



MINISTRY OF EDUCATION, HERITAGE & ARTS



EXPERIMENTS IN SIXTH FORM PHYSICS

STUDENT'S LABORATORY MANUAL

**CURRICULUM DEVELOPMENT UNIT
1998**

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Laboratory Manual
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Curriculum Development Unit
Ministry of Education & technology
Suva, FIJI

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Introduction

The Experiments in Sixth Form Physics Laboratory Manual is written for the second year of the FSLC physics course

Laboratory work is designed to help better understand the basic principles of physics. At the same time, you will gain a familiarity with the scientific methods and techniques employed in the laboratory. The chief aim of experimentation in science is to discover the laws which govern a certain phenomenon or to verify a given law which has been derived from a theory.

Seeing experiments being performed i.e. demonstration of experiments, are important for understanding the principles of science. However, hands-on experimentation is recommended because it involves learning by doing. It needs to be emphasised that for a systematic and scientific training of a young mind, genuine laboratory practice is a must. It is envisaged that whenever possible, students will be given the opportunity to do the experiments on their own.

This manual consists of 28 experiments pertaining to the topics of the form 6 year of the FSLC Physics prescription. Teachers are advised to consult other practical handbooks for experiments on the optional topics.

Apart from the processes of science such as observing, measuring controlling variables, designing experiments, predicting, questioning, inferring, interpreting data etc. One very important aspect of laboratory work is the communication of the results obtained during the investigation. With this in mind an appendix is attached which assist in the report will write - up and in comparing experimental values with 'accepted' values.

The importance of graphical work in physics cannot go unnoticed. With this in mind graph paper is also appended which could be photocopied and used.

The ministry of Education and Technology would like to thank the Australian International Development Assistance Bureau (AIDAB) for its financial support. A special gratitude is reserved for Allan Cook (Queensland University of Technology), John Stir and Neil Rusell (Griffith University) for their initiation of the project and the support in editing and writing these series of manuals for the FSLC Sciences.

The ministry would like to acknowledge the work of the Physics workgroup.

Thanks is also extended to the Science Resource Centre, Dunedin, New Zealand for its kind permission to adapt some of the experiments and diagrams from its manual.

S. Kumar

SEO Maths

AIM:

To estimate and calculate uncertainties when taking measurements.

INTRODUCTION:

A meter rule can normally be used to measure dimensions to the nearest millimetre. For measurements requiring the dimensions of an object to the nearest 0.1mm, vernier callipers are used. For even greater precision (± 0.01 mm), a micrometre screw gauge is used.

Examples

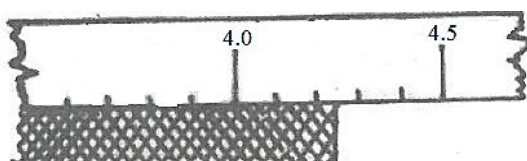


Fig 1.1 Meter rules reading to ± 0.05 cm. (0.5mm).The measurement is nearer to the 4.20 cm mark than 4.10 or 4.30 cm mark. The reading is therefore 4.20 ± 0.05 cm

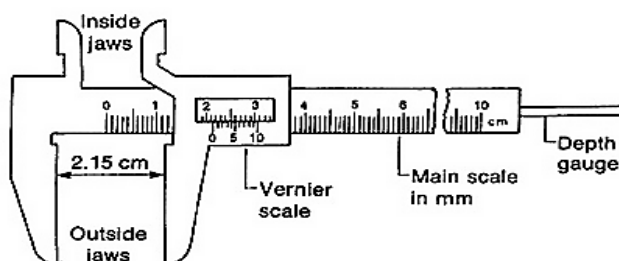


Fig 1.2 Vernier callipers reading to ± 0.1 mm (0.01cm). The main scale indicates a reading between 2.1 and 2.2cm. The 5th Division on the vernier coincides with the main scale division (2.6). The reading is therefore 2.15cm.

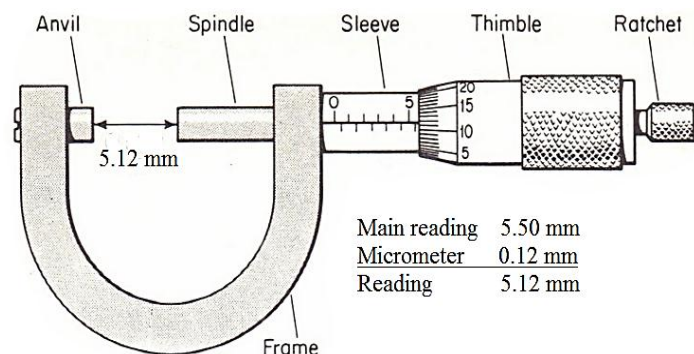


Fig 1.3 A micrometre screw gauge reading to ± 0.01 mm. the main scale is marked in mm and half mm divisions. The pitch of the micrometre screw is 0.55 mm, so each divisions on the micrometre (thimble scale is 0.01 mm

When adding and subtracting measurements the uncertainties are added. When multiplying and dividing measurements the percentage uncertainties are added.

MATERIALS:

meter ruler
micrometre screw g
microscope slides

vernier callipers
textbooks
sheets of paper

METHOD:

1. Take a series of measurements of the length, widths, thickness and masses necessary to determine the face areas, volumes and density of the object provided.
2. Show calculations to measure
 - (a) perimeter
 - (b) face areas
 - (c) Volume
 - (d) density
3. Show the uncertainty in each of the examples above.

RESULTS:

	MEASUREMENT	UNCERTANITY
Length		
Width		
Thickness		
Area		
Mass		
Volume		
Density		

QUESTIONS:

1. Are there any meaningless figures in your answers? Discuss if there are any.
2. What assumptions have been made about the measuring instruments used during this exercise?

FURTHER QUESTIONS:

3. A cylindrical object is measured to have a diameter d of 5.25 cm and a circumference c of 16.38 cm. What is the experimental value of π and the percentage error of the experimental value if the accepted value of π is 3.14?
4. In the formula $v_f = v_i + at$ at the values v_i , a and t are as follows :
 $v_i = 20.00 \pm 0.05 \text{ m/s}$ $a = 3.50 \pm 0.03 \text{ m/s}^2$ and $t = 3.00 \pm 0.01 \text{ s}$
Determine a value for v_f and correctly describe its uncertainty.

Experiment 2

Relationships (Pendulum Motion)

AIM:

To find the relationship between the period and the length for a simple pendulum

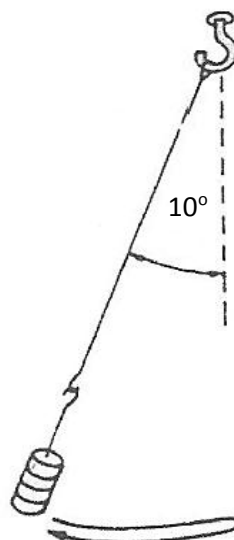
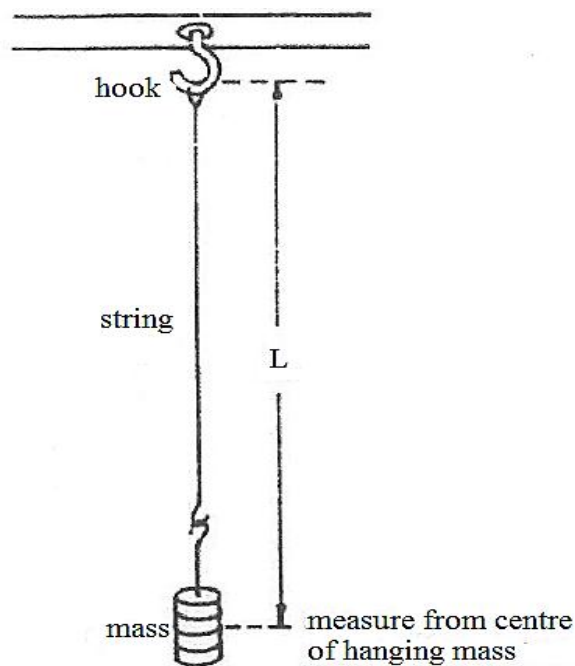
INTRODUCTION:

One of the most important reasons for experiment work is to investigate the relationship between two or more physical quantities. Taking a single set of readings of physical quantity often gives very little information on the form of the relationship between the readings and the limitations of their validity. Therefore it is important that several sets of readings be taken. Relationships between the readings and the limitations of their validity. Relationships can either be expressed by using equations or by drawings graphs.

MATERIALS: A stop clock/stop watch
String
200-500g mass
A metre rule
A hook

METHOD:

1. Screw a hook into a ceiling beam.
Tie one end of about 2.0 m metre string on to the hook. Tie the other end to a 200 - 500g mass.
2. Measure the length of the pendulum, L from the hook to the centre of the hanging mass (to the nearest cm).
3. Pull the mass so that the angle of swing is less than 10° ; release the mass so that it can swing freely. Take a time for 10 oscillations. One oscillation occurs when the mass swings away and then back again. Count quietly, not out loud.
4. Shorten the length by about 10 cm. Measure the new length and respect step 3 to find the new number of oscillations.
5. Continue until the length is less than 20 cm.



Experiment 2

Relationships (Pendulum Motion)

RESULTS:

Place results in a table.

Length (cm)	Time for oscillations	Period =	$T^2(s^2)$

DISCUSSION QUESTIONS:

1. Sketch a graph of T (vertical axis) against L (horizontal axis). What does the shape imply ?
2. Plot a graph of T^2 (vertical axis) against L (horizontal axis). What does the shape imply?
3. Find the slope of the line in the graph for 2.
4. Write a mathematical expression giving L as a function of T .
5. What prediction can you make about the length of the pendulum in proportion to the time of Oscillation?

AIM:

To study three forces acting under equilibrium conditions.

INTRODUCTION:

A vector quantity is completely described by its magnitude and direction.

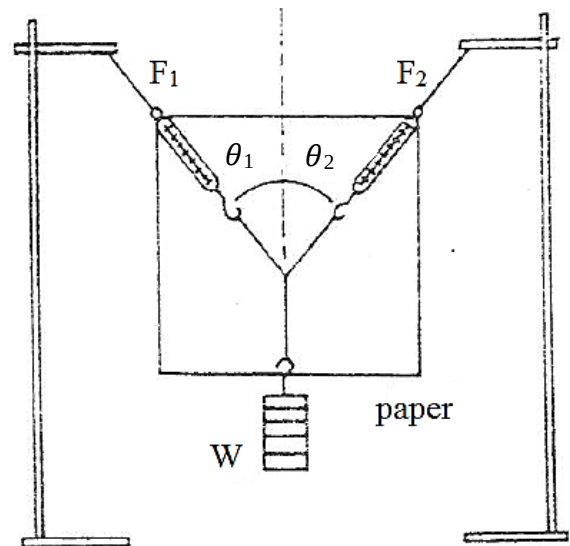
Understanding basic vector operations will enable us to analyse complex situations involving vector quantities such as displacement velocity and force. By adding the vector of forces, the concept of equilibrium will be developed. A study of the force acting on an object that is in equilibrium is called statics.

MATERIALS: two spring balance (range 0.5 N or 0 -1 N)
500 g mass stack (50 g masses)
two retort stands
string
protractor
A3 size white paper or vanguard

METHOD:

Set up the apparatus as shown below.

1. Hang the weight using the two spring balances against the white paper as shown.
2. On the white paper mark the equilibrium point O and draw the lines of forces F_1 , F_2 and W .
3. Measure the weight W of the hanging mass.
4. Record the readings on the balance F_1 and F_2
5. Measure the angles θ_1 and θ_2
6. Repeat the procedure for procedure for different weights.



RESULTS:

Record the results in the table given below.

No.	Weight (W)	$\tilde{F}_1$	θ_1	$\tilde{F}_2$	θ_2	$\tilde{F}_1 + \tilde{F}_2$
1						
2						
3						
4						

- Draw a force body diagram using a convenient scale.
- Calculate the resultant of $\tilde{F}_1$ and $\tilde{F}_2$
- Compare $\tilde{F}_1$ and $\tilde{F}_2$ with W and comment on the result

DISCUSSION QUESTIONS:

1. How would you obtain the vector which is known to be resultant of a number of forces?
2. For step 3, how did you represent
 - (a) the direction of a force?
 - (b) The magnitude of a force?
3. Considering the system of forces $\tilde{F}_1$, $\tilde{F}_2$ and W , show that the system is in equilibrium.
4. What are the chief sources of error in the experiment?

AIM:

Two investigate and determine the conditions for equilibrium of several parallel forces.

INTRODUCTION:

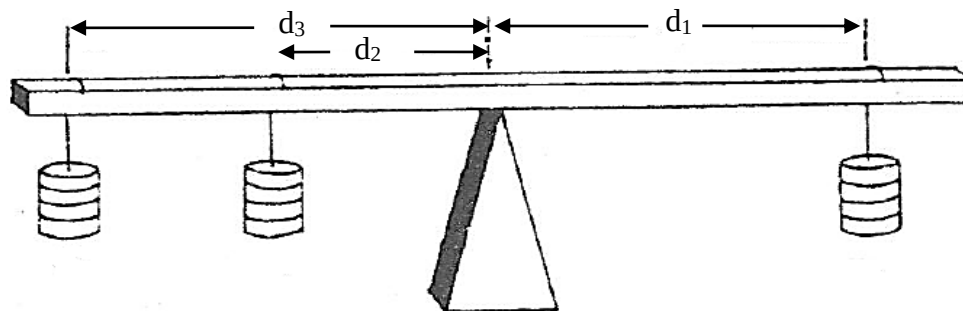
Two conditions are necessary in order for equilibrium to be attained with several parallel forces.

1. The sum of forces acting downwards must equal the sum of the forces acting upwards.
2. The sum of the clockwise torques (moments) must equal the sum of the counter clockwise torques.

MATERIALS: beam with two pivot points
 Stand
 A set of masses
 Ruler

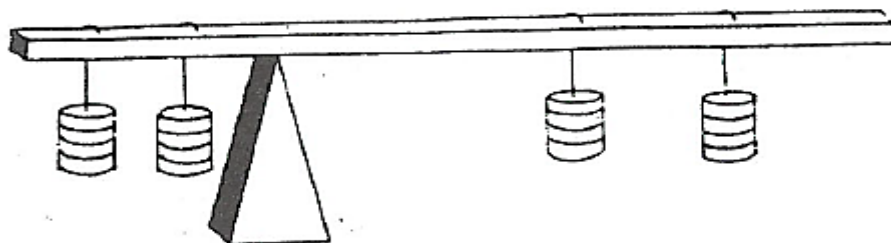
METHOD:

- A.
1. Set the beam on the centre pivot.
 2. Add one set of masses to the right hand side and two lots to the left hand side as shown in the diagram.
 3. Adjust their positions until the beam balances.



4. Record the number of masses, m , in each set and their distances, d , from the pivot.
5. Repeat for about 4 more different combinations.

- B.** Move the beam to an off-centre position and again get a balance with four different combination of masses and distances as shown.



RESULT:

Calculate the clockwise and anti-clockwise moments at balance positions and find the differences between them. Record your results in a table as shown below.

Clockwise		A	Anti-clockwise						B	Differences
m_1	d_1	m_1d_1	m_2	d_2	m_2d_2	m_3	d_3	m_3d_3	total	A-B

QUESTIONS:

1. Explain why we can use as the moment “mass x the distance from pivot” instead of force x distance from pivot.
2. For a “perfect experiment what values would you expect in the differences column.
3. Comment on the values that you have in your table.
4. In terms of moments write down the conditions necessary for the beam to be balanced.
5. In the above set-up (Part B) what have we neglected about the beam.

AIM:

- (1) To study the change in acceleration of a moving mass when then applied force changes.
- (2) To study the change in acceleration produced by a given force when the mass changes.

INTRODUCTION:

Newtons Law of acceleration states that an unbalanced force applied to mass produces an acceleration according to the formula $F = ma$. Because of friction, this law seems to contradict common experience.

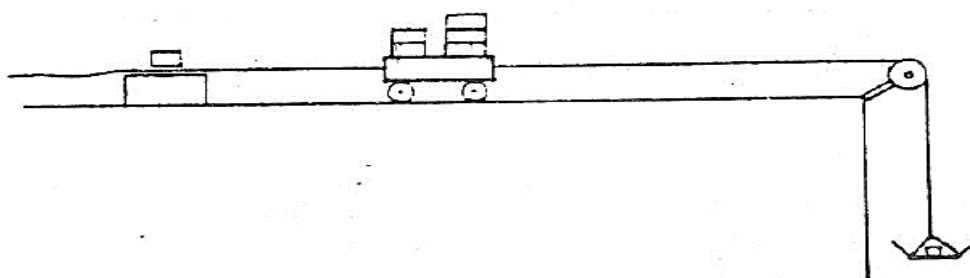
In this experiment you will study the law of acceleration, first by measuring the change in acceleration when a constant mass is subjected to a varying force, and then by noting the change in acceleration when the force remains constant and the mass varies. Friction will be compensated by using a trolley and a small counter weights.

MATERIALS: ticker timer and tape set of masse
 pulley trolley scale pan string

METHODS :

A. Constant mass, but varying force.

- (i) measure the mass of the trolley and set up the apparatus as shown below.



- (ii) Load the trolley with a number of different masses such as 5g, 10g, 20g, 50g, 100g, and 200g.
- (iii) To compensate for friction add small masses to the scale pan until the trolley moves uniformly forward when a push is given.
- (iv) Place a 5g mass from the trolley on the scale pan, start the timer and release the trolley.

- (v) When the mass hits the floor, stop the trolley, remove the tape and record the mass on it.
- (vi) Repeat the procedure with the 10g mass (replacing the 5g mass on the trolley). Remove the tape and label it 10g.
- (vii) Repeat with other masses until you have about 5 valid trials.
- (viii) Record your results in table 1.

B. Constant force but varying mass.

- (i) Use the same procedure as in the first part but this time keep a 10g or 20g mass on the string while changing the masses on the cart.
- (ii) Record your results in table 2. The total mass for each trial will include the 10g.

RESULTS:

From the tapes, calculate the acceleration in each case.

Mass of scale pan :

Mass of trolley :

(ii) Table 1

Total Mass causing acceleration (m) (kg)	Acceleration (m/s^2)	Force on trolley (N)

(ii) Table 2

Total mass causing acceleration (kg)	Acceleration (m/s^2)	Force on trolley (N)

- (iv) Plot a graph of force on the trolley against the acceleration of the mass in the field for part A.
- (v) Plot a graph of mass against acceleration for part B.

QUESTIONS:

1. Comment on the mass of the system in both parts of the experiment.
2. What do the graphs for this experiment tell you about acceleration?
3. Compare the motion of a freely falling object with the motion of the trolley in this experiment. How can the experiment be modified to study free fall.

AIM:

To obtain and investigate the path of a projectile.

INTRODUCTION:

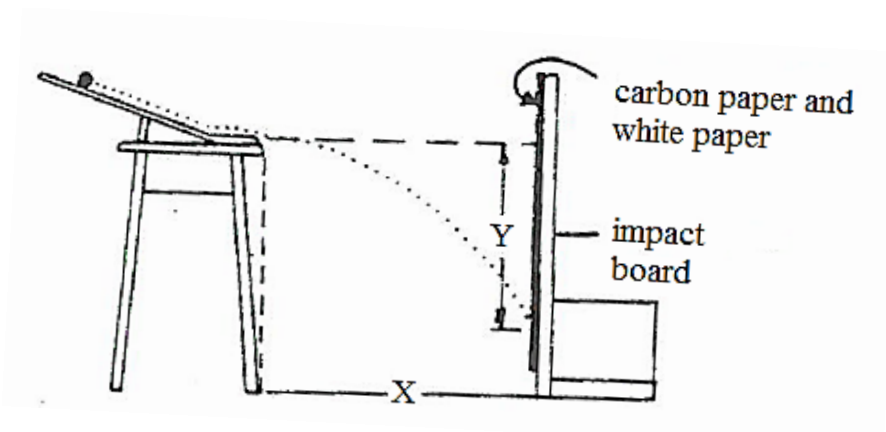
A projectile is any object that is known or otherwise projected into the air. The characteristic path followed by a projectile is a parabola and is called its trajectory.

Projectile motion describes the movement of a projectile along its trajectory.

MATERIALS:	a curved ramp	a lab stool
	a board with firm support	steel ball
	sheet of white paper	carbon paper
	meter rule	

METHOD:

1. Set up the apparatus as shown in the diagram.



Ensure that the ramp is set so that the ball leaves it horizontally. The impact board should be firmly held to avoid movement when the ball strikes it.

2. Tape a sheet of carbon paper to the board with the carbon out and the top of the sheet just above level of the end of the ramp.
3. Place a sheet of white paper over the carbon paper and tape it at the top only.
4. Place the impact board at a suitable distance from the end of the ramp (about 25-30 cm) so that the ball is released from the point on the ramp, it strikes near the bottom of the recording sheet.
5. Do not hold the ball in your fingers to release it. Instead hold it back at the release point with a ruler etc., and let it go by moving the ruler quickly away from it down the ramp.

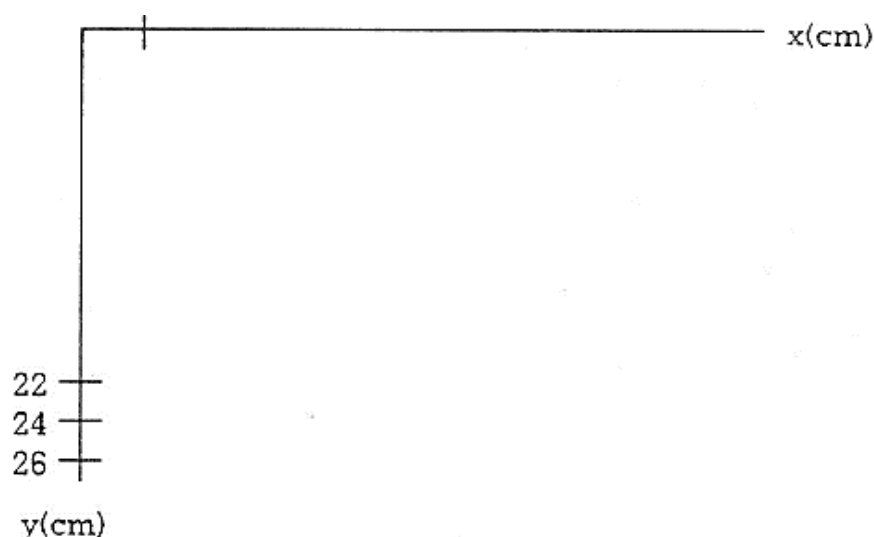
6. When the ball strikes the recording sheet, the point of impact is marked by the carbon paper, and can be seen through the white paper when the sheet is lifted out from the board. Beside the mark note the horizontal distance x from the end of the ramp to the board.
7. Move the ramp in equal steps of about 3 cm towards the board and at each stage record the points of impact when the ball is released from the same point on the ramp. Note beside each group of marks the horizontal distance x .
8. The last position should be with the ramp and impact board virtually touching so that the height of the point is recorded.

RESULT:

1. Transfer your data from the recording sheet to a table as shown below

X(cm)	Y(cm)	Limits of (cm)
30	2	22-26

2. Plot a graph labelling the axes as shown.



The error bars indicate the uncertainty in Y .

On your graph, draw a smooth curve which best hits the points.

QUESTIONS:

1. Describe the shape of your graph.
2. At any point on this trajectory, what is direction of the force acting on the ball?
3. Describe the horizontal velocity of the ball.
4. Describe the vertical velocity of the ball.

AIM:

To investigate the relationship between the radius and the velocity of an object moving in a circular path.

INTRODUCTION:

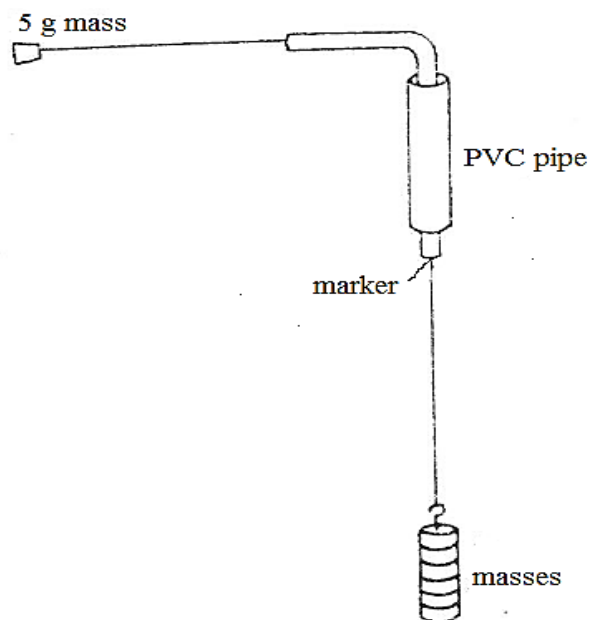
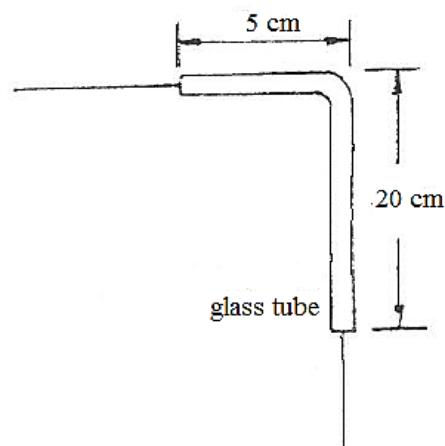
When any object is moving in a circle it is constantly changing its direction of motion. Thus it is accelerating, even if it moving with constant speed in the circle, and a force is necessary to maintain this acceleration.

MATERIALS: PVC pipe (15 cm long)
a 5g mass
strong cotton or nylon thread
stop watch
bent clip

A piece of bent glass tubing
5 x 10g masses
metre rule
marker

METHOD:

1. Pass the cotton or nylon thread inside the glass tube. (You can insert from one end of the glass tube and stuck from the other end to get the string inside the tube).
2. Insert the glass tube with the string inside the PVC pipe.
3. Attach a 5 g mass to one end of the string and the five 10 g masses to the other end as shown. Fasten the five 10 g masses with a paper clip.
4. From the centre of the 5 g mass to the centre of the rotation, measure a length of 1 metre. Place a piece of cellulose tape to the thread just below the lower end of the glass tube. This is to act as marker which will enable you to keep the radius constant as you whirl the 5 g mass above your head.



Experiment 7

Circular Motion

5. Hold the tube vertically and spin the stopper in a horizontal circle. Adjust the speed of revolution so that the marker is just below, but not touching the end of the tube. This may take some practice.
6. Have your partner measure the time while you count 20 revolutions.
7. Repeat step 6; each time reducing the radius by 10 cm. Calculate the frequency of the motion.

RESULTS:

Radius	Time for 20 revolutions (s)	Frequency of revolution (Hz)	Velocity of revolution (m/S)
100			
90			
80			
70			
60			
50			

Plot a graph of the velocity against the radius of revolution. What type of relationship do you observe?

DISCUSSION QUESTIONS:

1. A useful relationship to observe is between v^2 and r . What does the relationship v^2/r give us?
2. Calculate the centripetal acceleration of the mass.
3. The force on an object going in a circular path is given by $F = mv^2/r$. Express this force in terms of r and f .
4. Calculate the centripetal force of the mass.

Experiment 8

Energy In A Stretched Spring

AIM:

To determine the work done in stretching a spring.

INTRODUCTION:

The work done in extending a spring is equal to the potential energy available when the spring is allowed to contract.

$$E_p = kx^2$$

Where k is the spring constant in the linear relationship.

$$F = -kx$$

MATERIALS:

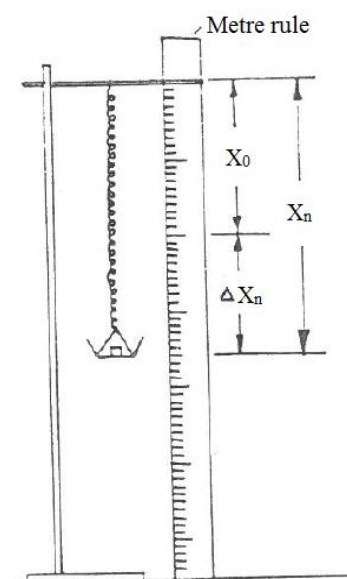
Metre rule
Suitable masses

Spring
Scale pan

Alternative materials: rubber band for spring

METHOD:

1. Set up the apparatus as shown. Mark the marker position on the metre rule when no mass is placed on the scale pan.
2. Add the masses one at a time. Record the applied force and the resultant length of the spring (or rubber band) in each case.
3. Work out the resulting extension in each case.



RESULTS:

1.

Force applied (N)	Final length x_n (m)	Extension ($x_n - x_0$) (m)

2. Plot a graph of force against extension. (Use proper graph paper).
3. Calculate the work done in stretching the spring from x_0 to x_2 (the second extended length) from your graph.

DISCUSSION QUESTIONS:

1. When the spring is extended, its energy content increases. Where is this energy stored and in what form?
2. Suppose we were to remove the masses one at a time and again record the respective lengths. We plot on the same axes as for extension, the graph of force against contraction. Do you expect the two graphs to be the same?
3. If the two graphs in (2) above are not the same, describe what could have happened. (Hint: describe in terms of energy losses in the spring).

AIM:

To investigate the conservation laws of collisions.

INTRODUCTION:

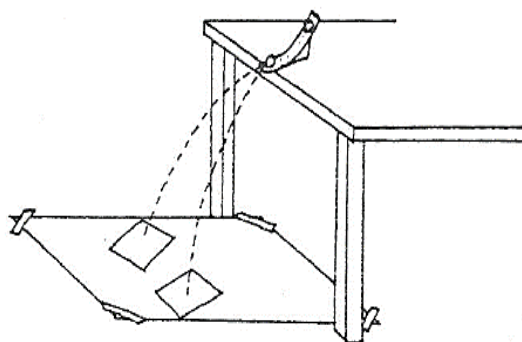
An isolated system is a system that has no net external force acting on it. The law of conservation of momentum always holds for any isolated system. For this reason, scientists consider this law to be of great importance. It helps them to understand what happens during all collisions. Because all interactions are collisions in one form or another, the law of conservation of momentum is a powerful tool.

MATERIALS:

ramp	large sheet of paper
clamp	two sheets of carbon paper
two large bearing	1 small bearing

METHOD:

- (i) Clamp the ramp to the bench. Place the large sheet of paper on the floor so that its back edge is just behind the end of the ramp; fix it down securely. Mark the point directly under the end of the ramp; fix it down securely. Mark the point directly under the end of the ramp by dropping a ball from there onto a piece of carbon paper.



- (ii) Release one of the large balls from about halfway up the ramp and watch where it lands. Find a release position on the ramp for which the ball lands somewhere between half and two-thirds of the way across the paper. Release the ball from the same point for the rest of the experiment.
- (iii) Swing the small support pin round so that it is in line and close to the end of the ramp. Run a ball down the ramp and see if it clears the pins; screw the pin up or down until the ball just clears it.

- (iv) Place the second large ball on the support pin and then run the first ball down the ramp to collide with it. Adjust the position of the stationary ball so that after the collision both balls fly off at roughly equal angles (and both land on the sheet of paper)
- (v) The apparatus is now ready to use. With it you will analyse the collision between the two balls by looking at the velocities before and after the collisions.

Note: “The displacement on the paper, between the point below the end of the ramp and landing point of the ball is proportional to the velocity of the ball as it left the ramp. This is because it represents the horizontal displacement that occurred during the flight, which is the same for all balls.”

- (vi) Run one ball down the ramp and mark its position using the carbon paper. Draw in the vector that represents its velocity at the bottom of the ramp without any collision. Place the second ball on the pin and run the first down the ramp to collide with it. Mark both landing positions. Draw in the vectors that represent the velocities after the collision.

On your diagram add the velocities after the collision and draw in the vector that represents their sum. What does the result suggest is conserved in the collision?

- (vii) Repeat the collision several times and examine the scatter of landing points that you get. Can say with confidence that within experimental uncertainty the velocity of the ball before the collision is the same as the sum of the velocities after collision.

Try another collision angle to see if the same holds true

- (vii) Turn your sheet of paper over or use another piece of paper. Mark in the vector representing the velocity of the ball before the collision. Put the small ball on the support pin and run the large one down to collide with it. Make sure both land on the paper then repeat several times marking the landing points each time.
- (ix) Draw vectors representing the velocities before and after the collision and make a statement, allowing for experimental uncertainty, about the velocities before and after the collision.

NOTE: The only change you have made is in the mass of one of the balls. To allow for this in the vectors you must scale them according to mass. What this means simply is that if the small ball is only three-quarters the mass of the large one then we reduce the length of the ball vectors to three quarters of its size. Since you are unlikely to get a simple fraction such as three quarters you will need to follow this procedure.

Find the mass of both balls of

eg. $m_{\text{small}} = 8 \text{ g}$ $m_{\text{large}} = 12 \text{ g}$

Find the rates $m_{\text{small}}/m_{\text{large}} = 8/12 = 2/3$

These are then the factors by which you scale then vectors.

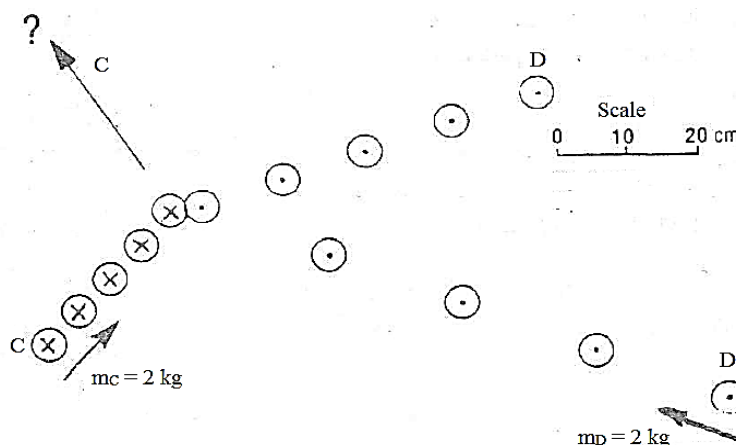
eg. Multiply the length of the small ball vector by $2/3$
 Multiply the length of the small ball vector by 1 (ie. leave them unaltered)

The vectors on your diagram now represent both mass and velocity. We call the product, mass x velocity, the **MOMENTUM** of an object.

Look at your scaled vector diagram and make a statement about the momentum before and after the collision.

QUESTIONS:

1. Is velocity conserved in the above experiment? Explain briefly when it is conserved and when it is not.
2. Is momentum conserved?
3. Determine the final velocity of part c in the multiple image photograph shown below.



Experiment 10

Bernoulli Effect

AIM:

For students to experience examples of the Bernoulli's Effect

INTRODUCTION:

Fast moving air exerts a lower pressure than slow moving air. In this experiment you will find that in method 1 the air below the paper has a higher pressure, the fast air above has lower pressure. In method 2 the 'fast' air near the ball has a lower pressure so air from farther out keeps pushing the ball back into the stream. In Method 3 the 'fast' air is below and around the ball, so air higher up pushes the ball back into the funnel.

MATERIALS: (1) 1 strip of paper 20 cm long and 3cm wide – the dimensions are not critical.
(2) a large balloon .
a piece of glass tube about 15 cm long, inside diameter 0.5cm (a piece of para grass or pawpaw stem will also suffice).
a Styrofoam ball or any light spherical object like a ping pong ball.

METHOD:

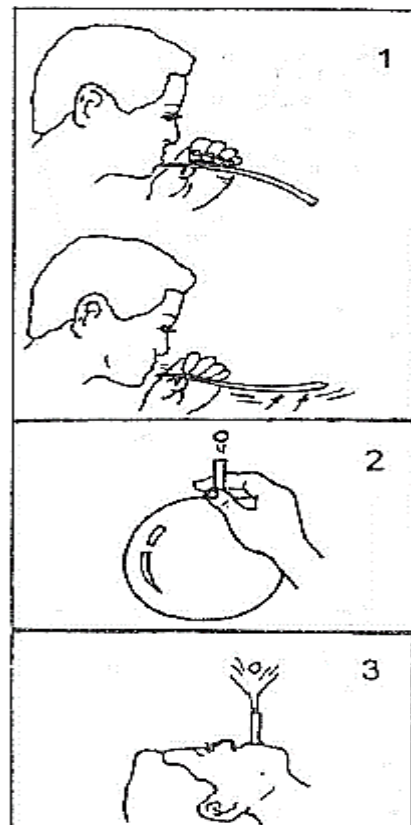
1. Each student cuts or tears a strip of paper of appropriate length 20 cm, width 3cm. Students hold one end of paper below lower lip.

The teacher asks students to blow hard along the top surface of the paper. Explain what happens to the paper.

2. Students blow up a balloon, attach the glass tube to the end and balance the ball on the top of the tube.

Allow air from the balloon to blow through the tube. Watch the ball 'balance' on the stream of air.

3. Students hold the tube and funnel above their heads and complete to see who can blow the ball from the funnel.



DISCUSSION QUESTIONS:

1. If you blew parallel to the paper in step 1 but beneath it, what would you expect to happen? Test your hypothesis. Explain the result.
2. In step 2 why does the ball seem to stay atop the stream coming from the straw?
3. In step 3 do you think the strongest man in Fiji would be able to blow the ball out of the funnel? Why, why not ?
4. Aeroplanes are kept up in the air because of the Bernoulli effect you have been studying. Fast moving air has a lower pressure than slow moving air. If a plane stays up in the air:
 - (a) is the pressure on top of the wing greater or less than the pressure on the bottom of the wing?
 - (b) should the air travelling over the top of the wing be faster or slower than the air travelling past the bottom of the wing?

AIM:

To find the relationship between potential energy and height.

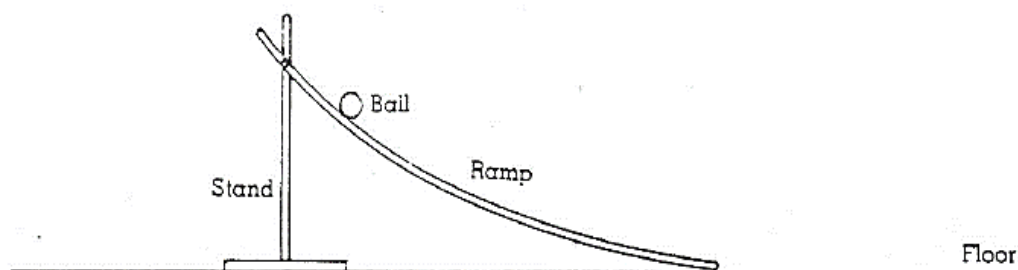
INTRODUCTION:

Potential Energy is the energy stored because of the position or state of the object. Gravitational potential energy of an object depends on the position of the object with respect to the ground level. When the object is rolled down a slope the potential energy changes to kinetic energy.

MATERIALS: a length of grooved flexible track eg. curtain rail
ball bearing
stand
laboratory floor
metre rule

METHOD:

- A. Set up a length of curtain track in the clamp stand on a length of floor. Curve the track so that there is no abrupt change of direction at the floor.



- (ii) Let the ball roll down the ramp from a measured height: h above the floor. Measure and record the distance rolled along the floor. Do this for at least five different heights. (At each height take five measurements, and then calculate the average.

Release height h (m)	Distance along for				Average distance d (m)
	d_1	d_2	d_3	d_4	

- (iii) Plot a height-distance graph for the motion.

QUESTIONS:

1. Calculate the slope of the hence write the relationship between the height of release and the distance travelled on the floor.
2. Write the equation for the work done by the floor on the ball. (Assume that the floor produces a constant deceleration force.)
3. What is the relationship between the distance travelled along the floor and the energy of the ball at the bottom of the clamp?
4. What is the relationship between the energy at the bottom of the ramp and the height the ball has fallen?

AIM:

To find a relationship between the temperature and volume of a gas.

INTRODUCTION:

When a gas is heated the particles of gas move faster on average. Many particles will hit the plug every second. Because they have more energy than before they will 'push' the plug further up the tube. This means that the volume occupied by the gas has increased.

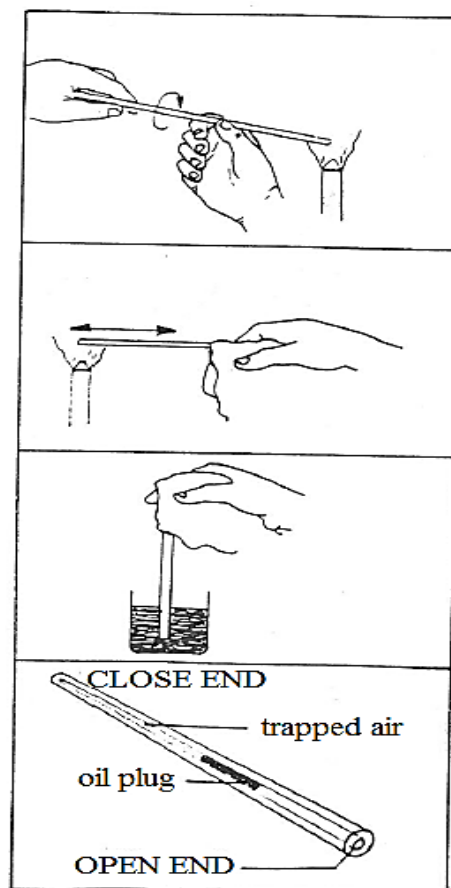
MATERIALS: For each group of students
1 piece of glass capillary tubing 20cm long, closed at one end and with an oil plug (see Method)
30 cm ruler
2 rubber bands
250 ml beaker
tripod and gauze
bunsen or other heat source
soya bean oil
thermometer

METHOD:

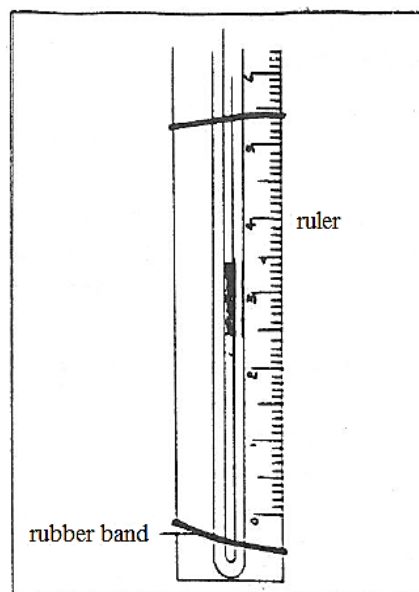
Preliminary teacher preparation:

Required: 20cm of glass capillary tubing for each student, Bunsen, beaker, file to cut glass.

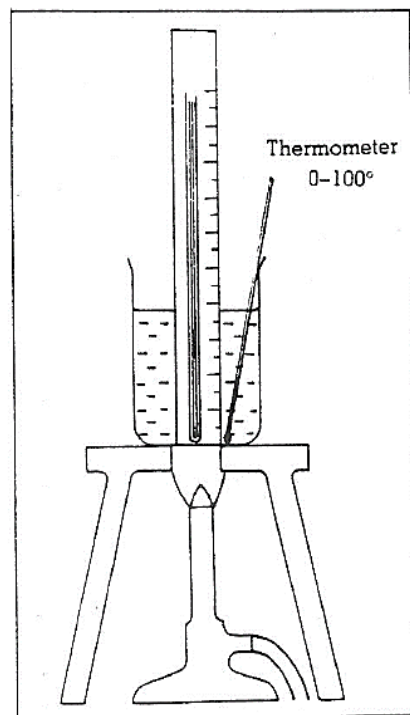
- A 1. Cut glass into 20cm lengths
2. Pour oil into a small container
3. Holding one end of glass tube close the other end by rotating it in a hot Bunsen flame.
4. Allow the tubes to cool to room temperature.
5. Hold the closed end of the tube in a cloth and heat the rest of the tube in a Bunsen burner for 1 minute.



6. Then dip the open end of the hot tube under the oil. As the air in the tube cools oil is pushed into the tube. Keep holding the tube in the oil until a 2 cm plug of oil in the tube.
7. Take the glass tube from the oil and allow it to cool. As the trapped air in the tube cools it will contract further and the plug will move up the tube.
8. Attach the tube to a ruler with rubber bands so that the length of the trapped air column can



- B.
1. Set up the apparatus as shown in diagram so that all of the trapped air is below the water but the open end of the glass tube is above the water.
 2. Measure the length of the trapped air, l , and the temperature, T . Record these in a table.
 3. Light the Bunsen and heat the water until its temperature is about 10°C higher than it was. Read length and temperature precisely. Record them in a table.
 4. Heat the water about 10 degrees more and repeat the readings.
 5. Continue until the temperature is about 80°C



Length of air column l (cm)	Volume of air column V (cm^3)	Temperature T ($^{\circ}\text{C}$)

QUESTIONS:

1. Why is it important that all the gas in the tube is under the water?
2. In this experiment you measured the length of the column of trapped air. What additional measurement could you make in order to find the volume of the gas column?
3. Calculate the volume of the air for each length of air column.
4. Draw a graph of V versus T.
5. What conclusion can you draw from the graph?

AIM:

To measure the specific heat capacity of brass.

INTRODUCTION:

The specific heat capacity, c , of a substance is the amount of heat energy required to change the temperature of 1 kilogram of that substance by 1°C , and is given by change the temperature of 1 kilogram of that substance by 1°C , and is given by

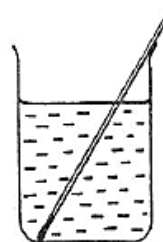
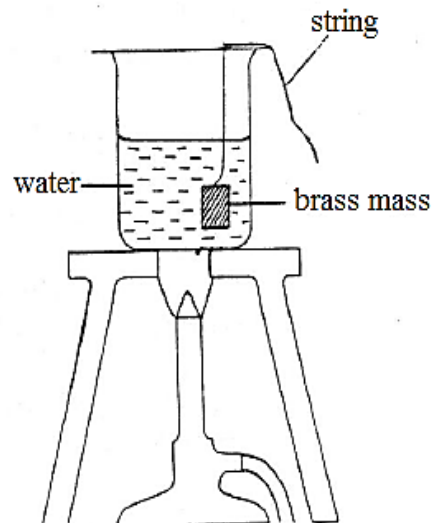
$$c = \frac{\Delta H}{m\Delta T} \text{ J/kg}^{\circ}\text{C}$$

MATERIALS:

- bunsen burner
- tripod
- gauze
- beakers
- 100gm brass mass
- various small metal masses
- thermometer

METHOD:

1. Tie a piece of string to a 100g mass.
2. Suspend the mass in the beaker and fill the beaker approximately half full of water.
3. Heat the beaker until the water boils and keep it boiling for at least 5 minutes.
4. While the water is boiling, take the second beaker and fill it with 100 ml of water. Take the temperature of this water.
5. When the brass has been in the hot water for three minutes transfer the brass mass quickly to the second beaker.
6. Swirl it gently in the water and note the highest temperature reached.
7. Record all your results as below and use the following instructions to determine the specific heat capacity of your brass mass.



RESULTS:

Arrange your data as shown below. In all calculations use specific heat capacity (water) 4200 J/Kg/°C.

- | | | |
|-----|--|----------------|
| 1. | Initial temperature of water | =°C |
| 2. | Final temperature of water. | =°C |
| 3. | Temperature change | =°C |
| 4. | Mass of the water (kg) | = kg |
| 5. | Heat absorbed by water (4200 x mass x temperature. rise) | = J |
| 6. | Heat given out by brass | = J |
| 7. | Initial temperature of brass | =°C |
| 8. | Final temp of brass | =°C |
| 9. | Temperature change of brass | = °C |
| 10. | Heat given out by cooling 100g (0.1 kg) of brass | = J |
| 11. | The specific heat capacity of brass | =J/kg/°C |

DISCUSSION QUESTION:

1. What is noticeable about the reason way as in which the bubbles of steam form where the brass touches the beaker?
2. What is the reason for boiling the metal for 5 minutes?
3. Why is a string used in the transfer of the mass?
4. Will the heat gained by the water in the second beaker be the same as the heat given out by the brass?
5. How does your value for the specific heat capacity for brass compare with the accepted value?
6. Would this be a method of identifying metals?
7. What are some possible sources of error in this experiment?

AIM:

To find the latent heat of vaporisation of water.

INTRODUCTION:

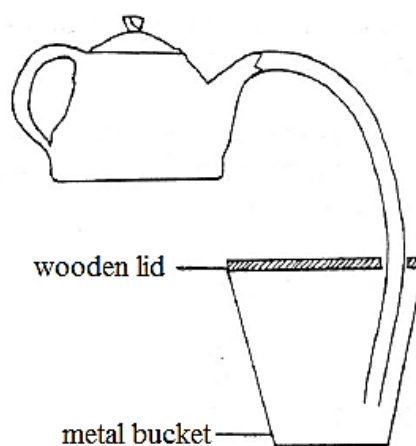
In this experiment the metal bucket is heated up by the steam condensing in the bucket and changing to water. If we can calculate how much heat is required to raise the temperature of the bucket we know the amount of heat given when the steam condenses.

MATERIALS:

- a heavy hollow metal solid (eg. a brass axle cap, a metal bucket, a cast iron cooking pot or a metal teapot)
- a source of heat (eg. an open fire)
- a kettle
- plastic tubing (to lead from kettle to metal container)
- a lid or wooden cover for the metal container
- a measuring cylinder or other measuring vessel
- a thermometer
- some means of measuring the mass of the bucket (see step 6)

DEMONSTRATION:**METHOD:**

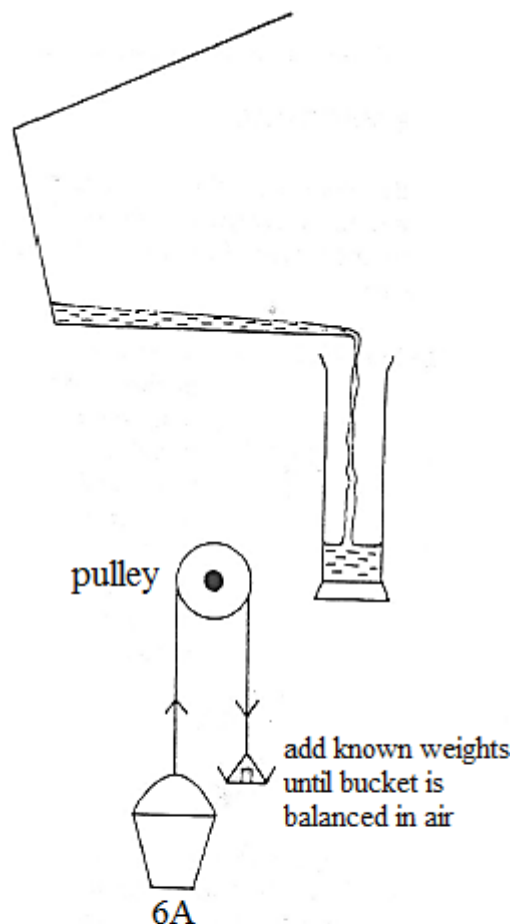
1. Fill the kettle with water, place the lid on the kettle and attach a plastic tube to the spout.
2. Put the heavy hollow metal solid (a steel bucket in this example) beside the heat source and put the plastic tubing into the bucket. Cover the bucket with a piece of wood or steel and find the temperature of the bucket. Remove the thermometer
3. Keeping the tube in the bucket place the kettle on a heat source (open fire, gas stove, Bunsen burner).



Experiment 14

Latent Heat of Vaporisation Of Water

4. It will take some time for the water in the kettle to boil. Steam will pass into the bucket and condense on the cold metal. The condensing steam will heat the bucket until the metal of the bucket is at 100 °C. After the steam has escaped around the bucket lid 2 minutes pull the tube from the bucket.
5. Allow the water in the bucket to cool a bit, then pour it into a graduated cylinder or some other measuring vessel to determine the volume of the water.
6. Find the mass in grams of the empty bucket. (This can be done by adding known weights to the pulley system as in diagram, 6A or by using a known weight such as a bag of sugar and the principle of moments as shown in diagram 6B.)
7. Look up the specific heat of the material of the heavy hollow metal solid (eg. steel bucket)
8. Calculate the latent heat of vaporisation of water by following the steps in the Results section.



SPECIFIC HEAT CAPACITIES (Jkg⁻¹K⁻¹)

BRASS	380
IRON	460
ALUMINIUM	900
COPPER	400

RESULTS:

The heat absorbed by the bucket is given by $M_B C T$

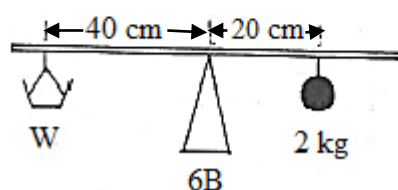
M_B is the mass of the bucket in kg.

C is the specific heat of the bucket in J kg⁻¹K⁻¹

T is the increase in temperature of the bucket.

The heat given out by the condensing steam is given by $M_s L$

M_s is the mass of the water in kg.



Experiment 14

Latent Heat of Vaporisation Of Water

L is the latent heat of vaporisation of water in JKg

So:

$$M_b c \Delta T = M_s L$$

Mass of bucket

$M_B = \dots\dots\dots$ kg

Specific heat of metal bucket from table

$c = \dots\dots\dots$ Jkg⁻¹K⁻¹

Final temp. of bucket

$= \dots\dots\dots$ °C

Final temp. of bucket

$= 100$ °C

Change in temperature. of bucket

$\Delta T = 100 - \dots\dots\dots = \dots\dots\dots$ °C

Volume of water

$= \dots\dots\dots$ mL

$$L = \frac{M_B c \Delta T}{M_s}$$

$= \dots\dots\dots$

QUESTIONS:

1. How does the result compare with the value for the Latent heat of vaporisation of water.
2. How can you alter the procedure to improve your result.

Experiment 15

Focal Point of Curved Mirrors

AIM:

To find the relationship between radius of curvature and focal point for concave mirrors.

INTRODUCTION:

For curved mirrors the focal length is half the radius of curvature. This can be shown mathematically with some effort, but it is verified experimentally.

MATERIALS :

Stiff paper (vanguard)

Aluminium foil

Tape

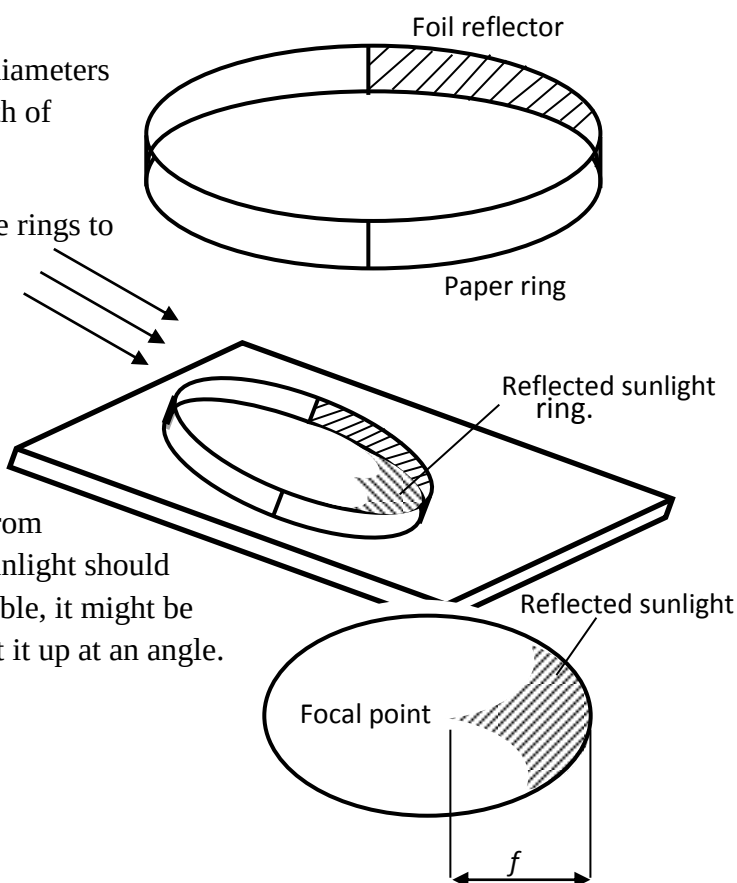
mm ruler

Compass

Sunlight/light box

METHOD:

1. Construct several rings of paper of various diameters (8cm, 10cm, 12cm, 14cm, 16cm) with a width of 1cm.
2. Attach foil to half of the inside of each of the rings to act as a concave mirror.
Alternatively concave mirrors could be used.
3. Measure the diameter [to nearest mm] of a
4. Allow sunlight or light box rays to reflect off the aluminium foil, and record distance from ring to the point of reflection pattern. The sunlight should be as parallel to the plane of the ring as possible, it might be necessary to place the ring on a board and tilt it up at an angle.



RESULT:

Place results in a table.

Diameter of Ring (D)(cm)	Radius of Ring (R) (cm)	Focal length (f) (cm)

DISCUSSION:

Plot the results on a graph paper with radius of curvature on the horizontal axis and focal length on the vertical axis.

Use the graph to show that the ratio of f to R is constant and find that constant.

QUESTIONS:

1. What purpose does the aluminium foil serve inside the ring?
2. Why should the light rays be parallel to the ring?
3. From your results comment on the relationship between the focal length and the radius of curvature.

AIM:

To determine the focal length of a convex mirror, and to establish a relationship between u , the distance of the object from the mirror and v , the distance of the image from the mirror.

INTRODUCTION:

A convex mirror spreads out parallel rays so that they appear to come from a single point F behind the mirror. This point F is called the focus. It is a virtual focus since no light rays actually pass through it. A convex mirror gives a wider field of view than a plane mirror.

In this experiment a plane mirror is used so that there is a virtual image of the object pin both the plane and the convex mirror. The image distances of the plane and the convex mirrors can be found by having no parallax between the images.

Since the object distance is same as the image distance of a plane mirror the image distance of the convex mirror can easily be determined.

The formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ can be used to determine the focal length of the convex mirror.

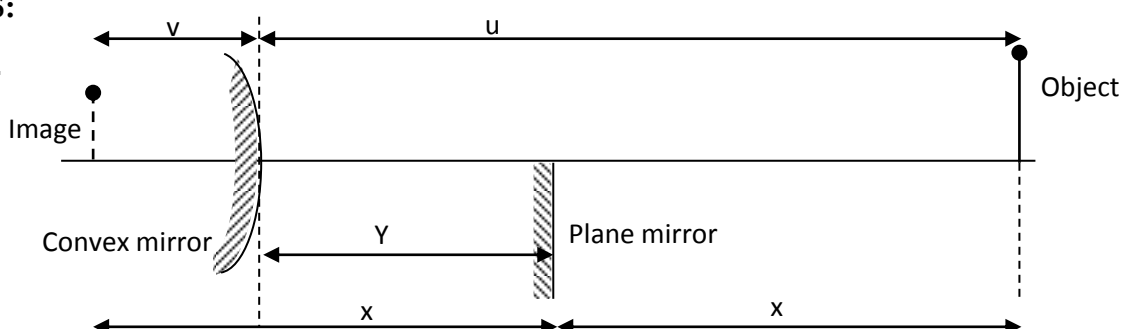
MATERIALS:

Convex mirror

Plane mirror

Office pins

MM ruler


METHOD:

1. Place the plane mirror in front of the convex mirror as shown above. Place the pin front of the plane mirrors. Familiarise yourself with the movement of the images by adjusting the position of the components. The movement of either mirror causes the movement of one image only, whereas the movement of the object causes the movement of both the images.
2. Adjust the plane mirror until both the images coincide i.e. There is no parallax.
3. Measure x and y values and determine the v and u values for each position of the pin.
4. Repeat the exercise for different values of u and record your results in the table given below.

Note: If u is positive, the virtual images distance v will be negative.

RESULTS:

1.

Object distance (u)	Image distance (v)	1/u	1/v	1/f	f (cm)

(a) Plot graphs of

(i) v versus u

(ii) 1/v versus u

(b) Determine the focal length of the convex mirror from your graphs if possible and compare this value with your calculated value.

QUESTIONS:

1. What is the purpose of the plane mirror in this experiment?
2. Is it easy or difficult to determine the local length of a convex mirror?

Give reasons for your answer.

3. Why is the image produced by a convex mirror a virtual image?

Note to the Teacher

Alternatively, teachers may ask their students to look at the relationship $S_i S_o = f^2$.

If S_i and S_o are defined as the image and the object distance from the focal point respectively, then the product of these distances is the square of the focal length. For different positions of S_o , S_i could be measured and graphs of S_i , Versus S_o and S_i versus $\frac{1}{S_o}$ plotted to determine f.

AIM:

To obtain a relationship between the object distance and the image distance for a convex lens.

INTRODUCTION:

Lenses produce images similar to those formed by curved mirrors, but they do so by refracting rather than reflecting. Lenses are either convex or concave in form. Light rays passing through a convex or converging lens are bent towards the principal axis, whereas rays passing through a concave or diverging lens are bent away from the principal axis.

MATERIALS:

Convex lens

Metre rule

Lamp

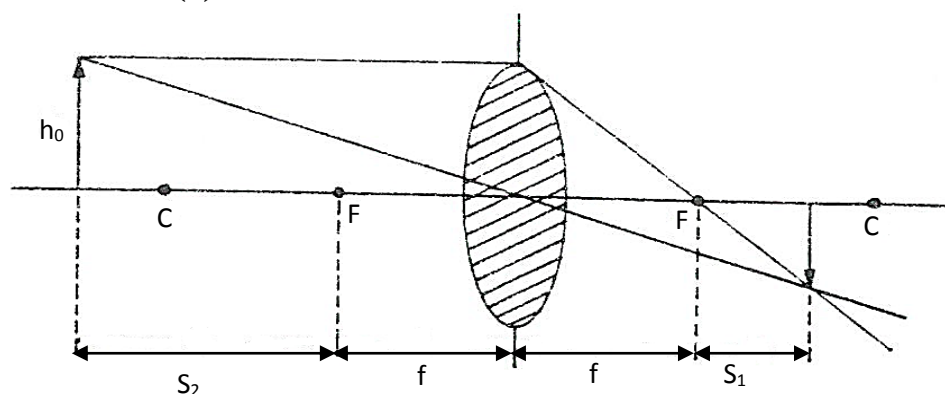
Screen

METHOD:

1. Stand the lens on the bench and determine its focal length. To find the focal length of the lens focus the sun's rays or a distant object [more than 10 metres] on to a stiff paper. A ray box could also be used. The distance from the paper to the lens is the focal length.
2. Stand the lamp on the bench as shown in the diagram below and measure the distance between the lamp and the focal point. This is S_0 .
3. Adjust the screen to get a clear focussed image of the clamp
4. Measure the distance from screen to the focal point. This is S_i .
5. Move the lens to several different positions in relation to the lamp and obtain a clear focussed image on the screen for these positions. (Take positions before C, at C and beyond C).
6. Record measurements of both S_i and S_0 on a suitable table as shown below.

Plot a graph of (i) S_i versus S_0

(ii) S_i versus $1/S_0$



RESULTS:

1. Complete the following table for your results.

S_i	S_o	$S_i S_o(\text{cm}^2)$	$1/S_o (\text{cm}^{-1})$	$f(\text{cm})$	$f^2(\text{cm}^2)$

QUESTIONS:

1. Use the following terms to describe the images formed:

Real or virtual

Upright or inverted

Magnified or diminished

[a] The image when the object is placed just outside the focus (before C)

[b] The image when the object is at C.

[c] The image when the object is beyond C.

2. Find the gradient of the second graph S_i versus S_o . Compare this value with any other values you have calculated in the table.

3. What conclusions can you draw from the graphs and values?

4. If a concave lens was used what kind of image would you produce. Can this image be found on a screen?

AIM :

To determine the critical angle for a water- air or a perspex – air boundary.

INTRODUCTION :

When light passes from regions of more optical density to regions of less optical density, it will be bent away from the normal according to Snell's law. If a certain angle of incidence is exceeded, there will be no transmitted ray, this angle is referred to as the critical angle. Although difficult to measure directly, the critical angle can be accurately found from a Snell's law type experiment.

MATERIALS :

2 office pins

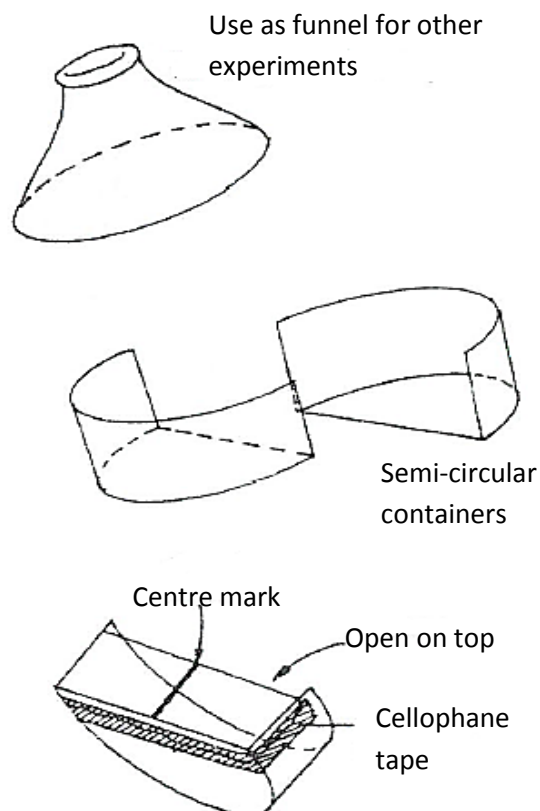
A protractor and a semi –circular Perspex plastic slab or glass slab

If no slab is available, then semi –circular container for water can be prepared from a clear cylindrical plastic bottle, some clear plastic wrap, and some cellophane tape

[optical ray box could be used if available)

METHOD :**A Construction of a container for water.**

1. A plastic container, about 10cm in diameter cut off bottom 5cm, and cut this in half, as accurately as possible. Smooth the cut edges with steel wool, but DON'T scratch the curved surface.
2. Wrap the open half with plastic, and seal with cellophane tape. Try not to distort the shape of the container. As container will be filled with water, it should be as water tight as possible. Mark, with a felt pen, the centre of the plastic wrap.
3. Fill the container 3/4 with water. If well put together, it will not leak for at least a lab period.

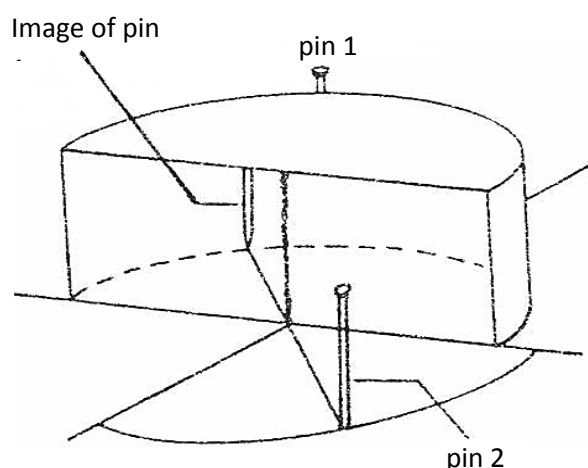
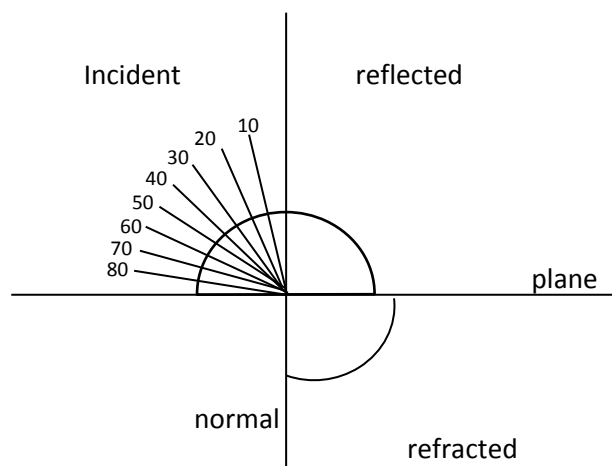


Experiment 18

Critical Angles

B Measurement of angle of incidence and refraction

1. On a sheet of white paper, mark off a diagram as shown, using a protractor to draw angles.
2. The semi-circular object will be placed in the outline, with the centre mark on the normal, and the flat side on the plane.
3. Place pin 1 into the incident side on the 0° line so that it is just touching the curved side of the container. Looking through the container's flat side, sight the image of pin 1 through the container. Place pin 2 so that it is collinear with the image of pin 1. Circle the resulting pinhole and mark as 0° .
4. Move pin 1 to 10° line, and repeat procedure to pin 2. Mark pinhole as 10° . Continue on with pin 1 at 20° , 30° etc. With water, pin1 can still be seen at 50° , but with Perspex the maximum is 40° .
5. Measure the angle of the various pinholes for pin 2 against the normal. These are the angles of refraction.



RESULTS:

Place results in a table.

Angle of incidence θ_i	Angle of refraction θ_r		$\sin \theta_i$	$\sin \theta_r$

Plot a graph of $\sin \theta_r$ on the horizontal axis and $\sin \theta_i$ on the vertical axis.

QUESTIONS:

1. From your graph calculate the refractive index of the substance used.

$$\text{Refractive index} = \frac{\sin \theta_i}{\sin \theta_r}$$

For light going from one substance into another.

$$n_{12} = \frac{\sin \theta_1}{\sin \theta_r} = \frac{n_2}{n_1}$$

2. Extrapolate the line to $\sin \theta_r = 1.0$. The $\sin \theta_i$ component when $\sin \theta_r = 1$ corresponds to $\sin \theta_c$ where is the critical angle. Determine the value of the critical angle.

AIM:

1. To investigate the reflection of water waves from various barriers.
2. To use the ripple tank to examine the refraction of water waves.

INTRODUCTION:

The ripple tank gives us a means to study waves in two dimensions. If a light source is used to project the waves on a screen, bright and dark bands are seen. This is because the crests act as convex lenses concentrating the light rays that pass through them. Thus bright bands correspond to crests. Similarly, troughs act as concave lenses, spreading out the light rays that pass through them. Therefore dark bands correspond to troughs.

MATERIALS:

Ripple tank set up with motor and rippler

Barriers – straight (eg block of wax or wood)

Curved [strips of aluminium]

Dropper

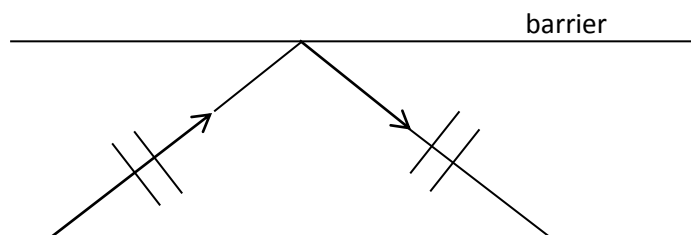
Glass plate

METHOD:**1 REFLECTION OF WATER WAVES**

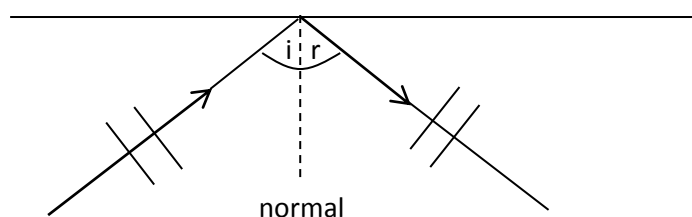
Investigation will include the following:

- [i] straight waves from a straight barrier
 - [ii] straight waves from a curved barrier
 - [iii] circular waves from a curved barrier
 - [iv] circular waves from a straight barrier
- [a] Place a straight barrier across the middle of the ripple tank. Make a circular wave with the drops from the dropper near the barrier and draw the resulting pattern that appears on the screen in the neighbourhood of the barrier.
- [b] Switch on your straight wave together and adjust it to produce straight waves. Send straight waves towards the barrier and note how the reflected waves behave.
- [c] Repeat this for several different angles between the barrier and the wavefronts, and draw the barriers, the incoming and the reflected waves. Draw arrows on your diagrams

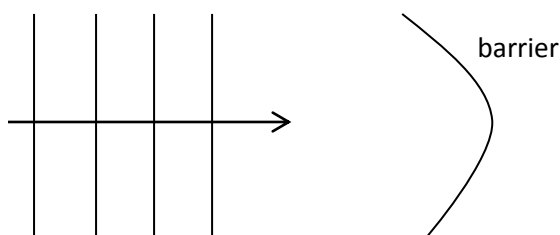
indicating the direction of travel of the waves. Produce these arrows until they meet the barrier. Your diagram should look like this:



[d] Draw in a dotted line perpendicular to the barrier and measure the angles marked i and r for YOUR waves.



[e] Replace the straight barrier with your curved barrier. Generate straight waves towards the barrier and sketch what you see on the screen. Look also at the surface of the water. Can you see a point where the amplitude of the waves is greatest? Mark this point on your sketch x.



[f] Use your dropper to generate circular waves towards it.

Draw the results on the paper screen.

[g] Reverse the curved barrier and observe the reflected waves for straight and circular incident waves.

RESULTS:

Draw incident and the reflected waves for all the situations above.

QUESTIONS:

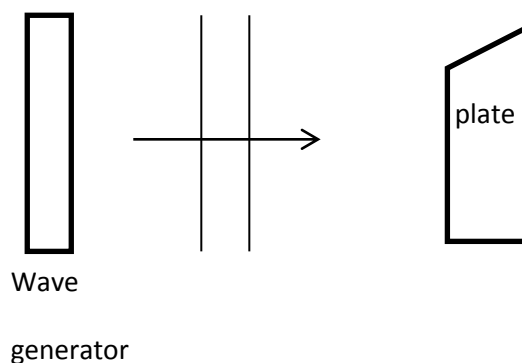
1. What is the relation between angles i and r for part (d)
2. What are the names for these angles?
3. What shape is the reflected wave in part (f)?

4. What is the point x called?
5. What difference did you notice between parts (e) and (f) and part (g).

II REFRACTION OF WATER WAVES

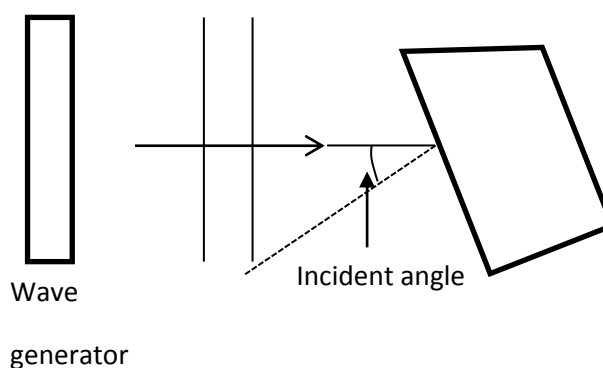
(a) Put the glass plate [preferably shaped as shown] into the ripple tank. Add just enough water to cover the plate (about 2mm).

(b) Set up the wave generator in motion and observe the wave as it travels from the deep water to the shallow water on the glass plate.



(c) Carefully observe the difference in the wavelengths in deep water and shallow water regions. Draw the pattern observed.

(d) Now send the waves WITHOUT ALTERING THE WAVE GENERATOR FREQUENCY toward the barrier set at an angle shown. Draw the incident and the refracted waves.



(e) The angle between the direction of travel of the incoming wave and the normal is called the incident angle. Similarly the angle between the normal and the direction of travel of the wave in the shallow water is called the angle of refraction.

RESULTS:

Draw the incident and the reflected wave patterns for the situations above.

QUESTIONS:

1. Can you detect a change in wave speed as it crosses onto the glass plate in part [a]?
2. What happens to the direction to the direction of travel of the wave as it crosses into the shallow water in part (d)?
3. In your ripple tank, which angle (incident or refracted) is larger?

It is more usual to remember whether a refracted wave bends towards or away from the normal. Which way does the refracted wave in the shallow water bend?

EXPERIMENT 20 Interference And Diffraction Of Water Waves

AIM:

To study interference and diffraction of water waves.

INTRODUCTION:

When two waves pass through the same place at the same time then a resultant wave is formed. The principle of superposition states that the displacement of the resultant wave at any point is the sum of displacements of the waves at that point. When two waves are in phase the crests add together forming an antinode. When two waves are out of phase, they cancel each other forming a node.

Diffraction occurs when a wave strikes a hole in a barrier. The hole should not be much wider than the wavelength otherwise shadow effects will occur.

MATERIALS:

Ripple tank set up with motor wave generator

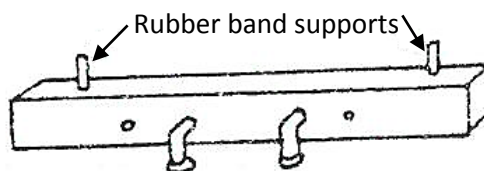
Dippers

Straight barriers

METHODS:

A Interference

- [i] Arrange the two dippers about 2cm apart and adjust the motor speed until the wavelength λ is equal to the distance d between the two sources (Measure λ by the same method you have used in previous ripple tank experiments, but choose a point well to the side of the tank to take your measurements).
- [ii] With both dippers producing waves you should now be able to see a stationary pattern WITHOUT using a stroboscope. You may find it helpful to look at the surface of the water as well as the screen. Sketch the position of the sources, the position of the nodal lines, and note the wavelength.
- [iii] Alter the separation of the dippers [leaving the wave generator motor running at the same frequency] so that the sources are 2 apart ie. twice as far apart as previously.
- [vi] Sketch results as previously.
- [v] Repeat C above 3 times more, setting $d = 3, 4$ and 5 .



Experiment 20

Interference And Diffraction Of Water Waves

RESULTS:

d (cm)	λ (cm)	d/ λ	No. Of nodals lines in total

QUESTIONS:

1. What is the relation between d/ λ and the number of nodal lines?
2. You have observed nodal lines. Where do you find antinodal lines?
3. To make your nodal lines spread further apart, what change you would make to

[a] d?

[b] λ

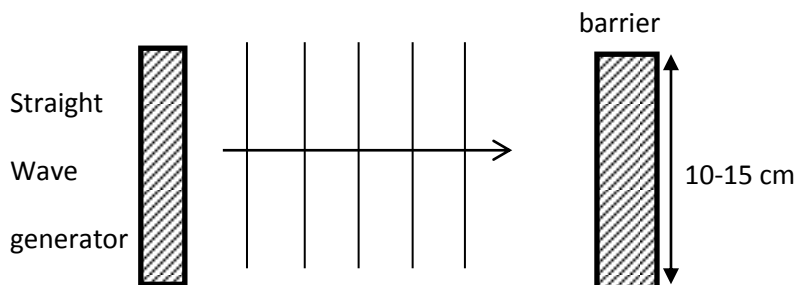
B Diffraction

- (i) Set up your ripple tank with the straight wave generator moving slowly, so that it produces waves of long wavelength in the water. Place a block of wax, perspex or wood etc, about 2-3 cm square in the path of the waves. Draw the pattern of the waves in the tank to show this barrier affects them.

- (ii) Increase the speed of the generator until it is quite fast, but you can still see the waves clearly.

Again draw the wave pattern to show how the barrier affects the waves.

- (iii) Repeat (i) and (ii) using a barrier about 10 -15 cm long in front of the waves.



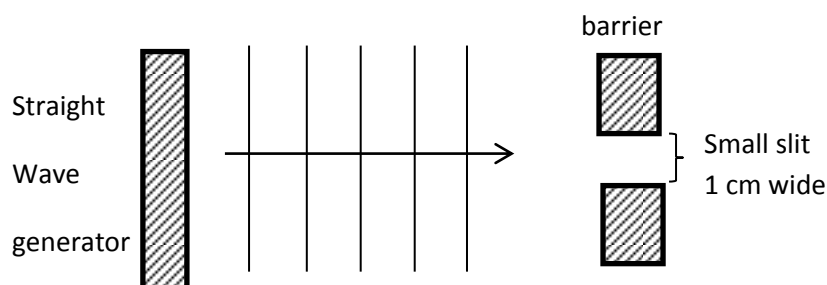
Draw the pattern of the waves for long wavelengths.

Draw the pattern of the waves for short wavelengths.

- (iv) Using barriers set up the ripple tank so that long wavelength straight waves are incident on a slit in a barrier that is smaller in size than the wavelength used.

Experiment 20

Interference And Diffraction Of Water Waves



(v) Now increase the frequency of the waves [ie, the wavelength is now smaller].

Draw a diagram of the wave pattern you see now.

(vi) Now increase the width of the slit to much larger than the wavelength of the waves [about 10cm]. Use long wavelength waves from the straight wave generator.

Draw the pattern of waves that emerge from the slit.

(vii) Now decrease the wavelength of the straight waves.

Draw a diagram to show the pattern you now see.

RESULTS:

1. Describe the wave pattern when the incident waves have

[a] smaller wavelength than the slit size

[b] same wavelength as the slit size

[c] bigger wavelength than the slit size

2. Give some examples of diffraction in the real world situation.

Experiment 21

Young's Interference Experiment

AIM :

To construct a twin slit apparatus that can be used to find the wavelength of light.

INTRODUCTION :

Interference phenomena show that light has the characteristics of wave. By creating a simple twin slit apparatus, a student can observe interference bands, and from measurements, calculate the wavelength of light.

MATERIALS :

2 razor blades

A glass slide

A candle

A single filament light source [a flashlight bulb]

A measuring tape, either a micrometer

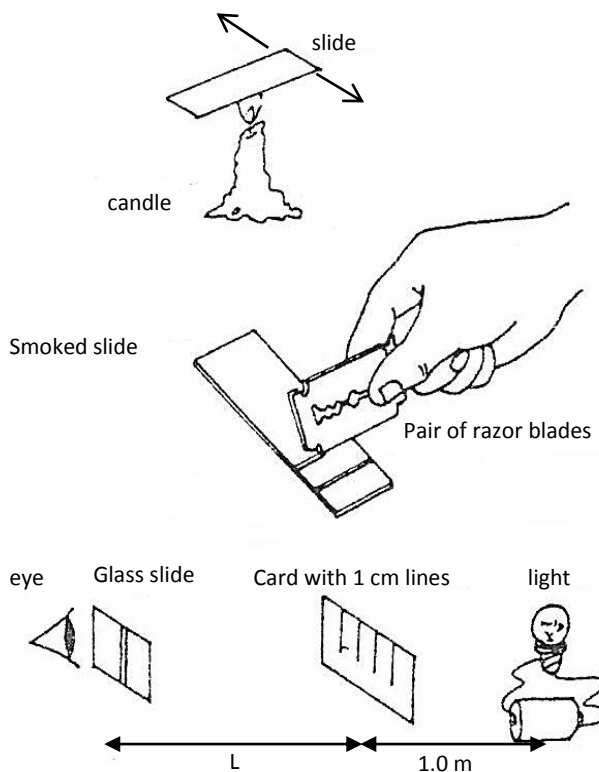
Vernier calliper or rule graduated in millimetres.

METHODS :

1. Lightly soot one side of glass slide by holding in hollow part flame. The lighter the soot, the better, you should be able to see through the soot. The slide should be moved back and forth in the flame to get an even coating OR use black paint on one side of the slide.

2. With a pair of razor blades held together, scratch the soot, leaving two parallel lines, separated by a small streak of soot. Try drawing several lines at once in several places; wipe clean razor blades [carefully] between tries. A dark film negative can be used instead of a smoked glass slide, but take care only to scratch surface, not to cut film in half.

3. Determine the width between the slits. This distance is d .

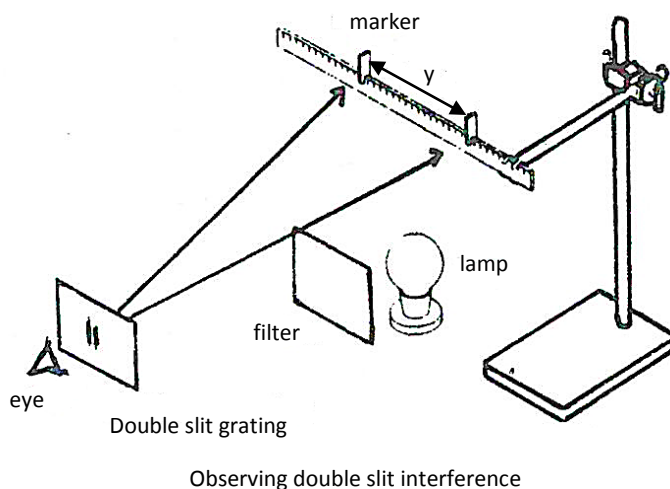


Experiment 21

Young's Interference Experiment

4. Hold the slide very close to the eye, and look through the slit to focus on a single filament light source several meters away. An interference pattern with five to nine fringes can be observed.

5. To measure the fringe separation, place markers at position of the third dark band on either side of the centre bright band and measure the distance between the two bands markers. The distance x is the average width of spacing between the dark lines.



6. The observer should move closer to, or further from, the markers to obtain a clear fringe spacing.

The distance from the markers or the slide should be about 2-3 meters. The distance between the slide and the markers is recorded as L , the markers representing the screen.

7. Somewhat better results might be obtained by holding a red, or blue, filter with the glass slide, but it is not necessary and probably won't make significant difference.

RESULTS:

Distance y (m)	Distance x (m)	Distance L (m)	Distance d (m)	Wave length (m)

QUESTIONS:

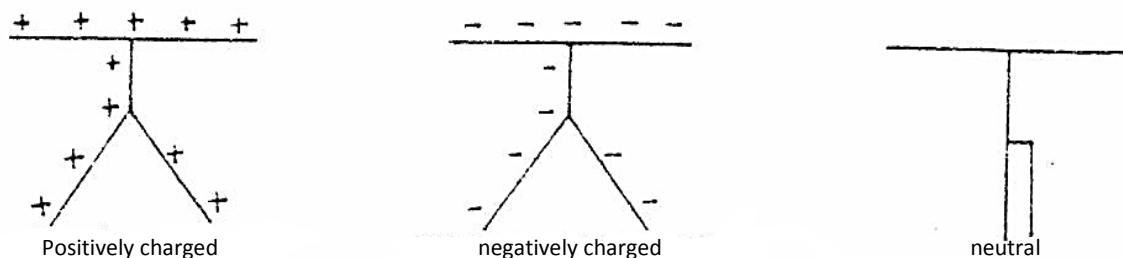
1. How did you measure the spacing between the slits on the slide?
2. What were your calculated wavelengths in each case?
3. How do they compare with the accepted value?
4. Is red a longer or shorter wavelength than blue?
5. Why for these measurements, does $\sin \theta =$ approximately equal to $\tan \theta$?

AIM:

To investigate electrostatic induction as a means of charging objects.

INTRODUCTION:

Induction is the “bringing about of an electric state in a body by proximity without touching. It is the process of separation positive and negative charge without contact”.



MATERIALS :

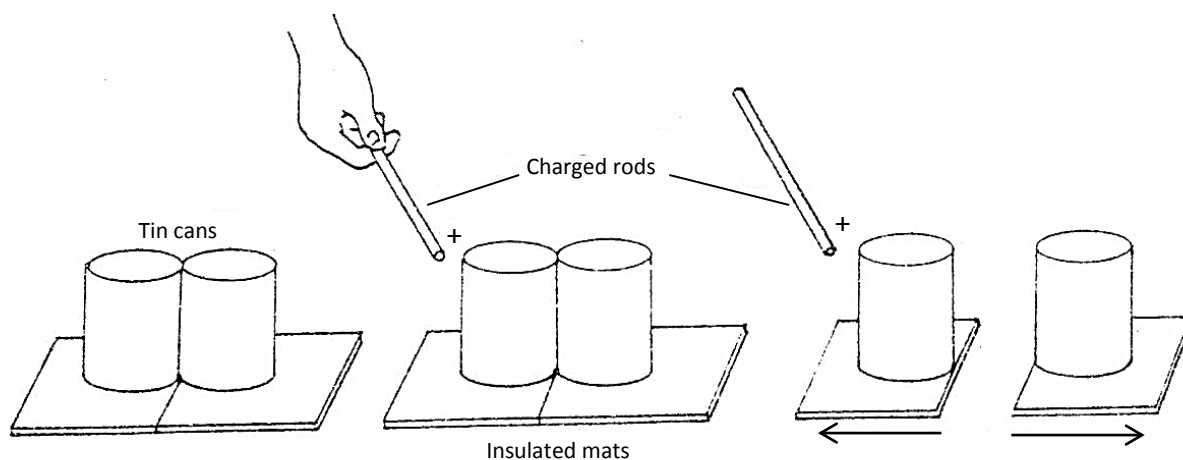
Two clean tin cans

Insulated mats

Electrostatic rods or strips of cloth

Electroscopes

DIAGRAMS:

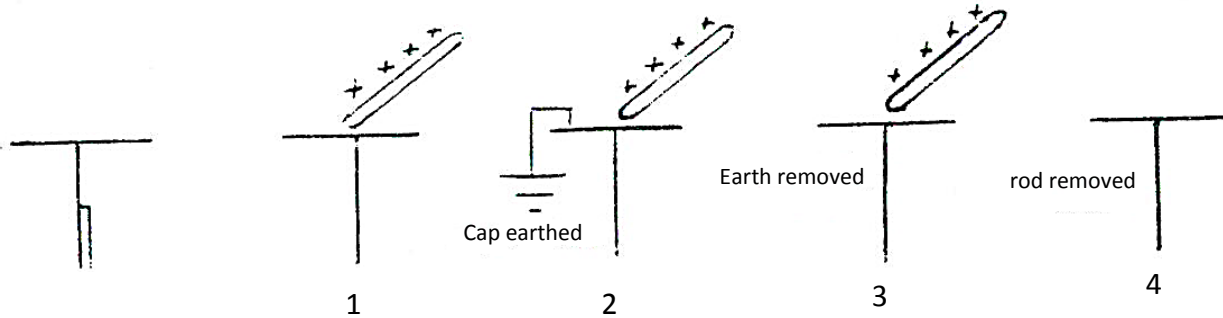


- (ii) Bring a charged rod close to the cans; take care not to touch the cans.
- (iii) Holding the rod in place, separate the cans by sliding the mats apart. Now remove the rod.
- (iv) Touch one of the cans with the cap of discharged electroscope. Discharge the electroscope and test the other can.
- (vii) Keeping the rod near to the cap, earth the can by touching it with your finger.
- (viii) Remove your finger while still holding the rod in place.
- (ix) Finally remove the rod.

RESULTS:

1. Copy the diagram 1,2, 3 and 4 below into your book and show clearly the distribution of the charges and the resulting deflection on the leaves.

2. Copy the diagram 1, 2,3, and 4 below into your book and show clearly the distribution of the charges and the resulting deflection on the leaves.



1. Which charged particles of an atom have the ability to move from one body to another?

2. When a body has been charged by induction how is its charge related to that on the body used to charge it?

3. Explain the main difference between charging by induction and charging by contact.

4. When a body is earthed describe the movement of electrons when that body is

(a) negatively charged

(b) positively charged

5. What does earthing the cap do to the charge distribution on the cap and leaves in the diagram fig (2).

AIM :

To find the internal resistance of a dry cell.

INTRODUCTION :

Although small, dry cells do have some internal resistance. This resistance cannot be measured directly, but only by analysis of a simple circuit. In this experiment a student can determine the significance of a graph of voltage against current for a simple circuit.

MATERIALS :

A [1.5 V] dry cell

A voltmeter [0 to 2 volts]

An ammeter [0-500 mA]

Variable resistor [0 – 10 000 Ω or more] OR

Several sources of resistance/assorted resistors

Connecting wires

METHODS:

1. Connect a series circuit: dry cell, ammeter and variable resistor.

Connect the voltmeter in parallel across the dry cell. Volume and tone controls from old radios make useful variable resistors. Different numbers of light bulbs or resistors in series will also

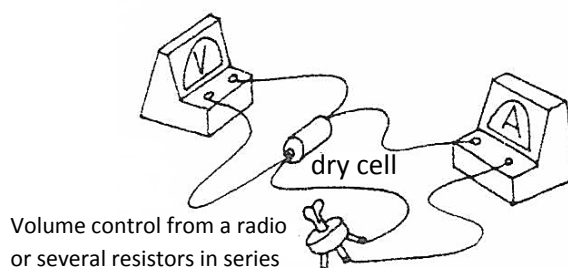
work.

2. Obtain various values for current and voltage by varying the resistance. This can be done by turning slowly the variable resistor, or by inserting extra resistance in series. Try to vary the current as much as possible.

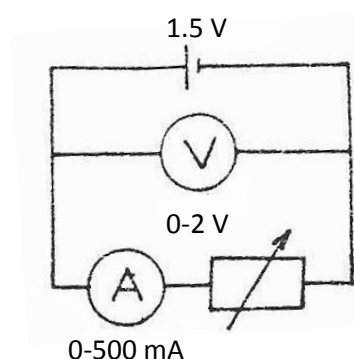
RESULTS:

Record results in a table.

Current mA	Voltage v



Plot a graph of V versus I on a graph paper.



DISCUSSION :

1. The following variables are useful:

ε True emf of cell [constant]

V Measured voltage from voltmeter [dependent variable]

I Measured current from ammeter [independent variable]

R_v Variable resistance

R_c resistance of cell [constant]

The student can be asked to derive these following relations, or these could be provided.

The student can be asked to derive these following relations, or these could be provided.

For the circuit $\varepsilon = I(R_v + R_c) = IR_v + IR_c$

But $V = IR_v$

So $\varepsilon = V + IR_c$

Rearrange $V = (-R_c)I + \varepsilon$

From the graph, therefore, $(-R_c)$ corresponds to the slope, while ε is the vertical intercept.

Note that the graph is not direct, but linear with a negative slope. The variable resistance is NOT being measured in this case.

QUESTIONS :

1. Calculate the values from the graph for ε and R_c .
2. How does the graph value for ε compare with the true value of ε ?
3. Calculate the voltage drop across the internal resistance of the cell.

Experiment 24

Voltage- Current Relations In A Light Bulb

AIM:

To investigate the relationship between voltage and current in a light bulb.

INTRODUCTION:

All resistors convert electrical energy to heat and sometimes light. The filament of a light bulb is a special kind of resistor. In common with most metals the tungsten which makes up light bulb filaments has a resistance which increases with temperature. The voltage /current graph of a light bulb may differ slightly from a graph of a standard resistor [ohmic conductor]. The gradient of the curve increases with current showing the resistance increases too.

MATERIALS:

Variable power supply (0 – 12V DC source)

Voltmeter

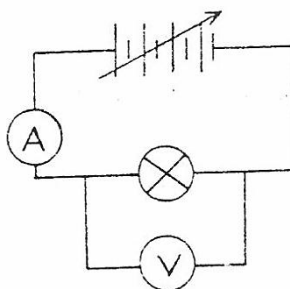
Connecting wires

Ammeter

Light bulb

METHOD:

(a) Wire up your circuit as shown.



(b) Adjust the power supply to vary the current. Measure the potential difference V , for 8 to 10 different values of current I .

RESULTS:

(i) Tabulate your results:

Current I [A]	Potential differences V [V]	V/I

[ii] Calculate the ratios V/I to complete the table.

[iii] Plot V against I

QUESTIONS:

1. What can you say about these ratios calculated in the result table above?
2. Do you get a straight line graph?

Mark and label the point on your graph where the bulb begins to glow.

3. What happens to the shape of the graph after this point?
4. How does the temperature affect the resistance of the lamp?

[Consider the ratio V/I].

5. Explain your answer to Q4 in terms of electron movement in metals.
6. What is a non – ohmic conductor?

AIM:

To determine the shape and direction of the magnetic field near a long straight wire due to a current in the wire.

INTRODUCTION:

In 1819 the Dutch physicist Hans Oersted demonstrated that electric current in a wire had associated with it a magnetic effect. In this experiment we will study the effect with the aid of small magnetic dipoles.

MATERIALS:

1 meter length of connecting wire

Connecting leads

Small magnetic compass

2 retort stands, bosses and clamps

Variable DC power supply [0-12V]

Ammeter [0-10A, D.C]

Rheostat

Board [about 14cm squares with a small hole in the centre]

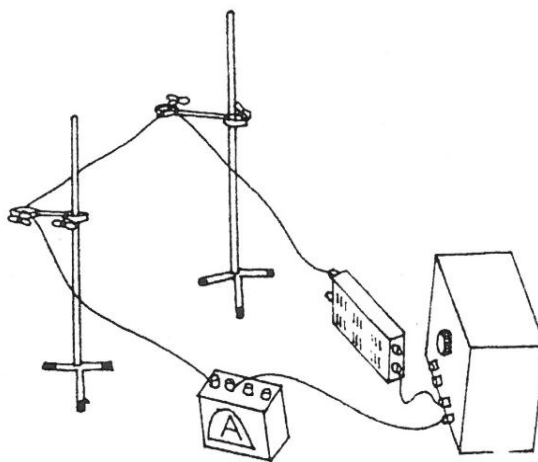
Iron filings

METHOD:

- (i) Set up the apparatus as shown in the diagram with about 50 cm of wire arranged horizontally in a north –south direction.
- (ii) Use the rheostat and variable D.C supply to adjust the current in the circuit to about 1A.
- (iii) Bring a magnetic compass needle up to the wire from below. Is there a magnetic effect associated with the wire?
- (iv) Switch off the current and place the magnetic compass just below the wire.

Is there now a magnetic effect? Comment on your answer.

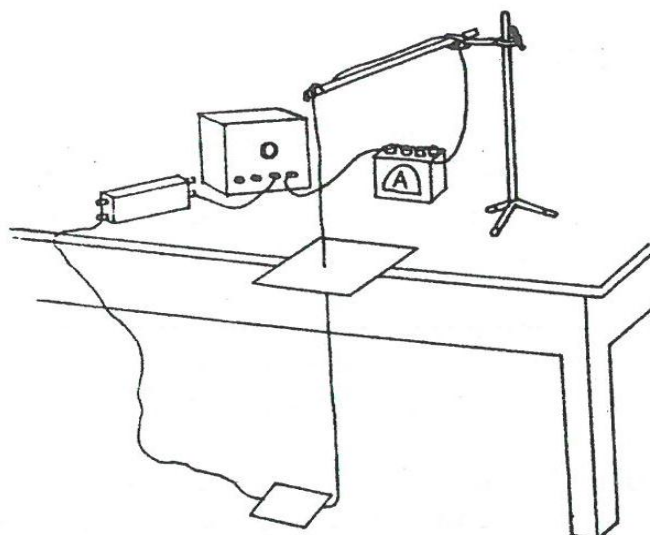
- (v) Switch on the current again and note carefully the direction of movement of N pole of the magnetic compass needle.



- (vi) Repeat the experiment but this time note the effect on the N pole of the compass needle when it is placed just above the wire and the current is switched on.
- (vii) Repeat with the compass needle on either side of the wire. [Place the needle in a vertical plane if necessary]. From your observations suggest the general shape and direction of the magnetic field associated with the wire carrying a current in this particular direction.
- (viii) Reverse the direction of the current by reversing the connections to both the D.C. power supply and the ammeter. Use your magnetic compass needle to determine the effect this has on the general shape and direction of the magnetic field.

The general shape of the magnetic field is best observed when the wire is placed vertically and is passed through a horizontal board as shown below. The wire should be at least be 1m away from any iron objects and the horizontal board should be placed midway along the vertical length of the wire.

- (ix) Place a piece of paper on the board [arranging for the wire to pass through its centre] and plot a field line for the magnetic field associated with a current of 1A in the wire by using the magnetic compass in the manner of experiment above.



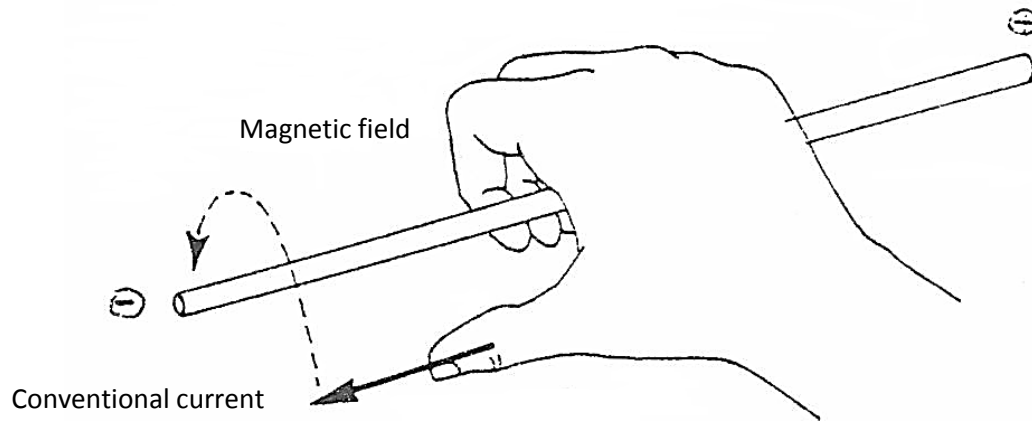
- (x) Reverse the current in the wire by reversing the connections to both the D.C power supply and ammeter and plot on the same sheet of paper a new field line.
- (xi) To confirm the general shape of the magnetic field, establish a current of 5A in the wire [by adjusting the rheostat] and sprinkle iron filings on the horizontal board. Tap the board gently and when a definite pattern has formed switch off the current. Represent on a diagram the magnetic field pattern in relation to the current in the wire.

QUESTIONS:

1. Why was it necessary to adjust the horizontal wire in a north-south direction?
2. Why was it necessary, when plotting the magnetic field associated with the current in the wire to keep the wire away from iron object?
3. What effect does reversing the current in the wire have on the associated magnetic field?

4. A useful rule which can be used to ascertain the direction of the magnetic field associated with a current –carrying wire is the following right hand rule, shown below.

If we imagine the thumb of the right hand to point in the direction of the conventional current (from the positive to the negative terminals) then the curled fingers of the right hand point in the direction of the magnetic field.



Is this rule consistent with your results?

AIM:

To construct a simple current balance, and with the current balance make a rough measurement of

magnetic field strength near a bar magnet.

INTRODUCTION:

Current moving perpendicular to a magnetic field experience of magnetic force. This force can be measured, as can be current and a value for the magnetic field strength can be found. The students in this experiment will construct a simple current balance suitable for making rough measurements of magnetic field strengths.

MATERIALS: For the current balance 30cm of 0.5mm copper wire

A 10cm x 10cm block of soft wood

A razor blade

For the circuit; a D.C power supply (3-12 volts);

A flash light bulb;

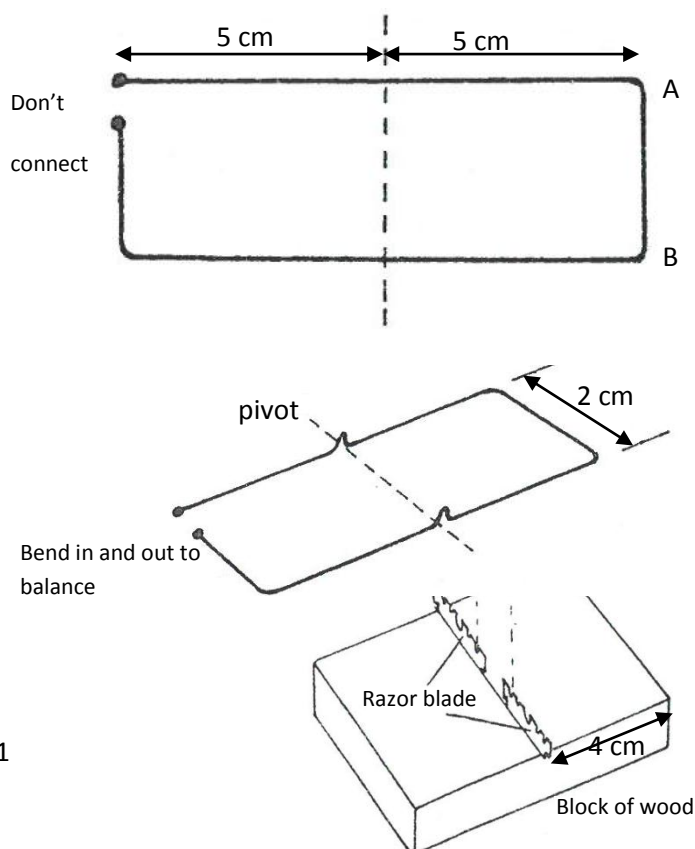
Solenoid

Beam balance, wire cutter, cm rule

Alternatively if the schools have the current balance and the suspension system then they can leave out the construction of the current and suspension part and proceed with the rest of the experiment.

METHOD:

- (i) Measure the length and mass of the copper wire. Obtain a value of mass /length.
- (ii) Bend a 24cm length of the copper into a rectangle. Include 2 bends in the wire to rest on the razor blade pivots. Don't close the rectangle. The magnetic field will act on the length AB.
- (iii) On the wooden block, cut a straight line with the razor blade. Break the razor blade in half, and slide both halves into the cut; they should not be touching.



Experiment 26

Current Balance

(iv) Place the rectangle wire on the razor blades so that it pivots freely. The unconnected end of wire rectangle can be bent in or out to achieve balance. The end AB will overhang by about 1cm.

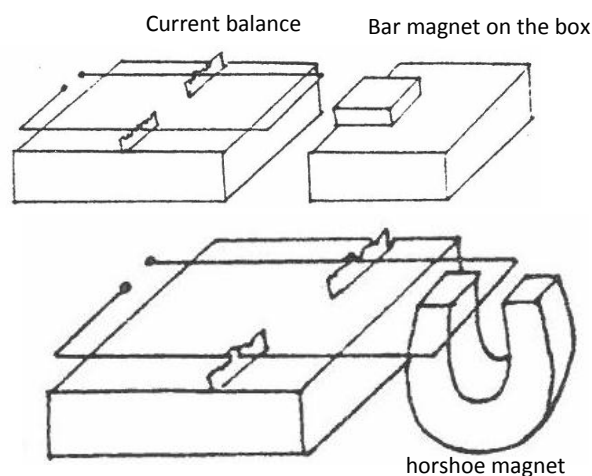
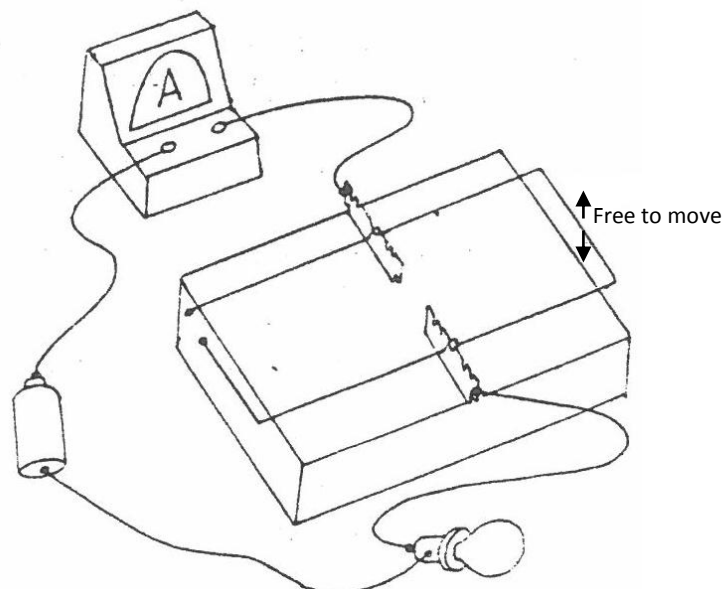
(v) Connect the circuit in series: power supply, ammeter, current balance, light bulb. If no current flows, clean the contacts between the current balance and razor blades by scraping. Expect current to be intermittent if the balance is moving.

(vii) With power source removed, locate a bar magnet [or horseshoe] near the side AB of the balance.

Tape the magnets and the wood base of the current balance so that they cannot move. The magnet should not be able to touch the wire rectangle.

Verify that the balance is unaffected when there is no current flowing.

(viii) To measure magnetic field strength, orient the circuit so the deflection of the balance is up! Place 2 cm lengths [shorter, if necessary] of bent copper wire on balance side AB. Add these masses until wire rectangle is balanced while current is flowing. This is difficult.



RESULTS:

- (i) Students draw a diagram of the balance and carefully record direction of the deflection of the balance.
- (ii) Students measuring magnetic field strength should record: the current in the balance, the length of wire section AB and the length of wire used to balance in part (viii).

DISCUSSION:

1. Using appropriate hand rule, find then direction of the magnetic field across the length AB for each instance in part [vii]
2. Determine (or verify) the north and south pole of the magnet.
3. Calculate the mass of wire added in part [viii]. Calculate the force of gravity on this mass.
4. Use $F = B \times I \times l$ to calculate the magnetic field strength.

Experiment 27

The Direction Of An Induced Current In A Coil

AIM:

To investigate the direction of an induced current in coil.

INTRODUCTION:

If an electric current produces a magnetic field, does a magnetic field produce a current? In about 1830, two scientists found the answer to this question. American Joseph Henry (1797-1878) and Michael Faraday (1791-1867) of England discovered that whenever there is a movement between a conductor and a magnetic field, an emf is induced. In this experiment you will investigate the direction of the induced emf in a coil.

MATERIALS:

Coil

Galvanometer

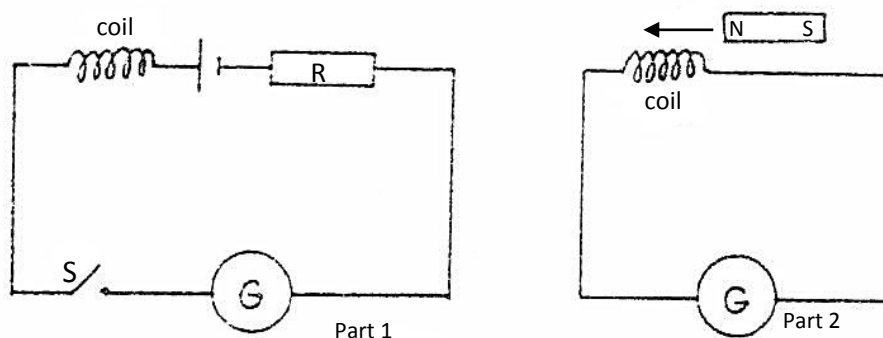
Switch

Bar magnet

Dry cell

Higher value

DIAGRAMS:



METHOD:

(I) Set up the equipment as shown in the diagram in part 1.

(ii) Close the switch and observe what happens to the galvanometer.

Reverse the connections to the dry cell and observe the galvanometer deflection.

(iii) Now connect the coil and the galvanometer as shown in the diagram (Part 2). Move the magnet in relation to coil and record the direction of the induced current.

(iv) Repeat [iii] with the pole of the magnet reversed and record your observations.

(v) Copy these diagrams and indicate on each the direction of the induced current. The diagrams show the relative motion between the magnet and the coil.

QUESTIONS:

1. When the dry cell is used the conventional current flows from [+] to [-] and the galvanometer needle responds accordingly. With the knowledge gained in [ii] determine the direction of the induced current in the coil in part [iii]
2. Can you suggest a rule for predicting the direction of the induced current in the coil?

EXPERIMENT 28

Induced Current In A secondary Coil

AIM:

To investigate the induced current in a secondary coil.

INTRODUCTION:

Whenever the balance of a current loop and a magnetic field is changed, a current is produced which opposes the change. The current produced is called induced current.

The effect is called electromagnetic induction.

MATERIALS: Two coils

Galvanometer

Dry cell

Switch

DIAGRAM:

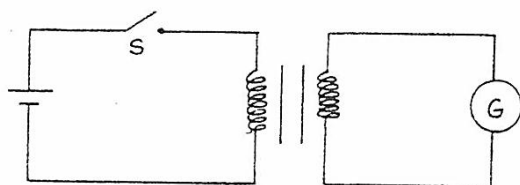


Fig. 1

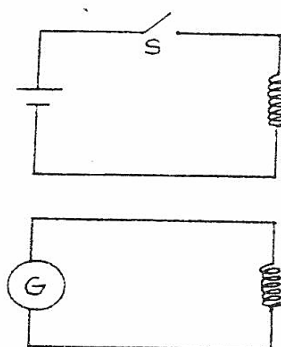


Fig. 2

METHOD:

- (i) Set up the equipment as shown in Fig. 1
- (ii) Close the switch and quickly open it again. Observe the deflection on the galvanometer.
- (iii) Reposition the second coil as shown in fig. 2. Close the switch and quickly open it again. Observe the deflection on the galvanometer.
- (iv) Place a soft iron core inside the coil and observe any difference in the deflection.
- (v) Describe a rule that would predict the direction of the induced current in the secondary coil.
- (vi) Increase the current in the primary coil in suitable steps and compare the deflection produced in the secondary coil.
- (vi) Increase the current in the primary coil suitable steps and compare the deflection produced in the secondary coil.

(vii) Place one coil inside the other and switch the current on and off quickly. Record your observations.

RESULTS:

Record your observations for each of the steps above.

QUESTIONS:

1. What observed difference is there in the galvanometer deflection when the current is switched on and off?
2. What effect has the soft iron core on the galvanometer deflection?
3. What happened to the current in the secondary coil when you increased the current in the primary coil?
4. What is the name of a device which uses coils in this way? Explain how you can tell the primary coil from the secondary coil.
5. Explain briefly how an inducted current is formed in the secondary coil by the act of switching ON/OFF.

Appendix

Table 1 prefixes of the metric System

Factor	Prefix	symbol
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hector	h
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Table 2 Physical Constants

Quantity	Symbol	value
Atmospheric pressure, normal	atm	$1.01325 \times 10^5 \text{ n/ m}^2$
atomic mass unit, unified	u	$1.66024 \times 10^{-27} \text{ kg}$
Avogadro Constant	N_A	$6.02252 \times 10^{23} / \text{mole}$
Charge to mass ratio for electron	e/ m_e	$1.758796 \times 10^{11} \text{ c/kg}$
electron rest mass	m_e	$9.1091 \times 10^{-31} \text{ kg}$
Electron volt	ev	$1.60207 \times 10^{-19} \text{ j}$
Electrostatic constant	k	$9.00 \times 10^9 \text{ n m}^2/\text{c}^2$
elementary charge	e	$1.60210 \times 10^{-19} \text{ c}$
gas constant, universal	R	$6.236 \text{ mm cm}^3/\text{g}^\circ\text{K}$
gravitational acceleration, Standard	g	$9.80665 \times 10^0 \text{ m/sec}^2$
Mechanical equivalent of heat	J	$4.1868 \times 10^0 \text{ j/cal}$
neutron rest mass	m_n	$1.67482 \times 10^{-27} \text{ kg}$
Planck's constant	h	$6.6256 \times 10^{-34} \text{ j sec}$
proton rest mass	m_p	$1.67252 \times 10^{-27} \text{ kg}$
speed of light in vacuum	c	$2.997925 \times 10^8 \text{ m/s}$
speed of sound in air at S.T.P	v	331.45 m/sec
Universal gravitational constant	G	$6.673 \times 10^{-11} \text{ n m}^2/\text{kg}$
Volume of ideal gas, standard	V_0	$2.24136 \times 10^1 \text{ l/mole}$

Table 3 The International System of Units

Quantity	Quantity symbol	Units	Unit symbol	dimensions
Fundamental units				
length	l	meter	m	m
mass	m	kilogram	kg	kg
time	t	second	s	s
current	I	Ampere	A	A
temperature	T	°Kelvin	°K	°K
luminous intensity	I	candela	cd	cd
Derived units				
acceleration	a	meter per second squared	m/s ²	m/s ²
area	A	square meter	m ²	m ²
capacitance	C	farad	F	C ² ·s ² /kg·m ²
density	D	kilogram per cubic meter	kg/m ³	kg/m ³
electric current	I	ampere	A	C/s
electric field intensity	E	newton per coulomb	N/C	kg·m/C·s ²
electric resistance	R	ohm	Ω	kg·m ² /C ² ·s
emf	ξ	volt	V	kg·m ² /C·s ²
energy	E	joule	J	kg·m ² /s ²
force	F	newton	N	kg·m/s ²
frequency	f	hertz	Hz	s ⁻¹
heat	Q	joule	J	kg·m ² /s ²
illumination	E	lux (lumen per square meter)	lx	cd/m ²
inductance	L	henry	H	kg·m ² /C ²
magnetic flux	ϕ	weber	Wb	kg·m ² /C·s
potential difference	V	volt	V	kg·m ² /C·s ²
power	P	watt	W	kg·m ² /s ³
pressure	p	pascal (newton per square meter)	Pa	kg/m·s ²
velocity	v	meter per second	m/s	m/s
volume	V	cubic meter	m ³	m ³
work	W	joule	J	kg·m ² /s ²

Table 5 Electrical Symbols

OBSOLETE SYMBOL	PREFERRED SYMBOL		OBSOLETE SYMBOL	PREFERRED SYMBOL	
		wire crossing			Earth
		wires joined			Arial
		resistance			diode
		rheostat			zener diode
		potential divider			Transistor (npn)
		potentionmeter			Transistor (pnp)
		fuse			Transistor (unijunction p type base)
		heater			Thyristor (n gate)
		lamp			Thyristor (p gate)
		Terminal			Triac
		Plug and Socket			Diac
		Switch (single Pole)			Photo - conductive cell
		Switch (double pole)			photo-voltiac cell
		Contact (normally open)			Photocell device
		Contact (normally closed)			Photo-diode
		Contact (change over)			Light-emitting diode
		Relay cell (with coil resistance)			
		Cell			
		Battery			

Table 5 Conversion Factors

LENGTH $1\text{m} = 10^{-3}\text{km} = 10^2\text{cm} = 10^3\text{mm} = 10^{10}\text{\AA}$ $1\mu = 10^{-6}\text{m} = 10^{-4}\text{cm} = 10^{-3}\text{mm} = 10^3\text{m}\mu = 10^4\text{\AA}$ $1\text{m}\mu = 10^{-6}\text{m} = 10^{-7}\text{cm} = 10^{-8}\text{mm} = 101\text{\AA}$ $1\text{\AA} = 10^{-10}\text{m} = 10^{-8}\text{cm} = 10^{-4}\mu = 10^{-1}\text{m}\mu$
AREA $1\text{m}^2 = 10^{-6}\text{km}^2 = 10^4\text{cm}^2 = 10^6\text{mm}^2$
VOLUME $1\text{m}^3 = 10^{-9}\text{km}^3 = 10^3\text{l} = 10^6\text{cm}^3$ $1\text{l} = 103\text{ml} = 10^3\text{cm}^3 = 10^{-3}\text{m}^3$
ANGULAR $1^\circ = 1.74 \times 10^{-2}\text{radian} = 2.78 \times 10^{-3}\text{revolution}$ $1\text{radian} = 57.3^\circ = 1.59 \times 10^{-1}\text{revolution}$ $1\text{revolution} = 360^\circ = 6.28\text{radians}$
MASS $1\text{kg} = 10^3\text{g} = 10^6\text{mg} = 6.02 \times 10^{26}\text{u}$ $1\text{g} = 10^{-3}\text{kg} = 10^3\text{mg} = 6.02 \times 10^{23}\text{u}$ $1\text{u} = 1.66 \times 10^{-24}\text{g} = 1.66 \times 10^{-21}\text{mg} = 1.66 \times 10^{-27}\text{kg}$
TIME $1\text{hr} = 60\text{min} = 3.6 \times 10^3\text{sec}$ $1\text{min} = 60\text{sec} = 1.67 \times 10^{-2}\text{hr}$ $1\text{sec} = 1.67 \times 10^{-2}\text{min} = 2.78 \times 10^{-4}\text{hr}$
VELOCITY $1\text{km/hr} = 10^3\text{m/hr} = 16.7\text{m/min} = 2.78 \times 10^{-1}\text{m/sec}$ $1\text{m/min} = 10^2\text{cm/min} = 1.67 \times 10^{-2}\text{m/sec} = 1.67\text{cm/sec}$ $1\text{m/sec} = 10^{-3}\text{km/sec} = 3.6\text{km/hr} = 10^2\text{cm/sec}$
ACCELERATION $1\text{cm/sec}^2 = 10^{-2}\text{m/sec}^2 = 10^{-5}\text{km/sec}^2$ $1\text{m/sec}^2 = 10^2\text{cm/sec}^2 = 10^{-3}\text{km/sec}^2$ $1\text{km/hr/sec} = 10^3\text{m/hr/sec} = 2.78 \times 10^{-1}\text{m/sec}^2 = 2.78 \times 10^1\text{cm/sec}^2 = 2.78 \times 10^2\text{mm/sec}^2$
PRESSURE $1\text{atm} = 760.00\text{mmHg} = 1.013 \times 10^5\text{N/m}^2 = 1.013 \times 10^6\text{dynes/cm}^2$ $1\text{N/m}^2 = 10\text{dynes/cm}^2 = 9.87 \times 10^{-6}\text{atm}$
ENERGY $1\text{j} = 10^7\text{ergs} = 2.39 \times 10^{-1}\text{cal} = 2.39 \times 10^{-4}\text{kcal} = 2.78 \times 10^{-7}\text{kw hr} = 1.49 \times 10^{18}\text{ev}$ $1\text{cal} = 10^{-3}\text{kcal} = 4.19\text{j} = 1.16 \times 10^{-6}\text{kw hr}$ $1\text{kcal} = 10^3\text{cal} = 4.19 \times 10^3\text{j} = 1.16 \times 10^{-3}\text{kw hr}$ $1\text{ev} = 10^{-3}\text{mev} = 1.60 \times 10^{-12}\text{erg} = 1.60 \times 10^{-19}\text{j}$ $1\text{kw hr} = 10^3\text{w hr} = 3.6 \times 10^3\text{kw sec} = 3.6 \times 10^6\text{w sec} = 8.6 \times 10^3\text{cal}$ $1\text{w sec} = 2.78 \times 10^{-4}\text{w hr} = 2.78 \times 10^{-7}\text{kw hr}$
MASS-ENERGY $1\text{j} = 1.11 \times 10^{-17}\text{kg} = 1.11 \times 10^{-14}\text{g} = 6.69 \times 10^9\text{u}$ $1\text{ev} = 1.07 \times 10^{-9}\text{u} = 1.78 \times 10^{-33}\text{g}$ $1\text{u} = 1.49 \times 10^{-3}\text{erg} = 1.49 \times 10^{-10}\text{j} = 931\text{Mev} = 9.31 \times 10^8\text{ev}$ $1\text{kg} = 9.00 \times 10^{16}\text{j} = 9.00 \times 10^{23}\text{ergs}$

