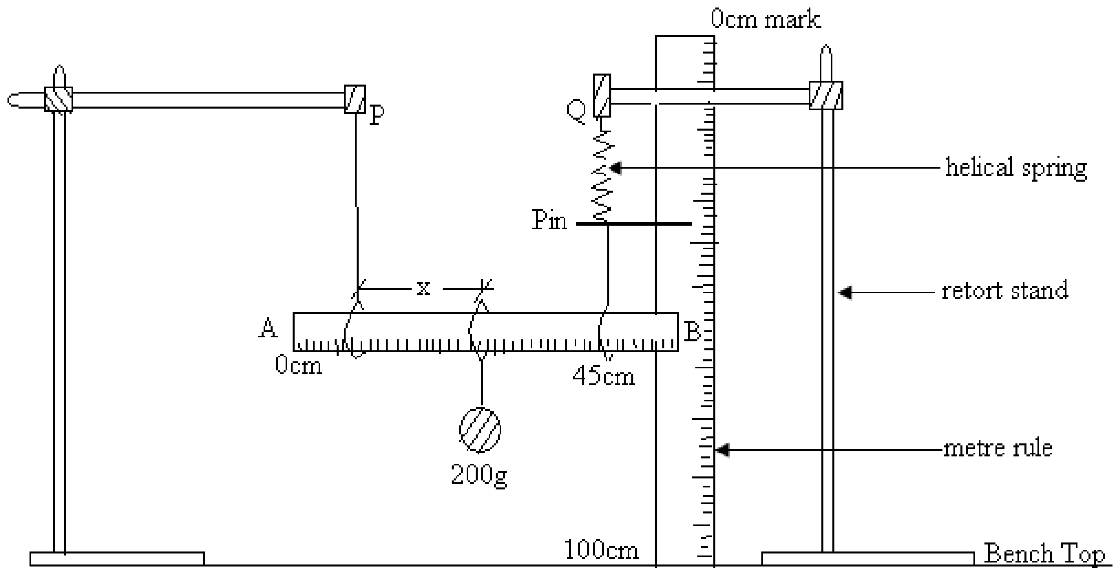


Fig. 9

(a) Set up the apparatus as shown in Fig. 9 without the 200 g mass, where:

(i) Points of suspension P and Q are 40 cm apart,

(ii) Loops 1 and 2 are at 5 cm and 45 cm marks, respectively,

(iii) The pin is attached to the lower end of the helical spring using plasticine,

(iv) A short string connects the lower end of the spring to loop 2.

(v) Loop 1 is attached to P with a long string, and

(vi) The half metre-rule, AB is horizontal such that the edges A and B are at equal heights from the bench. This is achieved by adjusting the length of the string suspended from P.

(b) Measure the height of the pin from the bench. Record it as Y_0.

(c) (i) Suspend the 200 g mass provided, at loop 3. Use a short string.

(ii) Adjust loop 3 so that the 200 g mass hangs at the 40 cm mark. i.e. X=35cm.

(iii) Adjust the string length from P such that AB is horizontal again.

(iv) Record the distance X, between the loops 1 and 3 and measure the corresponding height, Y of the pin from the bench. Hence determine $Y-Y_0$.

(v) Repeat steps (c) (ii), (iii) and (iv) for values of X = 30, 25. 20, 15 and 10 cm, and record the corresponding values of Y and $Y-Y_0$.

(d) Plot a graph of $Y-Y_0$ (y-axis) against X.

(e) (i) Determine the slope, S of the graph and hence

(ii) Calculate the value of k given that:

$$K = \frac{M}{PQ(S)} \quad \textit{Where } M = 200g \textit{ and } PQ = 40cm$$

Experiment No. M – 10

The aim of this experiment is to determine the acceleration, g due to gravity by means of oscillations and extensions of masses on a spiral spring.

Proceed as follows:

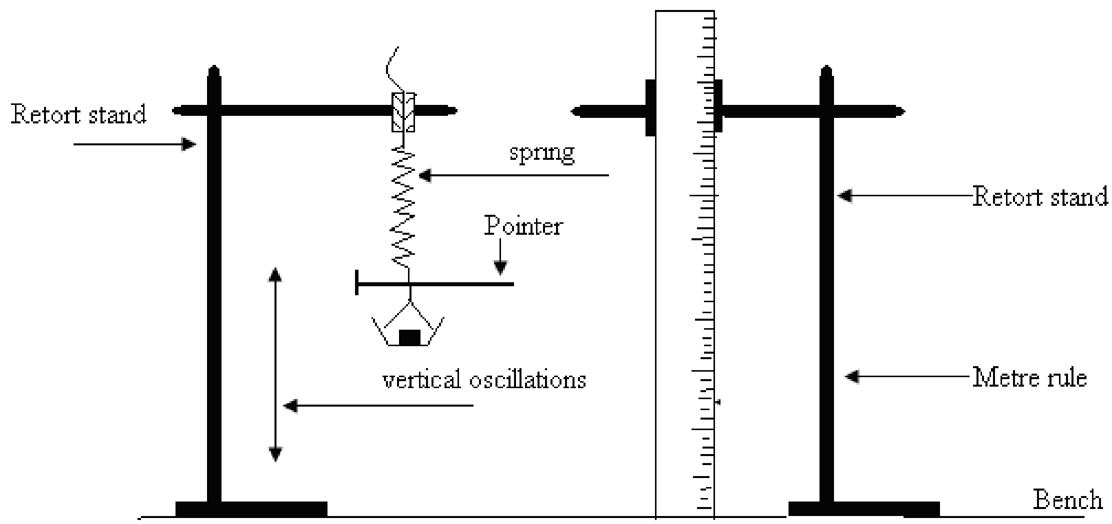


Fig 10(a) Fig 10(b)

(a) Set up the apparatus as shown in Fig. 10 (a). Put on the scale pan a mass, m say, 100 gm and record the time T taken to complete 10 oscillations.
Repeat the procedure for at least four other masses, and for each record the corresponding time T for 10 oscillations. Record the values of m and T.

(b) Move the vertical metre-rule scale and the retort stand (Fig. 10 (b) towards the spring so that the pointer on the spring can be used to record readings on the metre-rule (whose 100 cm-mark should be at the bottom)

(c) With a mass m_1, say 50 gm record the corresponding reading of the pointer as r_1 on a vertical metre-rule. Repeat this procedure with another mass, m_2 and record the corresponding pointer reading r_2.

(d) Plot a graph of T^2 (vertical axis) against mass, m (horizontal axis). From your graph determine the slope, S.

(e) Calculate the acceleration due to gravity, g given that:

$$g = \frac{400\pi^2 (r_1 - r_2)}{S(m_1 - m_2)}$$

(f) State any sources of errors and precautions taken in this experiment.

Experiment No. M - 11

The aim of this experiment is to determine the gravitational intensity, g and the radius of gyration, k of the given block of wood.

Proceed as follows:

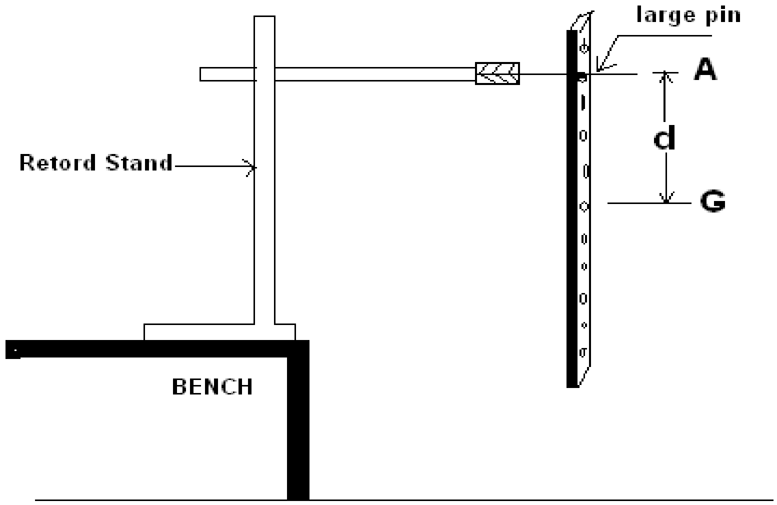


Fig. 11

(a) (i) Set up the apparatus as shown in Fig. 11. The length AG is the distance, d measured from the center of gravity G of the block.
Suspend the block of wood from a hole made at one end.

(ii) With a stop watch, take the time t for 10 small complete oscillations of the block, and hence determine the periodic time, T.

(iii) Repeat the above procedures with 6 other values of d, and in each case, record the corresponding time, t and hence the periodic time T.
Make a table that includes the following headings:-
d, t, T, T^2, T^2d and d^2

(b) Given that the periodic time, T is given by:-

$$T = 2\pi\sqrt{\frac{d^2 + k^2}{gd}}$$

Where k is the radius of gyration of the block of wood about the center of gravity, then:-

(c) Plot a graph of T^2d (y-axis) against d^2. (Both axes of the graph should start at the origin).

(d) Use your graph and the equation above to determine:

(i) The gravitational intensity, g

(ii) (iii) The radius of gyration, k

Experiment No. M – 12

The aim of this experiment is to determine the value of the acceleration, g due to gravity by means of a compound pendulum.

Proceed as follows:

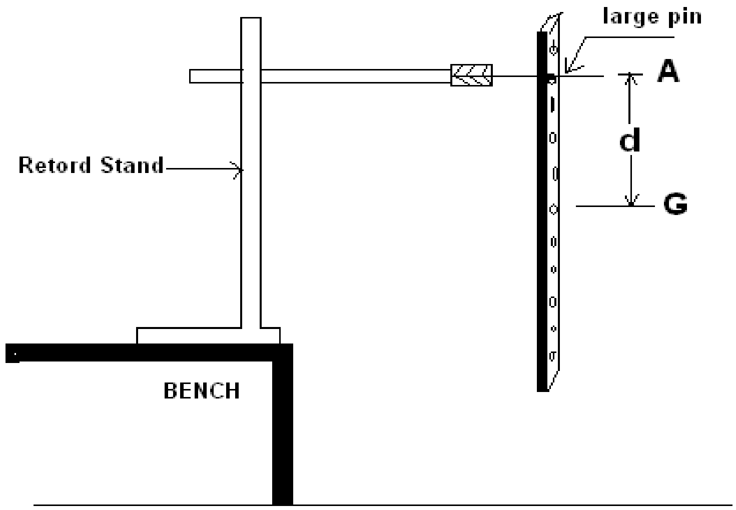


Fig. 12

(a) Set up the apparatus shown in Fig.12, where the wooden bar is suspended by a nail or thick pin through a hole nearest the line marked G. Use the pieces of wood or split corks to hold the nail or thick pin in the clamp. The holes in the wooden bar are drilled at 5 cm intervals.

(b) Displace the bar through a small angle and find the time for 20 complete oscillations. Change the point of suspension, so that the distance, h is 10 cm as measured from G and again find the time for 20 complete oscillations.

Continue with this procedures until you arrive at the hole nearest to the end marked A.

Tabulate your results and include a column for the periodic time, T.

(c) Plot a graph of T against h. The graph is a smooth curve.

(d) Draw a horizontal tangent on the curve and use this to read the coordinates of the minimum point on your graph.

Record the coordinates as (h_m,T_m).

(e) Calculate the value of the acceleration due to gravity, g using the relation:

$$g = \frac{8\pi^2 d_m}{T_m^{\ 2}}$$

Give your answer in SI units.

(f) (i) What would have been the periodic time, t if a hole were drilled at G and used as a point of suspension?

(ii) What would you expect to happen if the bar were displaced through a small angle when suspended through a hole at G?

Experiment No. M-13

The aim of this experiment is to determine the moment of inertia, I of a wooden bar acting as a bifilar pendulum.

Proceed as follows:-

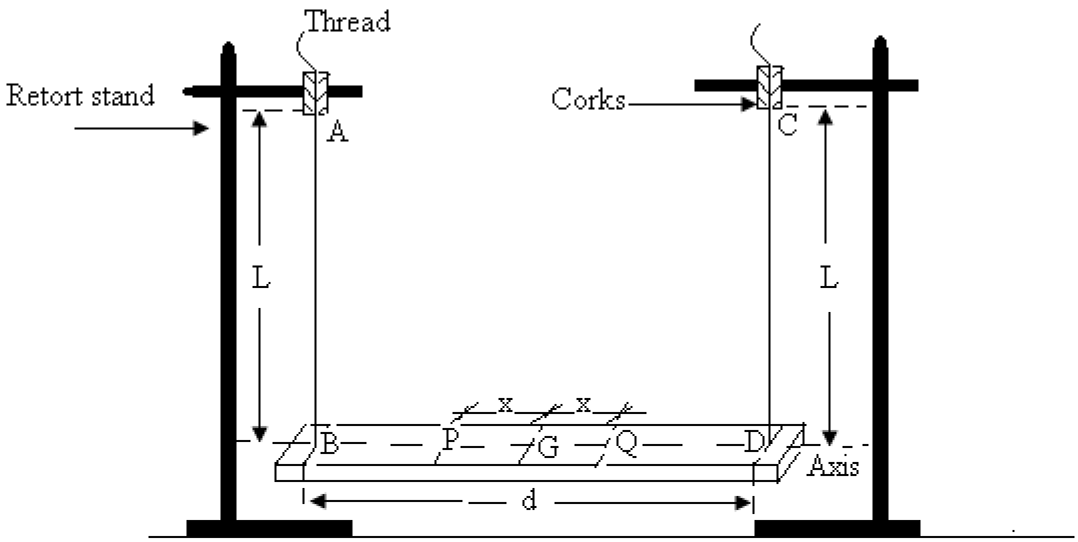


Fig. 13

(a) Locate the center of gravity, G, of the wooden bar by balancing it on a knife edge. Draw the horizontal axis of the bar through G.

(b) Using the pieces of cork and pieces of thread provided, suspend the wooden bar as shown in Fig. 13, such that L = d = AB = CD = 100 cm. Make sure that the threads are vertical and parallel.

(c) Make adjustments so that the wooden bar is perfectly horizontal, and the length, d is symmetrical about G. (i.e. GB = GD).

(d) Measure distance x = 5 cm from each side of G and let the arbitrary distance positions be P and Q as shown in Fig. 13.

(e) Place a 100 g mass at P and another 100 g at Q. Tie them firmly on the wooden bar using the light rubber bands provided. Set the wooden bar oscillating about a vertical axis through G. Record the time for 10 complete oscillations and calculate the corresponding periodic time, T.

(f) Move the 100 g masses along the horizontal axis about the center of mass of the wooden bar by increasing the distance x intervals of 5 cm from each side of G. At each position of the masses, measure the time, t for 10 complete oscillations and determine the corresponding periodic time, T. Tabulate your results.

(g) Plot a graph of T^2 (vertical axis) against x^2 (horizontal axis).

(h) Given that: $T^2 = \frac{16\pi^2 L}{(M+m)gd^2} + \frac{16\pi^2 mLx^2}{(M+m)gd^2}$

Where L and d are expressed in S.I units, g=9.81 ms^{-2} and m = 0.2 kg, use your graph to determine M and I ,What does M represent?

(i) Mention any precaution(s) that you took in performing this experiment.

Experiment No. M – 14

The aim of this experiment is to investigate the relationship concerning the periodic time, T and the separation, X of a bifilar pendulum.

Proceed as follows:

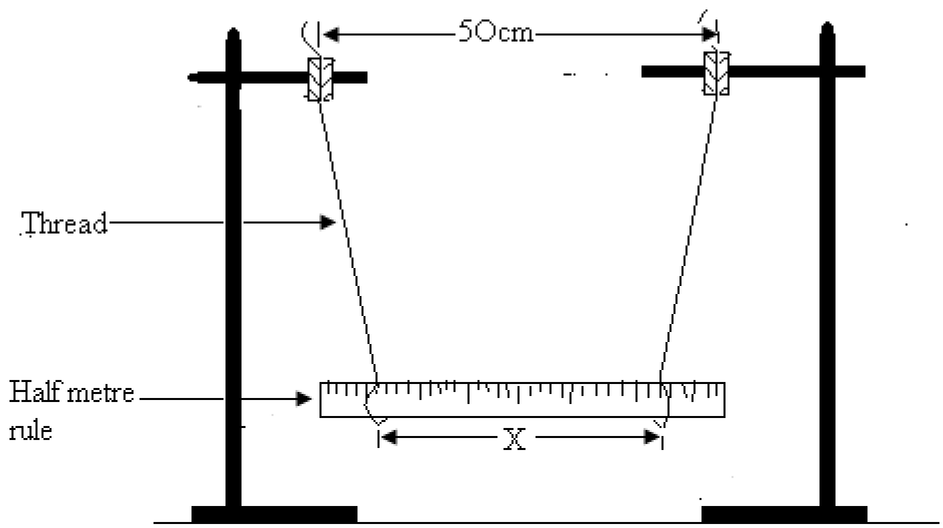


Fig. 14

(a) Suspended the half metre-rule using threads of about 80 cm each from the top of the clamps, which should be about 50 cm apart as shown in Fig.14. The lower ends of the threads are looped to the rule at equal distances from the mid-point of the rule. Record the separation X between the loops.

(b) Set the pendulum (the rule) swinging horizontally by displacing the ends of the rule in the opposite direction through a small angle.

Determine the time, t needed for 10 such oscillations of the pendulum.

(c) Keeping the lengths of the threads fixed and the distance between the clamps unchanged; reduce the separation, X between the loops making sure that the loops are equidistant from the mid-point of the rule.

Repeat the oscillations and determine the time, t for 10 oscillations.

(d) Continue this way so that at least six different observations of t corresponding to X are obtained.

Record your observations neatly, including values of the periodic time, T (time for one oscillation), $\log_{10}T$ and $\log_{10}X$.

(e) Assuming that $T \propto X^{-n}$, we have $T = kX^{-n}$ where k is a constant and n is a fraction.

Taking logarithms, we obtain:

$\text{Log}_{10}T = -n\log_{10}X + \log_{10}k$

(i) Plot a graph of $\log_{10}T$ (vertical axis) against $\log_{10}X$ (start your axes at (0,0)).
Hence determine the values n and k, each correct to one decimal place.

(ii) Rounding the values of k and n, deduce the form of equation concerning the relationship between the periodic time, T and the separation, X.

Experiment No. M – 15

The aim of this experiment is to determine the radius of gyration, k of the square sheet of cardboard provided and the acceleration, g due to gravity.

Proceed as follows:

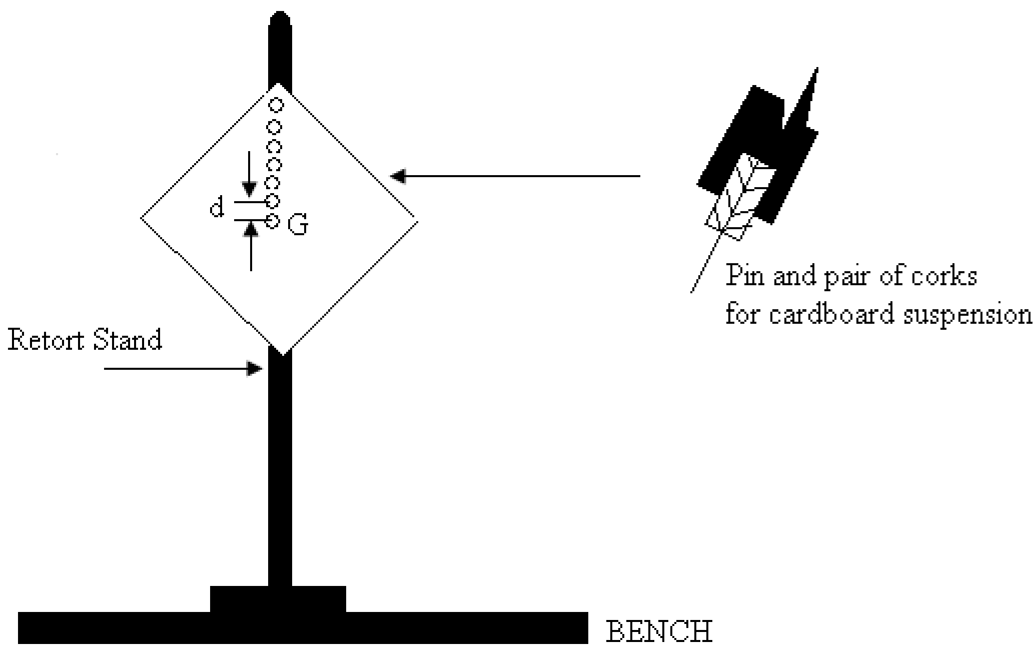


Fig. 15

(a) Using the weighted string (or plumbline), locate the centre of gravity G of the card-board provided. Briefly, with the aid of sketch diagrams, explain how you locate the centre of gravity G.

(b) Draw a line from the centre of gravity G to any of the four corners of the card-board. Measure a distance of 2 cm from G along this line and make a hole at this point. Make five other holes along the line such that all the holes are at distances of 2 cm from each other.

(c) Set up the apparatus as shown in Fig. 15 above.
Suspend the card-board from a hole nearest to the centre of gravity G.
Record the distance, d which is the distance of the hole from G.
Using the stop-watch provided, obtain the time for 10 small complete oscillations of the card-board; and hence calculate the periodic time, T.

Repeat the above procedure with 5 other values of d and obtain the corresponding values of T.

(d) Given that:

$$T = 2\pi\sqrt{\frac{(d^2 + k^2)}{gd}}$$

Plot a graph of T^2d against d^2, with both axes starting at the origin.
Use the graph and the equation to determine:

(i) The radius of gyration, k of the square sheet of card-board.

(ii) The acceleration, g due to gravity

(e) Mention any two random errors and any two systematic errors in this experiment. Explain the precautions necessary for each source of error you mention.

Experiment No. M – 16

The aim of this experiment is to determine the acceleration due to gravity, g and radius of gyration, k of the triangular sheet of card-board provided.

Proceed as follows:

(a) Using the weighted string (or plumbline) provided, locate the center of gravity G of the triangular sheet of card-board. Briefly, with the aid of a sketch diagram, explain how you obtain G.

(b) Draw a line joining G and the farthest angle (Apex) A of the card-board. Measure a distance 2 cm from G, along the line GA. Make a hole at this point. Make five other holes along GA at distances 2 cm from each other.

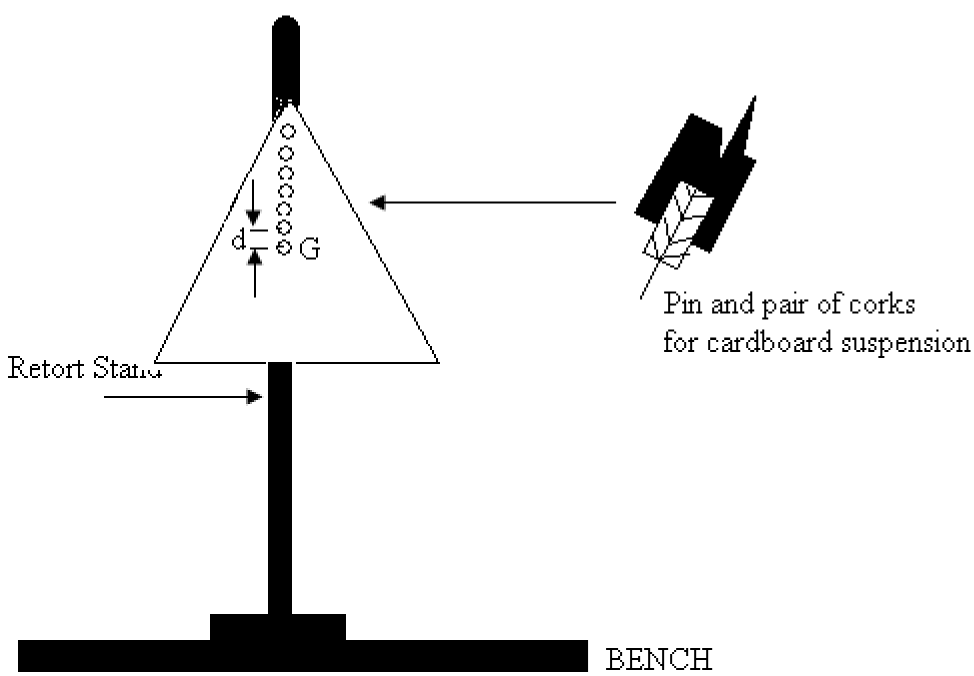


Fig. 16

(c) Set up the apparatus as shown in Fig. 16 above. The pin should be clamped tightly between the two pieces of corks. Suspend the triangular card-board from a hole nearest the center of Gravity G. Record h, which is the distance of the point of suspension from G.

With the stop watch provided, obtain the time, t for 10 small complete oscillations of the card-board and hence determine the periodic time, T.

Repeat the above procedure with five other values of h to obtain corresponding values of t and T.

(d) Plot a graph of h^2 against T^2h, with the origin at (0,0)

Give that: $T^2h = \frac{4\pi^2(k^2 + h^2)}{g}$

Determine, with the aid of your graph,

(i) The acceleration, g, due to gravity, and

(ii) The radius of gyration, k.

Experiment No. M-17

The aim of this experiment is to determine the radius of gyration of a solid spherical ball about an axis through its center.

Proceed as follows:

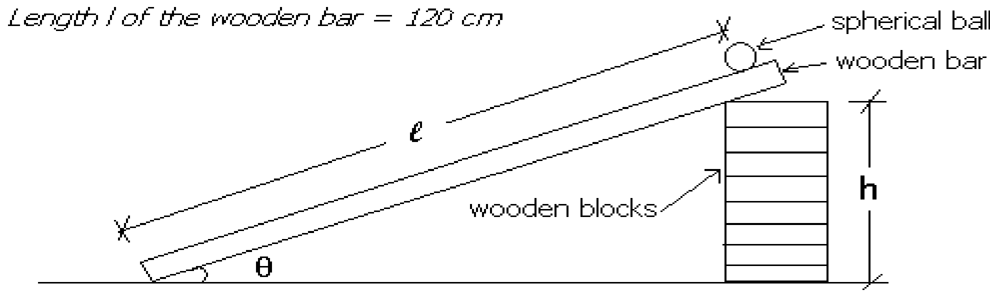


Fig. 17

(a) (i) Place ten (10) wooden blocks of dimensions 5 cm x 3 cm x 0.9 cm one on top of the other so that the total height h is 9 cm.

(ii) Place a wooden bar of length 120 cm so that is makes an inclination as shown in Fig. 17. The wooden bar should have a track made at its center to enable the ball to roll.

(iii) With L = 110 cm, start the ball from rest at M and measure the time, t taken to reach the bottom at N.

Repeat this three times.

(b) Repeat the procedure in (a) above by removing six (6) blocks one at a time, in order to obtain a total of six readings.

Tabulate your results as follows:

Height h(cm)	t_1 (s)	t_2 (s)	t_3 (s)	Average Time, t (s)	t^2 (s^2)	$\text{Sin}\theta$ $=h/L$	Acceleration $A=2L/t^2$(cm/s^2)

(c) Using a micrometer screw gauge, measure the mean diameter, d of the ball and hence calculate its mean radius, r in centimetres.

(d) Plot a graph of acceleration, A against Sinθ (horizontal axis).

(e) Calculate the slope S of your graph.

(f) Calculate the radius of gyration, k of the ball given that:-

$$I = Mr^2 \frac{g - S}{S}$$

Where: M is the mass of the ball and g = 9.81 ms^{-2}

(g) State any two sources of errors in this experiment.

Experiment No. pM – 01

The aim of this experiment is to determine the mass of a loaded metre rule by balancing it on a knife-edge.

Requirements

S/No	ITEM	SPECIFICATIONS	QUANTITY/ STUDENT
1.	Masses	100 g	2
2.	Metre-rule	Millimetre scale	1
3.	Knife edge	wooden	1
4.	Wooden block	20 cm height	1
5.	Cotton string	50 cm -Inelastic	set
6.	Graph paper	Metric type	1

C: Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of **y** against **x** (with both axes starting at the origin).

(d) Determine the slope of the graph.

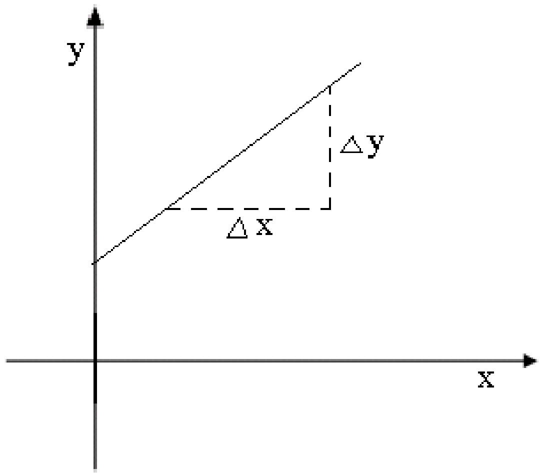
(e) Determine the y-axis intercept.

(f) Use the given relation to calculate the mass of the metre-rule.

(g) Discuss sources of random and systematic (persistent) errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

Graph of y against x



Given:

$$y = \frac{M_a}{2M_a - M_r}x + k$$

This is an equation of a straight line.

It's slope = $\dfrac{M_a}{2M_a - M_r}$

From the graph, slope = $\dfrac{\Delta y}{\Delta x}$

Hence:

$$\frac{M_a}{2M_a - M_r} = \frac{\Delta y}{\Delta x}$$

Proceed as follows:-

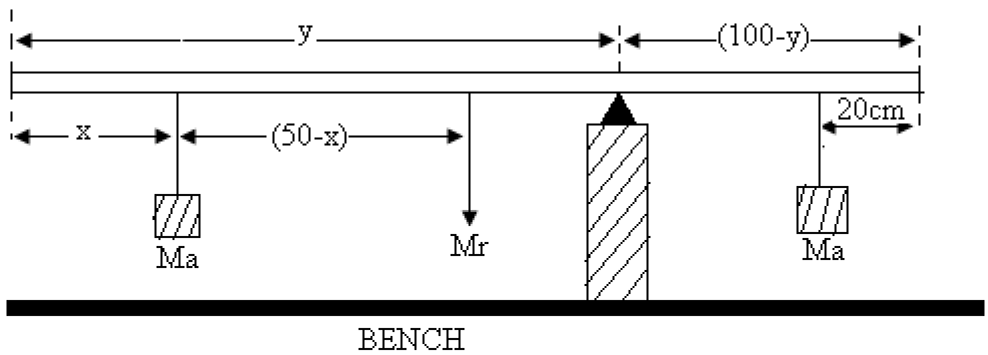


Fig. 18 .

(a) By means of a strong elastic band, securely fix 100 g brass weight underneath the 80 cm mark of a metre-rule, the flat base of the weight being in contact with the rule. Let the mass of the rule be M_r

(b) Attach a small loop of thread to the second 100 g mass, (M_a). Suspend this weight at a distance x from the zero end of the rule. Using the values of x indicated on the table below, balance the rule on the knife-edge and note the distance y of the knife-edge from the zero end of the rule.

(c) Plot the graph of y (vertical axis) against x (horizontal axis).

(d) Find the gradient of the graph and the intercept on the y-axis.

(e) Given that, your graph obeys the equation:

$$y = \frac{M_a}{2M_a - M_r}x + k$$

Deduce the value of M_r

Table of results

x (cm)	15	20	30	40	50	60
y (cm)						

Experiment No. pM-02

In this experiment you are to determine the mass of a given wooden rectangular rod and that of another object labeled 'm'.

Requirements

S/No	ITEM	SPECIFICATIONS	QUANTITY/ STUDENT
1.	Wooden rectangular rod (or a metre-rule)	With a hole at the centre	1
2.	Mass	200 g	
3.	Unknown Mass, **m**	About 100g	1
4.	Metre-rule	Millimetre scale	1
5.	Retort stand with accesories		1
6.	Knife edge	wooden	1
7.	Cotton string	50 cm -Inelastic	set
8.	Graph paper	Metric type	1

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of **x** against **y** (with both axes starting at the origin).

(d) Determine the slope of the graph.

(e) Determine the y-axis intercept.

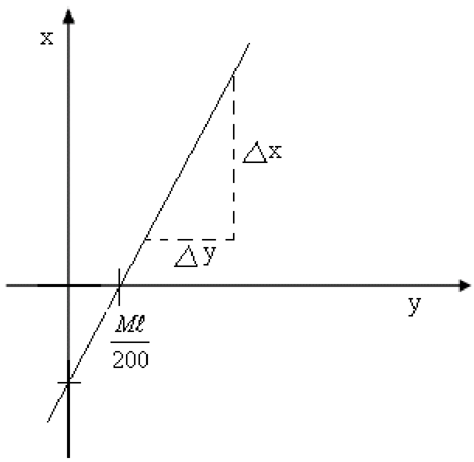
(f) Use the given relation to deduce the mass, M of the wooden rectangular rod.

(g) Use the given relation to deduce the unknown mass, **m**

(h) Discuss sources of random and systematic (persistent) errors related to the experiment and suggest precautions/ways/methods of minimizing them.

D: Theory

Graph of x against y



Given:

$$200y = mx + M\ell$$

Make x the subject of the formula:

$$x = \frac{200y}{m} - \frac{M\ell}{m}$$

Where: m is the mass of the unknown mass and M is the mass of the rectangular rod.

This is an equation of a straight line.

(a) From the equation; it's slope = $\frac{200}{m}$

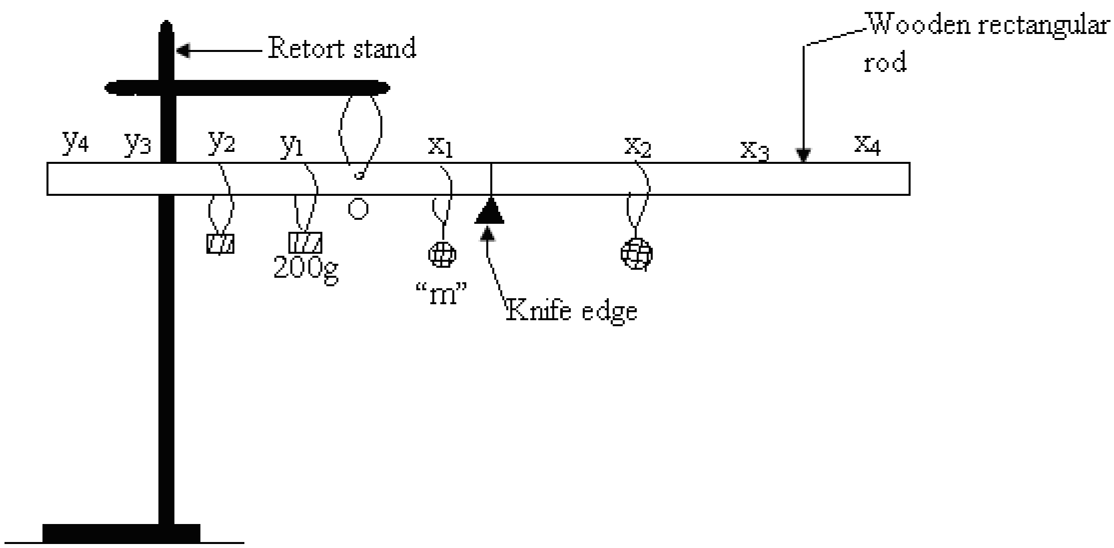
From the graph, slope = $\Delta y/\Delta x$

Hence: m = 200/slope

(b) From the graph, the y-axis intercept, $y_0 = \frac{M\ell}{200}$

Hence: $M = \frac{200y_0}{\ell}$

Proceed as follows:-



(a) Suspend the given wooden rectangular rod to a retort stand with a thread through a hole marked 'O'. (Note that O is not the center of gravity of the rod)

Suspend the given standard mass of 200 g on the shorter arm and the unknown mass labeled 'm' on the longer arm of the rod; mark the position of the thread suspending the known mass with pencil and label it y_1 (see

Fig. 2).

The position of the unknown mass where the rod is balanced in horizontal equilibrium is also marked with pencil along the position of thread and labeled x_1.

(b) Move the position of the known mass about 5cm from the first position away from the pivot 'O' and mark this position y_2. Balance it with the unknown mass 'm' by moving it until the level is again in horizontal equilibrium. This position of the unknown mass is labeled x_2.

(c) Repeat the same procedure while in each step, the known mass is moved through distances of about 5 cm, away from the previous position. Mark these positions as y_3, y_4, y_5, y_6, etc and their corresponding positions x_3, x_4, x_5, x_6, etc of the unknown mass 'm' which sets the level in horizontal equilibrium at each stage.

(d) Remove the wooden rod from the point of suspension and take away the two masses.Measure the distances Ox_1, Ox_2, Ox_3, etc and their corresponding distances Oy_1, Oy_2, Oy_3, etc and tabulate them as x and y values respectively.

(e) Without anything on the wooden rod, balance it on a knife edge to determine point 'C' where it balances freely in horizontal equilibrium. Measure and record distance OC = L.

(f) When the rod is in equilibrium (i.e balanced), it is governed by the equation:

$$200y = mx + M\ell$$

Where: m is the mass of the unknown mass 'm' and M is the mass of the given wooden rectangular rod.

Plot a graph of x against y and use it to determine:-

(i) The values of m and M.

(ii) State any sources of errors in this experiment.

Table of results

y(cm)	5	10	15	20	25	30
x(cm)						

Experiment No. pM-03

The aim of this experiment is to determine the density of wood.

Requirements

S/No	ITEM	SPECIFICATIONS	QUANTITY/ STUDENT
1.	Mass	100 g	1
2.	Wooden Bar	e.g Metre-rule	1
3.	Knife edge	wooden	1
4.	Wooden block	20 cm height	1
5.	Vernier Calipers	Millimetre scale	1
6.	Cotton string	50 cm -Inelastic	set
7.	Graph paper	Metric type	1

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of **Y** against **X**.

(d) Determine the gradient, G of the graph.

(e) Deduce the value of the mass of the wooden bar using the given relation.

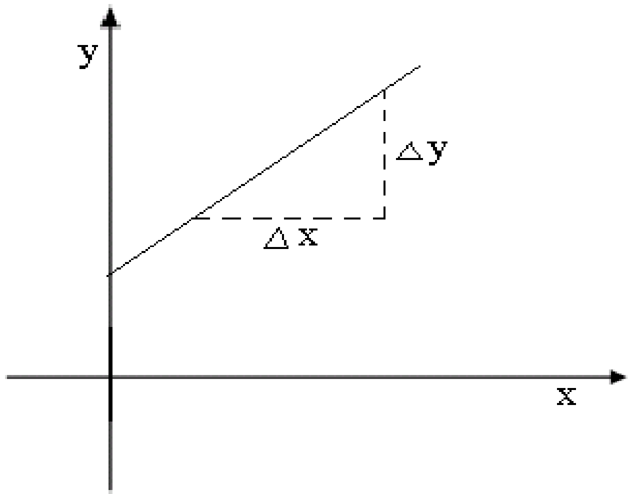
(f) Use the vernier calipers to measure width and thickness of the wooden bar.

(g) Use the given relation to calculate the density of the wooden bar.

(h) Discuss sources of random and systematic (persistent) errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

Graph of Y against X



The center of gravity, C is located as described.

The gradient, G is related to the mass, M of the wooden bar by:

G = $\frac{100}{M}$, from which, M = $\frac{100}{G}$

From the graph, gradient, G = $\frac{\Delta y}{\Delta x}$

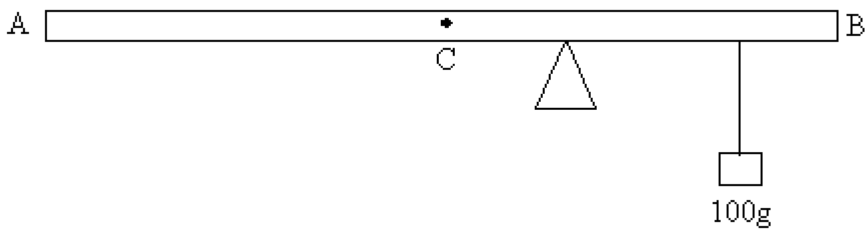
Hence, density of wood, ρ = $\frac{M}{\ell wt}$,

Where: ℓ, w and t are the length, width and thickness of the wooden bar.

w and t are measured using vernier calipers.

Proceed as follows:

You are provided with a wooden bar, a knife edge and a 100 g mass



(a) Locate the center of gravity C of the wooden bar by balancing it freely about the knife-edge.

(b) Suspend the 100 g mass of the wooden bar at 10 cm from C and adjust the position of the knife edge to get a balance, as shown in Fig. 3.

(c) Record the distance of center of gravity C from the knife edge as Y and distance between the knife edge and 100 g mass as X.

(d) Repeat procedures (b) and (c) above, by increasing the distance of the 100 g mass to 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, respectively from the center of gravity C. Tabulate your results

(e) Draw a graph of Y against X and calculate its gradient, G. Calculate the mass, M of the wooden bar, given that:

Gradient, $G = \frac{100}{M}$

(f) Measure the length, L with, w and thickness, t of the wooden bar and hence calculate the density of wood given that:

Density of wood, $\rho = \frac{M}{\ell wt}$

Table of results

X(cm)	10	20	30	40	50	60
Y(cm)						

Experiment No. pM-04

The aim of this experiment is to determine the density of the material of wire W.

Time: 2 Hours

Requirements

S/No	ITEM	SPECIFICATIONS	QUANTITY/ STUDENT
1.	Wire W	Copper SWG 24	100cm
2.	30-cm ruler (Millimetre scale)	With a hole at center	1
3.	Weights	Set of 0.5 – 3.0 g	1
4.	Weight	5 g	1
5.	Retort stand	With accessories	1
6.	Large pin	Optical pin	1
7.	A pair of corks	to grip pin	1
8.	Micrometer screw gauge	Millimetre scale	1
9.	Pan	Made of the inside of a match box	1
10.	Wire	Thin (for loop)	15 cm
11.	Cotton string	50 cm -Inelastic	set
12.	Wire cutter	Prize	1
13.	Graph paper	Metric type	1

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of **y** against **m**.

(d) Determine the slope, S_1 of the graph.

(e) Plot a graph of y against L.

(f) Determine the slope, S_2.

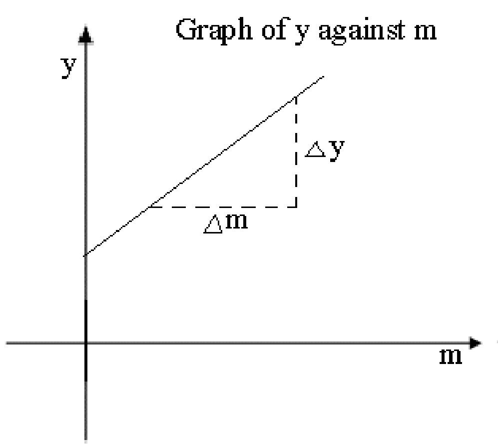
(g) Measure the diameter of wire W using a micrometer screw gauge.

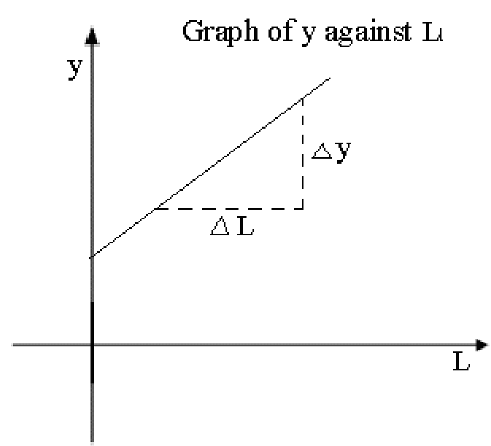
(h) Calculate k, the mass per unit length using the given relation.

(i) Calculate the density of the material of the wire W.

(j) Discuss sources of random and systematic (persistent) errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory





From the graph of y against m:

Slope, $S_1 = \frac{\Delta y}{\Delta m}$

From the graph of y against L:

Slope, $S_2 = \dfrac{\Delta y}{\Delta L}$

Hence: $k = \dfrac{S_2}{S_1}$ (units: gcm^{-1})

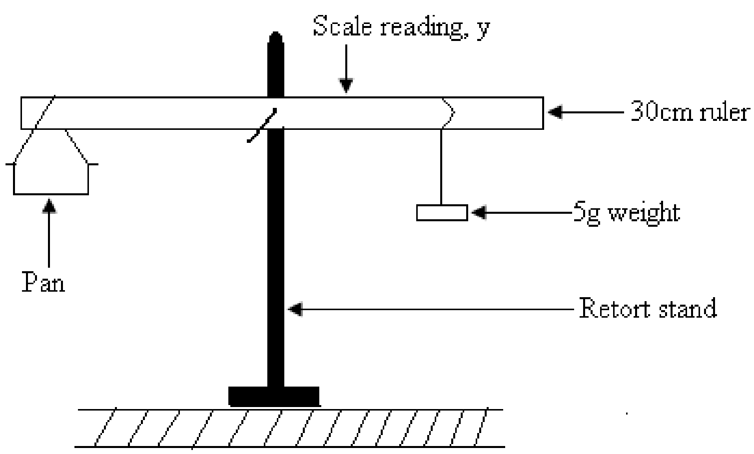
Since, density, $\rho = \dfrac{mass, m}{volume, V}$,where,volume, V = cross-sectional area, A x length, L

Area, $A = \dfrac{\pi d^2}{4}$ where,d is diameter of wire W.

Then, $\rho = \dfrac{4m}{\pi d^2 L}$ but, $\dfrac{m}{L}$ = k, the mass per unit length.

Hence, $\rho = \dfrac{4k}{\pi d^2}$

Proceed as follows



:

You are provided with a 30 cm ruler with a hole in the middle. Hang the ruler with the pin provided.

Hang the weighing pan, made of the inside of a match box, near the zero cm mark.

Balance this by hanging a 5 g mass in the loop of wire attached to the ruler.

Use the thread provided. Slide the loop until the ruler is balanced. Note the scale reading y where the loop of wire rests. This reading corresponds to zero mass in the pan. Denote it by y_o.

(a) Add a ½ g mass in the pan and move the 5 g weight until the ruler is balanced. Observe the new value of y and record it. Continue adding weights to the pan, ½ g at a time, and record the values of y corresponding to the mass, m in the pan. Plot a graph of y (y-axis) against m and record its slope S_1.

(b) Again starting with y_o, add to the weighing pan about 20 cm of the wire labeled W. Again balance the ruler and determine the scale reading y. Repeat this for at least 4 more values of L (where L is the total length of the wire in the pan) and record the corresponding values of y. Plot a graph of y(y-axis) against L and record the slope S_2.

(c) Measure the diameter of the wire W and calculate its cross sectional area, A.

(d) If the mass per unit length, k of the wire W is given by:

$$K = \frac{S_2}{S_1}$$

Determine K and hence calculate the density of the material of the material of the wire W.

Table of results

Table 1

m (g)	0.5	1.0	1.5	2.0	2.5	3.0
y (cm)						

Table 2

L (cm	20	40	60	80	100	20
y (cm)						

Experiment No. pM – 05

The aim of this experiment is to determine the density of the material of which the given test tube is made.

Proceed as follows:

(a) Find the average circumference, A_c of the test tube labeled A by wrapping 10 turns of the given wire labeled WW in a closely round spiral at three different places on the test tube.

  (i) Determine the radius, WW_r of the wire using the micrometer screw gauge provided.

  (ii) Find the average length, WW_1 of one turn of the spiral.

  (iii) Calculate the circumference, A_c of the test tube using the formula:

$$A_c = WW_1 - 6.3WW_r$$

  (iv) Calculate the mean external area of cross-section, A_e of the test tube given by the formula:

$$A_e = \frac{7.96A_c^{\ 2}}{100}$$

(b) Determine the internal area of cross-section, A_i of the test-tube by volumetric method as follows:

  (i) Clamp the test-tube vertically with its base resting on a flat surface.

  (ii) Fill the given measuring cylinder with liquid, LL to the 50 cm^3 mark.

(iii) Pour about 2.0 cm^3 of liquid LL from the measuring cylinder into the test tube A.

(iv) Record the reading, V of the liquid LL from the measuring cylinder and the height, h of the liquid LL level above the base of the test tube.

Repeat the experiment, each time adding about 2.0 cm^3 more of liquid LL to the test tube, without pouring out the initial liquid, to obtain six (6) more readings.

1. Tabulate h, V and W, where W is the volume of liquid LL poured into the test-tube.

2. Plot a graph of W against h.

3. Determine the gradient (slope), A_i (of the line) which is the internal area of cross-section of the test tube.

(c) Measure the length, L of the test tube, A and calculate the volume VV of the material of which the test tube is made from the formula:

$$VV = L(A_e - A_i).$$

(d) Weigh test-tube A to find its mass, m in grams.

Hence determine the density of the material of which the test tube is made.

Experiment No. pM-06

In this experiment you are required to determine the density of liquid L_2 relative to that of liquid L_1 and the mass, M of the metre-rule provided.

Proceed as follows:

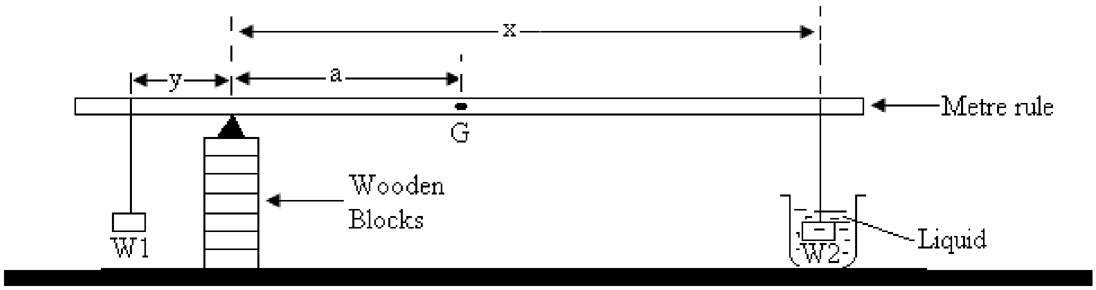


Fig. 23

(a) Locate and mark the center of gravity G of the metre rule.

(b) Set up the apparatus as illustrated in Fig. 6, where: a =50 cm, W_1 and W_2 are brass weights of mass 50 g and 20 g, respectively.

(c) With W_2 totally immersed in liquid L_1 and x = 10 cm, balance the metre-rule on the knife edge by adjusting the position of W_1. Read and record the distance, y. Repeat the procedure for x = 20 cm, 30 cm, 40 cm, 50 cm and 54 cm. Tabulate the values of x and y.

(d) Replace liquid L_1 by liquid L_2 and then repeat the procedure outlined in (c) above.

(e) Plot a graph of y against x using the table obtained in (c).

   (i) Read and record C_1 the value of y when x = 0. Calculate $10C_1$, which is equal to the mass of the metre-rule.

   (ii) Find the slope, S_1 of the graph.

   (iii) Find the value of λ_1 given that $\lambda_1 = 0.4 - S_1$

(f) Plot a graph of y against x using the table obtained in (d).

- (i) Find the slope S_2 of this graph.
- (ii) Find the value of λ_2 given that $\lambda_2 = 0.4 - S_2$.
- (iii) Evaluate the ratio λ_2/λ_1 which is equal to the density of liquid L_2 relative to that of liquid L_1.

(g) Discuss sources of errors in this experiment.

Experiment No. pM – 07

The aim of this experiment is to determine the density of motor oil L_0 relative to liquid L_1 and the density of the material of the metre-rule provided.

Proceed as follows:

(a) Locate and mark the center of gravity G of the metre-rule. Measure the width and thickness of the rule (use vernier calipers).

(b) Assemble the apparatus as shown in Fig. 7 below.

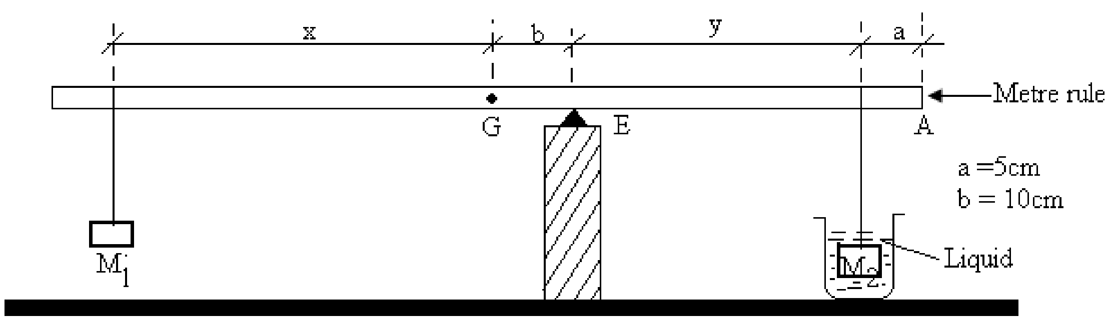


Fig. 24

(c) Fix the knife edge E, 10 cm from G towards A and the 100 g (M_1) 5 cm from the end marked A.

(d) With M_1 totally immersed in liquid L_1, adjust the position of the 50 g (M_2) until the rule is balanced horizontally. Record the positions of M_1, M_2, and distances x and y.

(e) Move M_1 five centimeters towards E and repeat the experiment. Record the new positions of M_1 and M_2 and the distances x and y as in (d).

(f) Do this experiment, each time moving M_1 by 5 cm towards E to obtain total of five sets of readings. Tabulate your results.

(g) Replace liquid L_1 by the motor oil L_0 and repeat the procedure outlined in (d), (e), and (f) above.

(h) Plot graphs of y against x for liquid L_1 and motor oil L_0 (use different graph papers).

(i) Find the slope S_1 for liquid L_1

(ii) Find the slope S_0 for motor oil L_0

(iii) Read the y – intercepts C_1 and C_0 for the two graphs.

(i) Find the value U_1 and U_o given that:

$$U_0 = M_1 - \frac{M_2}{S_0}$$

$$U_1 = M_1 - \frac{M_2}{S_1}$$

(j) Calculate the density of motor oil L_0 relative to liquid L_1 , given that:

$$RD = \frac{U_0}{U_1}$$

(k) Determine the mass M of the metre rule given that:-

$$C_1 = b\frac{M + M_2}{M_1 - U_1} \quad or \quad C_0 = b\frac{M + M_2}{M_1 - U_0}$$

Hence determine the density of the wooden material of the rule.

Experiment No. pM-08

The aim of this experiment is to determine the relative density of the liquid provided.

Proceed as follows:

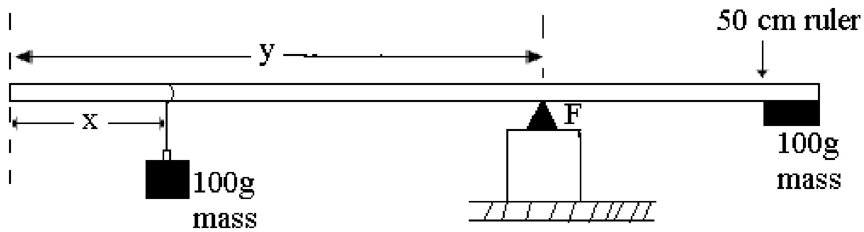


Fig. 25

First determine the mass M_r of the rule as follows:
Hang the 100 g mass at the 4 cm mark and balance the ruler by adjusting its position of support on the knife-edge F. Measure and record the value of X and Y as shown in Fig. 8.
Let these values be X_1 and Y_1 respectively. Next hang the 100 g mass at the 20 cm mark of the ruler, and again balance the ruler by adjusting its position of support on the knife edge. Measure and record the new values of X and Y.
Let these values be X_2 and Y_2, respectively
Calculate M_r from the equation:

$$M_r = \frac{100[(X_2 - X_2) - 2(Y_1 - Y_2)]}{(Y_2 - Y_1)}$$

(a) With the 100 g mass at the 4 cm mark of the ruler and submerged fully in water contained in the beaker provided, balance the ruler again and determine the corresponding value of Y. Repeat this procedure taking 5 readings of X and Y for values of X varying between 4 and 20 cm. Plot a graph of Y(y-axis) against X. Determine its slope S_1

(b) Repeat the procedure in(a), but this time submerging the 100 g mass in the liquid L. Record 5 readings of X and Y and plot a graph of Y against X on a separate graph. Determine the slope S_2 of the graph.

(c) If M_w and M_L represent the apparent mass of the 100 g mass in water and in L, respectively,

$$M_W = \frac{(M_r + 100)}{1 - S_1} S_1 \quad \text{and} \quad M_L = \frac{(M_r + 100)}{1 - S_2} S_2$$

Using the above equations, determine:

(i) M_w and M_L and thus

(ii) The relative density of the liquid L

Experiment No. pM-09

The aim of this experiment is to determine the relative density of the motor oil provided.

Proceed as follows:

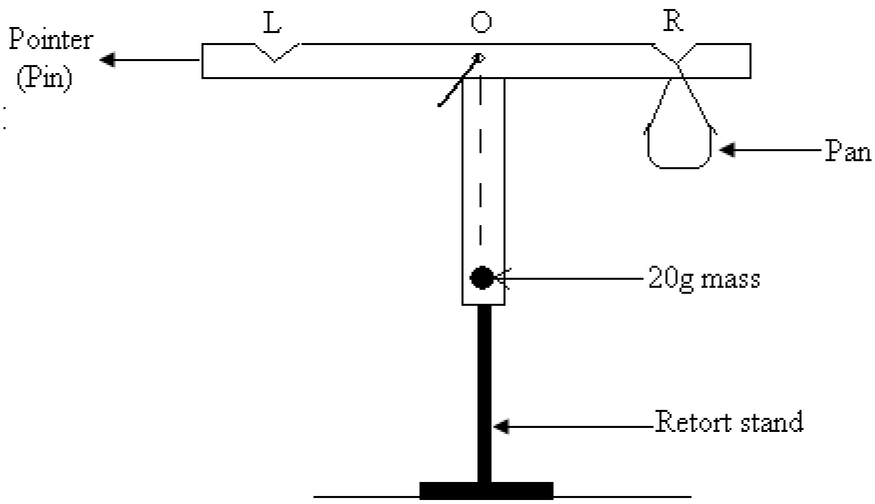


Fig. 26 (a)

(a) Hang the wooden T provided with a pin though the hole at 0.
On the lower end of the T fix a 20 g mass using a little plasticine.
On the left side L attach a large pin with some plasticine.
This pin acts as a pointer.
With the help of plasticine, balance the T so that its arm LR is approximately horizontal.

(b) First determine the height, h_0 of the pointer from the table. Adding two grammes to the pan, at a time, determine the corresponding heights, H of the pointer from the table.
Record your observations and plot a graph of $(H - h_0)$ against the mass, m

in the pan.

(Note that the graph is not a straight line).

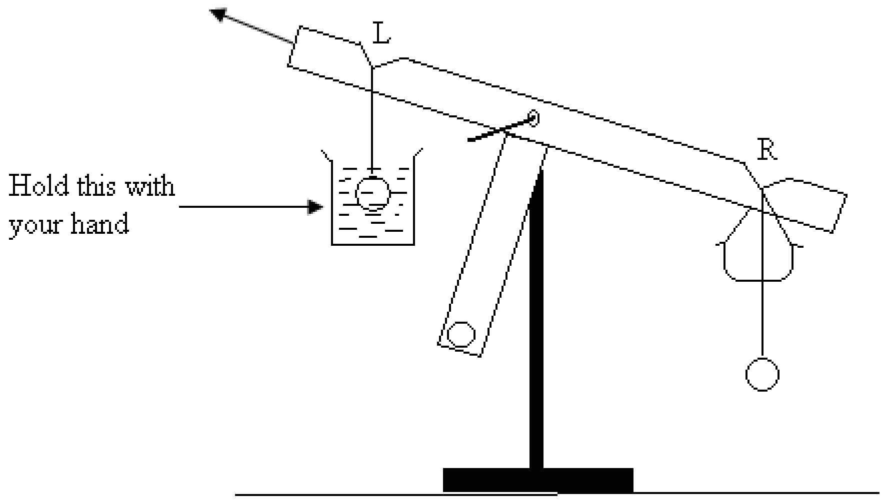


Fig. 26 (b)

(c) Take two 100 g masses and hang them with short pieces of thread on each side.
Adding plasticine, bring LR to an approximately horizontal position.
Measure again the new height h_0.
Now fill the beaker provided with water and raise the beaker so that the left hand mass is fully submerged in water.
Measure the new height H_w of the pointer.
From the graph determine the corresponding up thrust.

(d) Repeat the procedure in (c), but this time, submerge the left hand 100 g mass in the beaker containing the motor oil.
Measure the corresponding new height H_0.
From the graph determine the corresponding up thrust.

(e) From your observation in (c) and (d), determine the relative density of the motor oil under investigation. Give the theory by which you determine the answer.

Physics Practical

Experiment No. pM-10

The aim of this experiment is to determine the density of material of wire labeled X.

Proceed as follows:-

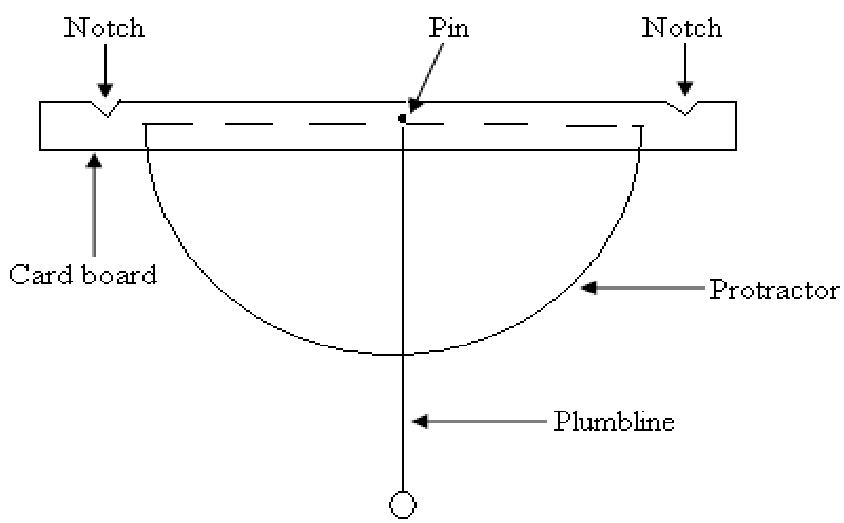


Fig 27

(a) (i) Determine the mass per metre of the wire labeled "A".

The supervisor will give you the value of the mass of the wire.

(ii) Cut a pair of notches on the cardboard strip and then attach it to the protractor with sellotape. The notches should be cut so that their tips are 10.0 cm from the pivot and on the same straight line passing through the pivot. Make a simple balance as shown in Fig. 27.

The balance should be adjusted so that the 0^o- 0^o line is horizontal. A small pellet of plasticine may be used for this purpose.

(b) Suspend the wire A on one of the notches and record the deflection θ_A of the balance it produces. Cut off a small length of the wire A and measure the length, L of the remaining portion. As before, suspend the length, L on the same notch and record the deflection.

Repeat as necessary. Plot a graph of the deflection, θ_A (vertical axis) against the length, L (Horizontal axis). The graph is a slight curve.

(c) Now cut the wire labeled X into two unequal but measured lengths L_{x1} and L_{x2}.

Observe and record the deflection θ_x produced when L_{x1} and L_{x2} are suspended in turn from the same notch.

(d) From your data evaluate the mass per metre of the wire X.

Make any other necessary measurements on X and hence determine the density of the material of X.

For the purpose of calculations you may assume the deflection of the balance is

proportional to the mass suspended on it.

Experiment No. pM – 11

The aim of this experiment is to determine the Young's modulus of the material of the metre rule provided.

Proceed as follows:-

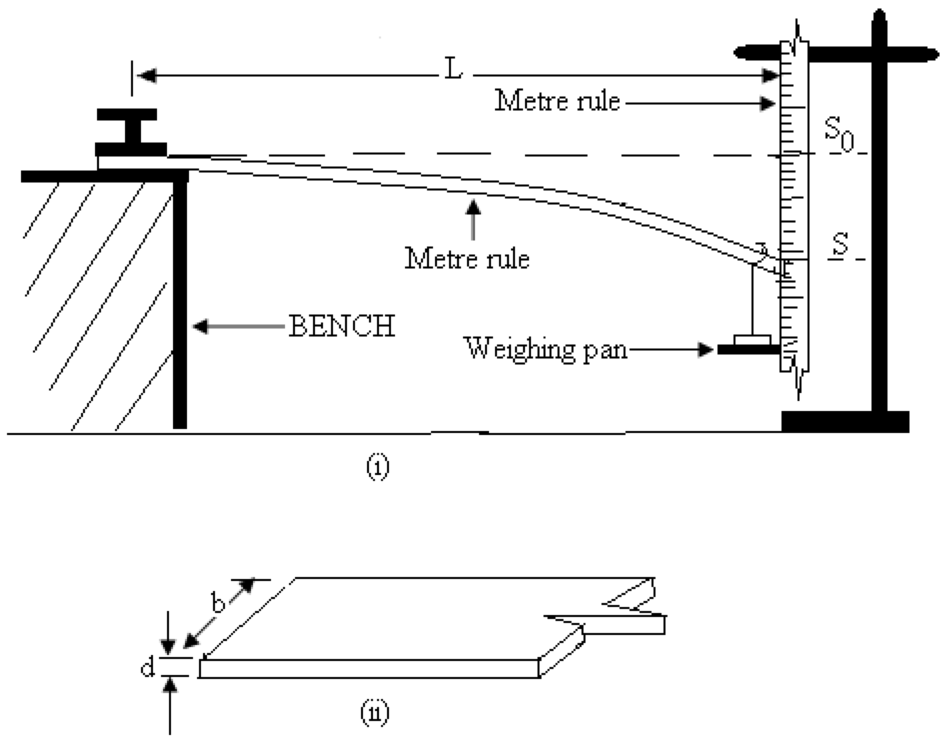


Fig. 28

(a) Clamp the metre-rule firmly with a distance L of about 90 cm. Overhanging from the bench. The free end is such that it acts as a pointer along the metre-rule clamped in the vertical position. Note the scale reading, S_0 on the vertical metre-rule when the horizontal metre-rule is not loaded.

(b) Fasten the weighing pan at the free end of the horizontal metre- rule with a piece of strong thread.

Add on to the weighing pan a mass, m of 20 g and record the scale reading S on the vertical metre- rule.

Calculate the depression, $D = S - S_0$, corresponding to the added mass.

Keeping the length L constant, add a series of masses from say 20 g to 150 g in steps of 10 g or 20 g.

With each added mass, record S and calculate D.
(see Fig. 11 (i))

(c) Use vernier calipers to measure the breadth, b and thickness, d of the horizontal metre-rule. (see Fig. 11 (ii)).

(d) Plot a graph of depression, D against the added masses,m.
From your graph, determine:

(i) The slope.

(ii) Calculate the Young's modulus, Y of the material of the metre-rule by using the formula:

$$Y = \frac{4gL^3}{bd^3(slope)}$$

Where $g = 9.8\ ms^{-2}$

Experiment No. pM – 12

You are to find Young's modulus of elasticity for wood by measuring the depression of a loaded half metre-rule.

Proceed as follows:-

Clamp the two half metre-rules firmly between the wooden blocks with a length L = 450 mm projecting as shown in Fig. 12

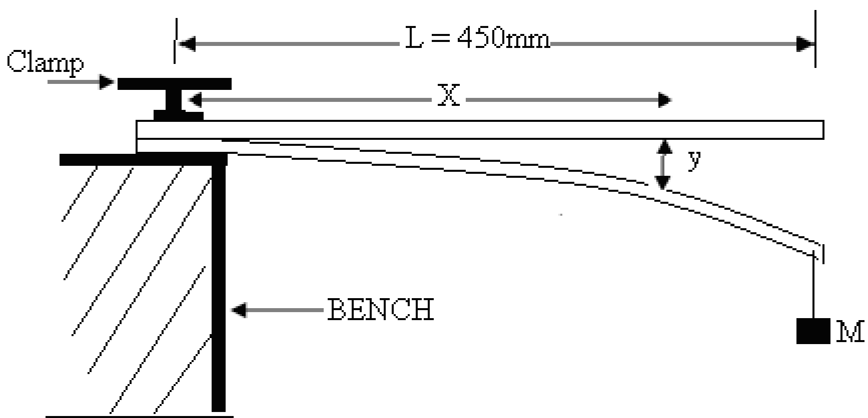


Fig. 29

Hang the mass, M over the end of the lower rule and measure the depression, y for different distances, x from the support.

Dismantle the apparatus and measure the width, a and the thickness, b of the half-metre rule which had been loaded.

(i) Plot a graph of y against x.

(ii) Find the value, $S = \frac{\partial y}{\partial x} \quad when \quad x = 300mm$

(iii) Calculate a value for the Young modulus, E of the wood, given that:

$$E = \frac{16MgL^2}{3ab^3S}$$

Where: $g = 9.8\ ms^{-2}$

Experiment No. pM-13

The aim of this experiment is to determine the Young's Modulus, E of elasticity of a cantilever.

Proceed as follows:-

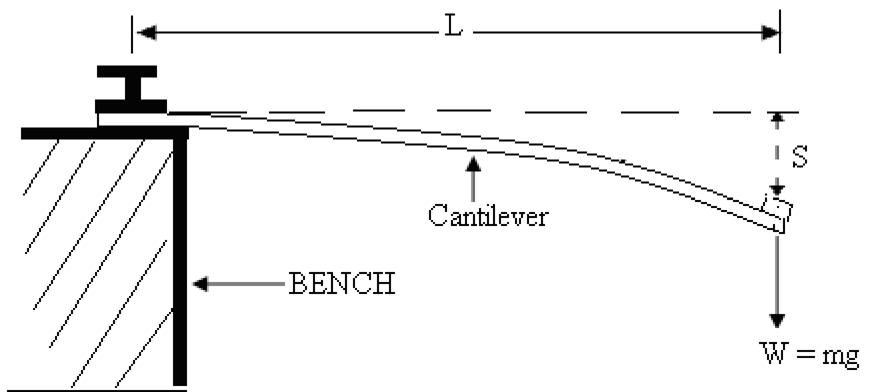


Fig. 30

Clamp the cantilever beam on a bench using a G-clamp as shown. Load the beam using the 200 g mass and fasten it rigidly at distance, L = 90 cm from the G-clamp.
Use the cello tape or any other means available for this purpose.
The load is affixed to the cantilever such as to cause but a small depression, S when the beam is at rest. Depress the load slightly so that it starts to vibrate.
Record the time for 20 complete oscillations and hence the period, T for one complete oscillation.
Repeat the above procedure for at least five more values of L, each time decreasing by 5 cm, changing the position of the 200 g mass; the clamped end should not be disturbed.
For each value of L determine the time, and the period, T.
Neatly tabulate your results.

If the period of oscillation, T is related to the length, L by:

$$T = 4\pi\sqrt{\frac{ML^3}{Ebd^3}}$$

Where M is the load, b and d are the width and thickness respectively; then plot a graph of T^2 against L^3.

Use your graph to calculate:

(i) The slope of the resulting graph, and hence

(ii) The Young's Modulus, E.

Experiment No. pM – 14

Use the experimental procedure outlined below to determine the viscosity, η of liquid L.

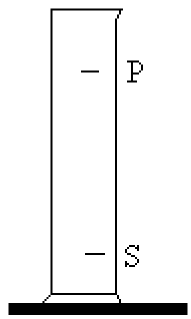


Fig. 31

You are provided with a measuring cylinder, glycerine, stop-watch, small steel ball bearings of varying diameters, micrometer screw-gauge, metre rule, hydrometer, and thermometer (0 – 100^{o}C).

Proceed as follows:

Measure the diameter of each steel ball bearing and also measure the density and temperature of glycerine.

Fix a mark, P with a sticky label well below the top of the liquid and fix a second mark, Q near the bottom of the cylinder.

Measure the distance, S between P and Q.

Fill the measuring cylinder with glycerine, and then drop in the largest steel ball bearing.

Record the time, t of fall of the steel ball bearing between the marks P and Q.

Do the same with the other steel ball bearings and tabulate your results as indicated below:

Diameter of	r^2	S	t	v

balls (cm)	(cm^2)	(cm)	(s)	(cms^{-1})

Where: r is the radius of the steel balls and v is velocity.

(a) Plot a graph of r^2 against v and find its slope.

(b) Find the viscosity, η of the liquid, given that:-

$$\eta = \frac{2g(\rho_1 - \rho_2)r^2}{9v}$$

Where:

$$\frac{r}{v} = slope$$

Density of steel, $\rho_1 = 7.7 \times 10^3\ kgm^{-3}$

Density of glycerine, $\rho_2 = 1.26 \times 10^3\ kgm^{-3}$

$g = 9.8ms^{-2}$

(c) What is the temperature of glycerine?

Experiment No. pM – 15

The aim of this experiment is to investigate the flow of water in a constricted vertical tube.

Proceed as follows:-

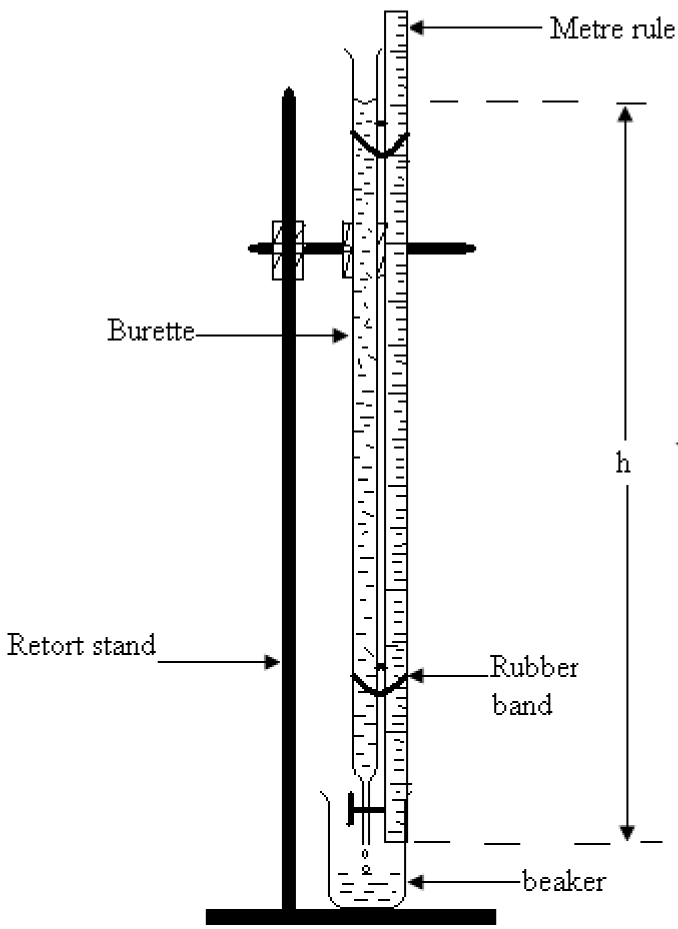


Fig. 32

(a) (i) Fix the burette on the retort stand so that it maintains an upright vertical position.

(ii) Fix the metre-rule beside the burette using rubber bands so that the zero end of the rule is on the same level as the ejecting end 0 of the burette.

(iii) Fill the burette with water to within 1.0 cm of the top.

(iv) Using the burette tap or clip adjust the water level L to a readable mark to enable the water head (height) h be recorded easily. Record the initial value of water head h_0.

(v) Allow the water to run out of the burette and simultaneously start the stop-watch.

(vi) Record the water head h_1 at 15 seconds intervals in a tabular form (shown below) to obtain at least 10 readings of height h_1 and time t.

(vii) Repeat the experiment making sure that the same initial level L is maintained when the timing starts. Record the water head h_2 against time t.

(viii) Obtain a column of average values of water head:

$$h = \frac{(h_1 - h_2)}{2}$$

Time, t (s)	h_1 (cm)	h_2 (cm)	Water head $h = \frac{(h_1 - h_2)}{2}$ (cm)

(b) (i) Plot a graph of water head, h(cm) as ordinates against Time, t (s) as abscissae.

(ii) On the graph locate points P_0, P_1 and P_2 corresponding to ordinates

$$h_o, \frac{h_o}{2}, \frac{h_o}{4}$$

Extract corresponding values of time T_0, T_1 and T_2.

(iii) Draw tangents to the curve at:

$(T_O, h_O), (T_1, \frac{h_o}{2})$ *and* $(T_2, \frac{h_o}{4})$

(iv) Determine the values of slope S_0, S_1 and S_2 corresponding to the three tangents drawn in (b) (iii) above.

These values represent the rate of flow decay $\frac{dh}{dt}$

(c) (i) Plot a graph of values of $\frac{dh}{dt}$ against h.

(ii) Determine the gradient G of this graph.

(iii) Deduce the physical meaning of k = - G.

(iv) Write the relationship existing between dh/dt, h and k.

(v) What physical process does the curve in the first graph define?

(vi) What law governs the flow of water in a constricted vertical tube?

(vii) Suggest one other physical process which obeys the law stated in (c) (vi) above.

(d) (viii) State any two sources of errors in this experiment.

Experiment No. pM – 16

You are required to determine the surface tensions γ_a of liquid A and γ_b of liquid B.

Proceed as follows:

Set up the apparatus shown in Fig. 16.

With the clip closed, fill the funnel with the liquid A.

Adjust the gripping of the clip so that the rate of issuing of the drops at the lower open end is between 20 and 30 drops per minute. Initially, when making the adjustments the drops may be collected in the measuring cylinder.

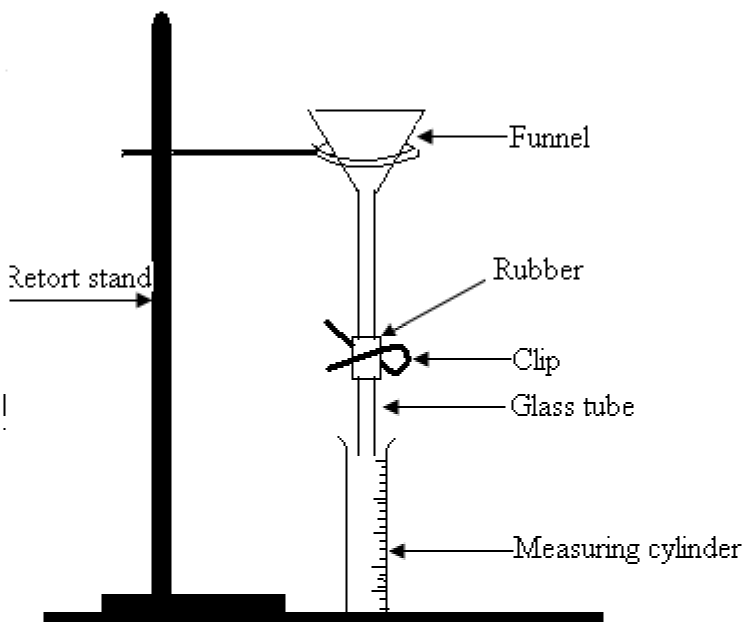


Fig. 33

Starting with a convenient reading V_0 of the volume of liquid already collected in the measuring cylinder, observe the new volume V of the liquid in the measuring cylinder when a known number n of drops has been collected.
Without losing the sequence of count of n, observe series of pairs of V and n.

Tabulate your observations.

Plot a graph of V-Vo (vertical axis) against n.
Assuming that the drops are all equal, determine from the resulting graph the diameter, d and the mass, m_a of one drop.

Hence using Lord Rayleigh's formula:

$$m_a = \frac{1.9\gamma_a}{g}$$

Where: g = 9.8 ms^{-2}, the acceleration due to gravity.

Calculate γ_a.

You may assume that the density of the liquid A is $1.0cm^{-3}$.

Now empty the entire apparatus and refill it with the liquid B. Adjust the rate of flow as before.

Collect 10 drops of the liquid B into the small beaker and contents so as to obtain the mass of 10 drops of the liquid.

From your observations determine the mass m_b of one drop.

Calculate the surface tension, γ_b of the liquid B given that:

$$m_b = \frac{1.9\gamma_b}{g}$$

Where: g and d have the same values as above.

Assume that the density of the liquid B is 0.85 gcm^{-3}

2.0. OPTICS

Experiment OP 1

The aim of this experiment is to show that the image is as far behind a plane mirror as the object is in front.

Proceed as follows:

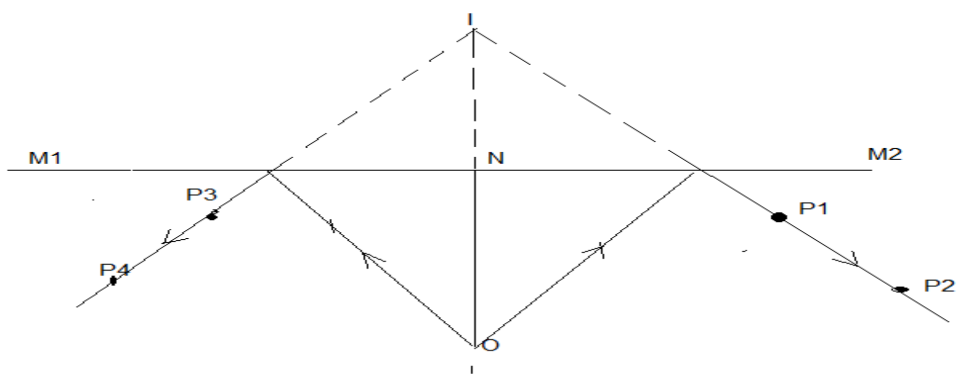


Fig. OP 1

(a) Pin the drawing paper on the board.

(b) Draw a straight line M_1M_2 on the paper and place the reflecting surface of the mirror along it.

(c) Insert a pin O as an object about 5 cm in front of the mirror, and place pins P_1 and P_2 so as to appear in line with the image of O seen in the mirror (see fig.OP1).

(d) Remove P_1 and P_2 and mark their positions with pencil points.

(e) Using the same two pins, repeat the procedure for positions P_3 and P_4.

(f) Remove the mirror, join $P_2$and P_1,P_4 and P_3 and produce both lines to meet at I, the position of the virtual image O.

(g) Join OI cutting the reflecting surface at N .

(h) Measure ON,NI, and angle ONM_2.

(i) Repeat the above procedure for three other values of ON, using a new drawing each time.

(j) Copy the table below and enter your results.

No. of reading	1	2	3	4
ON (cm)				
IN (cm)				
Angle ONM_2				

1. What do you notice of the distances ON and IN for each of the experiments performed.
2. What conclusion can you draw from the observations?
3. What is the average value of the angle ONM_2?
4. Mention one random error and one systematic error possible in this experiment. What is the precaution that would minimize the error?

Experiment OP2

The aim of this experiment is to investigate the connection between the angle of incidence and the angle of reflection using a plane mirror,

Proceed as follows:

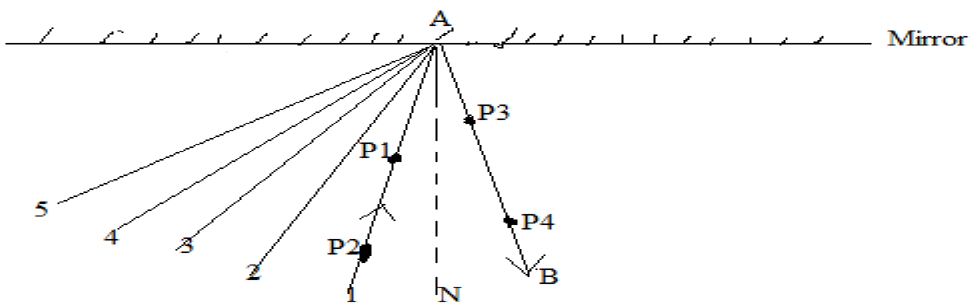


Fig.OP2

(a) Set up the mirror with its plane vertical and one long edge resting on the drawing paper on the drawing board.

(b) The mirror can conveniently be placed near to one edge of the paper facing inwards, as shown in the fig. OP2.above.

(c) With a sharp pencil carefully draw a line on the paper where the reflecting surface of the mirror rests so that if it is disturbed it can be replaced in exactly the same position.

(d) Mark approximately the centre of this line and remove the mirror.

(e) Construct at the marked point a line AN at right angles to the mirror, then trace and mark off to one side of it angles angle of 10^0, 20^0 , 30^o, 40^0 and 50^0.Number these 1-5 (see fig.OP2).

(f) Replace the mirror and place two optical pins P1 and P2 vertically along the 10^0 line.

(g) Look into the mirror until the image of pinP1 is seen to cover the image of P2.

(h) Place two other pins,P3 and P4 so that on looking in the direction of P4 to P3 only P4 is seen, and P4 and P3 and the reflections of P2 and P1 appear to be in the same straight line.

(i) Check that the positions of P3 and P4 is correct and pencil rings lightly round P3 and P4, labeling these "1".

(j) Remove the pins and repeat the experiment with P1and P2 along the line marking out 20^0 Label "2" the rings marking the appropriate positions of P1 and P2.

(k) Repeat the experiment for each of the other angles.

(l) Remove the pins and mirror and join points(1) to A and "2"to A, etc.

(m) Measure the angles BAN, CAN and DAN.

(n) Copy the table and enter the results as shown

Angle of incidence, i, in degree	Angle of incidence, r in degree
10	BAN
20	CAN
30	DAN
40	EAN
50	FAN

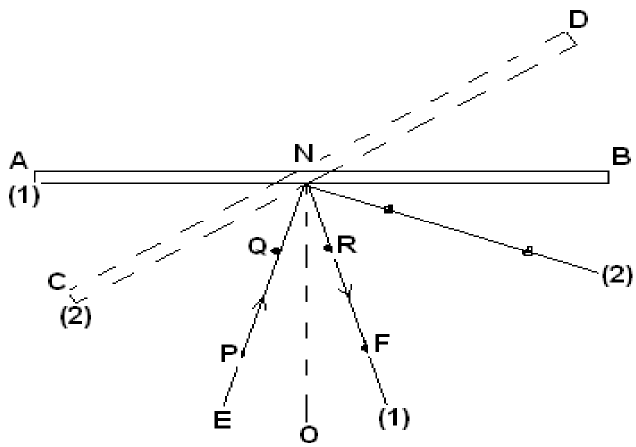
Required:

1. Using the same scale on both axes, plot a graph of, i, against , r .
2. Determine the gradient of the graph.
3. How does the value of the gradient provide a proof that the angle of incidence is equal to the angle of the reflection?

Experiment OP3

The aim of this experiment is to show that a reflected beam turns through twice the angle turned through by mirror.

Proceed as follows :



a. Set up the mirror in its holders with its plane vertical and long edge resting on the drawing paper on the drawing board. With a sharp pencil carefully draw a line on a paper where the back reflecting surface rests.
Remove the mirror and draw a normal NO at the mid point of the line.
Through N draw first a line CND so that the angle CAN is 20^o exactly and then a line NE so that the angle ENO is also 20^o, as shown in the figure.

b. Carefully replace the mirror so that its back surface is along ANB ,and place two pins, P and Q, along EN

Place a third pin R so that on looking into the mirror it covers the images of both P and Q and a fourth pin, so that F,R and the images of P and Q are in the same straight line. Remove the pins R, F and the mirror AB, but not pins P and Q .Join the positions of R and F to N label this line (1)

c. Now replace the mirror so that its rear surface lies along CND. By the same methods, find the position of the reflected ray NG.

Remove the pins and mirror, join GN through the points occupied by the pins and measure the angle FNG.

d. (i) Repeat the experiment ,making angle ANC successively 10^o,30^o, 40^o

(ii) Plot a graph with angle ANC along the y-axis and angle FNG along the x-axis.

(iii) From graph determine the ratio of the angle turned through by the reflected beam to the angle turned through by mirror

(iv) Comment on your results

(v) State two sources of errors and their precautions

(vi) Handle the drawing with your answer book

Experiment OP4

The aim of this experiment is to determine the relative refractive index for light passing from air to glass.

Proceed as follows:

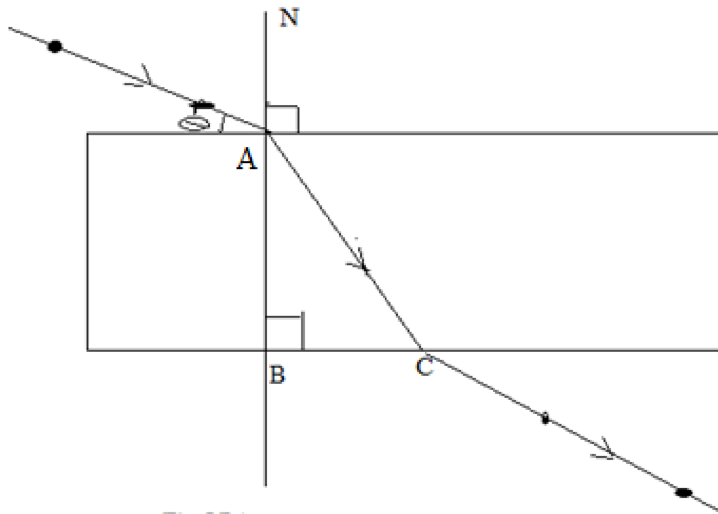


Fig.OP4

(a) Place the rectangular glass block flat on the drawing paper fixed on the board,

(b) Using a sharp pencil trace the outline of the block.

(c) Remove the block and draw the line making an angle, Ɵ of 20^0 with the surface of the block and erect two pins on this line at a suitable distance apart.

(d) Replace the block and erect two more pins at positions which appear to be in straight line with the other two as seen through the block.

(e) Again remove the block and draw the complete path of the ray (see fig. OP 4)

(f) Measure the distances BC and AC.

(g) Repeat this procedure for values of Ɵ equal to 30^0, 40^0, 50^0 and 60^0 and in each case make your drawing on a fresh part of the drawing paper Record clearly the values Ɵ, BC and AC.

(h) Find Cosθ and calculate $k = \frac{BC}{AC}$.

Required:

(1) Plot the graph Cosθ against k.

(2) Determine the relative refractive index, given that:

$\mu = \frac{Cos\theta}{k}$ is the slope of your graph

(3) State any source of errors and precautions in this experiment

Experiment OP5

The aim of this experiment is to find the critical angle A of the given glass block.

Proceed as follows:

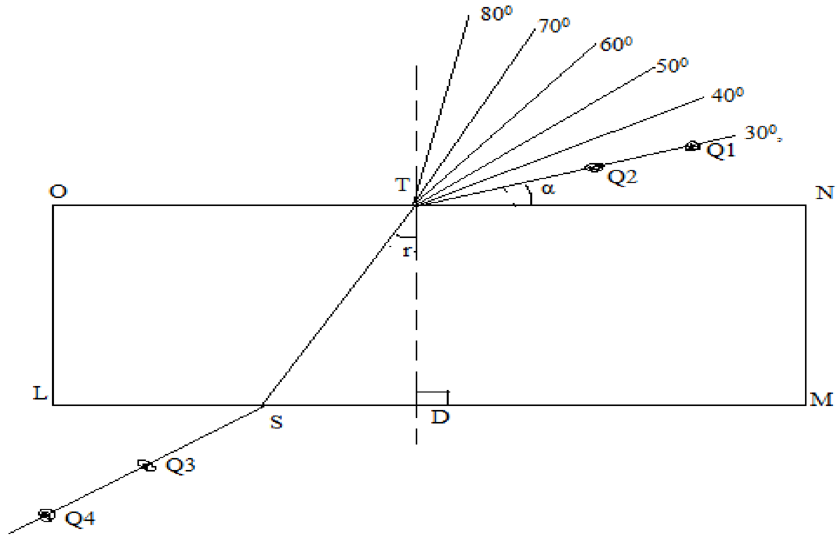


Fig. OP 5.

(a) Place a white piece of paper on the horizontal surface of the bench.

(b) Place the glass block with one of its largest surface top most on top of the white paper.

(c) Mark the outline of the glass block on the paper with a pencil.

(d) Remove the glass block and draw a line which cuts its longest sides normally at T and D as shown in figure OP 5 above.

(e) Using a protractor, draw angles $\alpha = 30^0, 40^0, 50^0, 60^0, 70^0$ and 80^0 as shown in the above diagram.

(f) Replace the glass block in its original position and stick the first pin Q1 and second pin Q2, along the line of angle 30^0

(g) Stick the third and forth pin Q3 and Q4 respectively, on the opposite side of the glass block such that Q3 and Q4 fall on a straight line with Q1 and Q2 when viewed through side LM of the glass block.

(h) Remove the glass block and trace the straight path taken by the ray SQ3Q4.Using a ruler join S and T.

(i) Measure the angle of refraction, r, then calculate the values of $\cos\alpha$ and $\sin r$.

(j) Repeat the same procedure for values of $\alpha = 40^0, 50^0, 60^0, 70^0$ and 80^0.

(k) Record your results in a tabular form for the values of α, $\cos\alpha$ and $\sin r$.

Required:

1. Plot a graph of $\sin r$ against $\cos\alpha$
2. Find the slope of the graph
3. Calculate the value of A when slope = $\sin A$.
4. State any sources of error and precaution taken during the experiment.

Experiment OP6

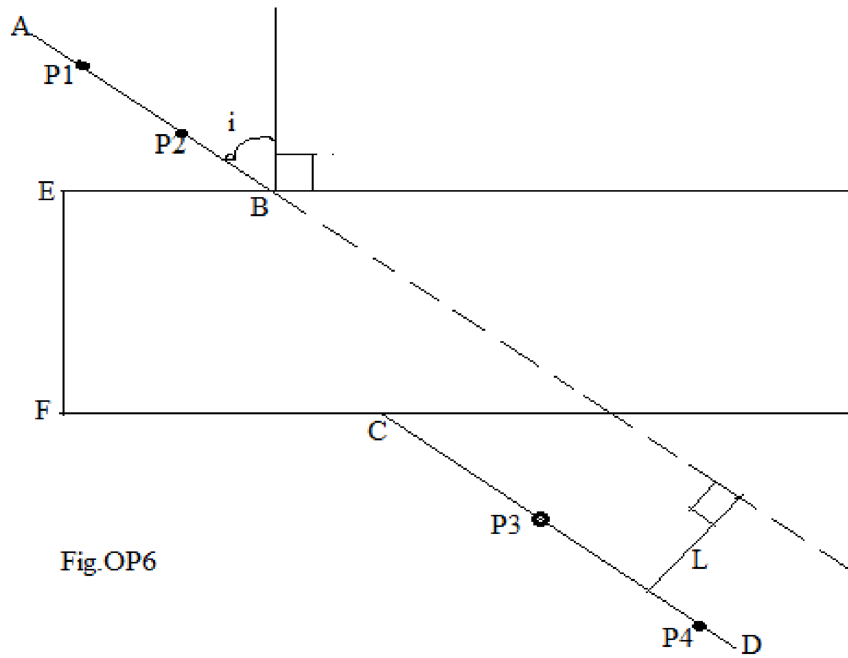


Fig.OP6

The diagram, Fig.OP6, show the passage of ray of light through a rectangular block of glass. You are required to:

(a) Measure the perpendicular distance L between the incident ray AB and emergent ray CD for various angles of incidence i

(b) Trace the outline of the given rectangular block of glass.

(c) Construct the incident ray AB by pushing two pins P1 and P2 into the paper as shown in fig OP6.The emergent ray CD is constructed by pushing two more pins P3 and P4 into the paper so that they appear to be in line with the images of P1 and P2 when viewed through the block. Join the appropriate pin marks and then measure L and i

(d) Repeat this process with at least four other values for i covering a wide range of angles of incidence, using a new drawing for each.

Required:

1. Draw a graph of L against i

2. Measure the width EF of the block and use the graph to find the value of i for which

$$L = \frac{1}{2}EF.$$

3. Without using the graph, state the value of L for which, (i) $i = 90^0$ and (ii) $i = 0^0$

Experiment OP7

The diagram in Fig.OP 7 shows the passage of ray of light through a glass prism.

Proceed as follows:

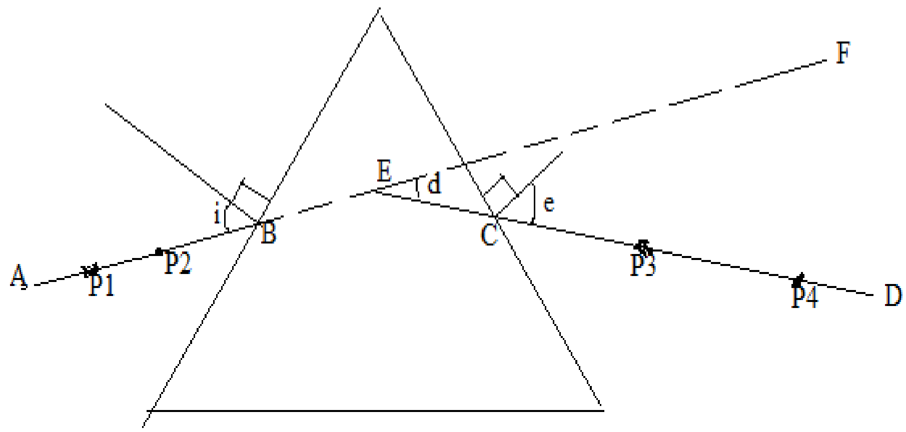


Fig.OP 7

1. Place the given glass prism on a sheet of paper and trace its outline.
2. Remove the prism.
3. Construct a normal at B and a line AB such that the angle of incidence, $i = 30^0$
4. Push two pins P1 and P2 into the paper along AB as shown in fig.OP7 and thereafter replace the prism.
5. Construct the emergency ray CD by pushing two pins P3 and P4 into the paper so that they appear to be in the line with the images of of P1 and P 2 when viewed through the prism. Again remove the prism
6. Join the pin marks P3 and P4 so that line CD results. Produce CD so as to meet ABEF at E.
7. Measure the angle of deviation, d.
8. Construct a normal at C and hence measure angle ,e.

9. Repeat this process for $i = 35^0, 40^0, 50^0, 55^0$, and 65^0 .Note that a separate diagram should be drawn for each value of, i.

10. Tabulate the values of i, e , d and (d-e).

    (a) Plot a graph of d against i

    (b) From your graph , read and record ,D, the minimum value of d.

    (c) Plot a graph of (d-e) against i.

    (d) From your graph , read and record the intercept ,I, on the i- axis.

(e) Find the value of $\dfrac{Sin\frac{1}{2}(I+D)}{Sin\frac{1}{2}(I)}$

3.0. HEAT

Experiment No. H – 01

The aim of this experiment is to determine the specific heat capacity of the oil provided by the method of cooling.

Proceed as follows:-

You are provided with a calorimeter whose specific heat capacity is known, oil, stop-watch, water and thermometer (of range 0-100 ^{o}C)

Pour about 120 cm^3 of the oil in a beaker and warm it until it reaches a temperature of about 60 ^{o}C.

Weigh the calorimeter and place it on insulting supports as shown in Fig. 2.

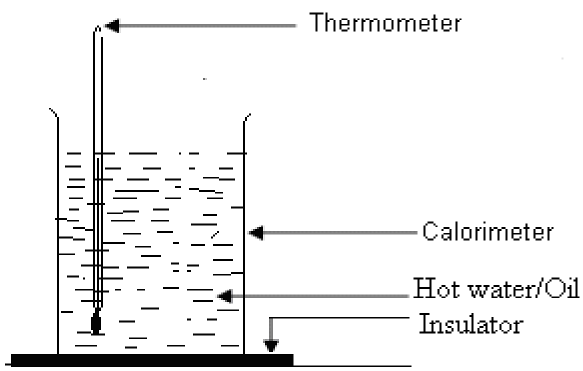


Fig. 2

Measure 100 cm^3 of the warm oil and pour it into the calorimeter.

Record the temperature fall at intervals of 30 seconds until a temperature of about 45 ^{o}C is reached.

Reweigh the calorimeter with oil.

Repeat the experiment using water in place of oil.

Tabulate your results.

a) Plot on the same scale, and axes of your graph paper, a graph of temperature, θ against time, t for both water and oil.
b) Find the time, in seconds, for the water and the oil to cool by two degrees from the graph. Record these at t_1 and t_2 for water and oil respectively.
c) Using the formula:

$$\frac{(mc + m_1c_1)(\theta_2 - \theta_1)}{t_2} = \frac{(m_2c_w + m_1c_1)(\theta_2 - \theta_1)}{t_1}$$

Where :

m = mass of oil

m_1 = mass of calorimeter

m_2 = mass of water

c = specific heat capacity of oil

c_w = specific heat capacity of water = 4200 $Jkg^{-1}K^{-1}$

c_1 = specific heat capacity of calorimeter = 380 $Jkg^{-1}K^{-1}$

Calculate c, the specific heat capacity of the oil

d) State any sources of errors and precautions taken.

Physics practical

Experiment No. H – 02

The aim of this experiment is to investigate how the nature of the surface of a calorimeter affects the rate of loss of heat.

Proceed as follows:

a) You are provided with a beaker which is nearly full of hot water and a polished copper calorimeter. Nearly fill the calorimeter with the hot water, whose temperature should initially be above 80 ^{o}C and set it up on the bench as illustrated in Fig. 3.

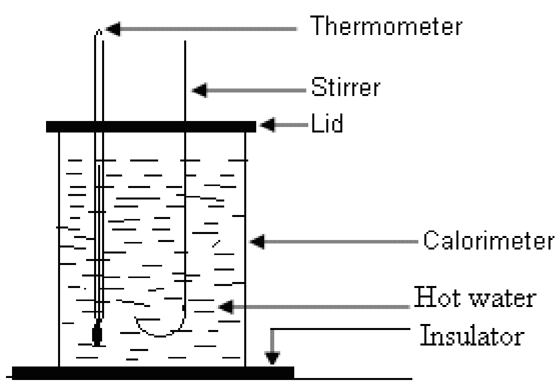


Fig. 3

b) Constantly, stir the hot water in the calorimeter and record its temperature, θ after every 1.0 minute using a stop-watch. Continue recording the temperature in this way for 15 minutes and tabulate temperature, θ and time, t.

c) Empty the water in the calorimeter into a measuring cylinder and record its volume, V.

d) Blacken the external surface of the calorimeter using smoke from the kerosene or diesel burner provided. Now pour volume V of hot water, whose temperature should initially be above 80 ^{o}C, into the blackened calorimeter and again set it up on the bench as illustrated in Fig. 3.

e) Repeat the procedure outlined in (b) above.

f) Using the same axes, plot a cooling curve for the polished calorimeter together with its contents and another cooling curve for the blackened calorimeter together with its contents.

g) If R_p represents the rate at which the polished calorimeter and contents lose heat and R_b represents the rate at which the blackened calorimeter and contents lose heat, determine the ratio.

R_p/R_b at:

(i) 78^{o}C
(ii) 70^{o}C

Comment on your results.

Experiment No. H – 03

The aim of this experiment is to determine the emissive power, k of aluminum at 65 ^{o}C.

Proceeded as follows:

(a) Heat some water in a beaker. There should be sufficient water to fill the calorimeter provided. While the water is being heated, do the following.

(i) Using the rubber bands available, rightly cover the external area (sides and bottom) of the calorimeter with the piece of aluminum foil provided.

(ii) Weigh the calorimeter (together with its aluminum cover and record its mass m (in kg) (you may henceforth assume that m represents the mass of the copper calorimeter).

(iii) Measure the average external diameter, d of the calorimeter and its height, h using vernier calipers. Thus determine its external area, A using the equation:

$$A = \pi dh + \pi d^2/4$$

(iv) Note the room temperature, θ_0.

(v) Open the jaws of the clamp on the retort stand and adjust it so that the calorimeter can rest on it steadily. You may have to twist the clamp a little so that the base of the calorimeter can sit on it securely.

(b) (i) Pour hot water (at least at 85 ^{o}C) into the calorimeter so that it just about fills the calorimeter. Put the wooden cover on the calorimeter lightly (do not tighten; otherwise it will not come off easily). Put the thermometer into the calorimeter and close the hole in the wooden cover using some cotton wool. Rest the calorimeter on the clamp.

(ii) Starting with the temperature, θ of water at about 75 ^{o}C and taking readings every two minutes record the temperature, θ corresponding to the time, t of cooling until the temperature drops to about 55 ^{o}C. While doing this, fan the calorimeter with some sheets of paper so that a current of air cools the calorimeter continually.

Record the values of θ and t.

(iii) Remove the cover from the calorimeter and reweigh the calorimeter together with the water.
Note its mass, M (in kg).

(c) Plot a graph of θ against t and from it determine the slope, at the temperature of 65 ^{o}C, and do the following:

(i) Calculate the rate of heat loss to the surroundings, ΔH/Δt
given that:

$$\frac{\Delta H}{\Delta t} = \left[(M - m)c_w + mc\right]\frac{\Delta \theta}{\Delta t}$$

Where:

$C_w = 4.2 \times 10^3$ Jkg^{-1} K^{-1}

$C = 4.0 \times 10^2$ Jkg^{-1}K^{-1}

(ii) Hence, using the Newton's law of cooling:

$\Delta H/\Delta t = kA(\theta - \theta_o)$, determine the value of k.

Experiment No. H – 04

The aim of this experiment is to investigate the manner in which a calorimeter containing hot water cools down.

Proceed as follows:

Fill cold water into the beaker provided.
Heat the beaker and contents on a Bunsen burner (or any suitable heater) until the water reaches a temperature of about 90 ^{o}C.
Now pour the hot water into the calorimeter until it is about three-quarters full and then set up the calorimeter as illustrated in Fig. 5 below:

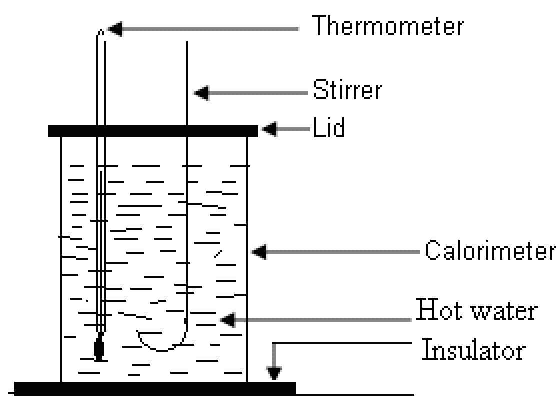


Fig. 5

Carefully observe and record the temperature, θ of the water inside the calorimeter after every two minutes.
Continue this process while stirring the calorimeter until the temperature of the water drops to about 50 ^{o}C.

(i) Tabulate the values of θ (in ^{o}C) and the corresponding values of time t (in minutes), starting at t = 0. Also measure and record the room temperature, θ_R.

(ii) Plot the cooling curve for the calorimeter and its contents using the table in (i) above.

(iii) Choose six points (θ,t) along the curve in (ii) above, then at each point draw the tangent to the curve and then determine the gradient, G of the curve at the point.

(iv) Calculate and record the excess temperature, $(\theta - \theta_R)$ corresponding to each of the six points chosen. Hence make up a table that consists of values of G as well as corresponding values of $(\theta - \theta_R)$.

(v) Using the results in (iv) above, draw a graph of "Rate of cooling, G" against "Excess Temperature, $(\theta - \theta_R)$".

(vi) Compare the results in (v) above with Newton's law of cooling and make any relevant comments.

Experiment No. H – 05

You are required to plot the cooling curves for hot water in a calorimeter for the following cases:

(i) about half full of water
(ii) about two-thirds full of water

Proceed as follows:

(a) Half fill with water a weighed calorimeter so that the temperature immediately after this operation is about 60 ^oC. Observe the temperature of the contents at intervals of two minutes as it cools over the temperature of between 60 ^oC – 45 ^oC.

(b) Weigh the calorimeter and water after the experiment.

(c) Repeat the procedure in (a) and (b) above with the calorimeter about two thirds full of water.

(d) Plot both cooling curves in the same frame of axes.
   (i) Use the two curves to obtain from them the ratio of the times taken to cool over the following temperature intervals 60 ^oC – 50 ^oC, 60 ^oC – 45 ^oC and 55 ^oC – 45 ^oC.
   (ii) Calculate the ratio of the total thermal capacities in the two experiments.
   (iii) Comment on the ratio obtained in (i) and (ii) above.
   (iv) Explain why the shapes of the two curves are different.

The specific heat for a copper calorimeter is 420 $Jkg^{-1}K^{-1}$

The specific heat for an aluminum calorimeter is 900 $Jkg^{-1}K^{-1}$

Experiment No. H – 06

The aim of this experiment is to determine the boiling points of liquids E and F and to find their rates of cooling at 70 ^{o}C temperature under the conditions of the surroundings.

Proceed as follows:

(a) Using one of the beakers, take about 200 cm^3 of the warm liquid E and heat it until it boils. Note and record the boiling temperature, θ_E of liquid E.

(b) Quickly transfer the beaker of boiling liquid E and place it on the wooden block provided as shown in Fig. 7.

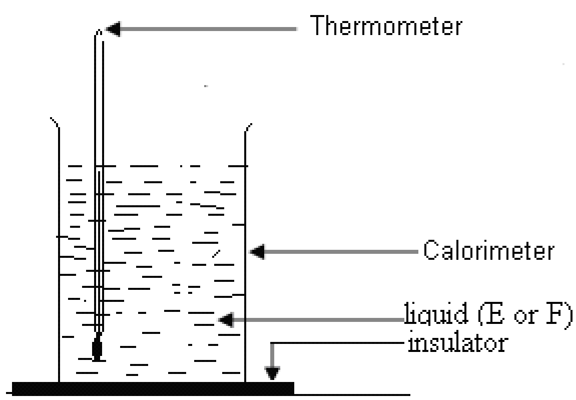


Fig. 7

Note the temperature and immediately start the stop-watch.

(c) While stirring the liquid with your thermometer and constantly fanning with the pieces of paper provided, note and record the temperature of the liquid E at two minute intervals as it cools.

(d) Keep on fanning the beaker, stirring the liquid noting and recording the temperature until the liquid has cooled to about 55 ^{o}C.

(e) Tabulate your values of temperature, θ and the corresponding time, t.

(f) Plot a graph of θ (vertical axis) against t (horizontal axis). Determine the rate of cooling of liquid E at 70 ^{o}C.

(g) Repeat the steps (a), (b), (c), (d), (e) and (f) above for the liquid labeled F.

(h) Based on the rates of cooling at 70 ^{0}C:

(i) What do you think liquid E is?
(ii) What do you think liquid F is?

Experiment No. H – 07

The aim of this experiment is to investigate the relation between the rate of loss of heat from a calorimeter and the temperature excess over its surroundings under conditions of forced convection.

Proceed as follows:

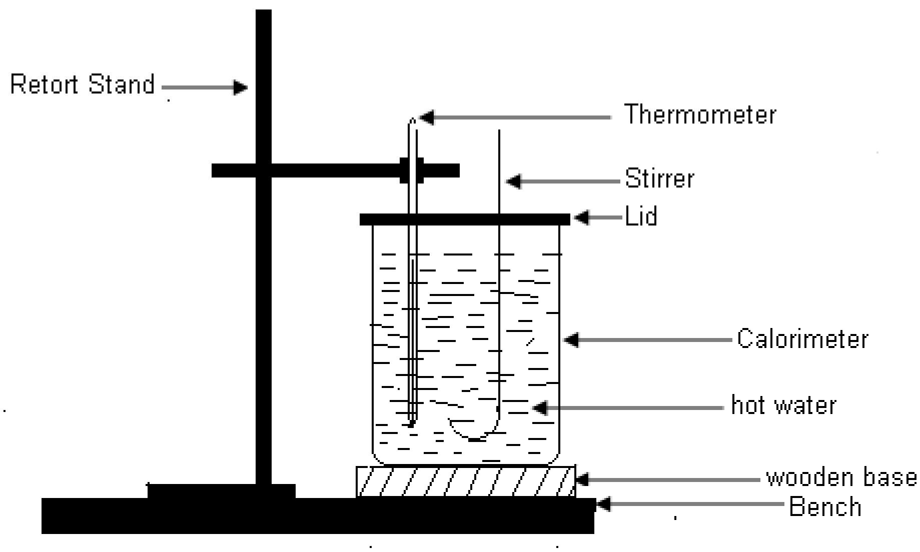


Fig. 8

(a) Put some water in the beaker provided and leave it to heat from the burner (or heater) till the water boils.

(b) While the water is being heated set up the apparatus as shown in Fig. 7 where the calorimeter is placed on a wooden base provided. Place the stirrer in the appropriate opening in the lid and cover the calorimeter. Clamp one of the thermometers to pass through the other opening in the lid so as to be able to read the temperature of the water.

(c) When the water in the beaker has boiled, transfer some to the calorimeter till the level of the water in the calorimeter is about three quarters full.

(d) Read and record the temperature, θ of the water at every 2 minute intervals, beginning when the temperature of the water is about 80 ^{o}C. As the experiment progresses, gently stir the water and fan the calorimeter with some paper. Take your readings for 20 minutes.

(e) Using the other thermometer, read and record the room temperature at the beginning and at the end of the experiment. Hence find the average room temperature, θ_0.

(f) (i) Plot a graph of $\log_{10}(\theta - \theta_o)$ against time, t.

(ii) Theoretically, the experiment obeys the relation:

$$\log_{10}(\theta-\theta_o) = -kt + \text{constant}.$$

Determine the values of k and the constant.

(iii) What is the physical meaning of k?

Experiment No. H – 08

You are to determine the specific heat capacity of a liquid by applying the principle of mixtures.

Proceed as follows:

Fig. 9 (i) Fig. 9 (ii)

Fig. 9

(a) Heat the solid S in a beaker B containing some water to about 100 ^{o}C. To do this, use a piece of thread T for suspending the solid from a retort stand, as shown in Fig. 9 (i).

(b) Meanwhile, determine the mass of the calorimeter C when empty and when filled with some cold liquid whose specific heat capacity is to be determined.

(c) Place the calorimeter filled with the liquid in the jacket J. Measure the initial temperature of the cold liquid.

(d) Quickly transfer the solid into the calorimeter and cover it to minimize heat losses. Stir well and record the equilibrium temperature.

Remove the solid from the calorimeter, dry it and measure its mass.

(e) Record your results in a table similar to the one below:

Mass of calorimeter, m_c	
Mass of calorimeter plus liquid, m_1	
Initial temperature of cold liquid, θ_1	
Initial temperature of the solid, θ_2	
Final temperature of the mixture (equilibrium temperature), θ	
Mass of solid, m_s	
Mass of liquid, $m_L = m_1 - m_c$	

(f) Applying the principle of mixture, show that the specific heat capacity,m C of the liquid is given by:

$$c_l = m_s c_s(\theta_2 - \theta) + m_c c_c(\theta - \theta_1)/m_L(\theta - \theta_1)$$

Where:

The specific heat capacities of solid, c_s and calorimeter, c_s are 400 and 380 Jkg^{-}

$^{1}K^{-1}$, respectively.

(g) Using the data you have collected, calculate a value for c_L.

(h) Answer the following questions:

(i) How are heat losses by conduction, convection and radiation minimized in this experiment?

(ii) In this kind of experiment, the solid should not be
soluble in the liquid placed in the calorimeter.
Explain why?

(iii) The equilibrium temperature, should not be too high,
Explain why?

Experiment No. H – 09

The aim of this experiment is to determine the specific heat capacity, c of the liquid provided.

Proceed as follows:

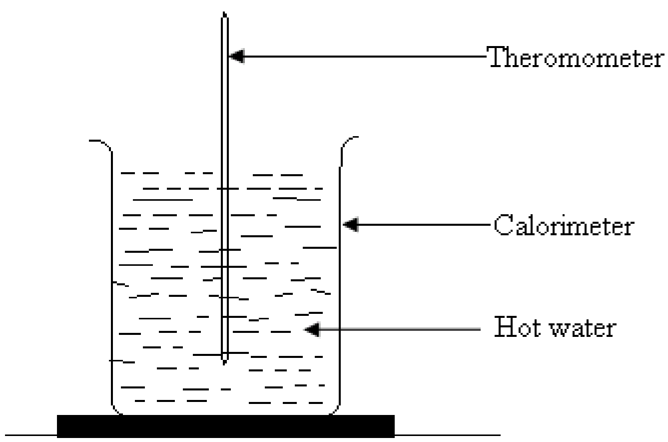


Fig. 10

(a) Mark the inside of the calorimeter provided using ink at a height of about two-third from the base.

(b) Take about half-full beaker of water and warm it to a temperature of about 90 ^{o}C.

(c) Meanwhile determine the mass of the calorimeter and replace it on the insulating support. Pour the warm water into the calorimeter up to the marked height.

(d) Using the thermometer provided observe the temperature drop of the water. As soon as it reaches 80 ^{o}C start timing. Record the time t_1 corresponding to temperature drops of every 5 ^{o}C until the water cools to a temperature of about 50 ^{o}C.

(e) Weigh the calorimeter and water and hence determine the mass of water used. Now empty the calorimeter and dry it thoroughly.

(f) Then take half-full beaker of the motor oil provided and warm it gently to a temperature of about 90 ^{o}C (NB: As oil is inflammable heat it carefully and be cautions not to heat it to a high temperature). Pour the warm oil into the calorimeter up to the same marked height. Again starting from 80 ^{o}C observe and record the time t_2 corresponding to temperature drops of every 5 ^{o}C until the oil cools to about 50 ^{o}C.

(g) Weigh the calorimeter and the oil and hence determine the mass of the oil used.

(h) Plot a graph of t_2 against t_1.

Given that: $(m_2c_2 + mc)/(m_1c_1 + mc) = t_2/t_1$

Where:

m_1 = mass of water used

c_1 = specific heat of water

= 4.2×10^3 $Jkg^{-1}K^{-1}$

m_2 = mass of motor oil

c_2 = specific heat of oil

m = mass of calorimeter

c = specific heat of copper

= 0.4×10^3 $Jkg^{-1}K^{-1}$

Determine the specific heat capacity of the motor oil.

Experiment No. H – 10

The aim of this experiment is to show that the rate of loss of heat of a body under conditions of forced convection is proportional to difference between its temperature and the room temperature.

Proceed as follows:

Heat enough water in the beaker provided to a temperature of about 70 ^oC and fill the calorimeter half full of this water.

Immediately thereafter, place the thermometer and stirrer into the calorimeter (Note: a lid is not required) and support the calorimeter on the three small block of wood as shown in Fig. 11

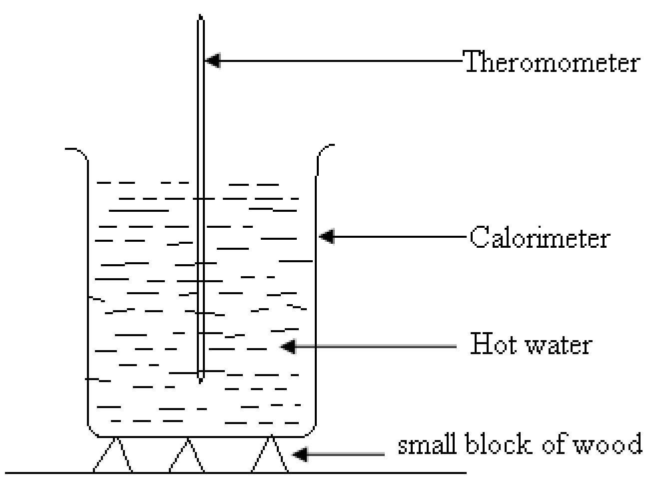


Fig. 11

Using a stop-watch, record the temperature of the water every minute, while continuously stirring, for about 20 minutes. Start with a temperature of 65 ^oC.

Record the temperature, θ_R of the room before your start and immediately after the experiment.

Plot a graph of the temperature, θ of the water and calorimeter against time. Choose 6 equally spaced points on the graph and draw the tangents at these points and determine the gradients.

Tabulate the values of the gradients and their corresponding temperatures.

Plot a graph of the gradients against their corresponding temperature.

What does the point at which the graph cuts the temperature axis correspond to?

The graph you have plotted is a straight line with a negative slope.

(i) What is the physical implication of the nature of the graph?

(ii) Determine the slop of the graph.

(iii) What is the physical significance of the slope bearing in mind that the rate of fall of temperature is proportional to the rate of loss of heat?

Experiment No. H – 11

Investigate the manner in which a calorimeter containing hot water cools down.

Procedure:

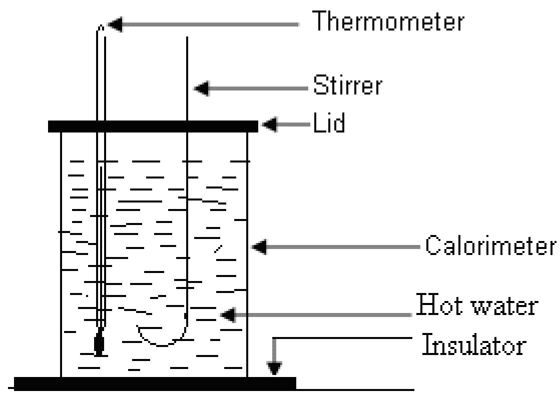


Fig. 12

Fill some cold water into the beaker provided.
Heat the beaker and contents on a Bunsen burner (or any other heating source) until the water reaches a temperature of about 90 ^{o}C.

Now pour the hot water into a calorimeter until it is about three quarters full and then set up the calorimeter as shown in Fig. 12.

Carefully observe and record the temperature, θ of the water inside the calorimeter after every two minutes.
Continue the process while stirring the water in the calorimeter until the temperature of the water drops to about 50 ^{o}C.

(i) Tabulate values of temperature, θ and the corresponding values of time, t (in minutes) starting at t = 0). Also measure and record the room temperature, θ_R.

(ii) Plot a cooling curve for the calorimeter and its contents using the table in part (i) above.

(iii) Choose six points (t,θ) along the curve in (ii) above and at each point draw the tangent to the curve and then determine the gradient, G to the curve at that point.

Calculate and record the excess temperature (θ - θ_R) corresponding to each of the six points chosen. Hence, make up a table that consists of values of G and values of (θ - θ_R).

(iv) Using the results in (iii) above draw a graph of rate of cooling, G against "excess temperature", (θ - θ_R)

(v) State Newton's law of cooling. Compare the results in (iv) above with Newton's low of cooling and make any relevant comments.

Experiment No. H – 12

The aim of this experiment is to determine the specific latent heat capacity of the solid provided.

Proceed as follows:

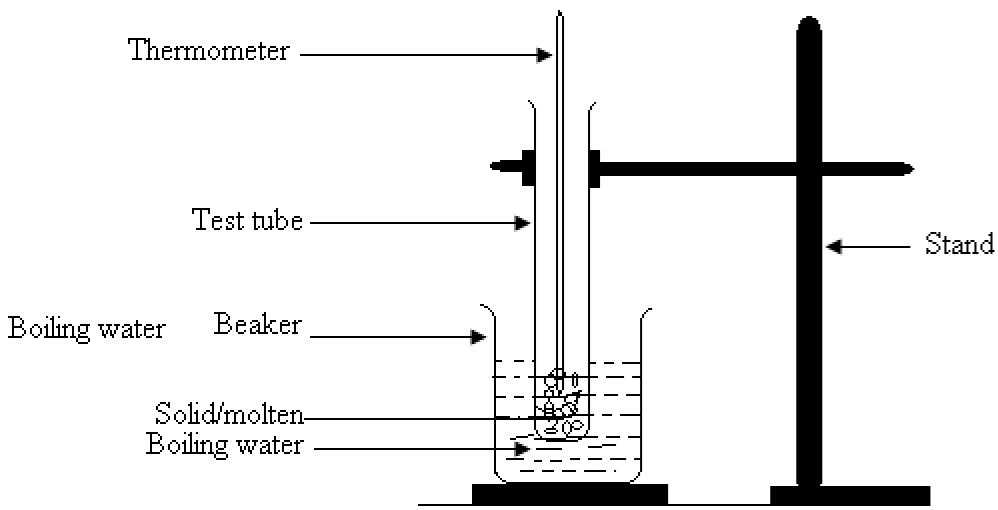


Fig. 13

(a) Place the solid provided into the test-tube. Put the test-tube into boiling water and leave it there until all the solid has melted. Then insert a thermometer into the molten solid and fix the test-tube and the thermometer (see Fig. 13) such that the thermometer does not touch the sides of the test-tube. Extinguish the heating flame, take off the boiling water and leave the test-tube suspended in air. As the liquid (in the test-tube) cools down, record its temperature at 30 seconds intervals.

Continue recording the temperature for up to 5 minutes after the liquid has solidified.

(b) (i) Plot a graph of temperature against time.

(ii) From your graph obtain the gradient, m of the cooling curve of the solid for the portion near the melting point.

(c) Measure the time interval, t_o from the start to the end of the flat portion of the cooling curve.

(d) Determine the specific latent heat of the solid, L_o, given that: $L_o = t_o cm$

Where, c is the specific heat capacity of the solid.

NOTE: The supervisor will tell you the value of c.

(e) State any sources of error involved and precautions taken in the experiment.

Experiment No. H – 13

The aim of this experiment is to determine the specific latent heat of vaporization, L of naphthalene.

Proceed as follows:

Fig. 14

Heat some water in a beaker.

While the water is being heated do the following.

(a) (i) Weigh the given test tube (empty).
Reweigh it with about 15 g of naphthalene in it.
Record the mass, m of naphthalene.

(ii) Weigh the given calorimeter first with the stirrer and then with stirrer plus water filling about half of it.
Record the mass m_c of the calorimeter plus stirrer and the mass m_w of the water.

(iii) Arrange the apparatus as shown in Fig. 14 (but without the test tube).

(b) With the test tube held in the test-tube holder provided, heat the naphthalene in boiling water until it is completely melted and reaches a temperature of about 95 ^oC.

Transfer the test tube into the calorimeter through the hole in the cover.

Stirring the water (with stirrer) and the naphthalene (with the thermometer in it), record the temperatures of the water and the naphthalene every one minute. (You may be able to do this by noting the temperature on each thermometer alternately every 30 seconds).

Continue recording the readings of temperatures against time until the naphthalene cools to about 65 ^oC.

Plot a graph of temperature, θ against time, t for both the water and naphthalene on the same graph paper.

(c) From the naphthalene graph determine as accurately as possible, the time interval over which the naphthalene is actually solidifying.
Thus from the water graph determine the rise in temperature, $\Delta\theta$ of water during this time interval.

Assuming that no heat is transferred by the test tube, during the period the naphthalene solidifies, calculate the value of L from the following equation:

$$mL = (mc + mc_w)\,\Delta\theta$$

Where:

$c = 4 \times 102\ Jkg^{-1}K^{-1}$

$c_w = 4.2 \times 10^3 Jkg^{-1}K^{-1}$

(Caution: All masses in the above equation are in kilograms).

Experiment No. H – 14

The aim of this experiment is to determine the thermal conductivity of the material of a rubber tubing.

Proceed as follows:

Fig. 15

(a) Determine and record the laboratory temperature.

(b) Arrange the apparatus as shown in Fig. 15

(c) Pass steam through the rubber rubbing immersed in the calorimeter containing water cooled to about 5 ^{o}C below the laboratory temperature.

While stirring, take readings of the temperature in the calorimeter and the time at an interval of one minute until the temperature of the water in the calorimeter has reached about 70 ^{o}C.

(i) Plot a graph of values of temperature against corresponding values of time in minutes.
(ii) From the graph, find the slope of the curve at the room temperature.
(iii) From the slope of this curve at the room temperature, deduce the thermal conductivity of the rubber tubing.

Experiment No. H – 15

The aim of this experiment is to determine the coefficient of expansion, γ of air at constant pressure.

Proceed as follows:

Fig. 16

You are provided with a glass capillary tube sealed at one end and containing a mercury thread, a large beaker, rubber bands, a 30 cm rule, stirrer and thermometer (0 ^{o}C – 100 ^{o}C), a retort stand and clamp.

Set up the apparatus as shown in Fig. 16.

The glass capillary tube is attached to the rule by rubber bands with the open end upwards.
Clamp the rule and place the tube and rule in a mixture of ice and water such that no water enters the tube.

Stir gently, until the temperature of the ice-water mixture is steady. Record this temperature, θ and the corresponding length, l of the enclosed air column; i.e. from the sealed end to the bottom of the mercury thread.

Heat the ice-water mixture until the temperature is about 20 ^{o}C.
Remove the burner, and stir the water for a short time. Then record the temperature and the corresponding length of the enclosed air column.

Repeat the above procedure with water at temperatures about 40 ^oC, 50 ^oC, 60 ^oC, 70 ^oC and 80 ^oC, in each case recording the temperatures and the corresponding lengths of the air column.

Plot a graph of the length, l against temperature, θ.

Determine the gradient, G of the graph.

Given that:

$\gamma = G/l_o$

Where l_o is the length of the enclosed air column at $\theta = 0\ ^0C$.

Determine the coefficient of expansion, γ of air.

What assumptions have you made during the cause of your work?

4.0. CURRENT ELECTRICITY

Experiment No. E-01

The aim of this experiment is to investigate the relationship that exists between electric current, I and potential difference, V across an unknown resistor (Verification of Ohm's Law)

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen resistor, R	≤ 0.5`Ω
3.	Rheostat	5 Ω
4.	Switch (key)	Plug type
5.	Ammeter	0 – 1.0 A
6.	Voltmeter	0 – 5.0 V
7.	Connecting wires	flexible
8.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.
(b) Take measurements and record data in a tabular form.
(c) Estimate uncertainty errors from the ammeter and voltmeter.
(d) Calculate ratios of voltage and current and make judgment on their magnitudes.
(e) Plot a graph of voltage against current and comment on its shape.
(f) Determine the slope of the graph.
(g) Compare the magnitudes of the slope of the graph and that of the average of the ratios.
(h) State Ohm's law and deduce the SI-unit of resistance, R of the unknown resistor.
(i) Discuss sources of errors related to the experiment and suggest ways/methods of minimizing them.

D: Theory

(i) Ohm's law states: **Electric current, i through a resistor is proportional to the potential difference, v across its ends, provided its temperature remains constant.**

i.e. $i \propto v$ or $i = Gv$, where G is a constant called conductance of the resistor.

Or, $v = 1/G\ i$, where $1/G = R$, called the resistance of the resistor.

(ii) In this experiment, the ratios v/i are expected to be constant and to be equal to the slope of the graph.

The nature of the graph is that of a straight line passing through the origin. This shows that voltage, v and current, i are proportional. This verifies Ohm's law.

Proceed as follows:

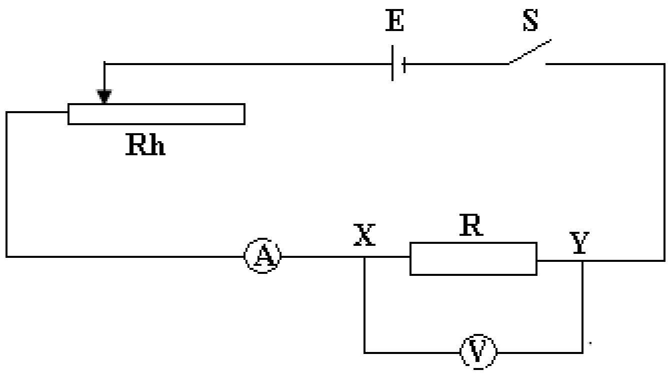


Figure E.01

(a) Connect the circuit as shown in figure above

(b) Adjust the rheostat so as to obtain a current of 0.2A on the ammeter. Record the corresponding reading on the voltmeter.

(c) Repeat step (b) above each time by increasing the value of the current in steps of 0.1A. Obtain about six readings of current and voltage.

(d) Tabulate your results in a table similar to the one shown below:

Trials	1	2	3	4	5	6
I (A)						
V(V)						
Ratio V/1(VA^{-1})						

(i) What can you say about the magnitude of the ratios you have computed? Calculate the average of the ratios.

(ii) Plot a graph of voltage, V against current, I. Start your axes at the origin.

(iii) Determine the slope of your graph.

(iv) What can you say about the magnitude of the slope compared to that of the average of the ratios?

(v) What is the SI unit of the value of the slope?

(vi) State Ohm's law and use it to deduce a value of the resistance of the unknown resistor R from the above experimental results.

(vii) What are the possible sources of errors in this type of experiment?

Experiment No. E-02

The aim of this experiment is to determine a value of an unknown resistance S by using the Wheatstone-Bridge principle.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen resistor, S	To be determined
3.	Resistance Box	0 - 30 Ω
4.	Metre-bridge	Standard type
5.	Switch (key)	Plug type
6.	Galvanometer	Zero-centered
7.	Jockey	-
8.	Connecting wires	flexible
9.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record in a tabular form.

(c) Plot a graph of P against R.

(d) Determine the slope, M of the best line.

(e) Calculate the reciprocal, N of the slope, M.

(f) Write the formula of the balanced bridge.

(g) Use the formula and the graph to show that N = S.

(h) Explain the physical meaning of N.

(i) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

(i) The metre-bridge principle gives:

At balance point: $\frac{R}{S} = \frac{\ell_1}{100 - \ell_1}$ where ℓ_1 is the balance length.

(ii) In this experiment, at balance point: $P = \frac{\ell_1}{100 - \ell_1}$, where ℓ_1 is the balance length. Thus, $P = \frac{R}{S}$. A graph of P against R is a straight line whose slope is $\frac{1}{S}$, $i.e\ M = \frac{1}{S}$ The reciprocal of M is N. $i.e\ N = S$

Proceed as follows:

(a) You are provided with a metre-bridge, one dry cell E, a switch K, a resistance box R or any type of variable resistor capable of providing resistance of magnitude 0,5,10,15,20,25 and 30 Ohms, galvanometer G, a jockey J and some connecting wires.

(b) Connect the circuit as shown in figure below

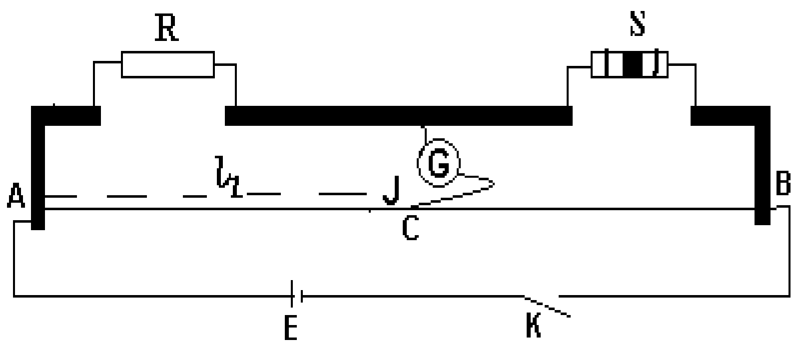


Figure E.02

(c) Starting with R = 30Ω find the balance length AC= L_1 along the metre-bridge wire AB to the nearest centimeter.

(d) Repeat the procedure in (c) above for other values of R obtained by decreasing in steps of 5Ω up to R = 0Ω.

(e) Tabulate the values of R against L_1 in increasing order of magnitudes as follows:

R(Ω)	0	5	10	15	20	25	30
L_1 (cm)							
P = $L_1/(100-L_1)$							

(f) Plot a graph of P against R.

(g) Evaluate:

(i) The slope M of the best line. What its units?

(ii) The reciprocal N of M where: N=1/M

(h) Write the formula of the balanced bridge; hence explain the physical meaning of N.

(i) Identify any two sources of errors in this experiment. For each source of error, what precaution must be taken

Experiment No. E-03

You are to determine the resistance of the wire per cm length and the length of the wire wound on the wooden block as illustrated in Fig. 3:

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, M wound on a wooden block,	100 cm of constantan wire, SWG 24
3.	Standard resistor, R_S	2 Ω
4.	Metre-bridge	Standard type
5.	Switch (key)	Plug type
6.	Galvanometer	Zero-centered
7.	Jockey	-
8.	Connecting wires	flexible
9.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of R against AB.

(d) Determine the slope, S of the graph.

(e) Use the equation and the graph to deduce a value for X.

(f) Measure diameter of wire, M using a micrometer screw gauge.

(g) Calculate the cross-sectional area, A of wire, M.

(h) Calculate the resistivity, ρ of the wire, M using the value of S and cross-sectional area, A.

(i) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

(i) The metre-bridge principle gives at balance point: $\frac{R_S}{R} = \frac{\ell_1}{\ell_2}$

where ℓ_1 is the balance length and ℓ_2 is $(100 - \ell_2)$. From which, values of R can be calculated for various lengths, AB of wire M.

(ii) In this experiment, given: R = S(AB + X).

This is an equation of a straight line, whose slope is S, the resistance per centimetre and has an AB – axis intercept equal to – X. X is the length of the wire wound permanently on the wooden block.

Resistivity, $\rho = \frac{RA}{\ell}$, where $\frac{R}{\ell} = S$, the resistance per centimetre.

Hence, ρ = SA.

Proceed as follows:

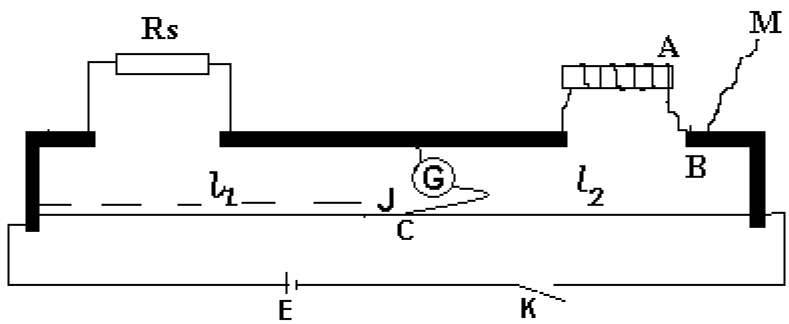


Figure E.03

(a) Set up the metre-bridge circuit as shown in the diagram above, where E is an accumulator or a 2 volt battery and G is a galvanometer. Place the 2 ohm standard resistor provided on the left hand gap of the metre-bridge. Connect the resistance wire M provided, which consists of a length of uniform wire part of which has been permanently wound on a wooden block, to the right hand gap of the metre-bridge, with AB = 60cm.

(b) Determine the balance point for the 2 ohm standard resistor and the resistance R of the wire M. Record L_1 and L_2 for which the galvanometer gives zero deflection when the slider is tapped onto the resistance wire of the metre-bridge and hence determine the value of R of wire M. (NB: Terminal B is adjustable to allow for different lengths of the wire M).

(c) Repeat the procedure in (b) above for values of AB = 50cm, 40cm, 30cm, 20cm and 10cm. Tabulate your results.

(d) Plot a graph of R against AB. Start your axes at the origin.

(i) Calculate the slope S of the graph. What are the units of S?

(ii) Use your graph and the formula $R=S(AB + X)$ to determine the value of X, where X is the length of the wire wound permanently on the wooden block.

(e) Measure the diameter of wire M. Calculate the resistivity, ρ of the wire, given that $\rho = SA$, where A is the cross sectional area of the wire.

(f) What does the value of S represent physically?

Table of results

AB(cm)	60	50	40	30	20	10
l_1(cm)						
l_2(cm)						
$R = \frac{\ell_2 Rs}{\ell_2}$ (Ω)						

Experiment No. E-04

The aim of this experiment is to determine the resistance per centimeter r, and resistivity, ρ of the wire W provided.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, W	100 cm of constantan wire, SWG 24
3.	Unknown standard resistor, Y	2 Ω
4.	Standard resistor, X	1 Ω
5.	Metre-bridge	Standard type
6.	Switch (key)	Plug type
7.	Galvanometer	Zero-centered
8.	Jockey	-
9.	Connecting wires	flexible
10.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Apply the metre-bridge principle to the circuit arrangement to determine the value of Y.

(d) Plot a graph of 1/d against l_W.

(e) Measure diameter of wire, W using a micrometer screw gauge.

(f) Calculate the cross-sectional area, A of wire, W.

(g) Determine the slope, G of the graph.

(h) Deduce the value of r using the given gradient, G equation.

(i) Calculate the resistivity, ρ of the wire, W using the value of r and cross-sectional area, A.

(j) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

(i) The variation of 1/d against l_W gives rise to straight line whose slope is:

$$G = \frac{(AB)r}{(AB)YL_0 - YL_0^2}$$ From which r can be calculated.

(ii) Since r is the resistance of wire W per centimetre, then the resistivity,

ρ = rA.

Proceed as follows:

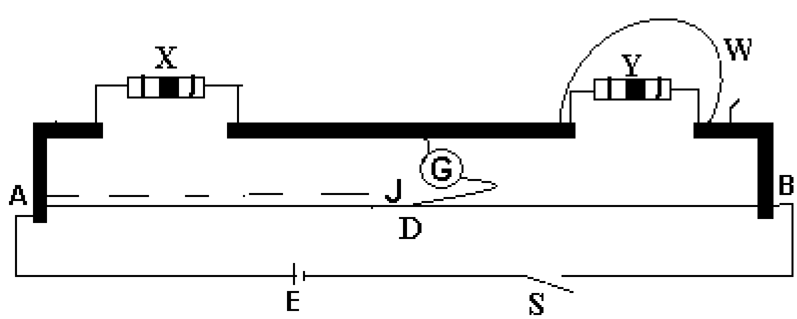


Figure E.04

(a) Connect the accumulator E and switch S to the terminals A and B of the resistance wire AB. Connect the standard resistors X and Y and the galvanometer G as shown in Fig. 4.

(b) Measure a length L_w =100 cm of the wire W and connect it in parallel with the standard resistor Y. Close the switch S and obtain a balance point, D using the jockey J. Record the length AD = L and open S.

(c) Repeat the above procedure with length of wire W equal to L_w = 80, 60, 50, 40 and 20cm and in each case record the corresponding values of L.

(d) Remove the wire W and obtain a balance point C as described above. Record the length AC = L_0.

(e) Using your readings determine the distance d given by d = L – L_0.

(f) Plot a graph of $\frac{1}{d}$ against L_w.

(g) Measure the diameter of the wire W and hence determine its cross-sectional area.

(h) Given that the gradient G of the graph is:

$$G = \frac{(AB)r}{(AB)YL_0 - YL_0^2}$$

(a) Calculate the value of r. (hint: use information from step (d) above to determine a value of Y first).

(b) Determine the resistivity, ρ of the wire W.

(The value of X = 1 Ω)

Table of results

The value of L_0 = …………………..(cm)

The diameter of wire W = …………(cm)

L_W(cm)	100	80	60	50	40	20

$d = L - L_0$ (cm)						
$1/d$ (cm^{-1})						

Experiment No. E-05

The aim of this experiment is to determine the resistivity, ρ of the material of the wire labeled W.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, W	180 cm of Manganin wire, SWG 24
3.	Standard resistor, R_s	1 Ω
4.	Metre-bridge	Standard type
5.	Switch (key)	Plug type
6.	Galvanometer	Zero-centered
7.	Jockey	-
8.	Connecting wires	flexible
9.	Graph paper	Metric

Objectives

The student should be able to:

(a) Prepare spacemen W into strands.

(b) Assemble the apparatus as indicated or described in the instructions.

(c) Take measurements and record data in a tabular form.

(d) Plot a graph of n against 1/x.

(e) Measure diameter of wire W using a micrometer screw gauge.

(f) Calculate the cross-sectional area, A of wire, W.

(g) Determine the slope of the graph.

(h) Deduce the value of ρ using the slope and the given equation.

(i) Deduce a value of L_0 from the 1/x –axis intercept.

(j) Calculate the percentage error in L, the length of the bridge wire.

(k) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

(i) From the given physical relation:

$$n = \frac{\rho \ell_0 L}{ARs}\frac{1}{X} - \frac{\rho \ell_0}{ARs}$$

slope = $\frac{\rho \ell_0 L}{ARs}$, from which ρ can be calculated.

(ii) Percentage error in $L = \frac{[(L - L_0)]}{L} \times 100\%$, where L_0 is determined from

the $\frac{1}{X}$ axis intercept.

Proceed as follows:

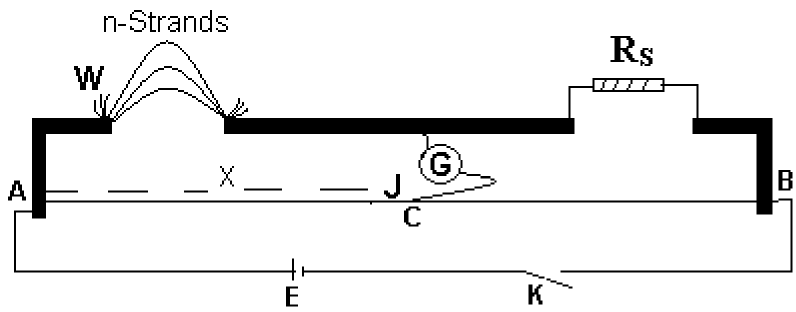


Figure E.05

Set up the circuit as in Figure E.05. AB is the metre-long wire of the whetstone-bridge, E is an accumulator and R_s is a standard resistance of one ohm. G and C are the galvanometer and contact maker, respectively.

(a) Cut the given wire W into six equal pieces, each piece of about 30 cm. Connect in the left-hand gap a single piece of length, ℓ_0 of W of about 20 cm, and obtain the balance length AC = x.

(b) Repeat this procedure with 2, 3, 4, 5 and 6 pieces of equal length,L_0 of W in the gap and record the corresponding values of x.

(c) Given that: $n = \frac{\rho \ell_0 L}{ARs} \frac{1}{X} - \frac{\rho \ell_0}{ARs}$

Where: n is the number of pieces of W in the gap, A is the cross-sectional area of the wire, and L = AB:

(i) Measure the diameter of the wire W and calculate A.

(ii) Plot a graph of n against 1/x and use it to determine the resistivity, ρ of the wire W.

(d) Determine the value of the intercept along the 1/x axis and hence, find a value of L call it L_1.

(e) Calculate the percentage error in L given that:

$$\% age\ error = \frac{[(L - L_0)]}{L} \times 100\%$$

Where L = AB, the true length of the bridge wire, and L_1 is the experimental value determined at step (d) above.

Table of results

N	1	2	3	4	5	6
x(cm)						
1/x (cm^{-1})						

Experiment No. E-06

The aim of this experiment is to determine the resistivity ρ of the wire of coil C.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, coil C	50 cm of Manganin wire, SWG 24
3.	Standard resistor, R_S	1 Ω
4.	Resistance box	1 –10 Ω
5.	Metre-bridge	Standard type
6.	Switch (key)	Plug type
7.	Galvanometer	Zero-centered
8.	Jockey	-
9.	Connecting wires	flexible
10.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of R against 1/x.

(d) Measure diameter of wire W using a micrometer screw gauge.

(e) Calculate the cross-sectional area, A of wire, W.

(f) Determine the slope of the graph.

(g) Deduce the value of ρ using the slope and the given equation.

(h) Express ρ in terms of slope, S for a graph of 1/x against R.

(i) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

(i) From the given physical relation:

$R = \frac{(\rho L_0 L + ALRs)}{A}\frac{1}{X} - \frac{(\rho L_0 + ARs)}{A}$, Slope = $\frac{(\rho L_0 L + ALRs)}{A}$, from which ρ can be calculated.

(ii) Expressing 1/x in terms of R, the slope S of the new equation can be deduced.

From which, $\rho = \frac{A}{L_0}\left(\frac{S - LRs}{L}\right)$

Proceed as follows:

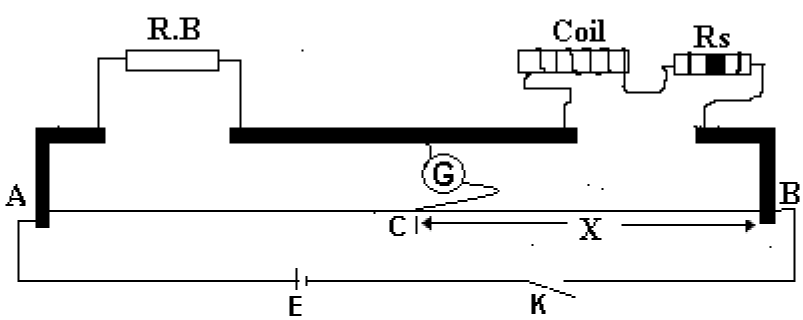


Figure E.06.

(a) Set up a metre-bridge circuit as shown in figure above. G, C, E, and K are galvanometer, jockey, an accumulator and key, respectively. Connect the coil C and the one-ohm standard resistor, R_S in series and connect the system across the right – hand gap. Across the left hand gap, connect up the resistance box (RB) provided.

(b) Put a resistance, r of 1- ohm from the resistance box and find the balance length, AC. Record the value of x of length CB repeat this procedure with values of R = 2, 3, 4, 5 and 6 ohms, each time recording the corresponding value of x.

(c) Given that:

$$R = \frac{(\rho L_0 L + ALRs)}{A}\frac{1}{X} - \frac{(\rho L_0 + ARs)}{A}$$

Where L_0 is the length of the coil C, A is the cross-sectional area of coil, C and L = AB:

(i) Calculate A.

(ii) Plot a graph of R against 1/x and use it together with the equation to determine the resistivity, ρ of the coil, C.

(d) If you were to plot a graph of 1/x against R, show that the resistivity, ρ would be given by:

$$\rho = \frac{A}{L_0}\left(\frac{S - LRs}{L}\right)$$

Where: S is the slope of the graph:

Table of results

R(Ω)	**1**	**2**	**3**	**4**	**5**	**6**
AC(cm)						
x =(100 – AC) (cm)						
$\frac{1}{X}$ **(cm^{-1})**						

Experiment No. E-07

Using the experimental procedure and the circuit diagram below), determine the resistivity, ρ of the wire labeled K.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, K	50 cm of nichrome wire, SWG 26
3.	Bare wire C	100 cm of constantan wire, SWG 24
4.	Standard resistors	1 and 0.5 Ω
5.	Metre-bridge	Standard type
6.	Micrometer Screw Gauge	± 0.001 cm
7.	Switch (key)	Plug type
8.	Galvanometer	Zero-centered
9.	Jockey	-
10.	Connecting wires	flexible
11.	Graph paper	Metric

Objectives

(a) The student should be able to:

(b) Assemble the apparatus as indicated or described in the instructions.

(c) Take measurements and record data in a tabular form.

(d) Apply the metre-bridge relation to find resistance, C_1

(e) Plot a graph of 1/z against L.

(f) Measure diameter of wire K using a micrometer screw gauge.

(g) Calculate the cross-sectional area, A of wire, K.

(h) Determine the gradient of the graph.

(i) Deduce the value of ρ using the slope and the given equation.

(j) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

From the given physical relation:

$$\frac{1}{Z} = \frac{\rho L}{100AC_1} + \frac{1}{100}$$

- slope = $\dfrac{\rho}{100AC_1}$ (from the equation)
- slope = $\dfrac{\Delta \frac{1}{Z}}{\Delta L}$ (from the graph)

Hence: ρ = slope x $100AC_1$

Where: $A = \dfrac{\pi d^2}{4}$ and $C_1 = \left(\dfrac{\ell}{100-\ell}\right)M$

Proceed as follows:

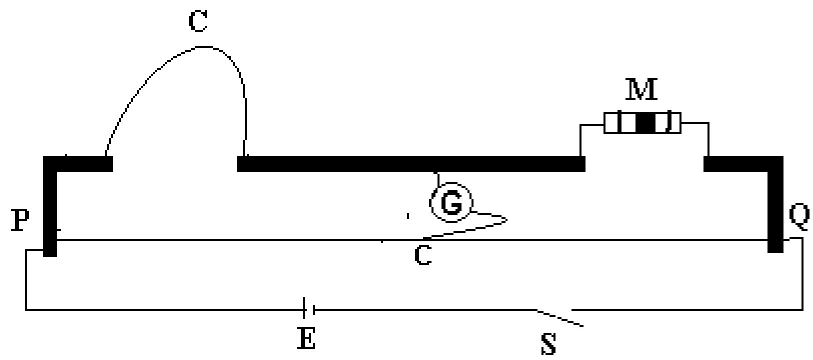


Figure E.07

(a) Set up a metre-bridge circuit in which exactly 100 cm of the bare wire labeled C is connected in the left-hand gap and a 1.0 Ω standard resistor is connected in the right-hand gap, M. Obtain the balance lengths, ℓ, of the metre-bridge wire and hence calculate the resistance C_1 of wire labeled C. Replace the 1.0Ω standard resistor at M with 0.5 Ω standard resistor and obtain a new balancing length. Again, determine the resistance of wire C and hence find the average value of C_1.

(b) Without cutting any wire, replace the 0.5 Ω standard resistor at M with a length, L=10cm of the bare wire labeled K. Measure the left-hand side balance length, z of the metre-bridge wire PQ.

(c) Repeat the procedure in (ii) above for values of L = 15 cm, 20 cm, 25 cm, 30 cm and 35 cm. Tabulate L, z and 1/z.

(d) Measure accurately the diameter of wire K, then:

(i) Plot a graph of 1/z against L

(ii) Given that L and z are related by the equation:

$$\frac{1}{Z} = \frac{\rho L}{100AC_1} + \frac{1}{100}$$

Where A is the cross-sectional area of wire K, determine the resistivity, ρ of the material of wire K.

Table of results

L(cm)	10.0	15.0	20.0	25.0	30.0	35.0
Z(cm)						
z^{-1} (cm^{-1})						

Experiment No. E-08

The aim of this experiment is to determine the electrical resistivity, ρ of the wire labeled X.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, X	50 cm of nichrome wire, SWG 26
3.	Standard resistor	2 Ω
4.	Resistance box	1 –20 Ω
5.	Metre-bridge	Standard type
6.	Switch (key)	Plug type
7.	Galvanometer	Zero-centered
8.	Micrometer Screw Gauge	± 0.001 cm
9.	Jockey	-
10.	Connecting wires	flexible
11.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of 1/R against 1/l.

(d) Measure diameter of wire X using a micrometer screw gauge.

(e) Calculate the cross-sectional area, A of wire, X.

(f) Determine the gradient of the graph.

(g) Deduce the value of ρ using the slope and the given equation.

(h) Discuss sources of errors related to the experiment and suggest precautions/ways/methods of minimizing them.

Theory

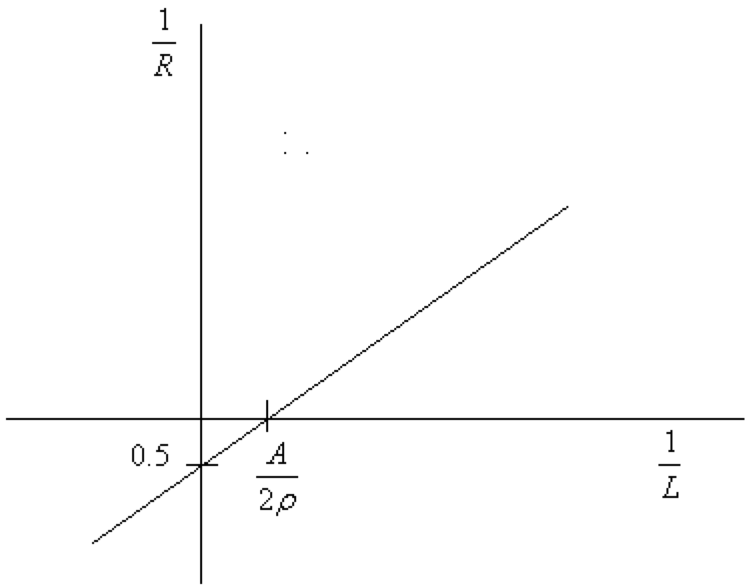
From the given physical relation:

$$\frac{1}{R} = \frac{A}{\rho}\frac{1}{L} - \frac{1}{2}$$

- slope = $\frac{A}{\rho}$ (from the equation)
- slope = $\frac{\Delta \frac{1}{R}}{\Delta \frac{1}{L}}$ (from the graph)

Hence: ρ = $\frac{A}{Slope}$ Where: A = $\frac{\pi d^2}{4}$

Nature of the graph



Proceed as follows:

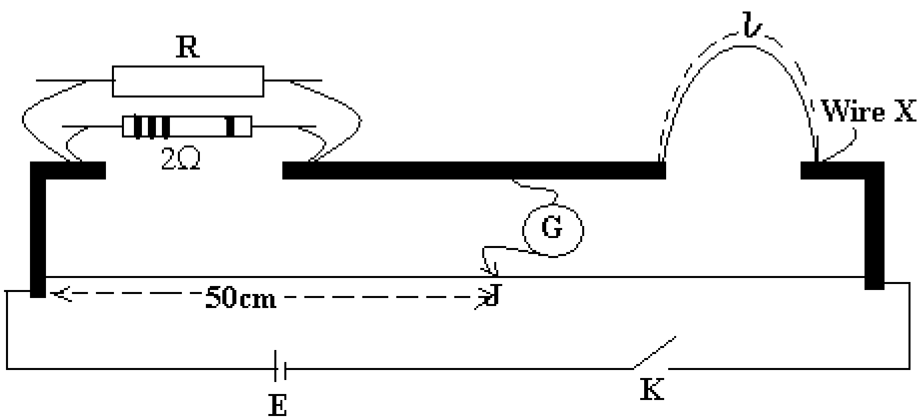


Figure E.08

(a) Set up a slide-wire metre bridge as illustrated in figure above, where E is an accumulator and G is a galvanometer. A length, L of wire x is connected across the right-hand gap of the bridge and the jockey or slider J is placed at the 50cm mark.

(b) With R= 20 Ω, find the value of length, L for which the galvanometer gives zero deflection when a slider is tapped onto the 50cm. mark as illustrated in Fig. 8.

(c) Repeat the procedure in (b) for values of R equal to 10Ω, 5Ω, 2Ω, 1Ω and 0.5Ω.

(i) Calculate and tabulate the values of 1/R and 1/L for the values of R = 20Ω, 10Ω,

5Ω, 2Ω, 1Ω and 5Ω obtained in (b) and (c) above.

(ii) By means of the micrometer screw gauge provided, measure the diameter of wire

X and hence calculate its average diameter, d.

(iii) Plot a graph of 1/R against 1/L (whose values are recorded in (i)) and determine

its gradient.

(iv) Determine the resistivity, ρ of wire X, given that

$\frac{1}{R} = \frac{A}{\rho}\frac{1}{L} - \frac{1}{2}$, where A is the cross-sectional area of wire X.

Table of results

R(Ω)	20	10	5	2	1	0.5
L(cm)						
$\frac{1}{R}$ **(Ω^{-1})**						
$\frac{1}{L}$ **(cm^{-1})**						

Experiment No. E-09

The aim of this experiment is to determine the value of the unknown resistance R and the resistivity, ρ of the material of wire W.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	Specimen of wire, W	150 cm of nichrome wire, SWG 26
3.	Resistor R	Unknown
4.	Standard resistor	4 Ω
5.	Crocodile clip	Soldered terminal
6.	Metre-bridge	Standard type
7.	Metre-rule	Mm scale
8.	Switch (key)	Plug type
9.	Micrometer Screw Gauge	± 0.001 cm
10.	Galvanometer	Zero-centered
11.	Jockey	-
12.	Connecting wires	flexible
13.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Calculate R_e using the metre-bridge formula $R_e/R_s = (100 - l)/l$

(d) Plot a graph of R_e against x.

(e) Deduce R from the R_e –axis intercept.

(f) Measure diameter of wire W using a micrometer screw gauge.

(g) Calculate the cross-sectional area, A of wire, W.

(h) Determine the gradient of the graph.

(i) Deduce the value of ρ using the slope and the given equation.

(j) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

(i) The physical relation can be deduced by considering the right hand gap as a series
connection between the unknown resistor R and the resistor of the wire W. Taking
their total resistor be equal to the calculated equivalent resistor, $R_{e.}$

i.e $R_e = R + R_w$ where R_w is the resistor of the wire W

but $R_w = \dfrac{\rho_w \ell_w}{A_w}$,since $\rho_w = \rho$ *and* $\ell_w = X$ *, then*

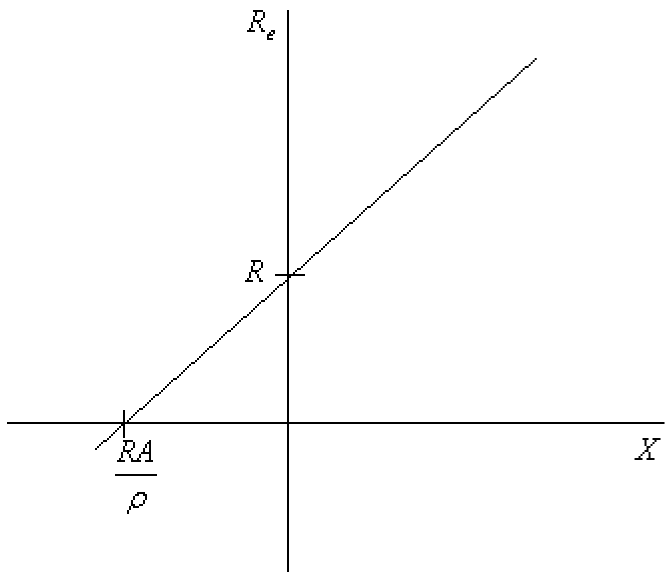
$$\text{Re} = \frac{\rho X}{A} + R \qquad \therefore \text{ Slope} = \frac{\rho}{A} \text{ (from equation)}$$

$$\text{Slope} = \frac{\Delta \text{Re}}{\Delta X} \text{ (from graph)}$$

Hence, ρ = A x slope, where slope is resistance per unit length and A = $\dfrac{\pi d^2}{4}$

(ii) Deduce value of R from the R_e-axis intercept.

(iii) Nature of the graph



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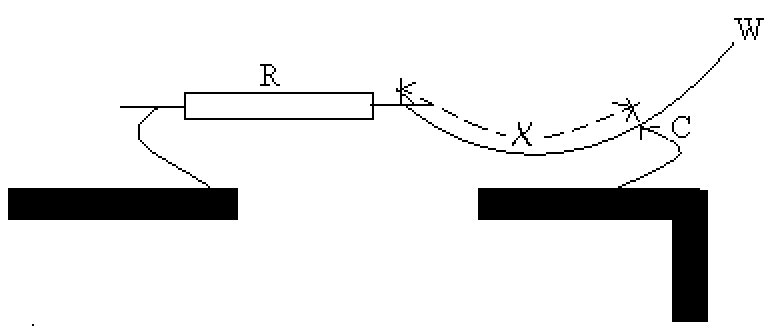


Figure E.09

(a) (i) Connect the unknown resistance, R, and the wire W in series. Connect the free end of R to the left terminal of the right-hand gap of the meter-bridge. Next connect the wire with a crocodile clip C to the other terminal of the right-hand gap as shown in figure E.09.

(ii) Connect the 4-ohm resistor in the left-hand gap and hence complete the Wheatstone-bridge circuit in the usual manner.

(b) Draw the complete circuit diagram of the set up outlined in (a) above.

(c) (i) Measure a length x of the wire W equal to 20 cm and clip the crocodile clip, C at the end of this length.

(ii) Find a balance point, L, as measured from end with the 4-ohm resistor.

(iii) Calculate the equivalent resistance R_e in the right-hand gap.

(iv) Increase x by 20cm each time and obtain corresponding values of L and R_e.

(v) Tabulate your readings (a total of six readings is required).

(d) Plot a graph of R_e against x.

(e) From the graph deduce:

(i) The value of the unknown resistance R.

(ii) The resistance per unit length of the wire, W.

(f) Measure the diameter of the wire, W, and hence find the resistivity, ρ of the material of the wire.

Table of results

x(cm)	20	40	60	80	100	120
L(cm)						
R_e (Ω)						

Experiment No. E-10

In this experiment you are required to determine the resistivity, ρ of the wire labeled W.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2 - 3 V
2.	wire, A	110 cm of nichrome wire, SWG 26
3.	Specimen wire W	50 cm of constantan wire SWG 24
4.	Resistor R	Unknown (2Ω)
5.	Metre-bridge	Standard type
6.	Metre-rule	Mm scale
7.	Switch (key)	Plug type
8.	Galvanometer	Zero-centered
9.	Jockey	-
10.	Micrometer Screw Gauge	± 0.001 cm
11.	Connecting wires	flexible
12.	Graph paper	Metric

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Determine average value of R_1 using the metre-bridge formula R_1/R_s = x/(100 – x)

(d) Plot a graph of L against 1/x.

(e) Measure diameter of wire W using a micrometer screw gauge.

(f) Calculate the cross-sectional area, A of wire, W.

(g) Determine the gradient of the graph.

(h) Deduce the value of ρ using the slope and the given equation.

(i) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

From the given relation:

$$L = \frac{100AR_1}{\rho X} - \frac{AR_1}{\rho}$$

- Slope = $\dfrac{100AR_1}{\rho}$ (from equation)

- Slope = $\dfrac{\Delta L}{\Delta \frac{1}{X}}$ (from graph)

Hence: ρ = $\dfrac{100AR_1}{Slope}$ Where: A = $\dfrac{\pi d^2}{4}$

Proceed as follows:

(a) (i) Set up a metre-bridge circuit in which exactly 100 cm of the bare wire labeled A is connected in the left-hand gap and a 1.0 Ω standard resistor is connected in the right-hand gap.

(ii) Obtain the balance lengths of the metre-bridge wire and hence calculate the resistance, R_1 of the wire labeled A.

(iii) Replace the 1.0 Ω standard resistor with a 0.5 Ω standard resistor and obtain balancing lengths. Again determine the resistance R_1 of the wire labeled A

(iv) Hence, find an average value of R_1.

(b) Without cutting any wire, replace the 0.5 Ω standard resistor with a length, L=10 cm of the bare wire labeled W. Measure the left-hand side balance length, x of the metre-bridge wire.

(c) Repeat the process mentioned in (b), above for values of L=15 cm, 20 cm, 25 cm, 30 cm, and 35 cm. Tabulate L, x and 1/x.

(d) Measure accurately the diameter of the wire labeled W.

(e) Plot graph of L against 1/x.

(f) Given that L and x are related by the equation:

$$L = \frac{100AR_1}{\rho X} - \frac{AR_1}{\rho}$$

Where A is the cross-sectional area of wire W, determine the resistivity, ρ of the material of wire W.

Table of results

L(cm)	10	15	20	25	30	35
x(cm)						
x^{-1} (cm^{-1})						

Experiment No. E-11

The aim of this experiment is to determine the specific resistance (i.e. resistivity, ρ) of the bare wire W provided.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS	QUANTITY/ STUDENT
1.	Accumulator	2 - 3 V	1
2.	Specimen wire W	150 cm of constantan wire SWG 26	160 cm
3.	Standard resistor	2Ω	1
4.	Metre-bridge	Standard type	1
5.	Metre-rule	Mm scale	1
6.	Switch (key)	Plug type	1
7.	Galvanometer	Zero-centered	1
8.	Jockey	-	1
9.	Crocodile clip	Soldered to a connecting wire	1
10.	Micrometer Screw Gauge	± 0.001 cm	1
11.	Connecting wires	flexible	
12.	Graph paper	Metric	1

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Calculate R_e using the metre-bridge formula $R_e/R_s = (100 – AJ)/AJ$

(d) Plot a graph of R_e/l against l.

(e) Determine the average value of the resistance per unit length, R_A fron the R_e/l – axis intercept.

(f) Measure diameter of wire W using a micrometer screw gauge.

(g) Calculate the cross-sectional area, A of wire, W.

(h) Deduce the value of ρ using the intercept and the cross-sectional area, A.

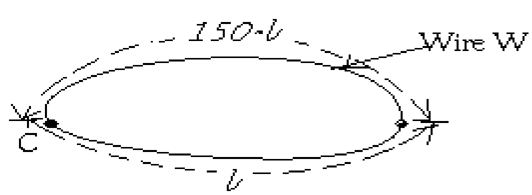
(i) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

The equivalent resistance, R_e on the Right hand side gap of the bridge is calculated from:

$$\frac{R_e}{R_s} = \frac{100 - AJ}{AJ}$$

The physical relation can be deduced by considering the right hand gap, as a combination of two wires of the same material, connected in parallel with different length.



And if the resistor of (150-l) cm is R_1 and that of l cm be R_2,then their total resistor can be considered as $R_T = \frac{R_1 R_2}{R_1 + R_2}$

But $R_1 = \frac{\rho_1(150-\ell)}{A_1}$ *and* $R_2 = \frac{\rho_2 \ell}{A_2}$

Since the wire is of the same material then $\rho = \rho_1 = \rho_2$ *and* $A = A_1 = A_2$

$$\therefore R_T = R_e = \frac{\rho(150-\ell)\rho\ell}{A^2} \div \left(\frac{\rho(150-\ell)}{A} + \frac{\rho\ell}{A}\right)$$

$$R_e = \frac{\rho^2\ell(150-\ell)}{150\rho A}$$

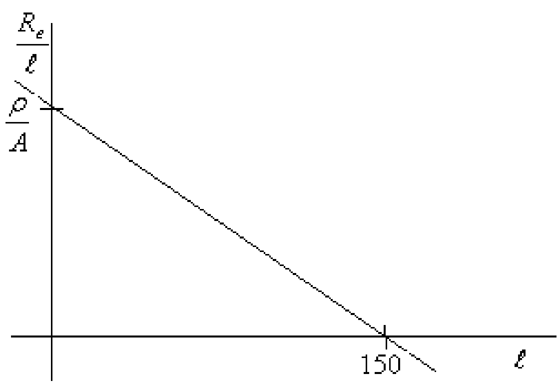
$$R_e = \frac{\rho\ell}{A} - \frac{\rho\ell^2}{A}$$

$$\therefore \frac{R_e}{\ell} = -\frac{\rho}{150A}\ell + \frac{\rho}{A}$$

The average value of the resistance per unit length, R_A is deduced from the $\frac{R_e}{\ell}$ – axis intercept and slope

Hence: $\rho = \frac{RA}{\ell}$ *where* $\frac{R}{\ell} = R_A$

$$\therefore \rho = R_A A \text{ where } A = \frac{\pi d^2}{4}$$



Proceed as follows:

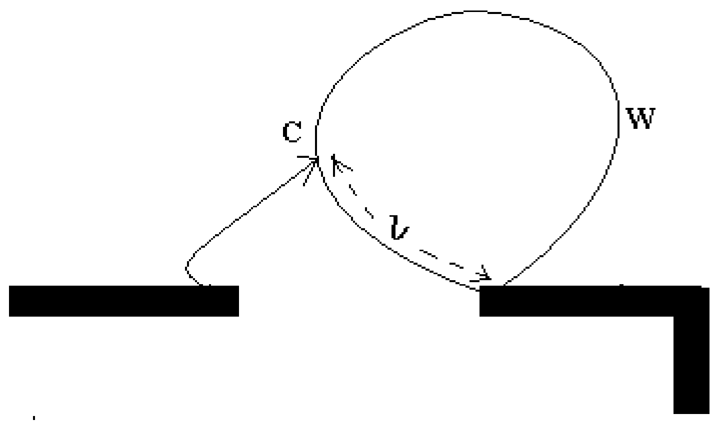


Figure E.11

(a) (i) Set up the metre-bridge circuit in which a two-ohms (standard) resistor is connected across the left-hand gap. To one of the terminals of the right hand-gap, connect both ends of the wire W supplied such that exactly 150 cm. makes up a loop (see figure E.11). Draw the complete circuit.

(ii) Using a crocodile clip V or any suitable method, connect a length L of 15 cm across the gap and balance the bridge.

(iii) Calculate the equivalent resistance, R_e in the right hand gap. Record this in a suitable table showing values of L and R_e. In your table include a column for R_e/L (i.e. the resistance per cm).

(b) Increase L in steps of 15 cm and for each value of L, calculate the equivalent resistance, R_e when the bridge is balanced. Obtain 5 other values.

(c) Plot a graph of R_e/L against L, starting both your scales at the origin.

(d) From you graph determine:

(i) The average value of the resistance per unit length R_A of the wire W.

(ii) The specific resistance of the wire. Note that you will be required in this case to measure the diameter of the wire W.

(e) State any sources of errors and the precautions taken in this experiment.

Table of results

ℓ (cm)	15	30	45	60	75	90
AJ (cm)						
R_e (Ω)						
R_e/ℓ (Ωcm^{-1})						

Experiment No. E-12

The aim of this experiment is to determine the resistance, R_v of a voltmeter, and the internal resistance, r of a battery.

Derivation of $R = \frac{ER_V}{V} - (R_V + r)$

Since E= I(R_T + r), where $R_T = R + R_v$

E= I(R + R_v + r), or

$\frac{E}{I}$ = R+ R_v + r, or

R = $\frac{E}{I}$ − (R_v + r),

r)

You are provided with the following: a battery of known e.m.f, a voltmeter, several connecting wires, a switch and either a decade resistance box capable of providing resistance of up to 4000 ohms, or seven resistors labeled: 400 Ω, 1000 Ω, 1600 Ω, 2200 Ω, 2800 Ω, 3400 Ω, 4000 Ω,

(a) Connect the battery, switch, voltmeter and the 400 Ω resistor (or resistance box adjusted to 400 Ω) so that the same current flows through all the components when the switch is closed.
(b) Draw a diagram of the circuit you have connected.
(c) Close the switch and obtain the voltmeter reading, V.
(d) Increase the value of the resistance, increasing it in steps of 600 Ω up to a maximum of 4000 Ω. Tabulate your values of resistance, R, voltmeter reading, V and 1/V.
(e) Plot a graph of R (vertical axis) against 1/V (horizontal axis).
(f) Given that, the resistance, R is related to to the voltage, V by :

$$R = \frac{ER_V}{V} - (R_V + r)$$

Use the graph in (e) above to determine.

(i) The resistance, R_v of the Voltmeter.

(ii) The internal resistance, r of the battery.

Table of results

R (Ω)	400	1000	1600	2200	2800	3400	4000
V (V)							
1/V (V^{-1})							

Experiment No. E-13

The aim of this experiment is to determine the resistivity, ρ of the material of the wire labeled W_1.

Requirements

S/No	**ITEM**	**SPECIFICATIONS**
1.	Accumulator	2-3 V
2.	Potentiometer wire	Standard type
3.	Daniel cell	1.5 V
4.	Specimen wire W_1	Constantan wire SWG 24
5.	Ammeter	0-5 A
6.	Galvanometer	Zero-centered
7.	Jockey	-
8.	Switch (key)	Plug type
9.	Micrometer screw	

	gauge	± 0.001 cm
10.	Connecting wires	flexible
11.	Graph paper	Metric type

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of Y against Ix.

(d) Measure diameter of wire W_1 using a micrometer screw gauge.

(e) Calculate the cross-sectional area, A of wire W_1.

(f) Determine the slope, S of the graph.

(g) Determine the value of K, the resistance per unit length of wire W_1.

(h) Calculate the resistivity, ρ using K and A.

(i) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

The graph of Y against Ix is a straight line.

(i) From the graph, Slope, $S = \Delta Y/\Delta(Ix)$

Then, from the given relation: $S = KY_0/E_0$

$$K = \frac{SE_O}{Y_O}$$

Where:

K is the resistance per unit length of wire W_1, Y_0 is the balance length when K_1 is open and E_0 is the emf of the Daniel cell.

(ii) Since $\rho = KA$, where $A = \pi d^2/4$, where d is the diameter of wire W_1, then ρ can be calculated.

Proceed as follows:

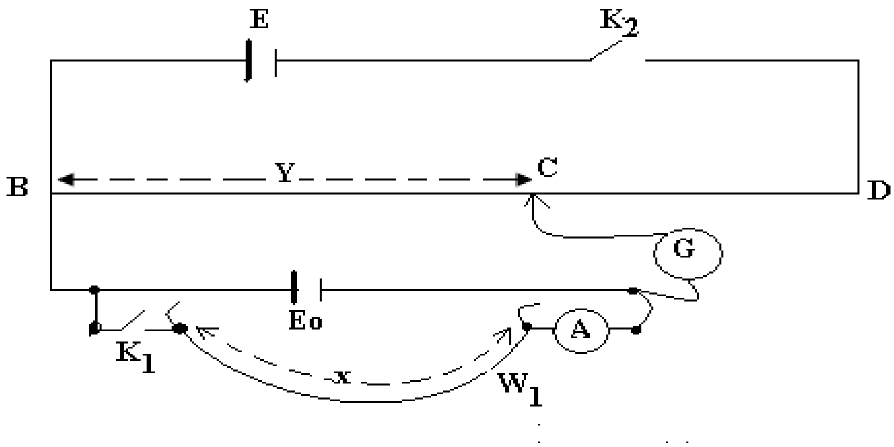


Figure E 13

Set up the circuit as shown in figure above. E is an accumulator connected across the potentiometer wire BD. E_o is a Daniel cell and G and C are the galvanometer and contact maker respectively.

Across the Daniel Cell E_o is connected the key K_1, wire W_1 and the ammeter A in series with one another.

(a) With K_1 open determine the balance length Y_o corresponding to the emf of the Daniel cell, E_o.

(b) With K_1 closed and about 50 cm of the wire W_1 in the circuit as shown in Fig. 13, record the ammeter reading, I corresponding to the new balance length, Y. Putting shorter lengths of W_1 in the circuit, repeat this procedure for at least 6 values of the length x of the wire W_1 and record the corresponding values of I and Y. Plot a graph of Y against Ix and determine its slope S

(c) Measure the diameter, d of the wire W_1 and determine its area, A of cross-section.

(d) Given that:

$$S = \frac{KY_0}{E_O}$$

Where K is the resistance per unity length of the wire W_1, determine the value of K, and hence calculate the resistivity, ρ of the material of the wire labeled W_1. Assume, E_o = 1.5 V

Table of results

x (cm)	50	40	30	20	15	10
Y (cm)						
I (A)						
Ix (Acm)						

Experiment No. E-14

The aim of this experiment is to determine the internal resistance, r of a dry-cell using a potentiometer circuit.

Time: 2 HOURS

Requirements

S/No	**ITEM**	**SPECIFICATIONS**
1.	Accumulator	2-3 V
2.	Potentiometer wire	Standard type
3.	Dry cell	1.5 V
4.	Resistance box	Up to 10 Ω
5.	Galvanometer	Zero-centered
6.	Jockey	-
7.	Switch (key)	Plug type
8.	Connecting wires	flexible
9.	Graph paper	Metric type

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.
(b) Take measurements and record data in a tabular form.
(c) Plot a graph of 1/x against 1/R.
(d) Determine the slope of the graph.
(e) Determine the 1/R –axis intercept
(f) Deduce a value of r using the slope
(g) Deduce a value of r using the 1/R – intercept
(h) Calculate an average value of r
(i) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

The graph of 1/x against 1/R is a straight line.

(i) From the graph, $slope = \frac{\Delta\, 1/x}{\Delta\, 1/R}$

From the equation, $slope = r/x_o$

Where:

r is the internal resistance of the dry cell and x_o is the balance length when K_2 is open

Hence, $r_1 = X_o$ x slope

(ii) From the graph, let the $1/R$ –axis intercept be $1/R_O$

From the equation, the $1/R$ –axis intercept is $1/r$

Hence $r_2 = R_0$

(iii) Average value of $r = \frac{r_1 + r_2}{2}$

Proceed as follows:

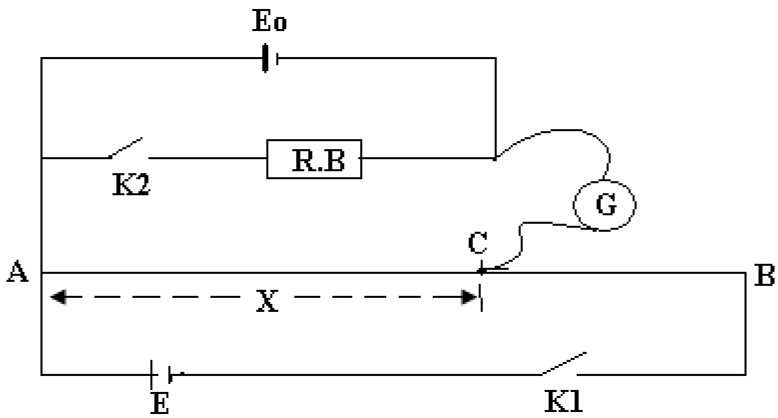


Figure E.14

Set up the circuit as shown in figure above, where E, E_0, AB, G, C and RB are an accumulator, dry-cell, potentiometer wire, galvanometer, jockey and a resistance box, respectively.

(a) With K_2 open, determine the balance length, AC = x_0.

(b) With K_2 closed and the RB set at R = 10 ohms, quickly measure the new balance point x. Open K_2 as soon as this has been done.

(c) Reduce the value of R in roughly five equal steps to 1 ohm, and each time obtain the balance length x as quickly as possible.

(d) The balance length x is related to the resistance R by the formula:

$$\frac{1}{x} = \frac{r}{x_o R} + \frac{1}{x_o}$$

Where, r is the internal resistance of the dry-cell.

Make a convenient table of results and Plot a graph of $1/x$ against $1/R$

Determine a value of r from:

(i) the slope (ii) the $1/R$ axis intercept.

Calculate an average value of r obtained from (i) and (ii).

Table of results

R (Ω)	10	8	6	4	2
x (cm)					
1/x (cm^{-1})					
1/R (Ω^{-1})					

Experiment No. E-15

The aim of this experiment is to determine the resistivity, ρ of a potentiometer wire using an ammeter and a voltmeter.

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2-3 V
2.	Potentiometer wire	Standard type
3.	Ammeter	0-5 A
4.	Voltmeter	0-5 V
5.	Standard resistor	1 Ω
6.	Jockey	-
7.	Switch (key)	Plug type
8.	Micrometer screw gauge	± 0.001 cm
9.	Connecting wires	flexible
10.	Graph paper	Metric type

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of S = 1/V against 1/l.

(d) Determine the slope of the graph.

(e) Determine the intercept, S_0 on the S–axis intercept.

(f) Calculate a value of the resistivity, ρ from the given relation.

(g) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

The graph of S against 1/l is a straight line.

(i) From the graph, $slope = \dfrac{\Delta S}{\Delta \frac{1}{I}}$

(ii) From the graph, the S –axis intercept is S_0

(iii) The resistivity, ρ can be found from the given relation:

$$\rho = \frac{\pi d^2 S_O}{4 \times Slope}$$

Proceed as follows:

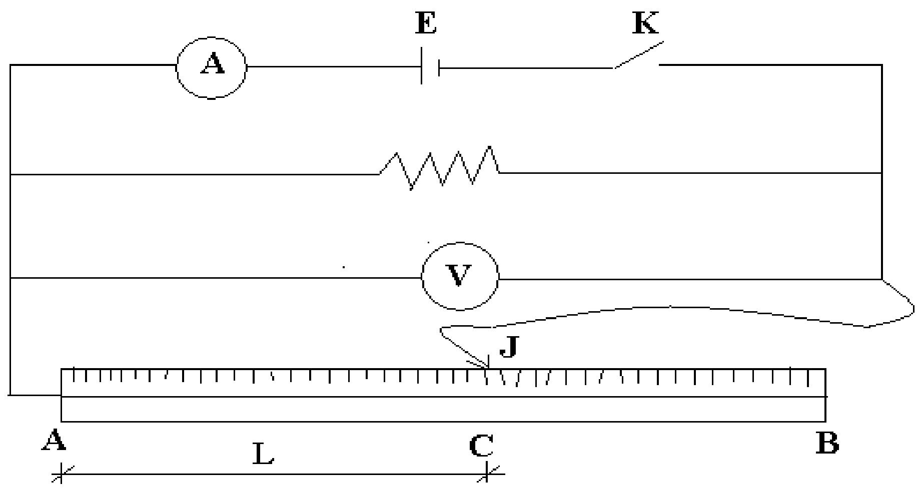


Figure E 15

(a) Set up the circuit as shown in Fig. 15 above.

(b) Measure the diameter, d of the wire AB using a micrometer screw gauge.

(c) Close the switch K and touch the wire AB at C so that AC = L = 10 cm; 20

cm; 25 cm; 30 cm; 35 cm. For each value of L record the corresponding ammeter, I and voltmeter, V readings.

(d) Find S = 1/V and 1/IL.

Tabulate your results.

(e) Plot a graph of S against 1/IL.

(f) From your graph record:

(i) The intercept (S_o) on the S axis and find $1/S_o$.

(ii) Determine the slope of your graph and hence calculate the resistivity, ρ of the wire AB, given that:

$$\rho = \frac{\pi d^2 S_O}{4 \times Slope}$$

Table of results

I (A)	10	20	25	30	35
V (V)					
l (cm)					
1/l (cm^{-1})					
S=1/V (V^{-1})					

Experiment No. E-16

The aim of this experiment is to determine the emf, E_o and internal resistance, r_o of a dry cell

Time: 2 HOURS

Requirements

S/No	ITEM	SPECIFICATIONS
1.	Accumulator	2-3 V
2.	Dry cell, E_0	1.5 V
3.	Potentiometer wire	Standard type
4.	Ammeter	0-5 A
5.	Voltmeter	0-5 V
6.	Standard resistor, R_s	1 Ω
7.	Jockey	-
8.	Switch (key)	Plug type
9.	Connecting wires	flexible
10.	Graph paper	Metric type

Objectives

The student should be able to:

(a) Assemble the apparatus as indicated or described in the instructions.

(b) Take measurements and record data in a tabular form.

(c) Plot a graph of V against I.

(d) Use the graph to deduce r_0 from the slope of the graph.

(e) Use the graph to determine E_0 from an intercept.

(f) Apply Kirchhoff's loop rule to deduce the given relation.

(g) Discuss sources of errors related to the experiment and suggest. precautions/ways/methods of minimizing them.

Theory

The graph of V against I is a straight line.

(i) From the graph, $slope = \frac{\Delta V}{\Delta I}$

From the equation, slope = $r_0 + R_s$

Hence, r_0 = slope - R_s

(ii) From the graph, the V –axis intercept is E_0.

(iii) When applying Kirchhoff's loop rule, regard $V = V_{BC}$ as a source of emf because of the effect of E.

Hence, taking anticlockwise as positive:

$V_{BC} - E_0 = Ir_0 + IR_s$

Or

$V_{BC} = (r_0 + R_s)I + E_0$

Proceed as follows:

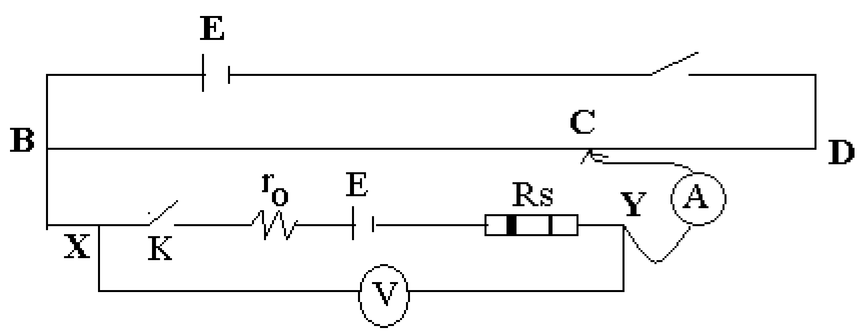


Figure E 16

Set up the circuit illustrated in figure above, where E is an accumulator (or a double Nife-cell), E_o is the dry cell under test and R_s is a standard resistance whose valve is 1 Ω. V, K, A and C are the voltmeter, key, ammeter and a contact maker, respectively. Note that the positive terminals of E and E_o are connected at B, which is the zero end of the potentiometer wire BD.

(a) Close the key K, and starting with the contact C near the end D and sliding it towards B, record the readings of the voltmeter, V and ammeter, I. Take about four readings until the ammeter reads just about zero. Record the values of I as positive.

(b) Reverse the connections at the terminals of the ammeter. Repeat the above procedure by making contacts further down the wire BD until you reach the end B. Record about four readings of V and I. Now record I as negative.

(c) The potential difference, V across XY is related to the electric current, I through the dry cell by:

$$V = (ro + R_s)\ I + E_o$$

(i) Plot a graph of V against I and use it to determine r_0 and E_o.

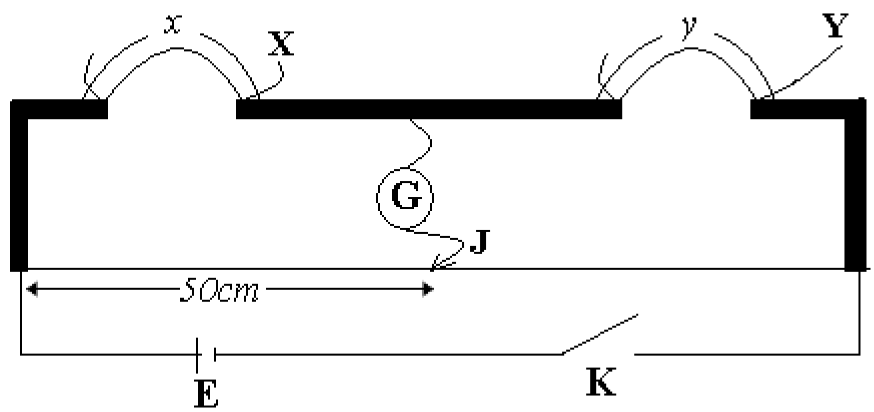
(ii) Use Kirchhoff's loop rule to deduce the given relation from loop BXYC.

Table of results

I (A)	Positive			Negative			
V (V)							

Experiment no.E17

In the experiment to determine the electrical resistivity of the wire labeled X, the following set up was done.



With a length y = 10 cm of the wire labelled **Y** connected to the right hand gap of the metre bridge; the left hand gap a length x of the wire labelled **X** was also connected to give a balance point at the 50cm mark of the bridge.

(a) The procedure was repeated for values of y = 20, 30, 40, 50 and 60cm while obtaining the corresponding length x of the wire X that gives the balance point at 50 cm mark.

(b) The following table of results was obtained.

y(±0.1)cm	10	20	30	40	50	60
x(±0.1)cm	14	25	42	52	67	77

If the diameters, d_x of wire **X** and d_y of **Y** are 0.45mm and 0.37mm respectively,

(c) Plot a graph of **y against x** and determine its slope S. ***(8 marks)***

(d) Deduce the equation which relate y and x.Use it with the aid of the drawn graph to determine the resistivity ρ_x of the wire **X**.The resistivity ρ_y of wire **Y** is *$5.21 \times 10^{-7}\Omega m$* ***(12 marks)***

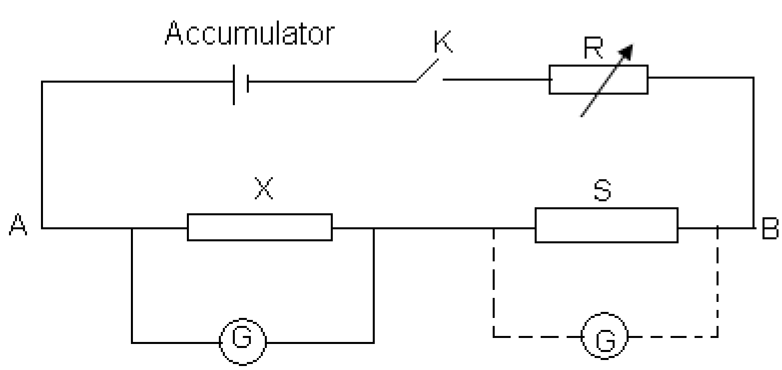
Hint: *Use metre bridge balance equation and* $\rho = \frac{RA}{L}$;

Where $\rho = resistivity\ of\ the\ wire,$
$R = resistace\ of\ the\ wire\ and$
$L = length\ of\ the\ wire$

In this experiment, you are required to determine the value of unknown resistance X.

Proceed as follows:

Arrange the circuit as shown below, where K is a switch, R is a variable resistor, S is a standard resistor (10Ω) and X is the unknown resistor.



(a) (i) Connect the galvanometer first in parallel with X and record the deflection
θ_X. Remove and connect the galvanometer in parallel with S and record the
deflection θ_S. The value of R is about 400Ω.

(ii) Repeat part (i) above by increasing the value of R in the interval of 100Ω.Each time record the deflections so as to obtain 8 more readings. Tabulate your results.

(b) Plot the graph of deflection θ_X against θ_S

(c) (i) From your graph obtain the value of the slope.

(ii) Use the slope obtained to find the value of X. Note: Potential drop is proportional to deflection, θ, in the galvanometer.

(d) State any two sources of errors

Experiment no.E18

The aim of this experiment is to determine the resistivity, ρ ,of the wire labeled W and the internal resistance of the battery provided.

Proceed as follows:

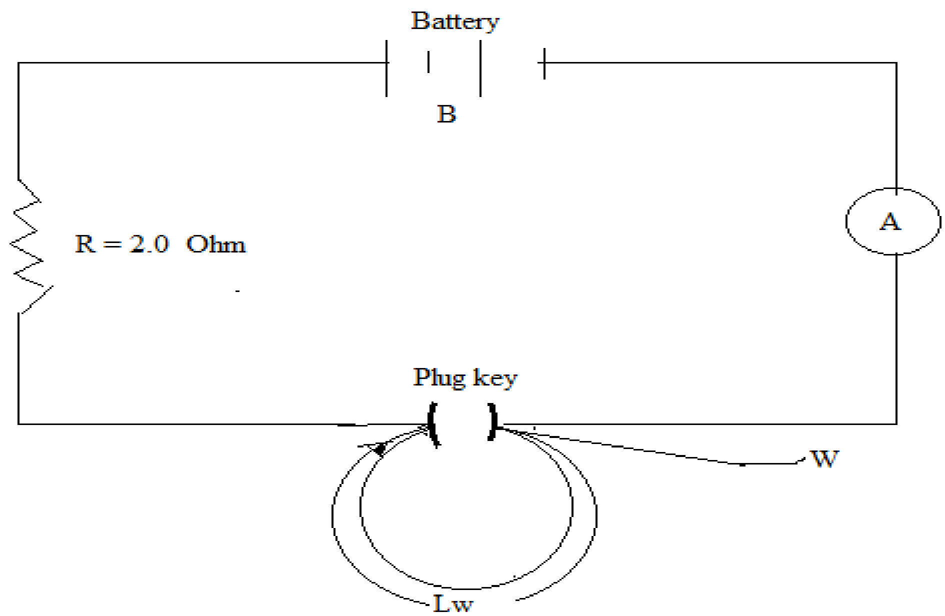


Fig.18.

Connect the circuit as shown in Fig.18 above. With the plug key open adjust the length of wire W to a value of 20 cm. Note the ammeter reading .

NB: Plug key should be open throughout the experiment.

(a) Repeat the procedure above for L_w = 40 cm ,60 cm, 80 cm and 100 cm each time recording the ammeter reading.

(b) Tabulate your results as shown in the table below.

Length L_w of wire(cm)	Current I (A)	$\frac{1}{I}(A^{-1})$

(c) (i) Plot a graph of $\frac{1}{I}$ against L_w

(ii) Determine the slope G.

(iii) Determine the Intercept Y on the vertical axis

(d) Measure and record the diameter at four different places on the wire. Hence find the mean value of diameter d.

(e) Given that $G = \frac{4\rho}{\pi d^2 E}$ and $Y = \frac{R + r}{E}$, Where E is the emf of the battery, and R=2 Ω:

Find the (i) The resistivity, ρ, of the wire.(ii) Internal resistance, r , of the battery.