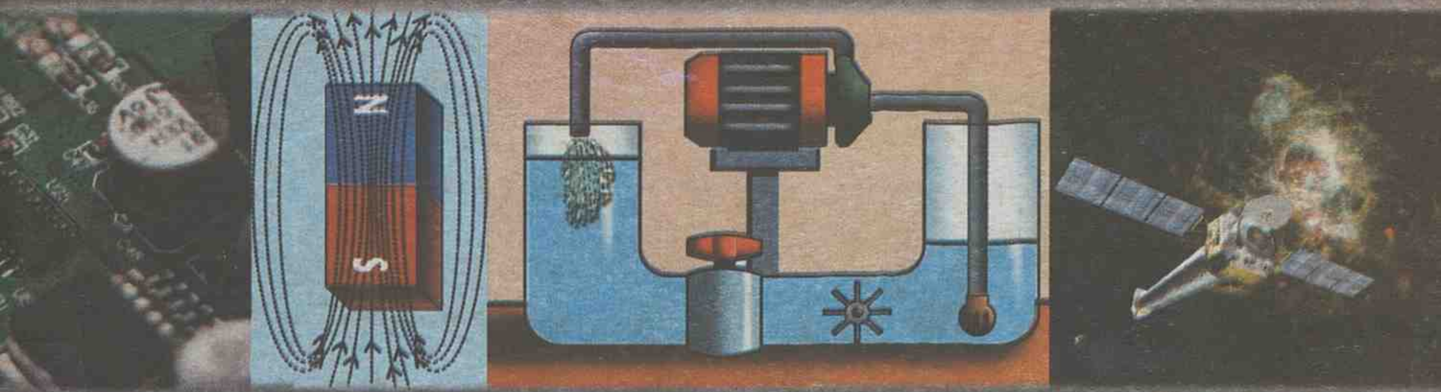
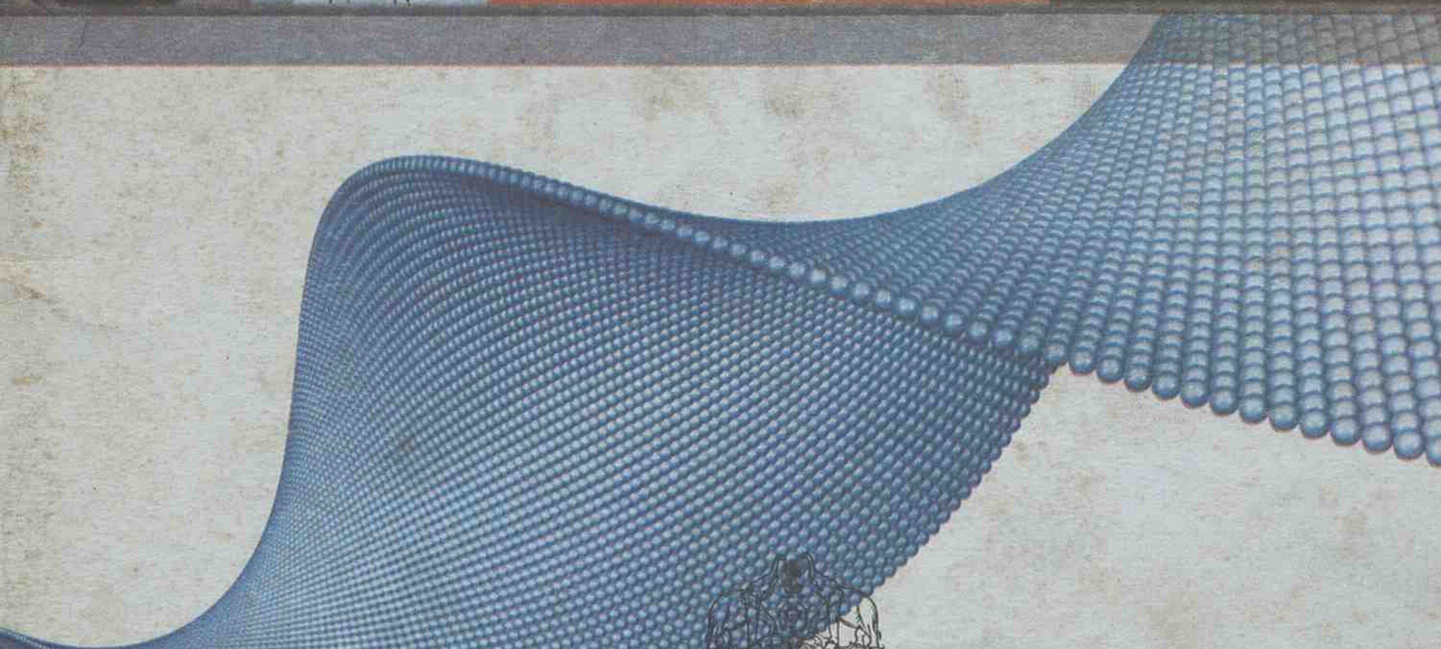
PHYSICS

IX

Part-1





Government of Kerala
Department of Education

CONSTITUTION OF INDIA

Part IV A

FUNDAMENTAL DUTIES OF CITIZENS

ARTICLE 51 A

Fundamental Duties- It shall be the duty of every citizen of India:

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievements;

(k) who is a parent or guardian to provide opportunities for education to his child or, as the case may be, ward between age of six and fourteen years.

PHYSICS

Standard IX

Part-1

Government of Kerala
Department of Education

State Council of Educational Research and Training (SCERT) Kerala

2016

KT 191-1/Physics-9(E) Vol-1

The National Anthem

Jana-gana-mana adhinayaka jaya he
Bharatha-bhagya-vidhata,
Punjab-Sindh-Gujarat-Maratha
Dravida-Utkala-Banga
Vindhya-Himachala-Yamuna-Ganga
Uchchala-Jaladhi-taranga
Tava subha name jage,
Tava subha asisa mage,
Gahe tava jaya gatha.
Jana-gana-mangala-dayaka jaya he
Bharatha-bhagya-vidhata,
Jaya he, jaya he, jaya he,
Jaya jaya jaya jaya he!

Pledge

India is my country. All Indians are my brothers and sisters.

I love my country, and I am proud of its rich and varied heritage. I shall always strive to be worthy of it.

I shall give my parents, teachers and all elders respect, and treat everyone with courtesy.

To my country and my people, I pledge my devotion. In their well-being and prosperity alone lies my happiness.

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Dear students,

You were provided with opportunities to observe your surroundings and engage in simple experiments and investigative activities in earlier classes. The classroom experience, undoubtedly, might have helped you to record the information systematically and assimilate ideas through discussion and analysis. While understanding the scientific approach, there should also be the attitude to take forward the skills to apply them in day-to-day life. Moreover, an eco-friendly perspective must be adopted too. All these, through direct experiences, enquiry and understanding preferably.

This textbook presents ideas in accordance with this. There are experiments, illustrations and explanatory details that enable the comprehension of these ideas. There are opportunities appropriate to the situation to make learning more enjoyable.

Go ahead, thinking, asking questions, approaching ideas critically and quizzing with teachers and friends.

Make learning a joyful experience.

Regards,

Dr. P. A. Fathima
Director, SCERT

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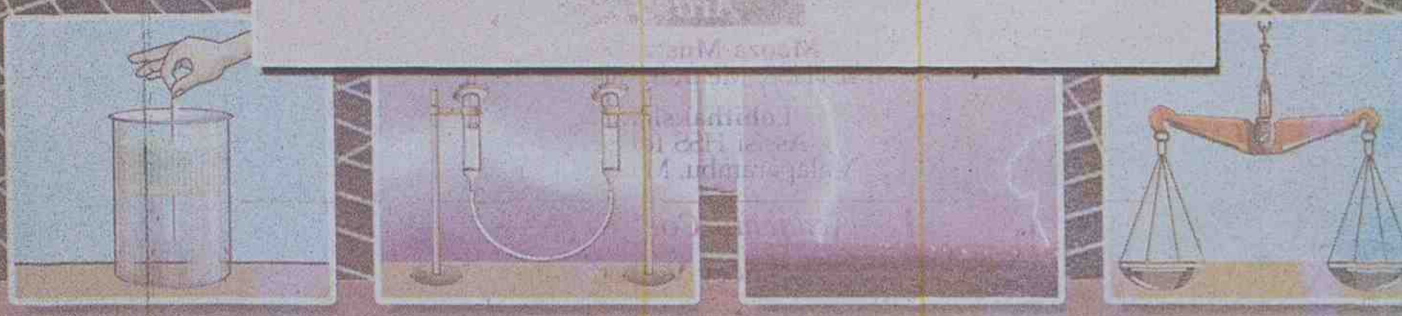


Certain icons are used in this textbook for convenience


For further reading (Evaluation not required)


ICT possibilities for making concepts clear


Significant learning outcomes


Let us assess


Extended activities

1

Forces of Fluids

Due to the surface tension, a razor blade floats on water. Is it for the same reason that a ship floats on water?

Why is it not possible for all substances to float on water?

Have you ever had such a doubt?

Take water in a bucket. Place a tightly closed bottle on it. What do you observe?

- -

Using your hand, immerse the plastic bottle to the bottom of the bucket. Don't you have to exert a force now? Why is it so?

Leave the bottle free. What do you observe?

Why does it rise to the surface of the water?

- Heavy substances are supposed to go down, aren't they?
- How is it that the bottle experienced an upward force greater than its own weight?
- Can liquids exert an upward force?

Fig. 1.1

Let's consider another situation.

When an object in water is lifted, its weight appears diminished when compared to that in air. What can be the reason? Write down your inference.


Fig. 1.2 (a)


Fig. 1.2 (b)

You have found that a liquid exerts an upward force on a body placed in it. This force is the buoyancy. It is exerted not only by liquids but also by gases. Liquids and gases together are generally called fluids.

A body situated in a liquid experiences two forces:

1. The weight of the body acting downwards.
2. The buoyancy, acting upwards on the body.

When a body is immersed completely or partially in a liquid, the liquid exerts an upward force on the body. This force is the buoyancy.

Tabulate some situations in your daily life where buoyant forces are experienced in liquids and gases.

- A hydrogen filled balloon rises in the air.
-

How can you measure the buoyancy experienced by a body in a liquid?

How to measure buoyancy

Take a piece of stone and a piece of metal of almost the same size. Find out the weight of each in air using a spring balance calibrated in newton. Then find the weight of each of them when immersed in water. Record the data obtained as shown in table 1.1.

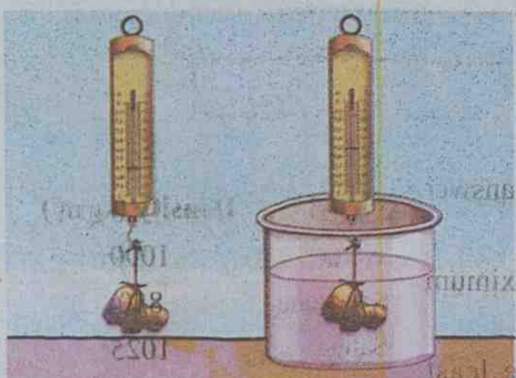


Fig. 1.3

Object	Weight in air (W_1)	Weight in water (W_2)	Decrease in weight (W_1-W_2)
Stone	____ N	____ N	____ N
Piece of metal	____ N	____ N	____ N

Table 1.1

Why did the stone and the metal piece lose weight in water?

Isn't the buoyancy the same as the loss of weight experienced in water?

Now you have understood that in order to calculate the buoyancy exprienced by a substance immersed in a fluid, it is enough to find out the loss of weight of the substance in that fluid.

Does the same substance experience the same buoyancy in all fluids?

Factors that influence buoyancy

What are the factors that influence buoyancy?

Let's see.

Take water, kerosene and saline water in three separate beakers. Find out the buoyancy of these liquids which is exerted on a piece of stone and tabulate.

See 'Buoyancy' in PhET in the IT @ School Edubuntu

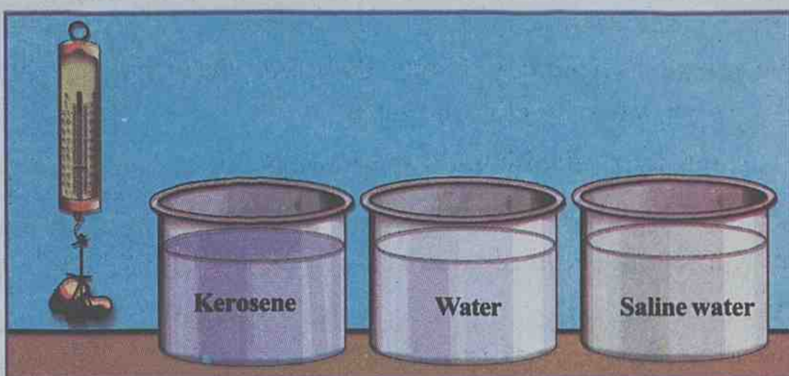


Fig. 1.4

Weight of stone in air = ... N

Liquid	Weight of stone	Loss of weight of stone or buoyancy (Weight in air - Weight in liquid)
Kerosene		
Water		
Saline water		

Table 1.2

Look at the details given in table 1.2 and table 1.3, and answer the following questions:

- In which liquid did the stone experience the maximum buoyancy?
- In which liquid did the stone experience the least buoyancy? Is the density of that liquid higher or lower than that of the other liquids?

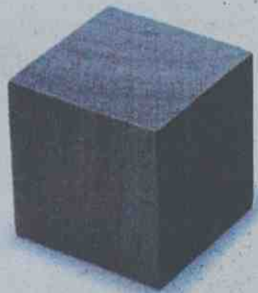
Liquid	Density (kg/m^3)
Water	1000
Kerosene	810
Saline water	1025 (approx.)

Table 1.3

- Is there any relation between the density of a liquid and buoyancy?

Density of a liquid is a factor that influences the buoyancy of a body in that liquid.

- Does a ship that enters a fresh water lake from the ocean sink more or rise more? Justify your answer.



Copper block

Iron block

Fig. 1.5

You know that buoyancy changes with the density of the liquid. But do all substances that have the same weight in a liquid experience the same buoyancy?

Calculate the buoyancy exerted by water on two blocks of equal weight, one of copper and the other of iron.

Object	Weight in air	Weight in water	Buoyancy
Copper block			
Iron block			

Table 1.4

Haven't you found out the buoyancy experienced by each block?

- Why do they differ?
- The mass of the copper and the iron blocks are the same because their weights are the same. But are their volumes the same?
- Why do their buoyancies differ?

Now you must have realised that the buoyancy acting on a body depends also on its volume.

When an object is in a fluid, is there any relation between the weight of the fluid displaced and its buoyancy?

Let's do an activity.

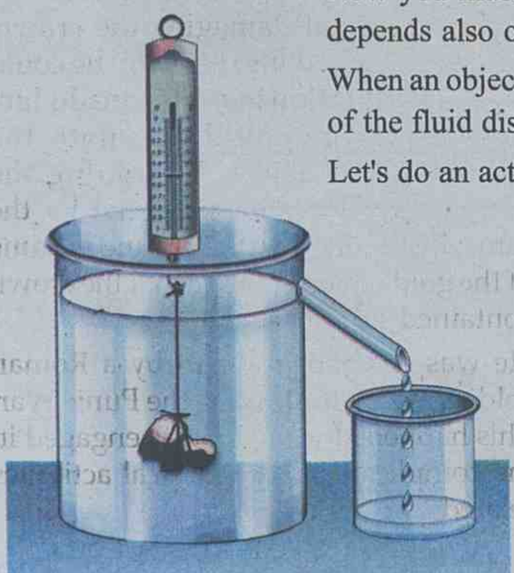


Fig. 1.6

Archimedes principle

Find out the buoyancy of a piece of stone and an iron block in water. Simultaneously, using an overflowing jar, find out the volume of water they displaced. Find out the weight of water overflowed using a spring balance. Tabulate the results in table 1.5.

Object	Weight of the object in air	Weight of the object in water	Loss of weight (Buoyancy)	Weight of water overflowed
Stone				
Iron block				

Table 1.5

Analyse table 1.5 and find answers to the following questions:

- What is the loss of weight (buoyant force) of the stone in water?
- What is the relation between the buoyancy experienced by the stone and the weight of water displaced by it?
- What is the relation between the buoyancy experienced by the iron block and the weight of water displaced by it?
- What do you infer from this?

You have learnt that the buoyancy that a liquid exerts on an object is equal to the weight of the liquid displaced by it. This is Archimedes Principle.

Archimedes principle

When an object is immersed partially or completely in a liquid, the buoyancy experienced by it will be equal to the weight of the liquid displaced by it.

Floatation

Let's do an activity.

Make a small vessel using aluminium foil of length and breadth 10 cm each. Place this small vessel on the surface of water in a trough. Does it sink? Unfold the vessel of

Archimedes

Archimedes was born in 273 BC at Syracuse, a port city in Italy. He lived during the rule of Hiero II. King Heiro commissioned a goldsmith to fabricate a crown. He commanded Archimedes to find out whether there was any impurity in the crown. This problem confounded him. He knew that the density of pure gold could be calculated by dividing the mass of the gold bar by its volume. His confusion was how to calculate the volume without damaging the crown. When he stepped into his bath, he could see water overflowing. This made him realise that he could calculate the volume of an object, by finding the volume of the water displaced by the same. By finding the density and volume of the gold he could prove that the crown contained impurities.

He was stabbed to death by a Roman soldier in 212 BC during the Punic War. This happened when he was engaged in the complicated mathematical activities related to circles.

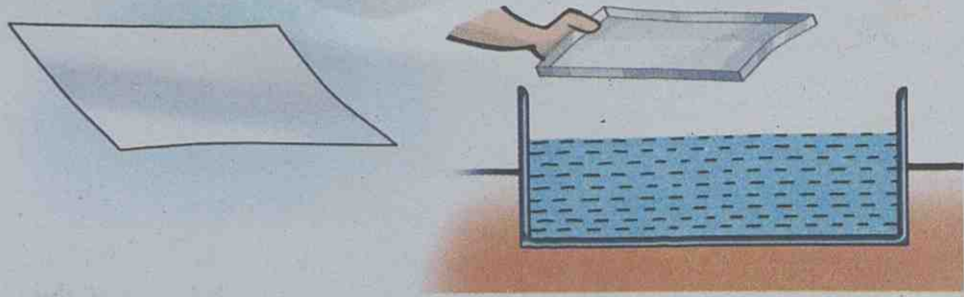


Fig. 1.7

aluminium foil. Fold it till it becomes a small piece. Then put it in water. What do you observe?

- When the aluminium foil was in the form of a vessel and then folded into a small piece, was there any change in its mass or weight?

- Is there any change in density?

What is the reason for the aluminium foil vessel to float and the folded foil to sink?

Put some pieces of stone, wood, rubber, cork, etc., one by one into water. Which among them do float on water? Note them down.

Why do they float on water?

Find out the buoyancy and the weight of the water displaced by each floating body and record them in table 1.6.

Sl. No.	Body	Weight in air	Weight in water	Buoyancy	Weight of displaced water
1					
2					
3					

Table 1.6

- Analyse table 1.6. How can we relate the weight, the buoyancy and the weight of the displaced water of each object.

- Write down the situation where a body will float on a liquid.

Law of floatation

Weight of a floating body is equal to the weight of the liquid displaced by it.

Why does a body placed in a liquid remain in the same position without rising or sinking?

Find out the reasons for the following from what you have learnt.

- A piece of stone experiences a loss of weight within water.

- Though an egg sinks in pure water, it floats on salt water.

- Kerosene floats on water.

- A ship floats on water.

Relative density

When kerosene and water are taken in a vessel, kerosene will float on water. You know that this is because the density of kerosene is less than that of water.

Write examples for liquids of density greater and lesser than that of water in table 1.7.

Density greater than that of water	Density lesser than that of water
• Honey	• Kerosene
•	•
•	•

Table 1.7

Density of water is 1000 kg/m^3. Densities of other substances are often stated relative to the density of water. Relative density of a substance states how many times the density of the substance is to that of water. Kerosene is a liquid, the density of which is less than that of water. In that case how can we find out that how many times the density of kerosene in relation to that of water?

For this, it is enough to find the ratio of the density of kerosene to that of water. This ratio is the relative density of kerosene.

If the density of water is 1000 kg/m^3 and that of kerosene is 810 kg/m^3, what will be the relative density of kerosene?

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$$\text{Relative density of kerosene} = \frac{\text{Density of kerosene}}{\text{Density of water}}$$

$$= \frac{810\,\text{kg/m}^3}{1000\,\text{kg/m}^3} = 0.81$$

Relative density of a substance is the ratio of the density of the substance to the density of water.

$$\textit{Relative density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

Since it is a ratio, relative density has no unit.

Hydrometer
Fig. 1.8

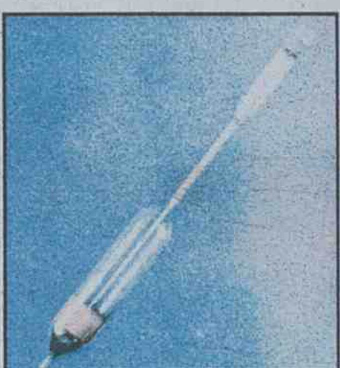
A hydrometer is a device used to measure the relative density of a liquid.

You might have studied in your lower classes how to make a lactometer. In the same manner make a hydrometer.

Using the hydrometer you have made, find out liquids of density greater and lower than that of water.

On the basis of your observations answer the following questions.

- What will be the reading when the hydrometer is dipped in water?
- Suppose the hydrometer is dipped in a liquid of density greater than that of water. Will the liquid surface be above or below the marking of 1?
- In which case does the hydrometer sink more? In liquids of greater density or those with a lower density?
- Why do the markings on the hydrometer increase towards the bottom?



Lactometer
Fig. 1.9 (a)

Have you seen how the quantity of water in milk is measured? Lactometer is an instrument used for this purpose. Adulteration of milk is an offence.

Using adulterated milk is harmful to our health.

Fig. 1.9 (b)

The lactometer which is a device to test the purity of milk is basically a hydrometer. Both hydrometer and lactometer work on the principle of floatation.

Pascal's Law

Reclamation of paddy fields with an excavator is a common sight.

Fig. 1.10

Such activities which are harmful to the environment and bio-diversity need to be controlled. Before the introduction of the excavator, earth moving was a strenuous job. But it became easy when the excavator came in to being. When the driver pushes a small lever, the heavy, mechanical arms of the excavator begin to move. How is it made possible?

Fill an empty tooth paste tube completely with water and close it tightly. Put two or three holes at random on the tube with a pin. Press with your finger anywhere on the tube and watch.

- Does water come out from all the holes?

When we use tooth paste for cleaning teeth, paste comes out of the filled tube on applying force anywhere on the tube.

Fig. 1.11

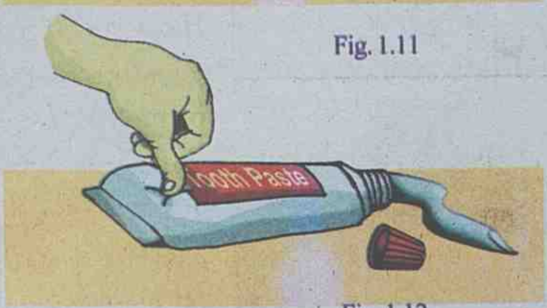


Fig. 1.12

Let's do another activity.

Take a plastic bag without holes and fill it with water. Tie its mouth tightly so that no air gets inside. Make holes on the bag with a pin. What do you observe?

Now press anywhere on the bag with your palm.

- There are identical streams of water from all the holes. Why?

Isn't this due to the fact that pressure applied at any point of the bag is transmitted equally to

Blaise Pascal

Blaise Pascal was born in France on 19 June 1623. He proved his proficiency in the fields of Mathematics, Physical Science, Philosophy and Theology. At the age of 16 he played a major role in the starting of projective geometry and probability theory, which are two research fields in Mathematics.

In 1642, at the age of 19, he started designing and making mathematical calculating machines. He made nearly 50 models and 20 machines. One of the calculating machines made by him is known as Pascal's calculator. He conducted studies in Hydrodynamics and Hydrostatics, which are fields related to liquids.

Have you heard of a number pyramid called Pascal's Triangle?

				1				
			1		1			
		1		2		1		
	1		3		3		1	
1		4		6		4		1

Think how the numbers in this triangle are related. Find out where this is applied.

Pascal passed away on 19 August 1662 at the age of 39 due to poor health.

the entire bag? The law related to this was first enunciated by Blaise Pascal.

Pascal's law

The pressure applied at any point of a liquid at rest in a closed system, will be experienced equally at all parts of the liquid.

This is because, one cannot change the volume of a liquid by applying pressure

Let's do an activity.

Fill two identical syringes with water. Connect them with a plastic tube. Then arrange them as shown in Fig.1.13.

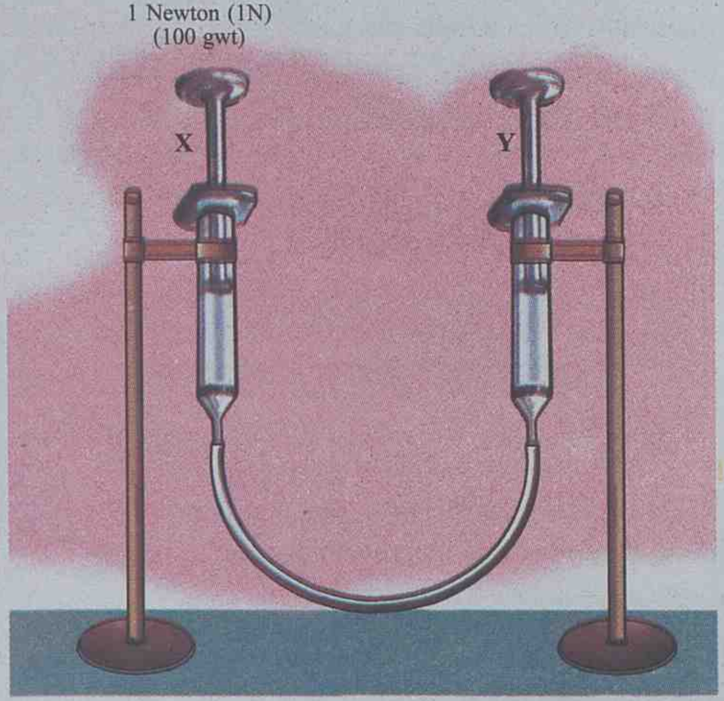


Fig. 1.13

- Press slightly on the end X. What do you observe?
- Bring the ends X and Y to the same level. Place a slotted weight of 1N (100 gwt) at the end of X. What happens at the end Y?
- Place at the end Y as well a weight of 1N. What do you observe now?

  Then replace the syringe X with one of slightly smaller diameter and repeat the activity.

- Will it be possible to balance with 1N at Y?

  Now increase the weight at Y and find out the weight required to bring both the ends to the same level.
- More weight was required at Y to attain equilibrium. Is it not due to the increased surface area of water at that end?

Observe Fig 1.14

Fig. 1.14

See "Fluid pressure and flow" in PhET in the IT @ School Edubuntu.

In the figure the surface area of the end X is 1 cm^2 and that of the end Y is 10 cm^2. Calculate the pressure experienced at X and Y.

Pressure at X, F = 1N,

$A = 1\ cm^2 = 0.0001\ m^2$

$$\therefore \frac{F}{A} = \frac{1}{0.0001} = 10000\ N/m^2$$

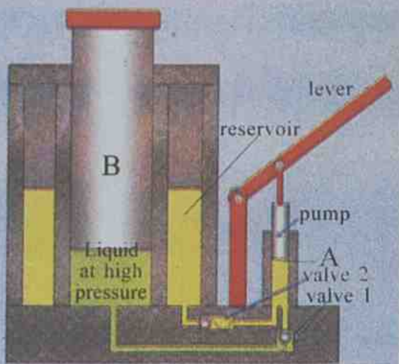
Now let's calculate the pressure at Y.

- Are the pressures at X and Y the same?
- What is the ratio of area of cross section of Y to that of X?
- What is the ratio of force exerted on Y to that on X?
- What are the conclusions you have drawn?
- If the area of cross section of one end is A and the force applied is F_1, and the area of cross section of the other is A_2 and the force applied is F_2,

  then $\frac{F_1}{F_2} = \frac{A_1}{A_2}$

Hydraulic Jack

In a service station you might have seen hydraulic lifts which are used to lift vehicles. This set up is known as hydraulic jack.



When the lever is lowered, the pump attached to it lowers and the liquid is compressed. The compressed liquid reaches the tank B via valve 1. When the lever is raised, the liquid from the reservoir reaches tank A through valve 2. As a result of the continuous operation of the lever, the jack is lifted up.

- Let the area of cross section at the end X of the tube shown in Fig 1.15 be 0.05 m^2 and that of the end Y be 0.6 m^2. If a force of 120 N is applied at the end X, what will be the force experienced at the end Y?

Let's find out.

$$\frac{F_y}{F_x} = \frac{A_y}{A_x}$$

$$F_y = \frac{F_x A_y}{A_x}$$

$$F_y = \frac{120 \times 0.6}{0.05}$$

$= 120 \times 12 = 1440$ N

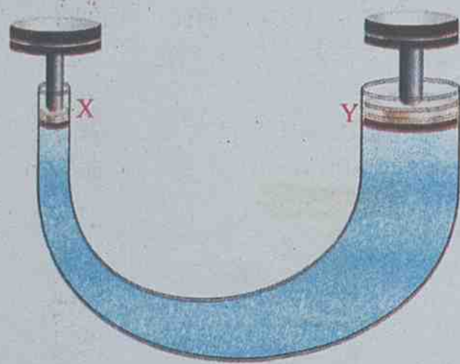


Fig. 1.15

You have seen that at the end of the tube where the area is greater, the force has become 12 times. But the work done at either end of the tube is the same.

Therefore if the section Y is to be raised by 1 cm, shouldn't the section X be lowered by 12 cm?

In that case, if the section Y is lowered by 1 cm, how much will the section X rise?

Certain devices constructed on the basis of Pascal's law are given. Expand the table with more examples.

- Hydraulic brake of vehicles
- Hydraulic jack
- Hydraulic press
- Excavator
-

Using syringes, a plastic tube and water, construct a simple model of a hydraulic jack and present it in the class.

Does a liquid rise up only when an external force is applied in this manner?

Capillarity

Examine certain situations given below.

- Ink can be blotted by a piece of chalk.
- Holding up the nib of certain fountain pens it is possible to write on a paper pasted on a wall.
- In rainy season dampness spreads on a wall.
- Sweat can be blotted with a piece of cotton cloth.

In the above situations why do liquids rise or spread to other parts, inspite of their weight?

Take two tumblers, one containing water, and the other mercury. Dip a capillary tube in each tumbler.

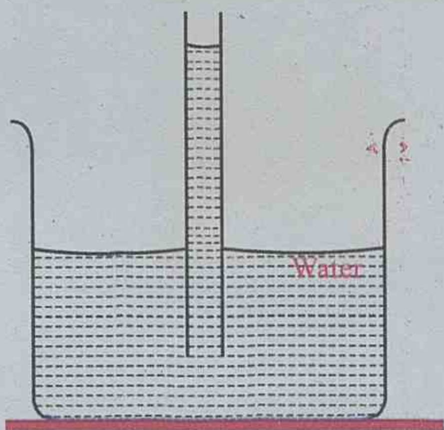


Fig. 1.16

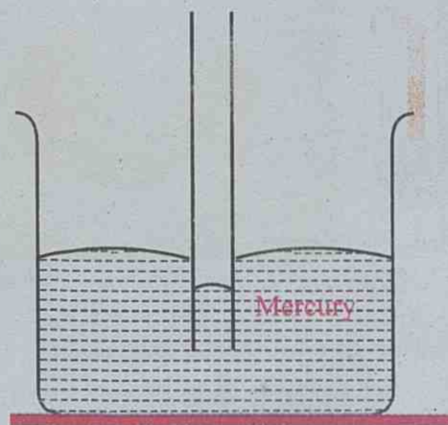


Fig. 1.17

- What happened to the water level in the capillary tube?

  The rising of water in a tube against gravitation or against the weight of water itself is capillary rise.

- Does the capillary rise occur in mercury as well?

  What did you observe?

The depression of liquid in a tube is capillary depression.

Capillarity

The rise or depression of a liquid in a narrow tube or a minute hole is capillarity.

What is the cause of the phenomenon capillary rise or depression?

Let's see.

You have learnt about surface tension.

Write down all that you know about it.

- Acts along the surface of the liquid
- Supports certain substances like a razor blade to float on water.
- Helps liquid drops to take a spherical shape.
-

What is the reason for the surface tension of liquids?

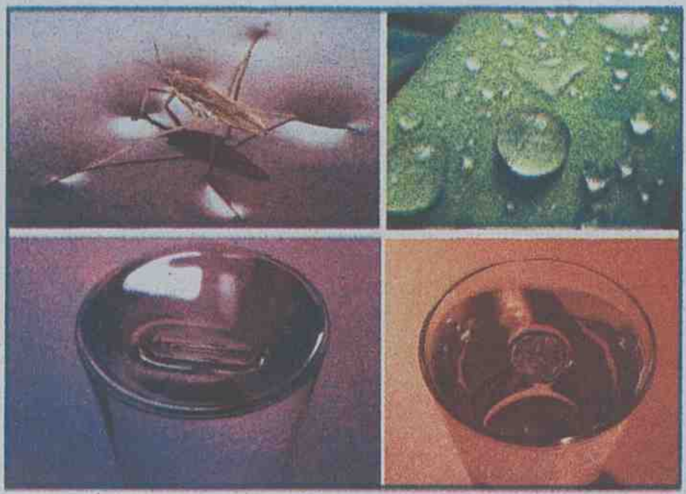


Fig. 1.18

Notice the following situations.

- When the midrib of a coconut tree leaf *(eerkil),* pencil, etc., are dipped in water and taken out, water is seen sticking to them.
- When a piece of chalk is used on a black board, particles of the chalk stick to the board.
- Fingers are wetted at intervals when currency notes are being counted.

Are the molecules of the substances which we used for each experiment identical?

The attractive force between different types of molecules is the reason for this phenomenon. This type of attractive force is the force of adhesion.

Adhesive force is the force of attraction between molecules of different types of substances .

Place two drops of mercury side by side on a glass plate. Using a pencil bring them close together.

What do you observe?

- Is there any difference between the molecules of the two drops?
- Isn't the attraction here between the molecules of the same type?

Attractive force of this type is the cohesive force.

Cohesive force is the force of attraction between molecules of the same type.

Write down in your science diary more examples of adhesive and cohesive forces.

Observe the molecules on the surface of the liquid in Fig. 1.19.

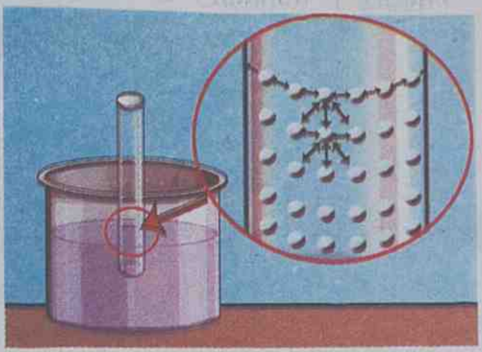


Fig. 1.19

- What are the different types of forces acting on the molecules in contact with the sides of the vessel?
- What about the forces acting between molecules on the liquid surface?
- Why did the molecules of water in contact with the sides of the vessel rise slightly higher than the others?
- What is the direction of the resultant force on a molecule in the liquid surface?
- What is the reason for the liquid surface to behave like an elastic membrane?
- Which attractive force between molecules is responsible for the surface tension that causes the liquid surface to behave like a membrane?

The surface tension is due to the cohesive force between the molecules on the surface of the liquid.

From what you have learnt so far, discuss and find out the cause of capillary rise and depression.

Capillary rise occurs when the adhesive force is greater than the cohesive force.

But when the cohesive force is greater than the adhesive force, capillary depression will take place.

Let's do another activity.

Arrange capillary tubes of different diameters on a piece of thermocol. Dip the capillary tubes in water. Compare the capillary rise in the tubes.

- Which has greater capillary rise?
  In the tube of smaller/ greater diameter
- Which has lower capillary rise?
  In the tube of smaller/ larger diameter
- How is the diameter of the tube and capillary rise related? Note down your inference.

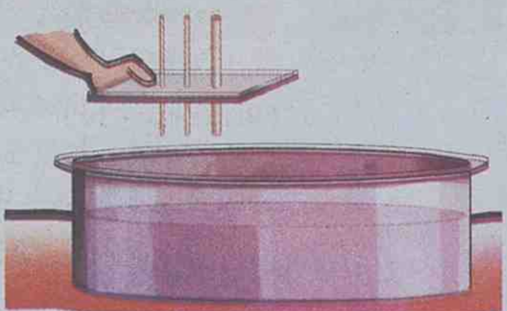


Fig. 1.20

Why does the capillary rise increase when the diameter of the tube decreases?

When the diameter of the tube decreases, the weight of the liquid it can contain also decreases. The weight of the liquid in the tube is supported by adhesive force. This force depends upon the liquid and the nature of the surface which comes into contact with it. The adhesive force with the tube is greater than the cohesive force of the liquid. So the liquid is able to rise. Capillary rise increases with the decrease in the diameter. This is the reason for the capillary rise in liquids such as water. But this is opposed by the weight of the liquid in the tube.

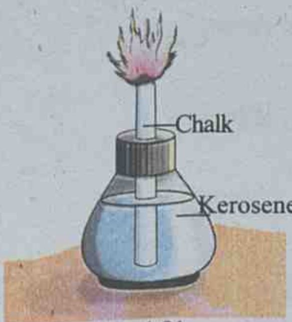


Fig. 1.21

Will the liquid rise even after the weight of the liquid in the tube has become same as the adhesive force?

Is it clear why the liquid level rises more when the diameter of the tube decreases? In a bigger tube, as the liquid level rises, the volume increases and subsequently the weight of the liquid also increases. In that case, why does the capillary rise decrease when the diameter is increased?

- We light lamps using wicks made of cotton cloth. How does the oil rise up along the wick?

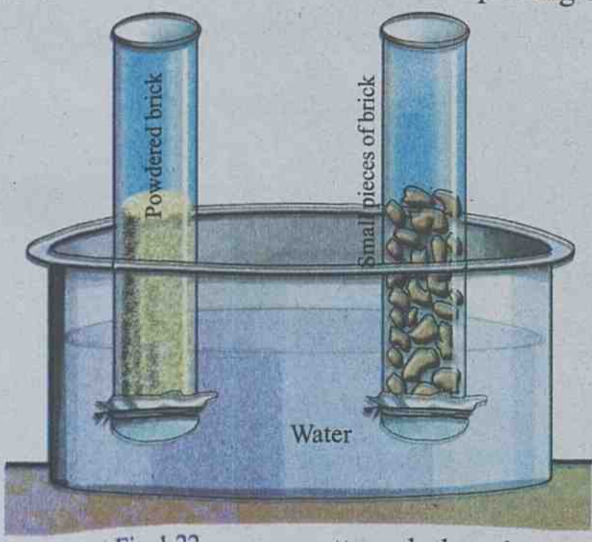


Fig. 1.22

Can you make a kerosene lamp using a piece of chalk?

Make a kerosene lamp as shown in Fig 1.21 and light it up.

- Why is the land ploughed before the beginning of summer?
- Does it have any relation to the capillary rise?

Let's do an activity.

Take two glass tubes of diameter 4 cm. Close one end of each tube by tying a piece of cotton cloth to it. Fill one of the tubes with powdered brick and the other with grains of the brick. Dip these glass tubes in a trough of water. Observe what happens after some time.

- In which tube does water rise higher?
- Why is the rise less in the tube filled with grains of brick?

- Does the separation between the soil particles increase or decrease when a land is ploughed?

Discuss this activity to explain how the ploughing of land before summer helps to retain moisture in the soil.

Find out and write down more situations where capillary rise is employed.

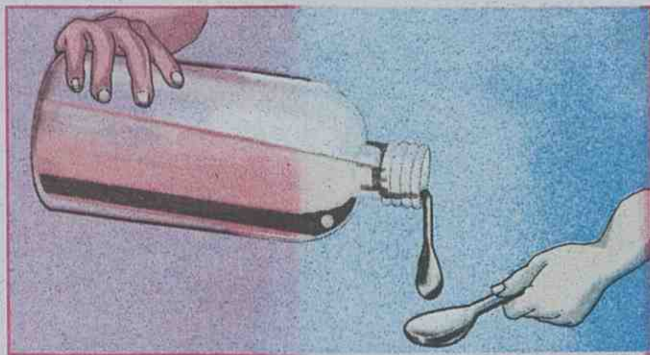


Fig. 1.23

Viscous force

Honey does not flow at the same speed as water. What is the reason?

Place one drop each of kerosene, water, glycerine and honey at various places along a single line at one end of a glass plate. Hold the glass plate slightly tilted. Compare the speed of flow of each liquid and write it down in your science diary.

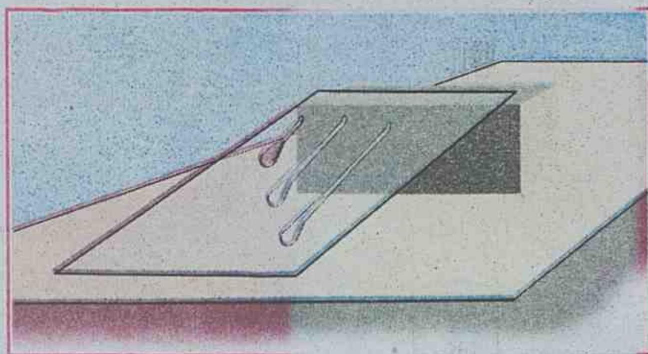


Fig. 1.24

- Water flows faster than honey.
-

- You have seen that different liquids flow at different speed. Why is it so?

Besides the friction due to the glass plate, there is frictional force between the layers of each liquid. It is this frictional force that prevents the flow of liquids.

Observe the figure.

Every layer of liquid prevents the flow of the layer in contact with it. This is the reason for the variation in speed between the layers of liquid.

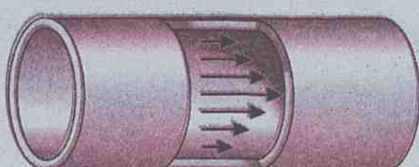


Fig. 1.25 (a)

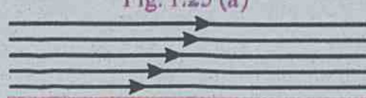


Fig. 1.25 (b)

Between the layers of a liquid in motion, there is a frictional force parallel to the layers which try to prevent the relative motion between the layers. This frictional force is the viscous force.

Viscosity is the characteristic property of a liquid to initiate a force that tries to prevent the relative motion between the layers of the liquid.

Find out liquids of viscosity greater and lower than that of water and tabulate them.

Greater viscosity	Lower viscosity
• Honey	• Kerosene

Table 1.8

Liquids of greater viscosity are the viscous liquids, and those of very low viscosity are the mobile liquids.

Haven't you studied in your earlier classes that a person who had an electric shock is to be massaged? Let's see what change it produces in our body.

Take some honey in two test tubes. Heat the honey in one of the test tubes. Then pour both at two points on a glass plate. Tilt the glass plate and observe the flow of the honey. Why did the hot honey flow fast? What is your inference?

When temperature increases, the viscosity of a liquid decreases.

The body temperature of a person who gets an electric shock falls suddenly. As a result the viscosity of the blood increases, causing hindrance to the flow of blood, resulting in a heart attack. When massaged, the body becomes warm and the viscosity of the blood attains normal level. The person thus overcomes the dangerous situation.

Significant Learning Outcomes

The learner can

- participate in the experiments related to buoyancy and identify and explain them in daily life.
- explain using the law of floatation why certain substances float, some others immerse, and some only partially immerse in water.
- find the relative density of liquids through experiment.
- explain the practical aspects of Pascal's Law through experiments.
- do experiments to differentiate between cohesive force and adhesive force and is able to explain capillary rise and capillary depression.
- explain viscosity and understand its importance in daily life.

Let us assess

1. The weight of a piece of stone in air is 120 N and its weight in water is 100 N. Calculate the buoyancy, experienced by the stone.
2. A body which floated in water sank, when put in kerosene. Why did it happen?
3. Observe the figures of an object placed in different liquids.

   a. Compare the gravitational force and the buoyancy acting on the body when it is in the liquids A, B and C.
   b. If the body is a solid substance, which is the liquid whose density is equal to that of the solid?
4. A body of weight 1000 N sinks in water. The weight of the liquid overflowed is 250 N.
   a. What will be the weight of the body in water?
   b. A body of the same weight as above floats in water. What is its weight in water? What will be the weight of the water displaced?

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5. The area of one end of a U-tube is 0.01 m^2 and that of the other end is 1 m^2. When a force was applied on the liquid at the first end the force experienced at the other end is 20000 N. What is the force applied on the liquid at the first end?
6. Write down the reason for the following:
   a. Ink can be blotted with chalk.
   b. Sweat can be blotted with tissue paper.
7. Which is the correct figure? Why?

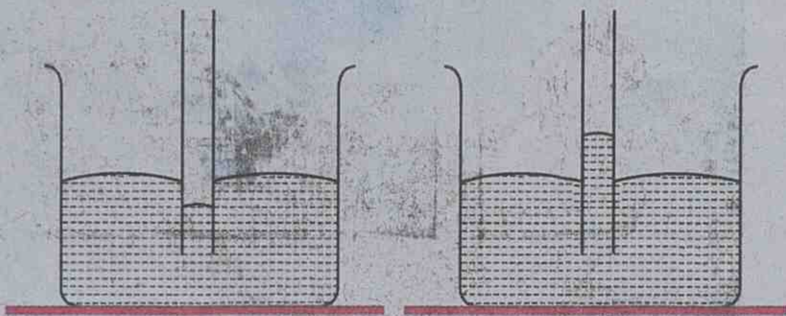


Fig. A　　Fig. B

Extended activities

1. Prepare a table of substances of density less than that of water.
2. Float a knitting needle on the surface of water.
3. Using a spring balance, water and overflow jar find out the densities of substances of different shapes and sizes and tabulate.
4. Using a hydrometer find out adulterated liquids.
5. Using syringes and rubber tubes of different sizes, make models of hydraulic lifts and exhibit.
6. Collect capillary tubes of different diameters. Find the capillary rise and depression of different liquids and record.
7. Collect different types of sand and find out their water absorbing capacity. Record your findings.
8. Can an egg be floated on water? Find out through an activity.

2

Motion and Laws of Motion

You might have gone on some amazing rides at an amusement park. Have you ever thought of the various types of motion in them?

Write down the concepts you have learnt about motion.

- Reference body
- Velocity
- Acceleration
- Displacement

Write down the symbols of the following terms related to the speed of moving objects.

Initial Velocity	u
Final Velocity	
Displacement	
Acceleration	
Time	

How can you express acceleration using symbols?

$$\text{Acceleration } a = \frac{\text{Final velocity - Initial velocity}}{\text{Time taken for change of velocity}} = \frac{v - \ldots}{\ldots\ldots}$$

- If a body travelling at a velocity of 10 m/s changes its velocity to 20 m/s after 20 s, what will be its acceleration?

  Initial velocity u = 10 m/s

  Final velocity v = 20 m/s

  Time taken for change of velocity t = 20 s

  $$\text{Acceleration } a = \frac{v - u}{t} = \frac{20 - 10}{20} = 0.5 \text{ m/s}^2$$

  How can you calculate the final velocity from $a = \frac{v - u}{t}$

  $v - u = at$

  $v = u + at$. This is the first equation of motion.

Similarly, there are two more equations of motion. $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$.

Equations of motion can be formulated using a graph. For this purpose, understand a few facts about graphs.

What is a graph?

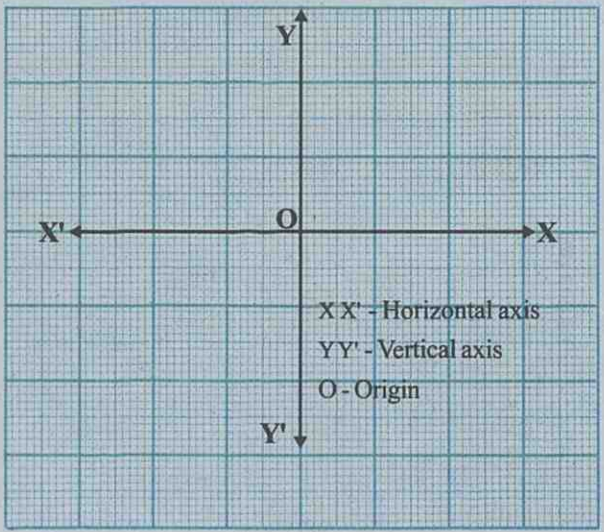


Fig. 2.1

This is a two dimensional diagram. It can be portrayed using two quantities. A graph has two axes. The horizontal axis is the 'X' axis and the vertical, 'Y' axis. The point 'O' is the origin. This is where X and Y axes meet.

The axis towards the right from the origin is taken as positive X axis (OX) and to the left as negative X axis (OX'). In a similar way OY and OY' are considered as positive and negative axes.

What is the use of a graph?

We can find out equations connecting the quantities represented by X and Y. Values obtained by these equations can be marked in a graph. Similarly we can find out the values of the other equations using this graph.

Draw on a graph paper the axes X'OX and Y'OY. Mark the values given in Table 2.1 on this graph. Join the markings. What is the nature of the graph obtained?

X – axis, time (s)	0	1	2	3
Y – axis, position (m)	0	1	2	3

Table 2.1

- Using the data given below, draw a position – time graph

Time (s)	0	1	2	3	4	5	6
Position (m)	0	2	4	6	8	10	12

Table 2.2

- The position – time graph of a car is given. Find out from the graph the distance travelled by the car in 8 second.

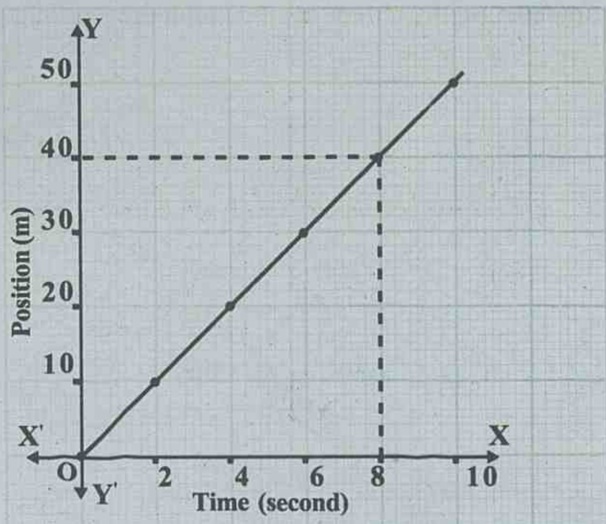


Fig. 2.2

How can we find the position of an object at a particular time from a position – time graph?

- Draw a perpendicular to the position – time graph at the eighth second.

- From the point where the perpendicular meets the graph, draw another perpendicular to the Y-axis. The point at which this perpendicular meets the Y-axis is the distance travelled by the car in 8 s.

Similarly let's see how to draw the speed – time graph and velocity – time graph of a moving object.

Speed – time graph

With the given data complete the speed – time graph.

Time (s)	0	2	4	6	8	10
Speed (m/s)	0	2	6	8	6	10

Table 2.3

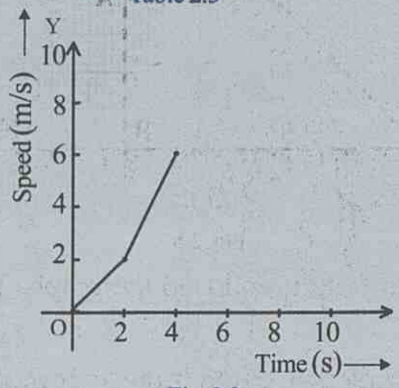


Fig. 2.3

Velocity-time graph

Velocity – time graph can be drawn by taking, on a convenient scale, time on X – axis and velocity on Y – axis.

Time (s)	0	1	2	3	4	5	6
Speed (m/s)	0	1	2	3	4	5	6

Table 2.4

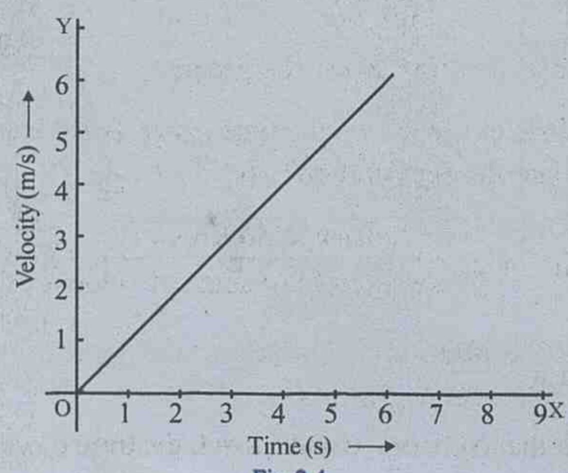


Fig. 2.4

Equations of motion

The velocity – time graph of an object travelling with uniform acceleration is given below:

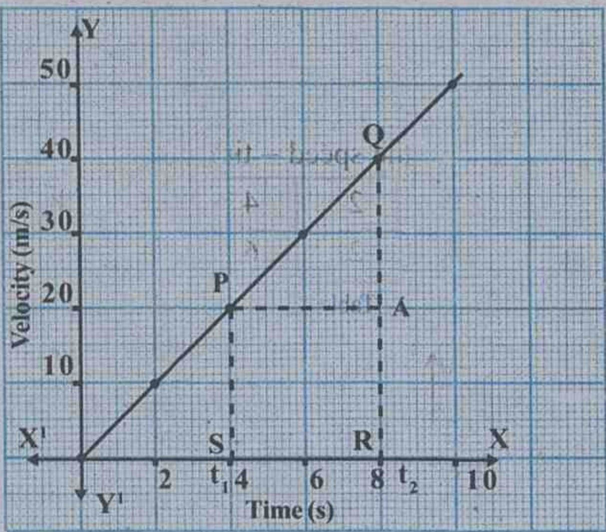


Fig. 2.5

- Draw perpendiculars from t_1 and t_2 to the graph. They meet at points P and Q.
- Draw another perpendicular to QR from P. It meets at A. Consider the trapezium PQRS. Let the velocity be u, when the object reaches the velocity represented by P and v when it reaches the velocity represented by Q.

$$PS = AR = u$$
$$QR = v$$
$$SR = t = t_2 - t_1$$
$$AQ = QR - AR$$
$$= v - u$$

How to find the acceleration from the graph

What is the difference in velocity in the time interval SR? Is it not AQ? If so how can we calculate the acceleration?

$$\text{Acceleration} = \frac{\text{Change of velocity}}{\text{Time taken for change of velocity}}$$

$$\text{Acceleration } a = \frac{AQ}{SR}$$

We have found out that AQ = v – u and SR = t, the time taken for the change of velocity.

Then acceleration $a = \frac{v - u}{t}$ .... (1)

So $at = v - u$

Or, $v = u + at$. This is the first equation of motion.

Let's calculate the displacement of the object in the time interval S to R.

To calculate the displacement in a particular time interval from the velocity – time graph, it is enough to find the area of the quadrilateral obtained by drawing perpendiculars to the velocity – time graph from the points representing instances of time. The area of the quadrilateral is numerically equal to the displacement.

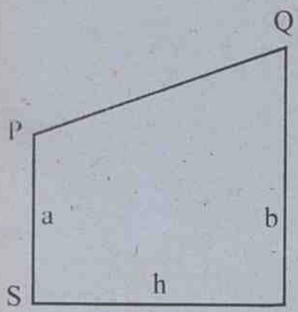


Fig. 2.6

Therefore to find the displacement in the time interval S to R, it is enough to find the area of the quadrilateral PQRS.

PQRS is a trapezium. The equation to find the area of a trapezium is $A = \frac{1}{2} h (a + b)$.

a, b are the length of the parallel sides and h the distance between them.

Displacement = area of trapezium PQRS

$= \frac{1}{2} SR \ (PS + QR)$

PS = u, QR = v, SR = t. When these values are applied in the equation,

$$\text{Area} = \frac{1}{2} t (u + v) \text{ .... (2)}$$

$$= \frac{1}{2} t (u + u + at)$$

$$= \frac{1}{2} t [2u + at]$$

$$= \frac{1}{2} t \times 2u + \frac{1}{2} t \times at$$

$$= ut + \frac{1}{2} at^2$$

Displacement (s) = area of the trapezium.

$s = ut + \frac{1}{2} at^2$. This is the second equation of motion.

Now let's find out the third equation of motion.

The displacement is equal to the area of the quadrilateral

According to equation (2), $s = \frac{1}{2} t (u + v)$

According to equation (1) $a = \frac{v - u}{t}$, from this, $t = \frac{v - u}{a}$

$$s = \frac{1}{2} \left(\frac{v - u}{a} \right) (v + u) = \frac{1}{2} \frac{(v - u)(v + u)}{a} = \frac{(v^2 - u^2)}{2a}$$

$$2as = v^2 - u^2$$

$$v^2 = u^2 + 2as$$

This equation helps us to calculate the final velocity v of an object using u, a and s, even if the time taken to travel is unknown.

$\mathbf{v^2 = u^2 + 2as}$

Let's now consolidate the equations of motion

$$v = u + at$$
$$s = ut + \tfrac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

These equations are applicable only to uniformly accelerated motion.

- The velocity of a body starting from rest is 20 m/s in the 4[th] second and 40 m/s in the 8[th] second. What is the distance travelled by the body between the 4[th] and 8[th] second?

Velocity at the 4[th] second $u = 20$ m/s

Velocity at the 8[th] second $v = 40$ m/s

$$\text{Acceleration } a = \frac{v - u}{t} = \frac{40 - 20}{4} = \frac{20}{4} = 5 \text{ m/s}^2$$

$$\text{Distance travelled } s = ut + \tfrac{1}{2}at^2$$
$$= 20 \times 4 + \tfrac{1}{2} \times 5 \times 4^2$$
$$= 80 + \tfrac{1}{2} \times 5 \times 16 = 120 \text{ m}$$

- A car starting from rest travels 100 m in 8 s with uniform acceleration. Find the acceleration of the car.
- An object starting from rest travels with an acceleration of 5 m/s². What will be its velocity after 3 s?

Motion and unbalanced external force

See IT@ school – PhET Forces and Motion Basic

See the portrayal of a tug of war competition.

Why doesn't the rope move to either side in Fig 2.7 (a)?

Isn't it due to the balanced force acting on the rope?

Rope at rest
Fig. 2.7 (a)

Rope when one side wins
Fig. 2.7 (b)

You know the various effects of force on an object. Write them down.

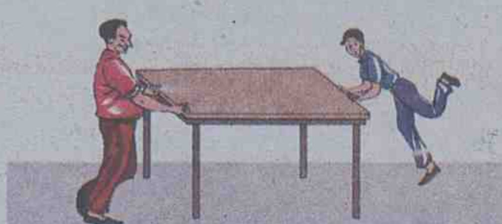
- To move an object
-

What is the type of force applied on the rope in Fig 2.7 (b)? Balanced or unbalanced?

Observe the following activities:

Two boys push a table in the same direction from the same side.
Fig. 2.8

Two boys push a table from opposite directions with equal force.
Fig. 2.9



Two persons push from opposite directions with different force.
Fig. 2.10

Three boys pull a ring with equal force.
Fig. 2.11

Tabulate each of the above forces marking them as balanced or unbalanced.

Figure	Balanced	Unbalanced
Fig. 2.8		✓
Fig. 2.9		
Fig. 2.10		
Fig. 2.11		

Table 2.5

In which of the following situations are the applied forces balanced or unbalanced? Record whether the object will move or not in each situation.

Situation	Balanced force	Unbalanced force	Does move/ does not move
Draws water from a well			Motion takes place
Lifts a cement bag from the ground			
Stands with a load on the head			
A book placed on a table			

Table 2.6

Examine Table 2.6. Which type of force causes motion? Do all the unbalanced forces cause motion?

Let's examine.

- What will be the result when people try to move a car or autorikshaw while sitting inside?

  The vehicle moves/the vehicle does not move.

- What if the same vehicle is pushed from outside?

Haven't you realised that an internal force cannot move an object, but that an unbalanced external force alone can cause motion?

Let's see how an unbalanced external force affects the state of rest and uniform rectilinear motion.

Newton's First Law of Motion

Do the following activities and draw your inferences.

Activity – 1

Fig. 2.12 (a)

Place a glass filled with water on a table as shown in the figure. Allow the water to become still. Pull the glass suddenly to one side.

- What happens?
- Does the water spill in the direction in which the glass was moved or in the opposite direction?
- Before the glass was moved, did the water continue at rest/in motion?
- When the glass starts moving, what is the tendency of water? Continues in the state of rest/ moves.

Activity – 2

Fig. 2.12 (b)

Drag the glass filled with water over the surface of the table. Stop the motion suddenly.

- What happens?
- Is the spilling of water in the same direction as the motion of glass or in the opposite direction?
- When the motion of the glass is suddenly stopped, is the water in a state of rest or motion?
- What is the tendency of the water when the glass is stopped? Continues in a state of motion/ the motion stops.

What is the tendency of the water when the glass just moves?

What is the inference we can arrive at about the tendencies of water in the glass on the basis of the activities given above?

- Water at rest shows the tendency to continue at rest
- Water in motion has a tendency to continue its motion

In the absence of an unbalanced external force, the state of rest or of uniform motion of an object along a straight line does not change. It was Sir Isaac Newton who first consolidated these ideas.

Every object continues in a state of rest or uniform motion along a straight line until an unbalanced external force is applied. This is Newton's first law of motion.

Discuss the following situations and find out the reasons.

- Place some carrom board coins in a pile. Using the striker, strike out the coin at the bottom. What do you observe?

  What is the reason?
- When a running bus is suddenly stopped, passengers standing in the bus show a tendency to fall forward.
- Place a small brick on a plank. When the plank is pulled suddenly the brick remains in the same position as before.

What do you infer from the above discussion?

- A body at rest will continue in its state of rest unless an external force is applied on it.
- A body will move uniformly along a straight line unless an external force is applied on it.

Inertia is the inability of a body to change its state of rest or of uniform motion along a straight line by itself.

Inertia of rest is the inability of a body to change its state of rest by itself.

- Then what about inertia of motion?

Inertia of motion is the inability of a body to change its state of motion by itself.

- When a running bus is suddenly stopped, the standing passengers fall forward. What type of inertia is this?

Expand Table 2.7 finding more such situations from daily life.

Inertia of rest	Inertia of motion
• When the branch of a mango tree is shaken, mangoes fall. •	• A running athlete cannot stop himself abruptly at the finishing line. •

Table 2.7

Find out the reason

- An athlete doing a long jump starts his run from a distance.
- A running elephant cannot change its direction suddenly.

Let's see how the mass of an object affects its inertia.

Mass and inertia

- It is dangerous for loaded vehicles to negotiate a curve in the road without reducing speed. What is the reason?

It is more difficult to roll a filled tar drum than an empty one, isn't it?

- Which of the two has a greater mass?
- Which has greater inertia?

We thus understand that the inertia of an object increases when its mass increases.

The inertia of an object depends upon its mass. When the mass increases, inertia also increases.

- If a tennis ball (mass 58.5 g) and a cricket ball (mass 163 g) are to reach a certain distance when hit with a cricket bat, which is to be hit with greater force?

  The tennis ball /the cricket ball?

Will the change of velocity be the same in both the cases?

Momentum

Fix a plastic channel (similar to the one used in electrical wiring) of length 1½ m as shown in the figure.

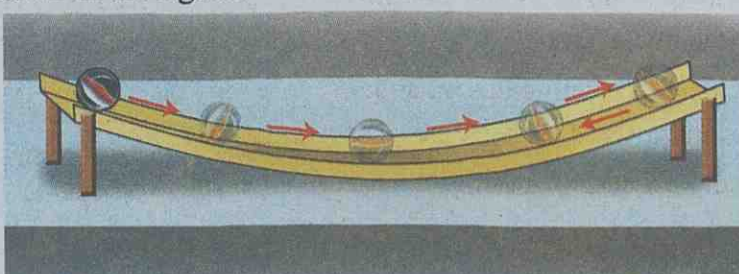


Fig. 2.13

Roll down a marble from one end. Observe the motion of the marble.

- When rolled down, does the velocity of the marble decrease/ increase?
- What about the velocity when the marble moves up?
- From where did the marble get the required force to roll up the second side?
- Isn't it due to the inertia of motion of the object?
- Lower the channel on one side and repeat the experiment. What do you observe?
- What happens if you keep one side of the channel horizontally on the table?

See Energy State Park : Basics in PhET in the IT @ School Edubuntu.

The ball will show a tendency to move continuously. Still it comes to rest gradually because of the friction of the surface.

Let's do one more activity.

As shown in Fig 2.13, place a marble at rest in the channel. Roll down a second marble with the same mass from a different height. The two marbles collide. Record the heights to which the first marble rises.

- What about the velocity of the marble that rolls down, as the height increases?

  Velocity increases/velocity decreases.

- As the velocity of the second marble increases, does the distance travelled by the first marble increase/ decrease?

We have seen that the impact a moving object produces upon another depends upon the velocity of the colliding object. Now allow marbles of different masses to roll down one by one from the same height and let them collide with a marble of smaller mass.

Observe the height to which the marble of smaller mass rises in each situation.

- When was the maximum height attained? Was it when the marble of greater mass collided or that of smaller mass collided?

From the above two activities we have seen that a physical

Galileo Galilei

Galileo Galilei is the scientist who made clear observations on bodies in motion. His observations on a freely falling body are famous. The discoveries of Galilei and Kepler are the basis of Newton's Law of Motion. His inference was that on a smooth horizontal surface, the motion of a body will continue indefinitely.

quantity depending on both mass and velocity of a moving object, acts on another body.

Momentum is a characteristic of moving objects. It is measured as the product of mass and velocity.

Momentum = mass × velocity

$p = m \times v$

$p = mv$

The unit of momentum = unit of mass × unit of velocity

= kg × m/s

= kg m/s

- A car of a mass 1000 kg runs with a velocity of 10 m/s. What is the momentum of this car?
- A loaded lorry of mass 1500 kg moves with a velocity of 12 m/s. Within a small interval of time the velocity becomes 10 m/s.
  a) What is the initial momentum of the lorry?
  b) What is its final momentum?
  c) What is the change in momentum?

Safety measures for applying brakes

Moving vehicles possess momentum. It is not easy to stop a vehicle that has higher momentum applying brakes all of a sudden. Even modern precise braking systems fail on the roads due to less friction and the poor quality of roads. How many accidents occur every day due to over speed and carelessness. For the safest braking, it is essential to maintain a minimum distance of 10 m between two moving vehicles. It is always advisable to increase the distance between the vehicles while travelling at a high speed.

In amusement parks, you might have seen children coming down in a giant wheel from a great height at a high speed and then going up. Have you understood the principle behind it?

The momentum of the moving object is applied here.

Rate of change of momentum

Let a body of mass m move with a velocity u. Let its velocity change to v when a force F is applied on it for a time t.

Initial momentum = m u

Final momentum = m v

Change of momentum = mv - mu

= m (v -u)

- What is the change of momentum that occurred in unit time?

$$\text{Rate of change of momentum} = \frac{\text{Change in momentum}}{\text{Time}} = \frac{m(v-u)}{t}$$

Rate of change of momentum is the change of momentum in unit time.

- A car of mass 1000 kg travels with a velocity of 10 m/s. By applying brakes it is brought to rest in 5 s. What is the initial momentum?

  What is the final momentum?

  What is the change in momentum?

  What is the rate of change of momentum?

  The initial momentum of the car = 1000 × 10 = 10000 kg m/s

  Final momentum = 1000 × 0 = 0

  Change of momentum = -10000 kg m/s

  Rate of change of momentum= $\frac{-10000}{5}$ = -2000 kg m/s^2

If this car is brought to rest in 1 s, what will be the rate of change of momentum?

$$= \frac{-10000}{1} = -10000 \text{ kg m/s}^2$$

The negative sign indicates that the force applied is in a direction opposite to that of motion. But the sign need not be considered for comparing measurements.

As the time to bring to rest decreases, the rate of change of momentum increases.

What if the impact lasts only for a small interval of time?

You have learnt about the change of momentum caused by impact.

Have you ever thought how a nail is hammered into a wall or a cricket ball is struck? Which is the type of force employed here?

Impulsive Force

A very large force acting for a very short time is an impulsive force. Impulse of force is the product of the force and the time.

Impulse of force = F× t

Its unit is newton second (N s).

What are the situations when impulsive forces are used in daily life? Write them down.

Fig. 2.14

- At the time of catching a cricket ball, the time of catching is extended by moving the hand backward with the ball.
- During a pole vault jump, the impact is reduced by falling on a foam bed.
-

Newton's Second Law of Motion

The First Law of Motion defines force and inertia. But the Second Law of Motion shows us how to measure force.

Let's see.

Let a force F act for t second on a body moving with a velocity u. Let the velocity change to v.

The rate of change of momentum of the body is $m\frac{(v-u)}{t}$

- If the force acting for t second is increased, what change will take place in the rate of change of momentum? Record your guess.
- What happens if the applied force is reduced?

Do you understand that the rate of change of momentum is proportional to the applied force? This is Newton's second law.

Newton's Second Law of Motion

The rate of change of momentum of a body is directly proportional to the unbalanced external force acting on it.

$$\text{Therefore, } F \alpha \frac{m(v-u)}{t}.$$

$$F \alpha ma$$

Using a constant k, the above relation can be written as,

$$F = kma$$

$$\text{Since } k = 1$$

$$F = 1 \times ma$$

$$\text{We get } F = ma$$

One Newton is the force required to produce an acceleration of 1 m/s^2 on a body of mass 1 kg.
F = kma when F = 1 unit and m and a are 1 unit each.
1 = k × 1 × 1 is k = 1

F = ma. This is the equation to calculate force.

- m_1 and m_2 are the masses of two bodies. When a force of 5 N is applied on each body, m_1 gets an acceleration of 10 m/s^2 and m_2, 20 m/s^2. If the two bodies are tied together and the same force is applied, find the acceleration of the combined body.

$$F = 5\text{ N}$$

$$\text{The acceleration of } m_1\ (a_1) = 10\text{ m/s}^2$$

$$\text{Acceleration of } m_2\ (a_2) = 20\text{ m/s}^2$$

$$F = ma$$

$$m = \frac{F}{a}$$

$$m_1 = \frac{5}{10} = 0.5 \text{ kg}$$

$$m_2 = \frac{5}{20} = 0.25 \text{ kg}$$

The mass of the two bodies together

$$= m_1 + m_2$$
$$= 0.5 \text{ kg} + 0.25 \text{ kg} = 0.75 \text{ kg}$$

The acceleration of the combined body

$$= a = \frac{F}{m} = \frac{5}{0.75}$$

$$= 6.67 \text{ m/s}^2$$

- A constant force is applied for 2 s on a body of mass 5 kg. As a result, if the velocity of the body is changed from 3 m/s to 7 m/s, find out the value of the applied force.

Newton's second law of motion shows the relation between a body's acceleration and the external force applied on it. Have you ever thought what the source of this external force will be? It is this thought that led Newton to the third law.

Newton's Third Law of Motion

Fig. 2.15

We used rockets for launching artificial satellites. How does a rocket shoot up?

Balloon rocket was an activity presented by school students in their science fair.

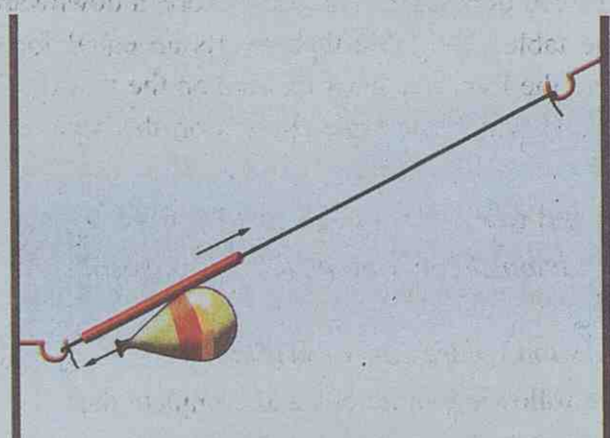


Fig. 2.16

A balloon rocket moves along a string stretched between two windows of a class room.

What is the principle behind it?

Let's examine.

- Inflate a balloon and release it suddenly. What happens?

The sudden release of air causes the balloon to move in the opposite direction.

Let's do an experiment.

Fill a boiling tube with some water and close it gently with a cork. Suspend it from a stand. Heat the boiling tube slowly.

What do you observe?

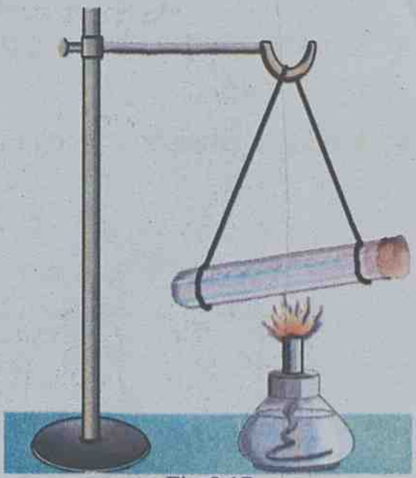


Fig. 2.17

- Is it not the steam from the boiling water that exerts a force on the cork?
- If the action is the cork being pushed out due to the force exerted by the steam on it, what is the reaction?

Write down what the action and the reaction are when you walk on a floor.

Fig. 2.18

From the chambers of the rocket, gas at high pressure goes out. It is the reaction of this force that propels the rocket forward.

- Are action and reaction equal and opposite?

A book is placed on a table. The book exerts a downward force on the table. The table then exerts an equal force upward. Here the force the book exerted on the table is an action, and that which the table exerted on the book is a reaction.

Here action and reaction are equal and opposite.

'To every action there is an equal and opposite reaction'.

This is Newton's third law of motion.

Examine the following situations and complete the table.

Action and reaction

The force which an object exerts on another is an action, and the equal force exerted in the opposite direction by the second body is the reaction.

Situation	Action (F_{12})	Reaction (F_{21})
• A man jumps from a boat to the shore	The man exerts a force on the boat. The boat moves backward.	The boat exerts an equal force on the man. The man lands on the shore.
• A bullet is fired from a gun		
• A boat is rowed		

Table 2.8

If a cart is pushed while on ice, it won't move. What may be the reason? This is because no reaction is obtained from the ice. The same will be the case of objects in mud. For work to materialise, an external object which can provide a reaction is necessary. When a man jumps to the shore from a boat, the external force is obtained from the boat. So pushing the boat back is action, and the force which the boat gives is the reaction. Though they are in opposite directions, they are equal in magnitude.

F_{12} is the force exerted on the first object by the second. F_{21} is the reaction exerted on the second object by the first.

According to Newton's third law of motion $F_{12} = -F_{21}$

Find out the object which supplied the reaction for every activity given in table 2.8 and write it down.

According to Newton's third law of motion, action and reaction are equal and opposite. But do they cancel each other? Why is it so?

Examine table 2.8. In the first situation, what is the object on which the action takes place? What about reaction?

Examine other situations.

Since action and reaction take place in two different objects, they do not cancel each other. According to Newton's third law, action and reaction are equal and opposite.

If so, does the total momentum of a system change?

Let's examine.

Law of conservation of momentum

Notice the figure.

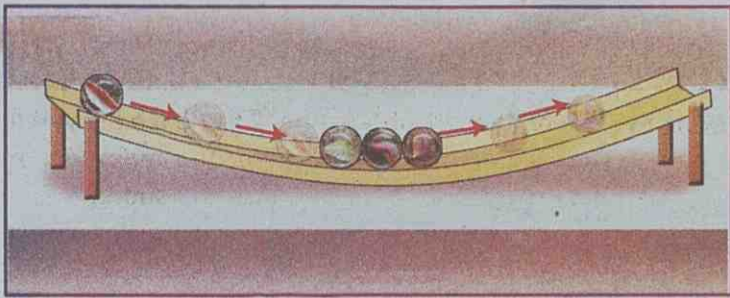


Fig. 2.19

Using wiring channels and marbles, conduct the following activities.

- Move the first marble slightly back and roll forward. What happens?

- Bring the two marbles into contact and let them roll. What happens?

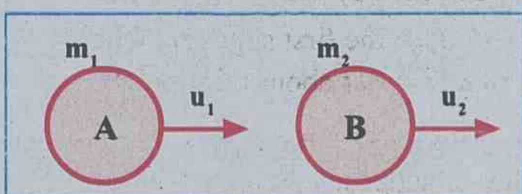
What is your inference?

When an object collides with another, the total momentum of the objects will remain constant. According to Newton's third law of Motion

$$F_{12} = - F_{21}.$$

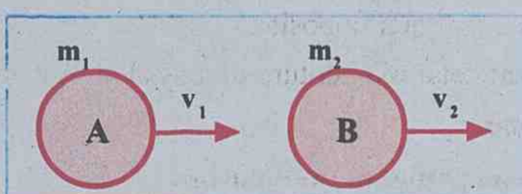
That is, when two objects collide, aren't the forces acting on them equal and opposite?

In that case, let's examine the total momentum of the system before and after collision.



Before collision

Fig. 2.20 (a)



After collision

Fig. 2.20 (b)

The total momentum before collision = $m_1u_1 + m_2u_2$

The total momentum after collision = $m_1v_1 + m_2v_2$

The forces acting on the two objects at the time of collision can be found out by the second law of motion.

- What is the initial momentum of A?

- What is the final momentum of A?

- What is the change in the momentum of A?

- The rate of change of momentum of A = $\frac{m_1v_1 - m_1u_1}{t}$

Let us find out equations for the above in the case of B.

- The initial momentum of B ....
- The final momentum of B ....
- The change in momentum of B ....
- The rate of change of momentum of B ....

According to the second law of motion, rate of change of momentum is directly proportional to the external force. $\left(F=\frac{m(v-u)}{t}\right)$

Therefore, force exerted by B on A:

$$F_{AB} = \frac{m_1v_1 - m_1u_1}{t}$$

Similarly, force exerted by A on B:

$$F_{BA} = \frac{m_2v_2 - m_2u_2}{t}$$

According to the third law of motion

$$F_{AB} = - F_{BA}$$

$$\frac{m_1v_1 - m_1u_1}{t} = -\left(\frac{m_2v_2 - m_2u_2}{t}\right)$$

$$m_1v_1 - m_1u_1 = -(m_2v_2 - m_2u_2)$$

$$m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$$

$$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$$

Thus we see that the total momentum after collision is equal to the total momentum before collision. It is to be remembered that the force exerted by A on B and that on A, by B, are internal forces as far as the system is concerned.

> *In the absence of an external force, the total momentum of a system is a constant. This is the law of conservation of momentum.*

So far we have been studying the rectilinear motion of objects. We have already understood the relation between motion and force. Let's see more about the forces that cause motion.

You know a lot about rectilinear motion.

Is the entire motion going on in our surroundings rectilinear? Write it down.

- Motion of the pendulum of a clock.
- Motion of a piece of sodium on water
- Motion of planets around the sun
- Whirling of a stone tied to a string

What type of motion is that of the stone whirling on the tip of a string?

- Rectilinear/circular?

Circular motion

Observe the figure. The figure shows the motion of an object along a circular path.

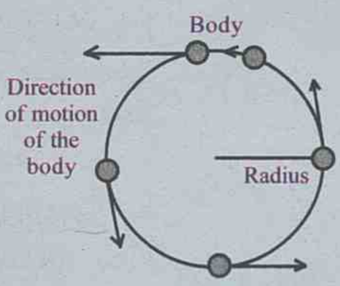


Fig. 2.21

The motion of an object along a circular path is circular motion.

- Does the velocity of an object moving with a uniform speed along a circular path change?
- How does this change in velocity happen?
  Due to change in speed/change in direction/due to change in both speed and direction.

A change of velocity produces acceleration. What will be the direction of this acceleration?

Let's examine.

Whirl a stone tied to a string. When this stone is in motion, from where does it get the necessary force for circular motion?

The force we apply from the centre of the circle reaches the object through the string. Therefore, won't the acceleration due to this force be towards the centre of the circle along the string?

The acceleration which a body in circular motion experiences towards the centre of the circle along a radius is centripetal acceleration. The force that creates a centripetal acceleration is a centripetal force.

If an object of mass m performs circular motion of radius r with a velocity v, its

$$\text{Centripetal force, } (F_c) = \frac{mv^2}{r}$$

Fig. 2.22

When the stone undergoes circular motion, the force that hand exerts through the string becomes a centripetal force.

What will happen to the object in circular motion if the centripetal force is lost?

When the stone is moving along the circle, release the string and see what happens. When we release the stone, at a point while it is in circular motion, it will be thrown off along the tangent at that point.

In hammer throw, before the hammer is let go off, why is it whirled around along a circular path? Record it in your science diary.

Haven't you noticed the motion of a giant wheel in an amusement park? Its speed is uniform except when starting and stopping.

If an object moving along a circular path covers equal distances in equal intervals of time, it is a uniform circular motion.

Eg: The motion of the tip of the second hand of an antique pendulum clock.

Find out more examples for uniform circular motion and record them in your science diary.

Significant Learning Outcomes

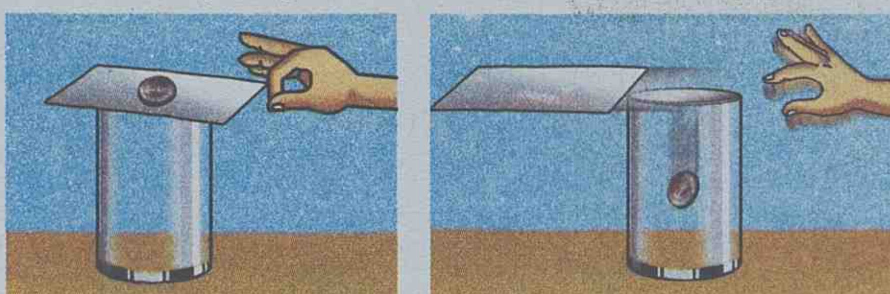
A learner can

- draw position-time and velocity-time graphs and explain their importance.
- draw the velocity-time graph of an object travelling with uniform acceleration and formulate the three equations of motion.
- distinguish between balanced and unbalanced forces, and between internal and external forces, through activities.

- find out examples for inertia and explain them, from situations in daily life
- distinguish and explain inertia of rest and inertia of motion.
- explain Newton's first law of motion and its applicability.
- explain through experiments momentum, change of momentum and rate of change of momentum.
- formulate the equation for force from the second law of motion.
- explain action and reaction based on the third law of motion.
- explain the law of conservation of momentum based on the third law of Newton.
- explain circular motion and uniform circular motion.

Let us assess

1. Observe the figures given below. Answer the following questions.



   a) When the card is suddenly struck off, what happens to the coin? Explain.
   b) What is the law to which this property is related?
   c) How is this property related to the mass of the object?
2. What are the balanced forces acting on a book at rest on a table?
3. To remove the dust from a carpet, it is suspended and hit with a stick. What is the scientific principle behind it?
4. A car and a bus are travelling with the same velocity. Which has greater momentum? Why?
5. On the basis of Newton's third law of motion, explain the source of force that helps to propel a rocket upward.
6. Draw the position-time graph with the given data.

Time (s)	0	3	6	9	12	15	18
Position (m)	0	5	10	15	20	25	30

7. Draw a speed-time graph using the given data.

Time (s)	0	2	4	6	8	10
Speed (m/s)	10	15	20	20	20	15

8. A car travels with a velocity of 15 m/s. The total mass of the car and the passengers in it is 1000 kg. Find the momentum of the car.

9. Find out the reasons:

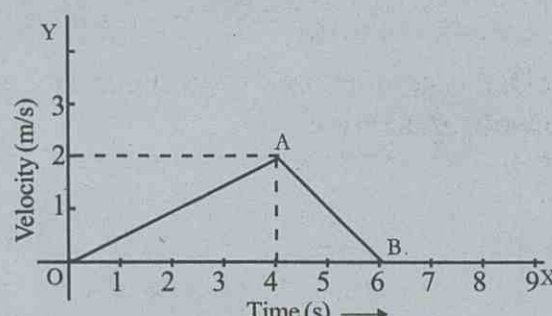
   a) When a bullet is fired from a gun, the gun recoils.

   b) When a horse pulls a cart, though action and reaction are equal and opposite, the carriage moves forward.

   c) When a bus at rest suddenly moves forward, the passengers, standing in the bus, fall backward.

   d) We slip on a mossy surface.

10. Examine the graph and answer the following questions:



   a) Is the motion of the object uniform/non-uniform?

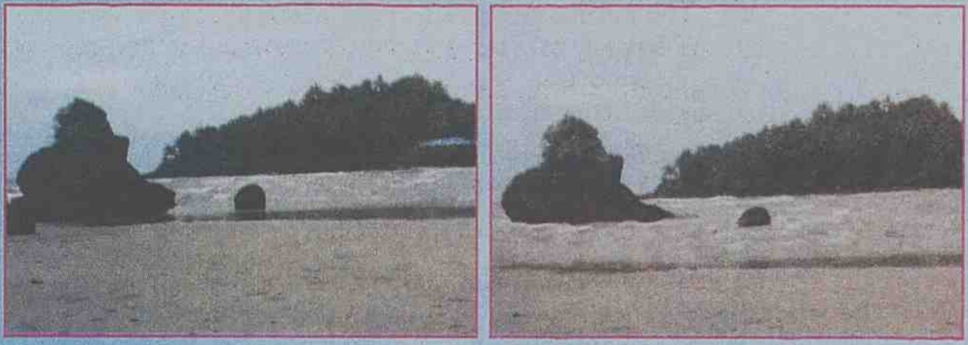
   b) From time 0 upto the point A, is the object in uniform acceleration? What about that from A to B?

Extended activities

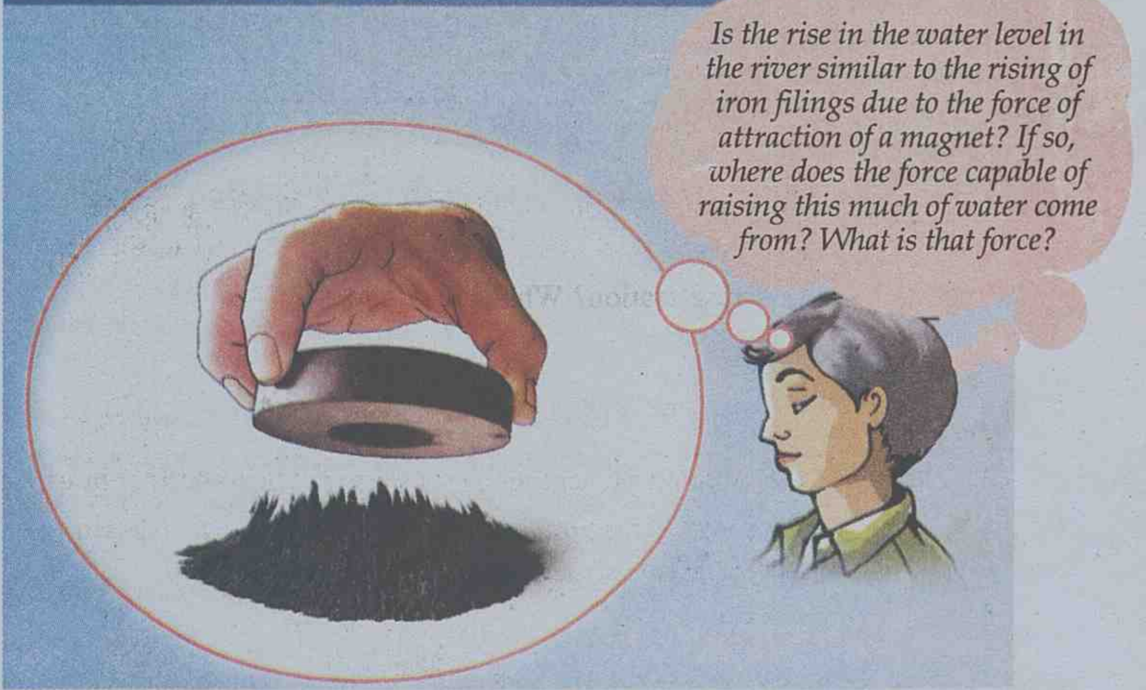
1. Prepare and present an experiment to illustrate inertia of rest.
2. Find out situations from our daily life to explain the law of conservation of momentum and note them down.

3

Gravitation



During high tide, water rises in the sea, causing a rise in the water level at the mouth of the river.



Lift a small stone to a certain height and then drop it.

- What do you observe?
- What could be the reason for the falling of the stone?
- What change takes place in the speed of the stone as it is thrown up?

- What about the speed when it falls down?
- Did you apply any force on the stone to bring it down?
- From where did the stone get the force for the acceleration?

Let's try to find the answers.

Tie a stone to a thread and suspend it from a spring balance.

- What do you observe?
- The spring stretched down when the stone was suspended from it. Why?

The earth attracts all objects towards its centre. This force of attraction is the force of gravity.

Write down instances where the force of gravity is felt.

- A mango falling down from a mango tree.
-

Take a stone of low mass and another one of slightly higher mass. Suspend them, one by one, from a spring balance.

Mass of a body is the amount of matter contained in it

- In which case was the reading higher?
- Which of the stones experienced greater force of attraction of the earth?
- On the basis of these observations, find out the factor that influences the force of attraction from the earth.

From the activities you have done, it follows that gravitational force depends on the mass of a body. Another factor which influences the force of gravity is the distance between the objects.

It was Sir Isaac Newton who formulated a law connecting these factors.

Sir Isaac Newton arrived at the law of gravitation on the basis of the observations made by Tycho Brahe, Kepler, Galileo and others. Thereafter he put forward the universal law of gravitation which is applicable to all bodies in the universe.

Universal Law of Gravitation

All bodies in the universe attract each other. The force of attraction between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

If two bodies of masses m_1 and m_2 are separated by a distance d, then ,

$$F \propto m_1 m_2 \rightarrow (1)$$

$$F \propto \frac{1}{d^2} \rightarrow (2)$$

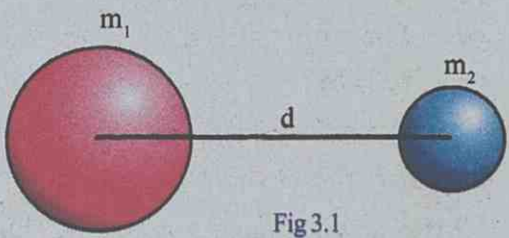


Fig 3.1

Combining the two, we get

$$F \propto \frac{m_1 m_2}{d^2}$$

$$F = G\frac{m_1 m_2}{d^2}$$

G is the gravitational constant.

The value of G is 6.67×10^{-11} Nm^2/kg^2. The scientist Henry Cavendish determined the value of G for the first time through experiments.

Complete the table given below, based on Newton's law of gravitation.

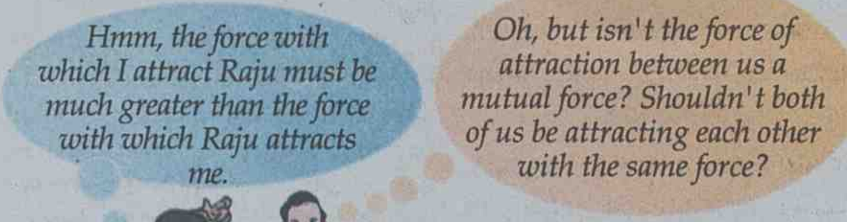
Sl. No.	Mass of the bodies		Distance between the bodies d (m)	Mutual force of attraction F (N)
	m_1 (kg)	m_2 (kg)		
1	5	10	2	$G \times \frac{5 \times 10}{2^2} = G \times 12.5$
2	10	10	2	G×.....
3	10	20	2	G×.....
4	5	10	4	G×.....
5	5	10	1	G×.....
6	10	20	1	G×.....
7	5	10	½	G×.....

Table 3.1

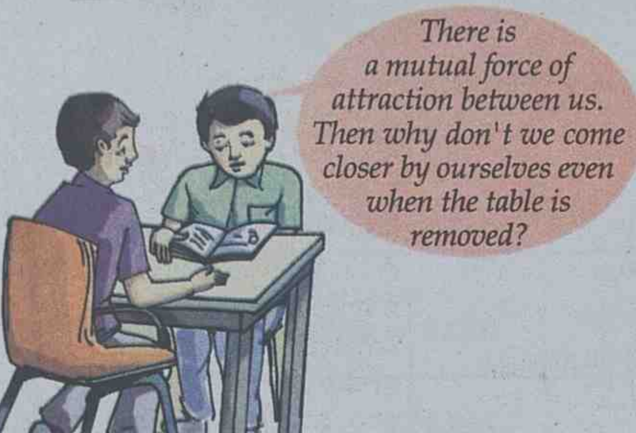
Observe the table and find out the answers to the following questions.

See 'Gravity Force Lab' in PhET in Edubuntu, IT @ School.

- Two bodies are at a specific distance so as to attract each other. How many times will the mutual force of attraction be if the mass of one of them is doubled?
- What if the mass of both the bodies are doubled?



- What if the distance between the bodies is doubled?
- What happens when the distance between the bodies is halved?
- What if the distance is made one fourth?
- A child of mass 40 kg is sitting at a distance of 1m from another child of mass 50 kg. Calculate the gravitational force of attraction between them.



$m_1 = 40$ kg

$m_2 = 50$ kg

$d = 1$ m

$G = 6.67 \times 10^{-11}$ Nm²/kg².

$$F = G\frac{m_1 m_2}{d^2}$$

$$= \frac{6.67 \times 10^{-11} \times 40 \times 50}{(1)^2}$$

$$= 13340 \times 10^{-11}$$

$$= 1.334 \times 10^{-7}$$

$$= 0.000000133 \text{ N}$$

The high tide

Earth attracts all objects towards its centre. It is because of this force that the oceans and the continents are all held together in the form of a globe. Similarly the moon also exerts its own gravitational force of attraction on the bodies on the earth. Because of this force of attraction exerted by the moon, the sea water facing the moon rises. This is the reason for the occurrence of high tide.

Didn't you understand how small this force is? As this is a very weak force, it is incapable of overcoming frictional and other forces.

Can't you now explain why two children sitting close to each other do not come closer due to mutual force of attraction?

- A body of mass 50 kg and another body of mass 60 kg are separated by a distance of 2 m. What is the force of attraction between them?

  $G = 6.67 \times 10^{-11}$ Nm²/kg²

Just like the force of attraction between bodies on earth, there is a force of attraction between the earth, sun, moon and other celestial bodies.

The high tide is one of the effects of the force of attraction exerted by the moon on terrestrial bodies. Now you might have understood why the water at the mouth of a river overflows during high tide.

Just as there is a force of attraction between objects, isn't there a force of attraction between the earth and other objects?

Force of gravity

- If the mass of the earth is M, and R its radius and m the mass placed on the surface of the earth, what will be the attractive force between them?

According to the law of gravitation, the force of attraction between two bodies is $F = G\frac{m_1m_2}{d^2}$

Here $m_1 = M$, $m_2 = m$ and $d = R$

Therefore the force of attraction between a body on the earth's surface and the earth is $\frac{GMm}{R^2}$

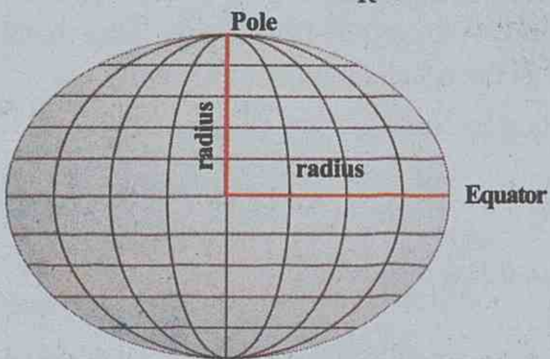


Fig 3.2

Is the force of attraction the same everywhere on the earth's surface?

- Is the earth really spherical in shape?
- Is the radius of the earth the same everywhere?
- Where on the surface of the earth is the radius maximum?
- Where is it minimum?
- At which part of the earth must a body be placed so that it will experience the maximum force of attraction? Where the radius is large/ where the radius is small

Certain forces in nature

There are different types of forces in nature. They can be conveniently classified into two - contact and non contact forces. Examples of contact forces are viscous force, surface tension, elastic force and force of friction. Nuclear force, electromagnetic force, gravitational force, etc., are non-contact forces. Among these, nuclear force is the strongest force and gravitational force the weakest.

The weight of a body and the distance from the centre of the earth

A body experiences maximum force of attraction due to gravity when it is placed on the surface of the earth. As the body goes above the earth, the force of attraction decreases gradually. Similarly, as it goes deeper into the earth, the force of attraction due to gravity decreases. When a body is placed at the centre of the earth, it is attracted equally towards all directions. Therefore the resultant force of attraction at the centre of the earth is zero.

- What change occurs in the force of attraction, if a body is being continuously raised from the surface of the earth?
  Increases/decreases
- Suppose if the body is moved from the surface of the earth to the centre. What happens?

Acceleration due to gravity

We know that the force of attraction between the earth and a body on its surface changes according to the mass of the body. Does the acceleration of the body change according to mass?

Let's examine.

Gravity and gravitation

Force of gravity is the force of attraction between a body and the earth whereas the mutual force of attraction between any two bodies is the force of gravitation.

You know that all bodies are attracted towards the centre of the earth.

If m is the mass of the body and F is the force by Newton's second law, F = ma

Thus $a = \frac{F}{m}$

That is, objects are accelerated towards the Earth due to the force of attraction from earth. This acceleration is known as the acceleration due to gravity (g).

According to Newton's law of gravitation,

$$F = G\frac{Mm}{R^2} \rightarrow (1)$$

By Newton's second law of motion, F = ma = mg → (2)

So, $mg = G\frac{Mm}{R^2}$

$$g = \frac{GMm}{R^2} \div m = \frac{GM}{R^2}$$

$$g = \frac{GM}{R^2}$$

From this, find the factors that influence the value of g and record them.

- Mass of the earth
-

Acceleration due to gravity will be the same for all bodies falling to the earth. It does not depend on the mass of the body.

Observe Fig 3.2.

Since the earth is not a perfect sphere, its radius is not the same everywhere.

- If so, will the value of g be the same everywhere on earth?
- Where will the value of g be the maximum on the earth's surface?
- Where will it be the minimum?
- What will be the value of g at the centre of the earth?

Haven't you understood how the value of g changes on the earth?

The value of g at the polar regions is 9.83 m/s^2. It is 9.78 m/s^2 at the Equator.

The average value of g on the surface of the earth is taken as 9.8 m/s^2 for solving numerical problems.

- A stone dropped from a height of 19.66 m took 2 seconds to reach the ground. What is the value of g here? Where on the surface of the earth did this activity take place?

$s = 19.66$ m, $u = 0$, $t = 2$ s, $a = g = ?$

$s = ut + \frac{1}{2}at^2$.

$19.66 = 0 \times 2 + \frac{1}{2} \times g \times 2 \times 2$

$19.66 = 2g$

$g = \frac{19.66}{2} = 9.83\ m/s^2$.

Since the value of g is 9.83 m/s^2, this activity must have taken place at the polar regions.

- When a stone of mass 50 kg and another of mass 5 kg fall down simultaneously from the top of a five-storey building, which one will reach the ground first?
- A stone and a sheet of paper are dropped together. Which of the following statements regarding their fall is true?
  - Both of them reach simultaneously
  - The paper reaches first
  - The stone reaches first

Value of *g* at moon

If M is the mass of the moon and R its radius, then value of g on the moon

$= GM/(R)^2$.

$= 6.67 \times 10^{-11} \times 7.36 \times 10^{22} / (1.74 \times 10^6)^2$

$= 1.62\ m/s^2$

This is approximately $\frac{1}{6}$ of the value of g on the earth.

Fig 3.3

Objects like paper fall slowly. Galileo was the first person to argue that this is due to air resistance. He wasn't able to prove it then because at that time there were no facilities to create a vacuum. Sir Isaac Newton could prove this later through the 'feather and coin' experiment.

Newton placed a feather and a coin in a long transparent tube with closed ends. The tube was kept vertical at first and then suddenly turned upside down. The coin reached the bottom first followed by the feather a short while later. The experiment was repeated after removing the air inside the tube and it was found that the feather and the coin reached the bottom simultaneously.

The conclusion was that the feather took more time to reach the bottom due to air resistance. Thus Galileo's argument was proved right.

When a stone falls, it attracts the earth just as the earth attracts the stone. But it is only the stone that falls; the earth does not rise up. What might be the reason?

From the equation, F= ma, if a body of mass m is acted upon by a force F, then $a = \frac{F}{m}$

Consider a stone of mass m falling down. What is the force of attraction between the stone and the earth?

Let's see what will be the acceleration of the stone and the earth. Let M be the mass of the earth and m the mass of the stone. As there is mutual attraction between them, don't they experience the same force? Therefore acceleration of the earth, $a_{earth} = \frac{F}{M}$ and acceleration of the stone $a_{stone} = \frac{F}{m}$

As the mass of the earth (M) is huge when compared to that of the stone (m), the acceleration experienced by the earth will be negligibly small and that by the stone will be much greater.

Mass and weight

Observe Fig 3.4. What are the uses of these devices? How do they differ?

You know that every object is attracted towards the centre of the earth.

How will you calculate this force of attraction?

The force with which a body of mass m is attracted by the earth towards its centre is

$$F = \frac{GMm}{R^2}$$

$$= m \times \frac{GM}{R^2}$$

$$\frac{GM}{R^2} = g$$

$$F = mg$$

Here mg indicates the weight of the body. In other words, the weight of a body is the force with which the earth attracts the body towards its centre.

Solar system and force of gravitation

We know that all planets revolve round the sun in the solar system. Satellites revolve round the planets. It is the force of gravitation that provides the necessary force required for retaining them at their orbits of revolution. While the gravitation from the sun provides the centripetal force for planets, the satellites get the force from the planets.

Common balance (a)

Spring balance (b)

Fig 3.4

Mass is measured using common balance. Spring balance is used to measure weight.

You know that the value of g on earth changes from place to place. Based on this, find out the answers for the following questions:

- Where does a body experience maximum weight on the earth? What is the reason?

1 kgwt

1 kgwt is equal to the force of attraction exerted by the earth on an object of mass 1 kg.

Since F = mg

$$1\ \text{kgwt} = 1\ \text{kg} \times 9.8\ \text{m/s}^2$$

$$= 9.8\ \text{kg m/s}^2$$

$$= 9.8\ \text{N}$$

i.e, 1 kgwt = 9.8 N

kilogram weight is another unit of force.

- Where on the earth does a body experience minimum weight? What is the reason?
- What is the weight of the body when it is at the centre of the earth? Give reasons.
- Find out the weight of a body of mass 20 kg. Express the value in newton.
- For a body of mass 60 kg:
  a) What is the weight on earth?
  b) What is the weight on the moon?

  Weight on the earth = mg

  $= 60 \times 9.8 = 588$ N.

  1 kgwt = 9.8 N

  $$\text{Weight on the earth} = \frac{588}{9.8} \text{ kgwt} = 60 \text{ kgwt}$$

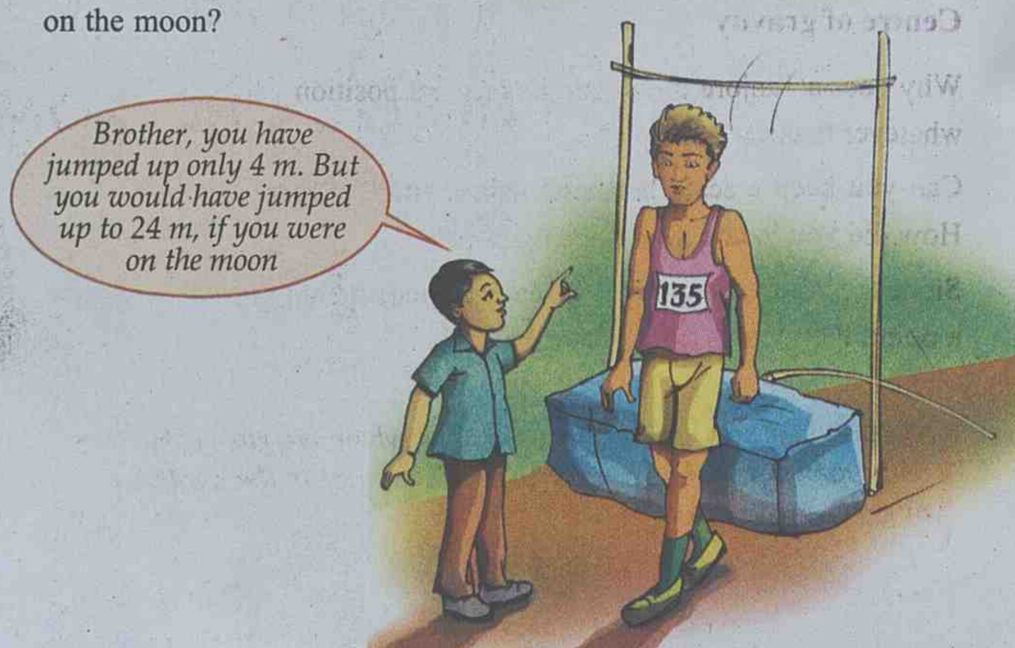
  Weight on the moon = m × Value of g on the moon

  $= 60 \times 1.62 = 97.2$ N

  1 kgwt = 9.8 N

  $$= \frac{97.2}{9.8} \text{ kgwt} = 9.918 \text{ kgwt}$$

- If a body of mass 42 kg is suspended from a spring balance, what will be the force exerted on the spring balance? What is the value when it is in Jupiter (the value of g on Jupiter = 23.1 m/s^2) and when placed on the moon?



You have understood that the weight of an object depends on the acceleration due to gravity at the place.

Free fall

What happens to a pencil when let go from a height? Will it not fall down?

- Suppose a spring balance with a body suspended from it is allowed to fall. What will be the reading shown by the balance?
- During the rotation of a giant wheel, a person experiences loss of weight on the descent. Explain why.
- Why does a freely falling body experience weightlessness? Note it down in your science diary.
- What is the weight of a body of mass 10 kg?
- If this body is allowed to fall freely, will there be any change in the force experienced by the body?

Drill a hole at the bottom of an open bottle and fill it with water. Water goes out through the hole. Then allow the bottle to fall freely. What do you observe? Explain the reason.

Free fall and weightlessness

When a body is allowed to fall from a certain height, it falls to the earth due to the force of gravity. This is free fall. If it is to be called free fall, it must fall down due to gravity alone without air resistance. Usually we do not consider air resistance as it is comparatively small.

When we are standing on an electronic platform balance, we are exerting a force on the balance. The reading on the balance is the force exerted by it on us. This is reaction force. This is the reason for the spring balance reading as well. Won't the reading of the balance be zero if it is allowed to fall freely? Since the balance and we are undergoing free fall, the balance cannot exert a reaction force. That is why weightlessness is experienced. The reaction from the surface is measured as weight.

Centre of gravity

Why does a Tanjore doll retain its original position, in whatever manner it is kept?

Can you keep a scale balanced with a single finger? How did you locate the balancing point?

Since the whole weight of the scale is concentrated at a point, the scale is thus kept in balance.

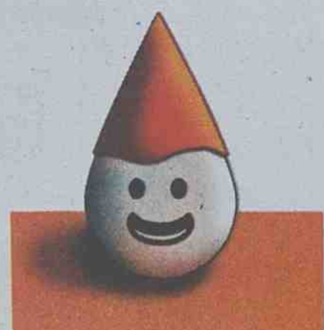


Fig 3.5

Every object has a point at which the whole weight of the body appears to be concentrated. This point is the centre of gravity of the body.

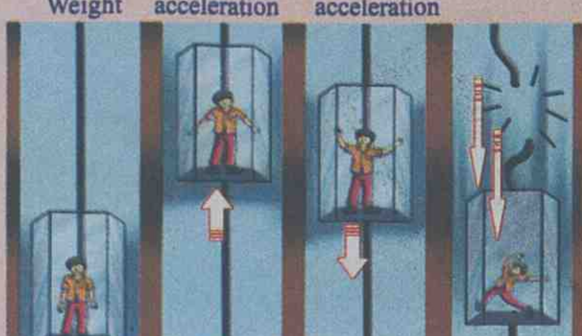
Weightlessness

When an object is suspended from a spring balance, the force (mg) exerted by the body on the spring balance is the weight measured. Observe a spring balance suspended from the ceiling of a lift. Suspend a mass m from the spring balance. When the lift is at rest, the spring balance shows the weight mg of the body. This is the true weight of the body. When the lift has an upward acceleration, the total force required is the sum of the weight of the body and the force needed to provide the acceleration.

This is greater than the force needed when there is no acceleration. When the lift has an upward acceleration, the weight of the body appears to increase as indicated by the increase in the reading. This is the apparent weight of the body. When the lift comes down with an acceleration the apparent weight is obtained by subtracting the force required for acceleration from the weight of the body. This is the reason why body appears to experience a loss of weight.

Imagine that the rope of the lift breaks and the lift falls freely. Then the apparent weight becomes zero. At this stage, the body experiences weightlessness. Even now the body is being attracted by the earth towards its centre. Normally the lift travels down with uniform speed and so no change in weight is felt.

We know that a person travelling in a space ship around the earth experiences weightlessness. A space vehicle is in an object which is in free fall. The person inside the vehicle experiences no weight and this is weightlessness.



If a force equal to the weight of the body is applied upward, through the centre of gravity of the body, it can be balanced. How can the centre of gravity of a lamina be determined?

Take a lamina in the shape of a polygon.

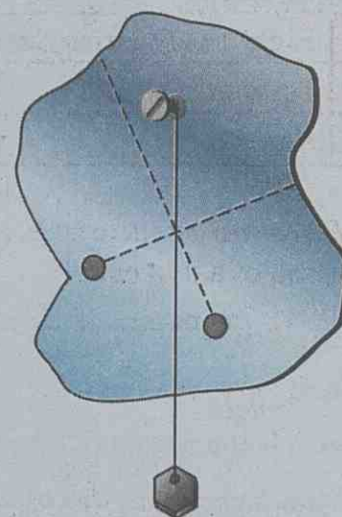


Fig 3.6

Drill holes at three different points. Pass a nail through one hole and suspend the Lamina from the nail. (The holes must be drilled in such a way that the lamina can turn freely). Suspend a plummet from the nail. Draw a straight line along the thread used for suspension.

Repeat the process using the other two holes. Don't you see that all the lines you have drawn, pass through the same point? This point is the centre of gravity of the lamina.

Locate the centres of gravity of the objects of the following shapes and record them.

Sl. No.	Shape of the body	Centre of gravity
1	Square	Point of intersection of diagonals
2	Rectangle	
3	Circle	
4.	Triangle	
5	Right angled triangle	
6.	Boomerang	Outside the object
7.	Bangle	

Table 3.2

- Where will be the centre of gravity, if a thick lamina is used instead of a thin one?

Write down the names of objects having centres of gravity inside them.

- Sphere
-

Write down the names of objects having centres of gravity outside them.

- Bangle
-

State of equilibrium

The figure shows a three tiered stand. The stand is constructed in such a way that the centre of gravity of the stand is located at the point **c** on the middle tier. There is a thread from **c**, with a nail at the other end. The sharp end of the nail is just above the midpoint of the base. The thread is along the vertical line through the centre of gravity.

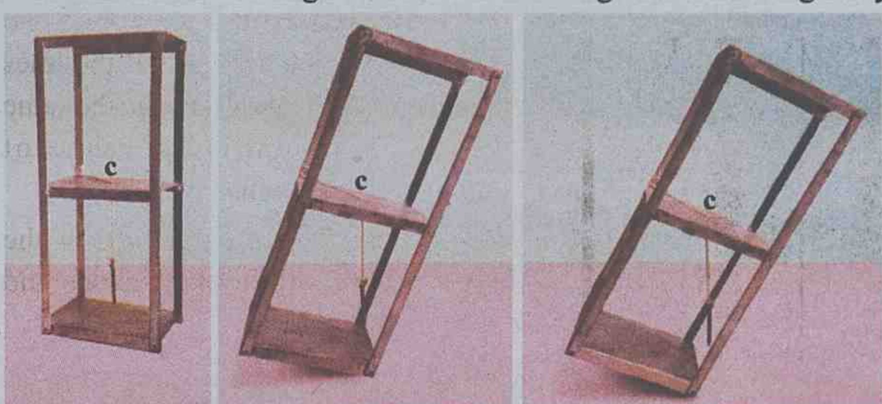


Fig 3.7

Observe the three figures and answer the following questions.

- Among these stands which one is likely to fall down very soon?
- Which one has no possibility of falling down?
- In which case does the vertical line through the centre of gravity pass through the base?
- In which case the vertical line through the centre of gravity does not pass beyond the base?

A body is stable when the vertical line through the centre of gravity passes through its base.

Suggest a method for maintaining the stability of a body.

Take a small, rectangular box. Take some pieces of iron too. Place the box at the edge of the table and push it forward gently. Now a part of the box projects outside the table. When the box is most likely to fall down, place a piece of iron at that portion of the box still remaining on the table. Does the box fall now? Again push the box and place another piece of iron in a similar way when it is about to fall. Does the box fall? Repeat this several times till a major portion of the box is outside the table. Even then the box does not fall down.

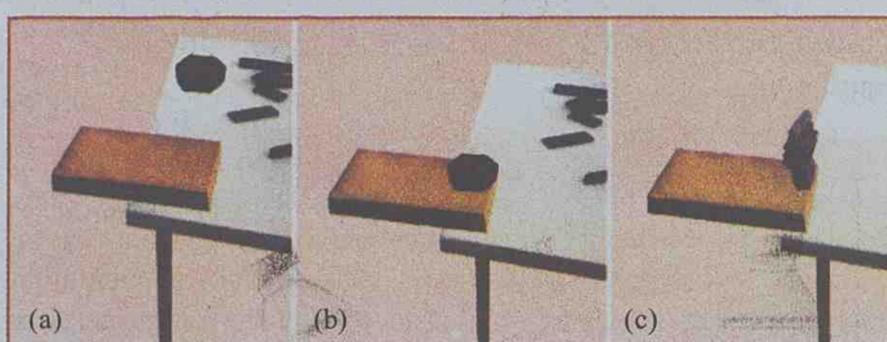


Fig 3.8

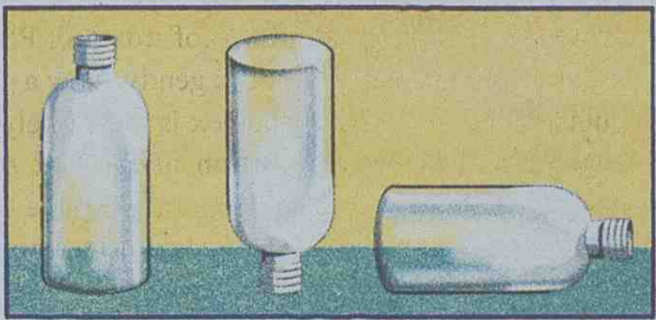
Based on what you have learnt, find out the reasons for the following:

- When the box was completely on the table, it didn't fall.
- When the box was pushed out, it fell at a particular stage.
- The box didn't fall when pieces of iron were placed on the portion of the box on the table.
- At one stage, the box didn't fall even when a major part of the box was not on the table (Fig. 3.8 c)

The centre of gravity of a body is shifted towards that part of the body where the weight of the body gets concentrated. We can shift the centre of gravity of a body towards a part of it, by concentrating the weight of the body at that part. If the vertical line through the centre of gravity passes through the base of the body, it will be in a state of stable equilibrium.

In Fig. 3.9 (a), the body is in a stable equilibrium and in Fig. 3.9 (b), the body is in an unstable equilibrium.

Find out the state of the body in Fig. 3.9 (c) and record the same.

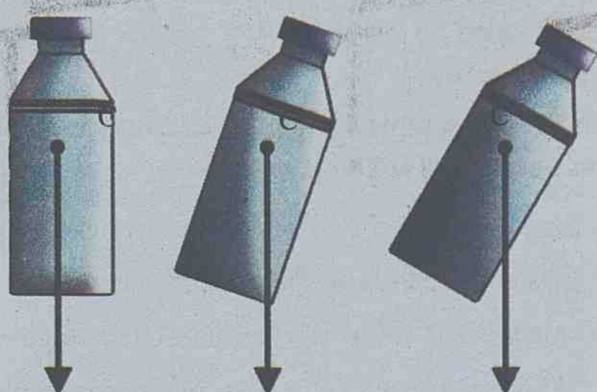


(a) (b) (c)

Fig 3.9

Observe Fig. 3.9 (c). This type of equilibrium is neutral equilibrium.

- Observe the Fig.3.10 and write down the state of equilibrium to which each of them belongs.



(a) (b) (c)

Fig 3.10

Take three identical plastic bottles of one litre capacity each and cut off their upper portions. Put three identical

State of stability and potential energy

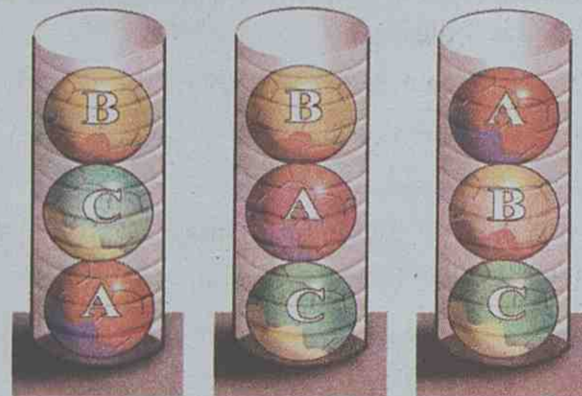
The energy possessed by a body by virtue of its position is its potential energy. A body is in stable equilibrium if the vertical line through the centre of gravity passes through the base of the body. At the same time its potential energy must be minimum.

(a) (b) (c)

In Fig.(a), the sphere at point B has minimum potential energy. Therefore the sphere continues to remain there itself. It is in a state of stable equilibrium. In Fig.(b), the ball is at Q. Even though the vertical line through the centre of gravity passes through the base, it has comparatively high potential energy. So when a favourable situation arises, the sphere rolls towards point P or point R for minimising potential energy. Hence this sphere is in a state of unstable equilibrium.

In Fig.(c), the potential energy does not change whenever the ball moves on its base. Hence these types of equilibrium are neutral equilibrium.

ice cream balls in each of them as shown in Fig.3.11. In all the three cases, the ball A must be filled with wet sand.



(a) (b) (c)

Fig 3.11

- Among these, in which case is the weight concentrated at the bottom?
- In which case is the weight concentrated at the top?
- What happens to the centre of gravity, as the point of concentration of weight changes?
- In which case is the possibility of toppling over the maximum?

Find out which of these has greater stability, on the basis of the answers to the above.

Make a Tanjore doll using the shell of an egg and exhibit in the class. Explain the reason for the stability of the doll.

- Passengers are not allowed to travel standing in the upper deck of a double decker bus. What is the reason?
- When cargo is being loaded on a lorry, heavy objects are packed at the bottom. What is the reason?

From your daily life, find more examples related to the force of attraction due to gravity and write them down in the science diary.

Significant Learning Outcomes

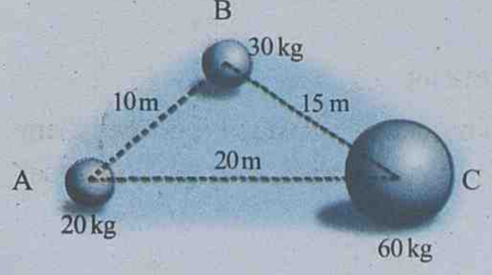
The learner can

- explain the universal law of gravitation
- explain the way in which mass of bodies and distances between them influence the force of attraction between bodies, through numerical problems
- identify and explain free fall

- find that the acceleration due to gravity depends on the mass and radius of the earth, and can explain the same
- explain reasonably that acceleration due to gravity is different at the Equator and the Poles
- distinguish between mass and weight, and explain it
- determine experimentally the centre of gravity of lamina of different shapes
- explain the relation between centre of gravity and stability by identifying the relation.

Let us assess

1. If the distance between two bodies that attract each other is trebled, how many times will their mutual force of attraction be?
   (9 times, 3 times, $\frac{1}{3}$, $\frac{1}{9}$).
2. A body, the mass and the weight of which were already determined at the Equator, is now placed at the Pole. In this context, choose the correct statement from the following:
   a. Mass does not change, weight is maximum
   b. Mass does not change, weight is minimum
   c. Both mass and weight are maximum
   d. Both mass and weight are minimum
3. a. What is meant by the terms mass and weight?
   b. Are they vector or scalar quantities? Why?
   c. The mass of a body is 30 kg. What is its weight on earth? ($g = 9.8\ m/s^2$)
   d. What is its weight on the moon? ($g = 1.62\ m/s^2$)
5. If a body of mass 40 kg is kept at a distance of 0.5 m from a body of mass 60 kg, what is the mutual force of attraction between them?
6. Observe the figure and complete the table.



Attracting bodies	Force of gravitation
A, B	
B, C	
C, A	

Extended activities

1. Collect different types of lamina and determine their centres of gravity.
2. Prepare a table of things that can keep their stability by overcoming great disturbances.
3. The values of g on different planets are given. Determine the weight of a body of mass 100 kg on these planets.

Planet	Value of g on each planet (approx. in m/s^2)
Earth	9.8
Mercury	3.7
Venus	8.9
Mars	3.7
Jupiter	23.1
Saturn	9.00
Uranus	8.7
Neptune	11.00

4

Work, Energy and Power

Listen to the conversation going on in a house:

Mother : We bought a new pump, but the water tank is not yet full.

Father : We should have bought a 1 HP pump instead of ½ HP

Son : Daddy, what is meant by ½ HP, 1 HP, etc?

Can you give an answer to this?

(a) (b) (c)

Fig. 4.1

Observe Fig. 4.1. Try to write down the activities shown in them.

- A man pushes a trolley
-

Write down more activities familiar to you.

- A man carrying a load
-

You have understood that a force is to be applied on a body to do an activity. Find out the source of applied force for every activity and note them down in the table.

Activity	Source of applied force
• Falling of a mango	• The earth
• A trolley being pushed	• The person pushing
•	•

Table 4.1

Objects undergo displacement only when force is applied on them.

- Does the displacement take place always in the direction of the force applied? Is there any situation in which no displacement takes place even if a force is applied? Write down in the table.

Displacement takes place in the direction of force applied	No displacement for the body in the direction of force applied
• A cricket ball is hit •	• A wall is pushed •

Table 4.2

Though forces are applied on the bodies in all the above situations, displacement does not take place in all cases. Work is said to be done in situations where displacement takes place in the direction of the force.

Work

Work is said to be done only when a body undergoes displacement under the action of a force.

Fig. 4.2

Observe Fig 4.2 and write down the situations where work is said to be done.

-

Notice some examples given in relation to work.

- A boy pushed an object of mass 30 kg horizontally across the floor through 50 m. Another boy pushed an object of mass 50 kg across the same floor through 50 m. Both of them gave the same speed for moving the objects.

- Who applied greater force here?
- In which case was the work greater?

Write down a factor influencing work.

- A boy pushed an object of mass 30 kg across a horizontal floor through 20 m. Another boy pushed the same body through 30 m, on the same floor with the same speed.

- Who pushed a greater distance here?
- What about the force applied?
- Who did the greater work?

Which is the factor influencing work here?

What are the factors to be considered to determine the work done by the force? Discuss.

- force
-

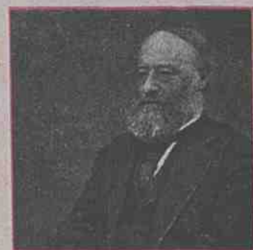
You have understood that the force applied on the body and the displacement of the body, are to be considered to determine the work done on it.

If a force of F newton is applied continuously on a body and the body undergoes a displacement of s metre in the direction of the force, then the work done by the force is W = Fs joule

- When a force of 10 N is applied continuously on a body, and its displacement is 2 m, find out the magnitude of the work done by the force.

$$F = 10\text{ N}$$
$$s = 2\text{ m}$$
$$W = Fs = 10\text{ N} \times 2\text{ m} = 20\text{ N m}$$

James Prescott Joule
(1818 – 1889)



Joule was a British scientist who researched the relation between mechanical energy, electrical energy and heat energy. Joules' Law, Law of Conservation of Energy, etc., were enunciated by him. The unit of work and energy the joule has been named after him.

We got the unit of work as N m here. This is a joule (J).

1000 J = 1 kJ (1 kilo joule)

Look at Figure 4.3.

- A body of mass m kg is placed on a table. What are the forces experienced by this body?

- In which directions do these forces act?

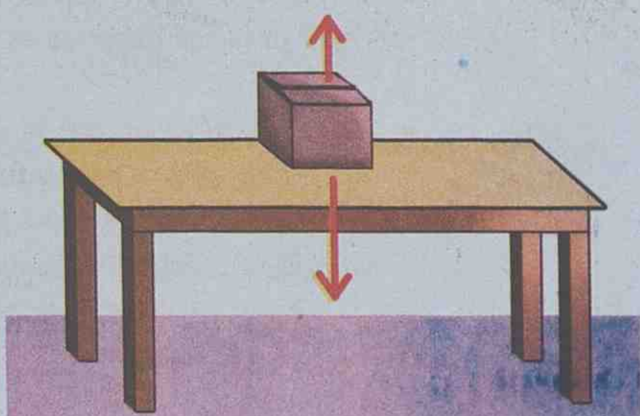


Fig. 4.3

- If this body is to be raised through h metre, in which direction has the force to be applied on the body?

You know that the magnitude of the force to be applied against the gravitational pull is

$F = mg$

- If it is raised through h metre, what would be the displacement?

The work done by the force applied against gravitational force

$$W = Fs$$
$$= mgh$$
$$W = mgh$$

When a body is raised, the work done against the gravitational force would be W = mgh.

- A book of mass 100 g is raised to the top of a table of height 1m. Find the magnitude of the work done by the force applied against the gravitational force ($g = 10\ m/s^2$).

$$m = 100\ g = 0.1\ kg$$
$$g = 10\ m/s^2$$
$$h = 1m$$
$$W = mgh$$
$$= 0.1 \times 10 \times 1 = 1\ J$$

1 J is the amount of work done to raise a body of mass 100 g through a height of 1m.

- If a force of 50 N is applied on a body and it undergoes a displacement of 2 m in the direction of the force, calculate the amount of work done.
- (a) If a force of 200 N is applied on a table of mass 50 kg, it undergoes a displacement of 0.5 m in th~ direction of force. Calculate the amount of work done.

  (b) If the same table is raised by 3 m, what would be the work done against the gravitational force?

Observe Figure 4.4

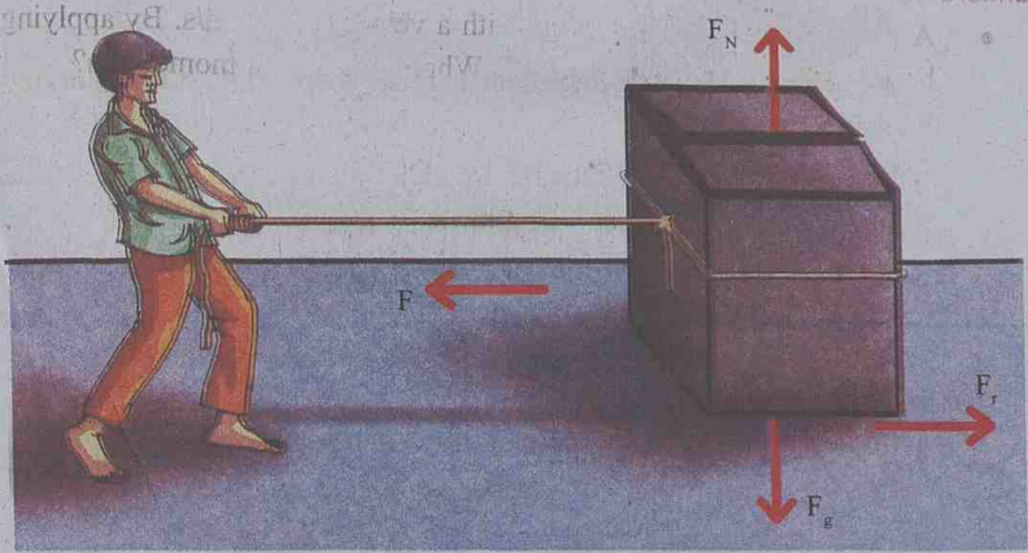


Fig. 4.4

Let a body of mass m be pulled by a force F. If the body has a displacement s in the direction of the force, then

- The work done by the force F, W_f = ... Here the displacement produced is in the direction of the force itself.

  Write whether this work is negative or positive.
- What will be the work done by the force of friction? Won't it be $W_r = F_r s$.
- Since the displacement is opposite to the frictional force, is the work done by the frictional force positive or negative?
- In which direction is the force of gravity on the body?

- Is there a displacement for the body in the direction of the gravitational force?

As the displacement of the body is zero, the work done by the gravitational force (F_g) is $W_g = 0$

- What about the work done by the reaction force F_N?

When a body on a floor is pulled and if it is displaced in the direction of the applied force, the work done by the applied force is positive while the work done by the frictional force exerted by the floor is negative.

Energy

- What is the work to be done to raise a body of mass m kg through h metre?

  ....

Energy is that which is utilised to do work.

Energy is the capacity to do work.

Amount of energy is the amount of work itself. Therefore, the unit of energy is joule (J) .

In daily life we use different forms of energy for various activities. List the forms of energy familiar to you:

- Mechanical energy
- Heat energy
- Electrical energy
-

Let's know more about mechanical energy.

There are two types of mechanical energy.

1. Kinetic energy
2. Potential energy

Kinetic energy

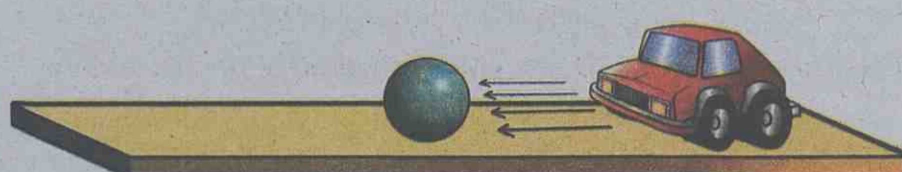


Fig. 4.5

Arrange a toy car and a plastic ball as shown in Fig. 4.5.

Pull the toy car backwards a little and allow it to hit the plastic ball.

- What happened to the ball when the moving car hit it?

- How did the car get the energy to move the ball forward?

Haven't you understood that the car got the ability to do work because of its motion? This is because moving bodies have kinetic energy.

The energy possessed by a body by virtue of its motion is the kinetic energy.

Let's do another activity. Allow a powder tin to slide down a polished, inclined plane as shown in the figure and let it hit a toy car. Try to measure the displacement of the toy car. Repeat the experiment by increasing the height of the inclined plane and filling the tin with sand.

Fig. 4.6

Let F be the force acted on the toy car and s its displacement. If the velocity of the car is changed to v on being hit by the tin, the work done by the force exerted by the powder tin is

$$W = Fs$$

Since F = ma by Newton's second law of motion, the work done on the toy car W = mas.

As per the second equation of motion, let's see what is 'as' in this expression:

$$v^2 = u^2 + 2as$$
$$= 0 + 2as. \text{ (Initial velocity of the car} = 0)$$
$$= 2as$$
$$as = \frac{v^2}{2}$$

So in W = mas, if we put $\frac{v^2}{2}$ Instead of as

$$W = \frac{mv^2}{2} = \frac{1}{2}mv^2$$

$$W = \frac{1}{2}mv^2$$

The work is the amount of kinetic energy received by the car.

Kinetic energy and momentum

Momentum p = mv

$$\text{So, } v = \frac{p}{m}$$

$$\text{Kinetic energy } K = \frac{1}{2}mv^2$$

$$\text{or } K = \frac{1}{2}m\left(\frac{p}{m}\right)^2$$

$$= \frac{1}{2} \times \frac{p^2}{m} = \frac{p^2}{2m}$$

That is, kinetic energy, $K = \frac{1}{2} mv^2$

> *When a body of mass m moves with a velocity v its kinetic energy is $K = \frac{1}{2} mv^2$*

- A man having a mass of 70 kg is riding a scooter of mass 80 kg. What is the total kinetic energy if the velocity of the scooter is 10 m/s?

$$m = 70 \text{ kg} + 80 \text{ kg} = 150 \text{ kg}$$
$$v = 10 \text{ m/s}$$
$$K = \frac{1}{2} mv^2 = \frac{1}{2} \times 150 \times 10^2$$
$$= 7500 \text{ J} = 7.5 \text{ kJ}$$

- A car of mass 1500 kg is moving at a velocity of 20 m/s. What is its kinetic energy?
- A boy of mass 50 kg is riding a bicycle with a speed 2 m/s. The bicycle has a mass of 10 kg. Calculate the total kinetic energy.

When the bodies are stationary, do they possess energy?

Potential energy

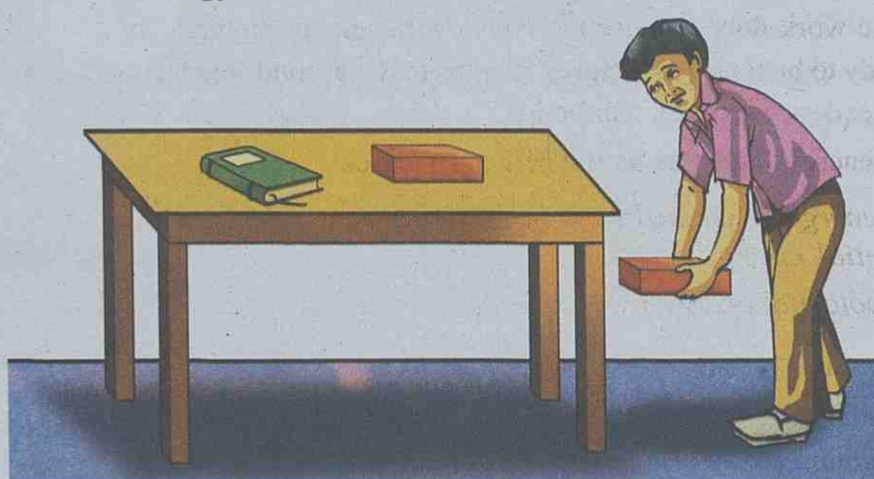


Fig. 4.7

Take a look at Fig 4.7. Work is to be done to lift the bodies.

- Against which force is work done here?

Note the amount of work done to raise a body of mass m kg to different heights in Fig. 4.8.

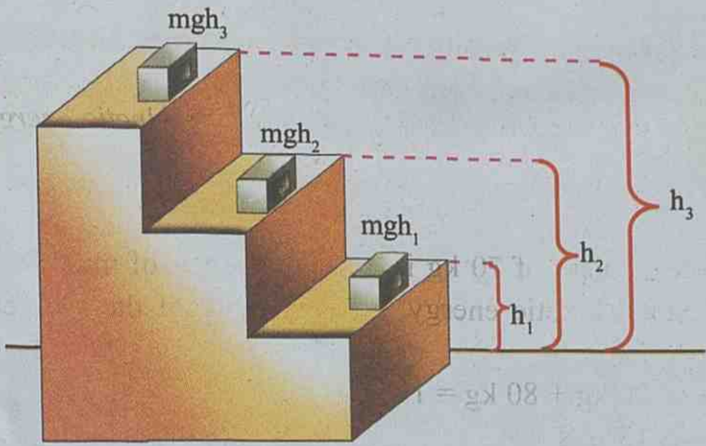


Fig. 4.8

At which height from the floor in Fig 4.8 was the work done on the body the maximum?

- -

- The energy received by the body is equal to the work done on it.

- -

- If so, in which position does the body get the maximum energy?

When height from the floor increases/decreases

- The work done to raise the body or the energy required for a body to be raised to a higher level from the ground is preserved as excess energy in that body.

So the energy increases as the height increases.

The energy possessed by a body due to its position is the potential energy.
i.e., potential energy $U = mgh$

Identify more situations in which potential energy is acquired by virtue of position and write them down.

- Coconut in a coconut tree
-

As the height varies, the potential energy also varies. Try to write down examples for varying potential energy situations.

- A coconut falls down from a coconut tree
- Water pumped to a tank at a height

Position and potential energy

The potential energy of a body at a specific height depends on the position at which the potential is considered zero. Usually the ground is considered as the position for zero potential.

What is the potential energy of a book of mass 200 g kept on a table of height 1m?

$$m = 200 \text{ g} = 0.2 \text{ kg}$$
$$g = 10 \text{ m/s}^2$$
$$h = 1 \text{ m}$$
$$U = mgh$$
$$= 0.2 \times 10 \times 1 = 2 \text{ J}$$

- Calculate the potential energy of a body of mass 1 kg at a height of 6 m from the ground.
- A bird of mass 0.5 kg is flying at the same speed at the same height of 5 m. In this state, if its kinetic energy and potential energy are equal,
  - (a) What is the potential energy of the bird?
  - (b) What is the velocity of the bird?

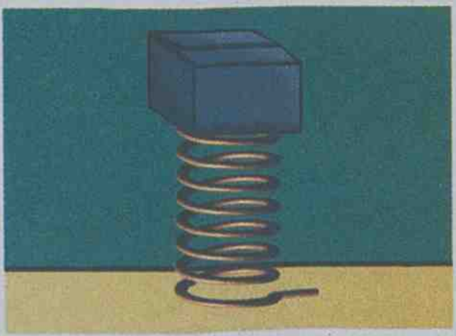


Fig. 4.9

Do bodies get potential energy due to their position alone? Let's see. Look at Fig.4.9.

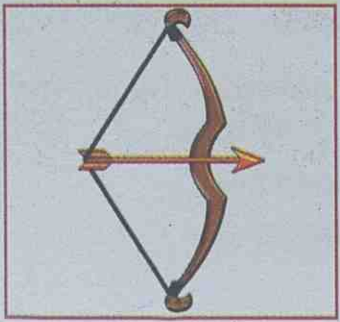
When the spring is pushed in or pulled out, it gets the ability to do work on a wooden block.

Are't we doing work on the spring when we push or pull it?

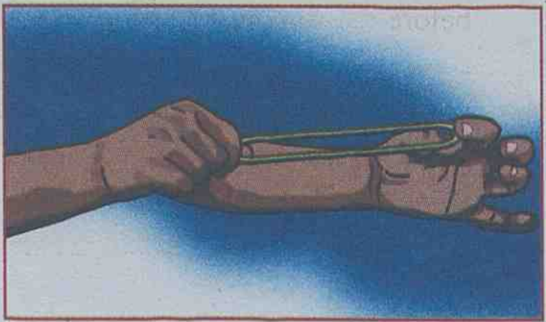
The work we have done on the spring to change its shape would remain as energy. This energy is the potential energy due to strain.

Write other examples for getting potential energy due to strain.

- A stretched bow
- An elongated rubber band
-



(a)



(b)

Fig. 4.10

Are there any situations where one form of energy is transformed into other forms? Is the energy destroyed in such situations?

Let's see.

Law of conservation of energy

The energy transformations in certain equipment are given in the table.

Equipment	Energy transformation
Electric generator	Mechanical energy → Electrical energy
Fan	Electrical energy → Mechanical energy
Electric iron box	Electrical energy → Heat energy
Electric bulb	Electrical energy → Light energy

Table 4.3

What happens when one form of energy is transformed into another form in this way? Observe Fig. 4.11.

- What form of energy does the flower pot have when it is on the sunshade of a building?

  -

- While the flower pot is falling down, what forms of energy does it possess?

  -

- Does its potential energy increase/ decrease when the pot falls down.

  -

- Will the kinetic energy increase/ decrease at that time?

  -

- What energy transformation takes place just before the flower pot reaches the ground?

  -

Fig. 4.11

- Let the mass of the flower pot be 15 kg and the height of the sunshade 4 m. When the flower pot is on the sunshade, what is its potential energy? ($g = 10\ m/s^2$).

  $U = mgh =$ ....

- When it is on the sunshade, what is its kinetic energy?

- If so, what is its total energy?

- While falling, when the flower pot is at a height of 2 m from the ground, what will be its kinetic energy?

$$K = \frac{1}{2}mv^2$$

$$= u = 0,\ g = 10\ m/s^2,\ s = 4 - 2 = 2\ m$$

$$v^2 = u^2 + 2as$$

$$= 0 + 2 \times 10 \times 2$$

$$= 40$$

$$K = \frac{1}{2} \times 15 \times 40$$

$$= \ldots\ldots\ J$$

- What is the potential energy when it is at a height of 2 m from the ground?
- What is the total energy now?
- What is the kinetic energy of the flower pot just before it touches the ground?

$$K = \frac{1}{2}mv^2$$

$$v^2 = u^2 + 2as$$

$$= 0 + 2 \times 10 \times 4 = 80$$

$$K = \frac{1}{2} \times 15 \times 80 = 600\ J$$

- The potential energy $U = mgh = 15 \times 10 \times 0 = 0$. What will be the total energy?
- To sum up the amount of energy at each situation:
  1. When on the sunshade = ...
  2. When at a height of 2 m from the ground = ...
  3. Just before hitting the ground = ...

What is the inference you arrive at?

Energy can neither be created nor destroyed. One form of energy can only be converted to another form. This is the law of Conservation of energy.

The sun is a major source of different forms of energy we use.
What are the different ways in which solar energy is utilised? Based on the figure, prepare a note and write it down in your science diary.

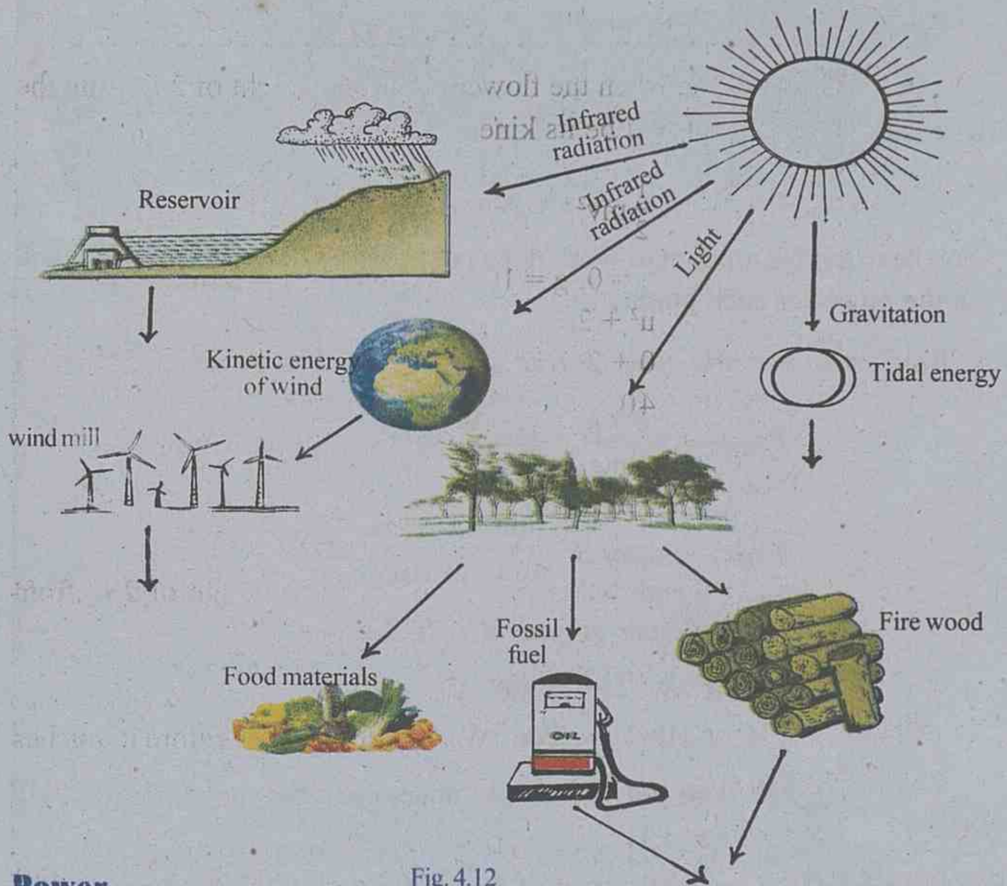


Fig. 4.12

Power

Given below is the information regarding the working of pumps in three neighbouring houses. Complete the table ($g = 10\ m/s^2$).

Pump	Capacity to hold water		Height from the water surface in the well h	Time required to fill the tank (s)	Work W = mgh (J)
	Volume (L)	Mass m (kg)			
A	1000	1000	15 m	100	150000 J
B	1000	1000	15 m	200	....
C	1000	1000	15 m	400	....

Table 4.4

- Is the amount of work done by the pump to fill water in the three tanks equal?

Now let's find the amount of work done per second by each pump.

Pump	Work done (J)	time (s)	Work done per second J/s
A			
B			
C			

Table 4.5

You have got the amount of work done per second by each pump. That will be the power of each pump.

Work done per unit time or rate of doing work is power.

$$\textit{Power} = \frac{\text{work}}{\text{time}}, \quad P = \frac{W}{t}$$

$$\textit{Unit of power} = \frac{\text{unit of work}}{\text{unit of time}} = \text{J/s}$$

Joule per second is called watt (W).

1 kW = 1000 W

1 HP = 746 W

Horsepower

In the early days horses were used for pulling carts and other purposes. A horse power or 1 HP is the power of a horse. This is estimated at about 746 W.

You may have now understood the meaning of ½, HP and 1 HP.

- If a man of mass 70 kg climbs up a mountain of height 30 m in 5 minutes, what is his power?.
- If a man of mass 50 kg takes 60 s to climb up 20 steps, each 15 cm high, calculate his power.

You have understood several facts regarding work, energy and power. Electricity is a form of energy used extensively in daily life. You will learn more in higher classes about how the amount of electrical energy is calculated.

Significant Learning Outcomes

The learner can

- identify different types of work in daily life, explain them and calculate the work done.
- identify the idea of energy and to give examples for different forms of energy
- explain how potential energy is obtained for bodies and find it mathematically
- explain with examples potential energy due to strain.
- explain the idea of kinetic energy and solve numerical problems.
- explain law of conservation of energy with examples.
- understand the idea of power and find the power by solving mathematical problems.

Let us assess

1. Which are the factors influencing the amount of work?
2. A boy is trying to push the concrete pillar of the building using a force of 300 N. Calculate the amount of work done by the boy.
3. A bench of mass 40 kg is brought from the first floor of the school to the second floor. The height difference between the floors is 3 m.
   (a) Calculate the work done against the gravitational force when the bench is raised up.
   (b) What is the work done against the gravitational force if the bench is shifted from one room to another by pushing it across the floor?
4. From what you have learnt of potential energy and kinetic energy, write down the form of energy possessed by the bodies given below.
   (a) running train
   (b) water in a dam
   (c) stretched rubber band
   (d) mango falling from a tree
5. Calculate the kinetic energy of an athlete of mass 60 kg running with a velocity 10 m/s.

6. Calculate the potential energy of a stone of mass 40 kg on the terrace of a building of height 12 m.
7. A stone of mass 2 kg is thrown upwards from the ground with a velocity of 3 m/s. When it reaches maximum height, calculate its potential energy.
8. The heart of a healthy person beats 72 times per minute and each beat uses up about 1 J of energy. Calculate the power of the heart.

Extended activities

1. Complete the table

Energy transformation	Context
1. Mechanical Energy → Electrical Energy	Working a generator
2. Electrical energy → Heat energy	
3. Electrical energy → Heat energy	
4. Electrical energy → Light energy	

2. Check whether the power marked in the motor used for pumping water from the well in your home and the power received during the working of it are equal, by considering the time taken to fill the tank and the height of the tank.

5

Refraction of Light

I aimed the arrow at a fish; but what I got was a frog!

Why does the position of an object inside water seem to have changed?

Observe a pencil placed in water in a glass (Fig. 5.1)

Fig 5.1

Why does the pencil appear broken? Let's do an activity.

Place a glass slab on a drawing sheet and mark its boundary as ABCD. Remove the glass slab and draw a line PQ on the side AB as shown in Fig.5.2. Keeping the glass slab in position, pass light from a laser torch through it along PQ. Observe the path of light through the glass slab.

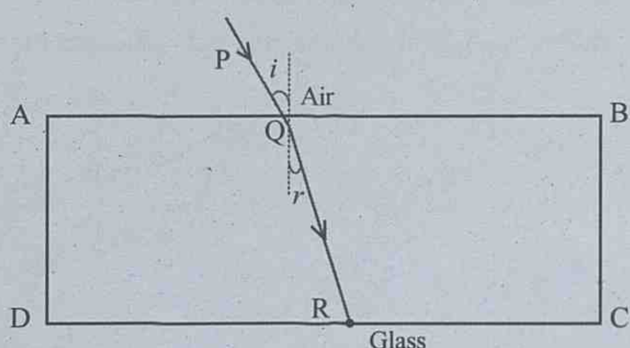


Fig 5.2

Join the points Q and R and observe the path of the light PQR. Ray PQ falling on the glass slab is the incident ray and QR is the refracted ray. Draw a normal at the point of incidence on the side AB.

- The angle between the incident ray and the normal is the angle of incidence(i)
- Observe the figure and write down the angle of refraction.
- While passing through the glass slab, when did the path of light deviate?

This deviation of a ray of light is the refraction.

When a light ray is incident obliquely from one transparent medium to another, its path undergoes a deviation. This is refraction.

What is the reason for refraction?

Observe the given table and compare the speed of light in different media.

Medium	Speed of light
Vacuum	3×10^8 m/s
Water	2.25×10^8 m/s
Glass	2×10^8 m/s (approx.)
Diamond	1.25×10^8 m/s

Table 5.1

- Why does the speed of light differ in different media?

Optical density is a measure which shows how a medium influences the speed of light passing through it.

Speed of light will be less in a medium of greater optical density.

- What about it in a medium of low optical density?

The ray diagram of light passing through different media is given.

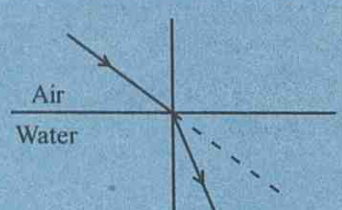


Fig 5.3 (a)

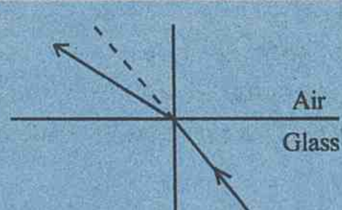


Fig 5.3 (b)

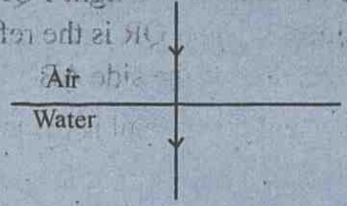


Fig 5.3 (c)

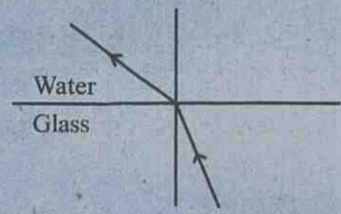


Fig 5.3 (d)

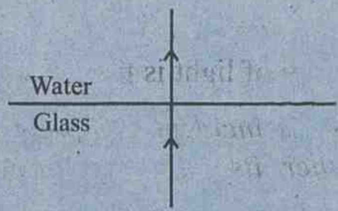


Fig 5.3 (e)

Observe the figures and answer the following questions.

- In which case does the refracted ray deviate towards the normal? When does it deviate away from the normal?
- Does the path of light always deviate?
- How do you relate the deviation of the ray with the optical density of the medium?

See the Bending of light in PhET IT @ School Edubuntu.

The special features related to refraction are given below. Find out the appropriate figures from Fig.5.3 and complete the table.

• Refraction takes place at the surface separating the two media when light passes obliquely from a transparent medium to another of different optical density	
• No deviation takes place in the case of a light ray falling normally on a medium	
• When light passes obliquely from a medium of higher optical density to one of lower optical density, the refracted ray deviates away from the normal.	
• When light is incident obliquely, from a medium of lower optical density to that of greater optical density, the refracted ray deviates towards the normal.	

Table 5.2

What are the situations in which we observe refraction in our day to day life?

- Stars in the sky appear, to be twinkling.

Let's try another activity related to refraction.

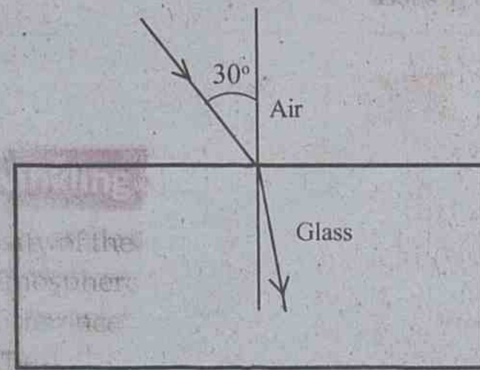


Fig 5.4 (a)

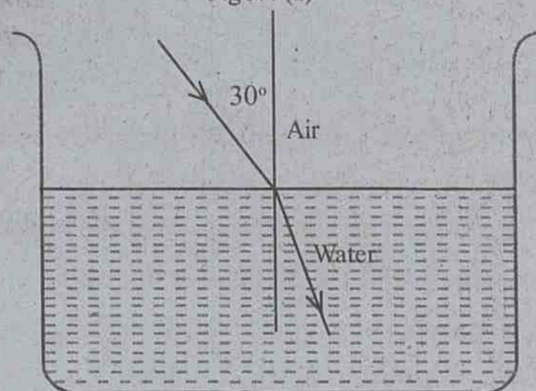


Fig 5.4 (b)

Twinkling of stars

The density of the different layers of the atmosphere varies because of the difference in temperature. When the light from the stars passes through layers of varying density, refraction occur continuously at different rates. As stars are situated far away, they appear as point sources. As the light from the star reaches the eye after refraction, they seem to come from some other point. This is the reason why stars appear to twinkle. If so, why don't the planets twinkle? The planets are closer to the earth than the stars. Therefore light from the planet does not appear as coming from a point source. If the planet is considered as a collection of point sources, the average deviation of light reaching the eye will be zero. So no twinkling is experienced. This helps us to distinguish between stars and planets.

Haven't you seen the refraction depicted when light is incident from air on a glass slab and water at the same angle of incidence?

- Is the deviation the same in the above two situations?

Discuss how the deviations that occur in different media are related to the speed of light in the corresponding media.

Refractive index

Refractive index of a medium is the ratio between the speed of light in vacuum and the speed in the medium.

$$\text{Refractive index } (n) = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the medium}}$$

$$n = \frac{c}{v}$$

Since the speed of light in air and that in the vacuum are almost equal, the speed of light in vacuum is taken as speed of light in air for finding the value of refractive index.

$$\text{Refractive index of glass} = \frac{\text{Speed of light in air}}{\text{Speed of light in glass}}$$

$$= \frac{3\times10^8}{2\times10^8} = 1.5$$

- Calculate the refractive index of water, when the light enters water from air.
- In an aquarium light at the speed 3×10^8 m/s is incident obliquely on the surface of water. If the refractive index of water is 1.33, find out the speed of light in water.

The refractive indices of different media are given. Analyse the table and answer the following questions.

Refractive index

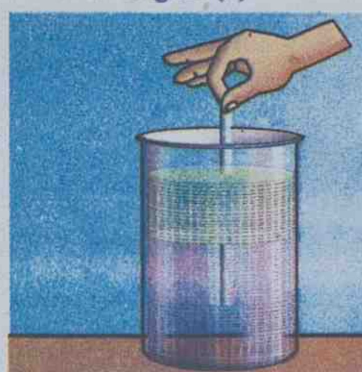
Do you know that the refractive index (n) is not a constant always?

When the wavelength of light increases, refractive index decreases and when wavelength decreases, refractive index increases. Likewise the speed of the light varies with refractive index.

Medium	Refractive index (approx.)
Water	1.33
Sunflower oil	1.47
Pyrex glass	1.47
Glycerine	1.47
Crown Glass	1.52
Flint glass	1.62

Table 5.3

Glass rod immersed
Fig 5.5 (a)



Pyrex glass rod immersed
Fig 5.5 (b)

- Which among the above media have the same refractive index?
- In which medium, will the speed of light be maximum?

Glycerine, water and sunflower oil are taken in two beakers in the same order as shown in the figures. An ordinary glass rod is dipped in the first beaker and a pyrex glass in the other.

- Are the ordinary glass rod and the pyrex glass rod visible in the same manner? Which are the media in which they are visible?

An object placed in a transparent medium is visible when light reflected from the object reaches our eyes. In this case the refractive indices of sunflower oil, pyrex glass and glycerine are almost the same and so the pyrex rod is not visible in sunflower oil and glycerine. In other words, the light ray passes without deviation through media of equal refractive index.

A person who looks at an aquarium as shown in Fig.5.6 can see the base reflected on the surface of water. What is the reason?

Take a clean mineral water bottle and fill it with water. Put a hole on one side of the bottle. Allow water to flow out while passing a laser ray through it as shown in Fig.5.7. What do you observe?

Fig 5.6

Stream of light
Fig 5.7

We know that light travels in straight line. But why does light travel here in a curved path along the path of water?

Total internal reflection

Take a round bottomed flask and fill it half with water. Add one spoon of milk to it.

Fig 5.8 (a)

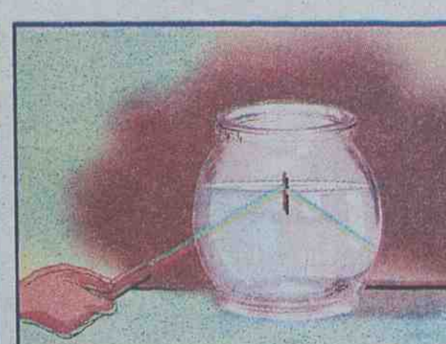


Fig 5.8 (b)

Allow light from a laser torch to fall on the water in the flask. Observe the path of the refracted ray. The angle of incidence is gradually increased. Note the deviation of the refracted ray.

- What will be the angle of refraction when the refracted ray passes along the surface of water?

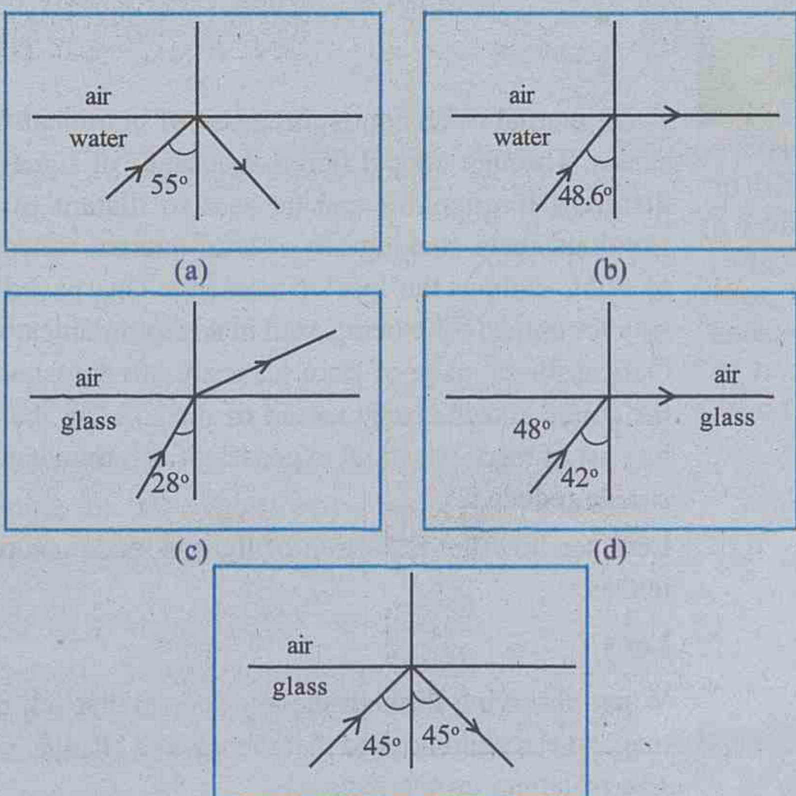
Observe the angle of incidence at this instance.

When a ray of light passes from a medium of greater optical density to that of lower optical density, the angle of incidence at which the angle of refraction becomes 90° is the critical angle. The critical angle in water is 48.6°.

Allow light to fall at an angle of incidence greater than the critical angle. What do you observe?

When a ray of light passes from a medium of higher optical density to a medium of lower optical density at an angle of incidence greater than the critical angle, the ray is reflected back to the same medium without undergoing refraction. This phenomenon is the total internal reflection.

The path of light in different media is shown in the figures. Analyse them and answer the following questions.



(e)

Fig 5.9

- Which are the figures that show total internal reflection?
- What is the critical angle of glass?
- Will total internal reflection take place when light enters from water to air at an angle of incidence of 45°? Why?

You have already realised that total internal reflection takes place if the angle of incidence is greater than the critical angle. On the basis of this how will you explain the light stream experiment done earlier?

Now, you can explain that it is because of total internal reflection that the bottom of the aquarium is seen at the surface of the water.

- Find out the practical applications of total internal reflection in our day to day life.
  - Medical field→Endoscope.
  - In the field of communications→Optical fibre cables.
  -
  -

Total internal reflection is made use of in optical fibre cables. Through optical fibres, thousands of signals of different frequencies can be sent to distant places simultaneously, making use of total internal reflection of light, without the loss of intensity. This paved the way for optical fibre being used in telecommunications. Optical fibres made of fibre glass are not damaged by the acidic and the basic nature of the soil. As there is no cost of reconstruction, expenses of communications can be reduced.

Let's see how the refraction of light is made use of in lenses.

Lens

When observing through the water drop that fell on a magazine, a child noticed that there was a change in the size of letters on the page.

Messina town seen in the sky

When the atmospheric temperature is very low, the water vapour at sea level cools very fast. So the density of air will be low in the upper region and high in the lower region. Light from the Messina town near the Mediterranean Sea is subjected to total internal reflection at nights and its image is seen high in the sky. When voyagers view it from a distance, it will appear as if Messina town were in the sky. This is due to the phenomena of optical looming.

Optical fibre in the field of treatment

After its invention, optical fibre was first used in the field of medicine for constructing a device called endoscope. Optical fibre cables are used for the diagnosis of diseases and to identify the action of medicines in the human body.

- Why did the letters appear to be bigger in size?

You know that a spherical transparent medium acts like a lens.

You have seen different types of lenses. Which are they? Write them down in the science diary

A lens is a transparent medium having spherical surfaces.

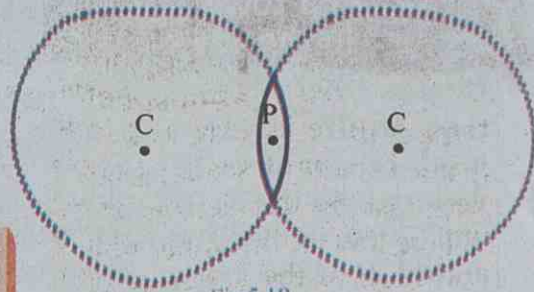


Fig 5.10

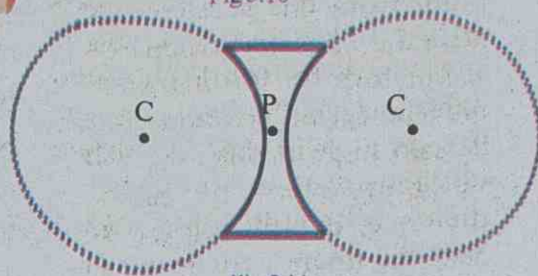


Fig 5.11

Convex and concave lenses are the important lenses that we use.

Let's see what are the terms and characteristics associated with convex and concave lenses.

Optic centre

Optic centre is the midpoint of a lens (P).

Centre of curvature

There are two spherical surfaces which are parts of the lens. Centre of curvature (C) is the centre of the imaginary spheres of which the sides of the lens are parts.

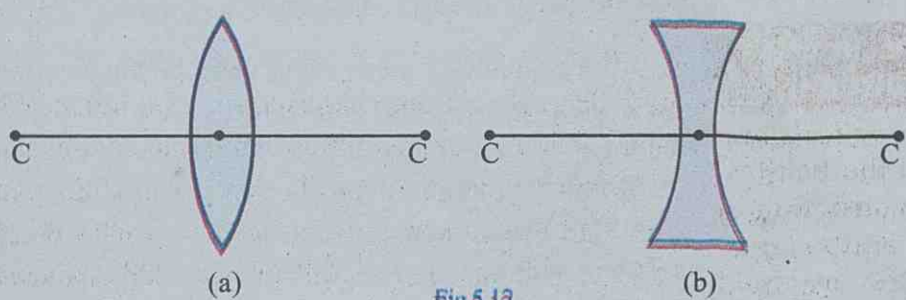


Fig 5.12

Principal axis

Principal axis is the imaginary line that passes through the optic centre joining the two centres of curvatures.

Principal focus

Let's do an experiment:

Take a rectangular box, the upper part of which is covered with a glass sheet. Place a thermocol stand at its centre. Arrange a slit on the shorter side as shown in the figure. Fill the box with smoke from an incense stick. Keeping the convex lens on the

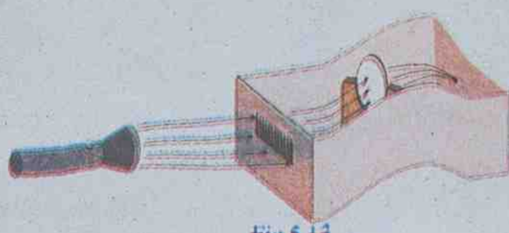


Fig 5.13

The International Year of Light (2015)

The United Nations has declared 2015 as the International Year of Light and also of technologies based on light. The global problems faced by mankind in the fields of education, communications, health etc. were tackled to a great extent by technical skills and devices that made use of light. Taking all these into account this declaration was made to create awareness among people about the achievements of the science of light. At the same time, 2015 is also considered the Year of the Studies of Scientists who have made many discoveries and achievements in the field of science.

thermocol stand, pass intense light from a torch through the slit. Observe the path of light through the glass sheet.

By adjusting the position of the lens, find out the point at which light is converged.

Light rays incident parallel and close to the principal axis converge at a point on the principal axis of a convex lens. This point is the principal focus of a convex lens.

The principal focus of a convex lens is real since the light rays converge at a point. This is indicated by the letter F.

- How many principal foci does a convex lens have? Why?

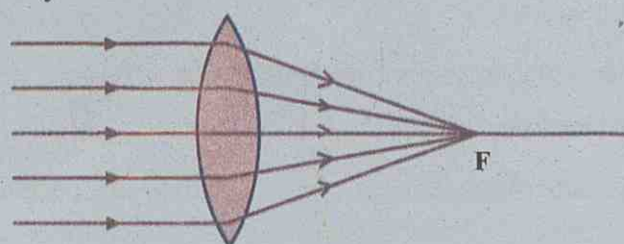


Fig 5.14

Principal focus of concave lens

Repeat the smoke box experiment using a concave lens. What is your observation?

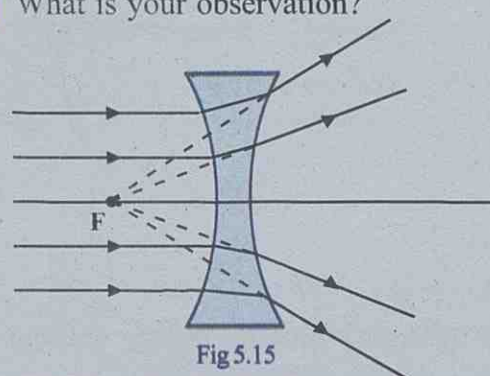


Fig 5.15

Light rays coming parallel and close to the principal axis diverge from one another after refraction. These rays appear to originate from a point on the same side. This point is the principal focus of a concave lens.

- Why is it said that the principal focus of a concave lens is virtual?

It is impossible to converge light at a point using a concave lens. Therefore the principal focus of a concave lens is virtual.

Focal length

Focal length is the distance to the principal focus from the optic centre. This is denoted by the letter f.

Formation of image using a lens

Cast the image of a distant object on the screen using a convex lens. Measure the distance between the lens and the screen. Repeat the experiment with different distant objects. Find the average of the distances measured. This gives the focal length of the convex lens.

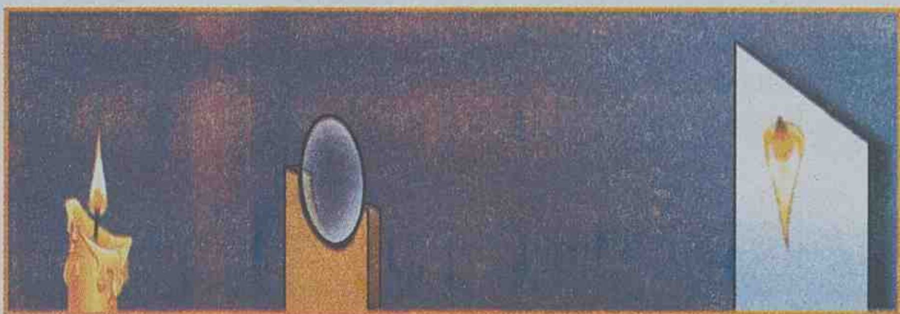


Fig 5.16

Adjust the screen as shown in the figure, keeping the convex lens at different positions on the principal axis in front of a lighted candle. See where the image is formed and observe its characteristics. Record them in Table 5.4.

Position of object	Position of image	Nature of image		
		Real/ virtual	Inverted/ erect	Magnified/ diminished/same size
1. At infinity	At F	Real	Inverted	Diminished
2. Beyond 2 F				
3. At 2 F				
4. Between 2F and F				
5. At F				
6. Between F and lens				

Table 5.4

Ray diagram of formation of images by lenses

We have seen positions of the images formed by lenses for objects at different distances and their characteristics. The positions and characteristics of images formed by lenses can also be found out using ray diagrams.

Let us see the points to be taken care of while drawing ray diagrams :

- When light ray passes through the optic centre of a thin lens, it does not undergo deviation.

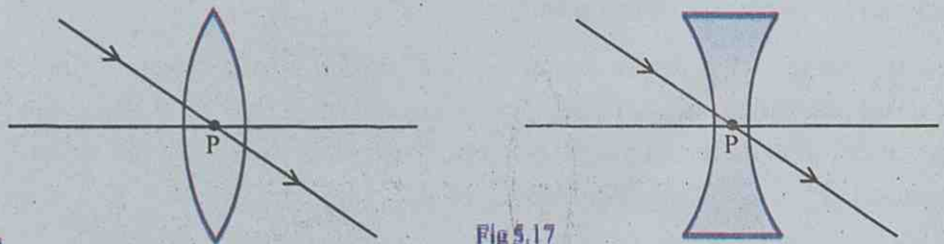


Fig 5.17

Make use of geometric optics in the IT @ School Edubuntu.

- A ray of light falling parallel to the principal axis of a convex lens passes through the principal focus after refraction.

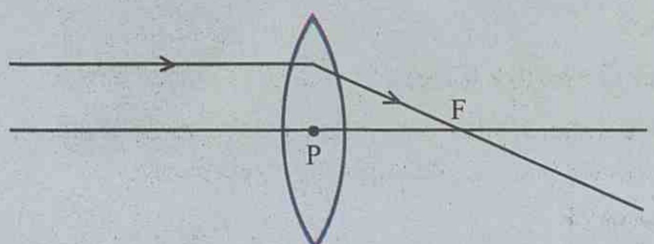


Fig 5.18

- A ray incident parallel to the principal axis of a concave lens appears to emerge from the focus on the same side of the lens.

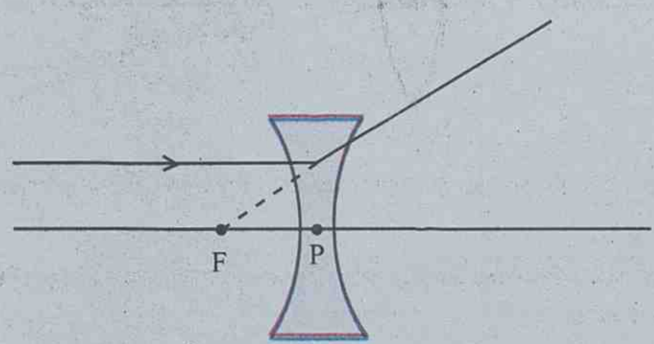


Fig 5.19

- A ray of light passing through the principal focus of a convex lens passes parallel to the principal axis after refraction.

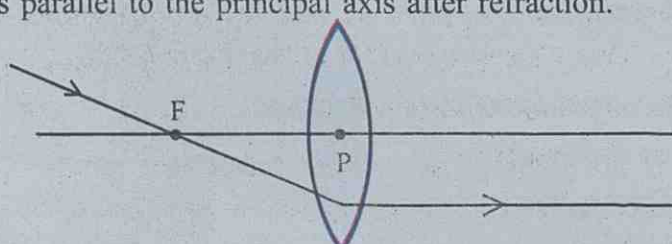


Fig 5.20

We can make use of any of these rays for drawing the ray diagram.

Object at infinity

Light rays coming from a distant object are considered as parallel rays.

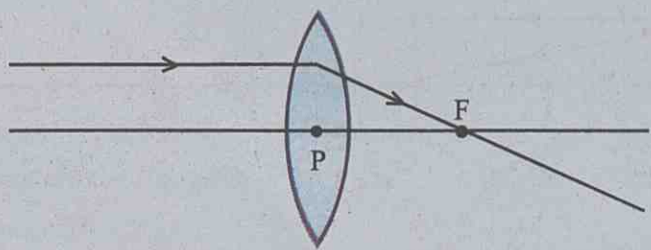


Fig 5.21

- Where will the rays coming parallel to the principal axis converge?
- Where is the image formed?

Compare the characteristics you found from the ray diagram with those observations you got through the experiment.

Object beyond 2F

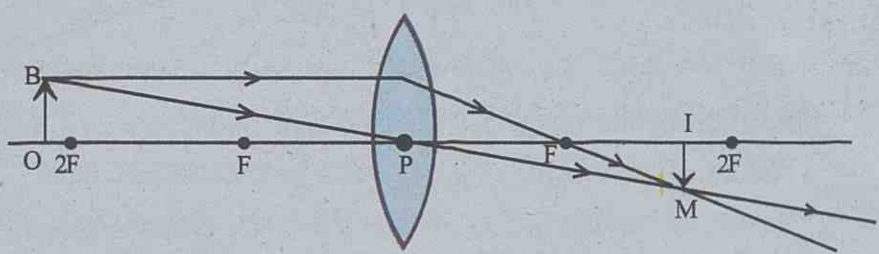


Fig 5.22

Consider two rays from an object placed beyond 2F as shown in the figure.

One ray is incident parallel to the principal axis and passes through the principal focus.

The second ray passing through the optic centre passes without any deviation.

Draw a perpendicular on the principal axis at the point where the two rays meet. This is the image (IM) of the object (OB).

Write down the characteristics of the image.

Position of the image : ....

Nature of the image : ....

Size of the image : ....

In this manner draw ray diagrams of images formed when the object is placed at different positions.

Object at 2F

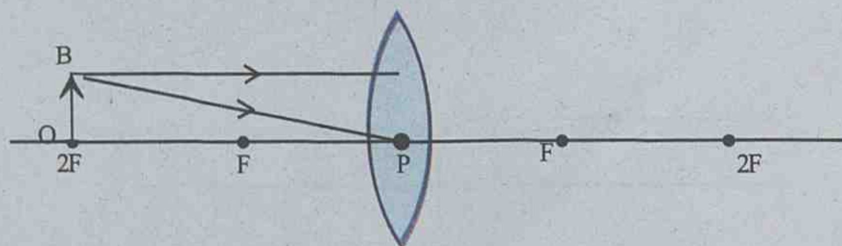


Fig 5.23

Position of the image : ....
Nature of the image : ....
Size of the image : ....

Object between F and 2F

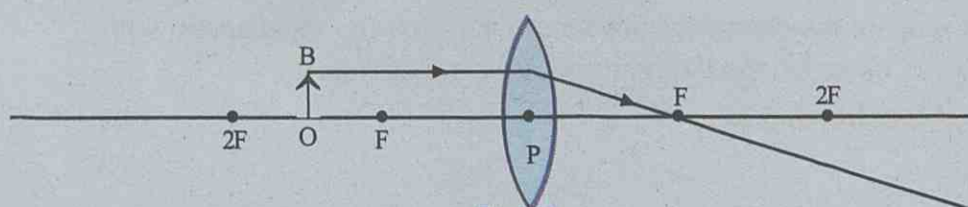


Fig 5.24

Position of the image : ....
Nature of the image : ....
Size of the image : ....

Object at F

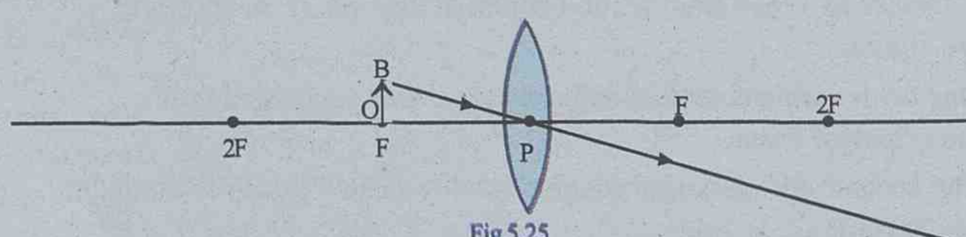


Fig 5.25

Position of the image : ....
Nature of the image : ....
Size of the image : ....

Object between F and lens

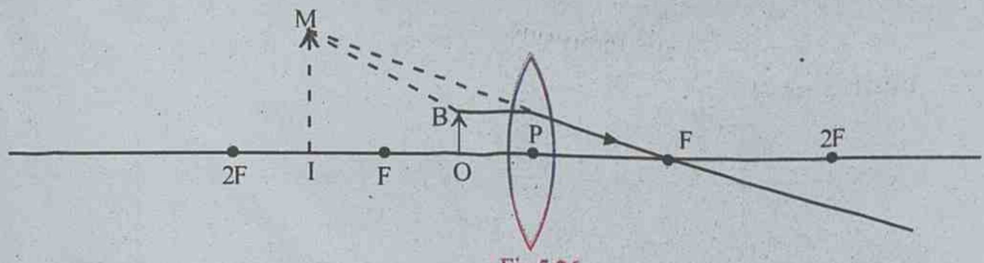


Fig 5.26

Position of the image : ....

Nature of the image : ....

Size of the image : ....

Images formed by concave lens

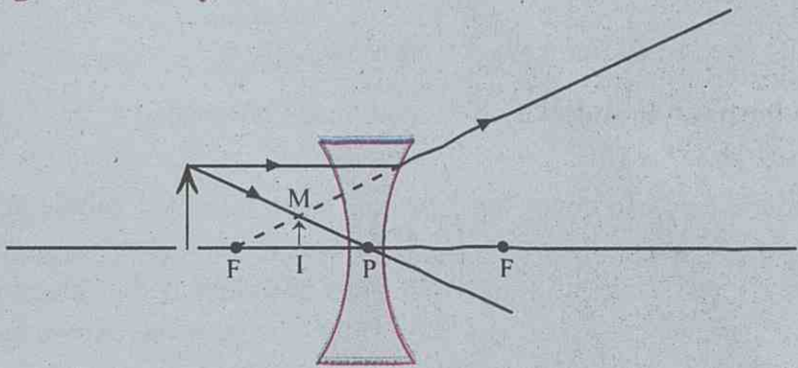


Fig 5.27

Have you observed images formed by a concave lens?

- What is the nature of the image?

From the diagram, find out the position of the image and write down the characteristics.

New cartesian sign conventions

In experiments related to lens and mirror, distances are measured in the same manner as in a graph. In the case of lenses, distances are measured considering the optic centre as the origin. All distances are to be measured from the origin.

Light ray is assumed to travel from left to right. Therefore all distances measured along the direction of light is positive and that in the opposite direction is negative. Distances measured upwards from X-axis are positive and those measured downwards are negative. Similarly the focal length of a convex lens is positive and that of a concave lens negative.

New Cartesian sign conventions

In mirrors, lenses etc., where the position of the object changes, the position of the image also changes. In these cases, the equations to find out the focal length will be different. The new Cartesian system is formulated to standardise these equations. But, for getting the real equation in each case, we will have to apply Cartesian sign conventions again.

Record the measurement shown in the figure as per the Cartesian system.

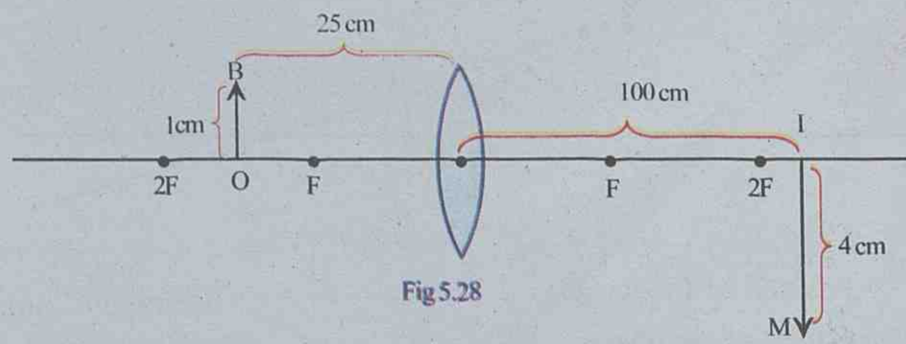


Fig 5.28

Distance of the object from the lens (u) = ...

Distance of the image from the lens (v) = ...

Height of object (OB) = ...

Height of image (IM) = ...

Let's examine how distances of object and image are related to the focal length of the lens.

Take a convex lens of known focal length. Keep a lighted candle at a certain distance from the lens and adjust the lens to get a clear image on the screen. Then measure the values of u and v and tabulate the values on the basis of the new cartesian sign conventions. Repeat the experiment by changing the position of the object.

Sl.No	u	v	$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$	$f = \frac{uv}{u-v}$
1						
2						
3						

Table 5.5 *Mean f =*

Compare the focal length obtained from the earlier experiment with the values in the above table.

We can make use of the equation $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$. This is the lens equation.

From this, we get, $v = \frac{uf}{u+f}$, $u = \frac{fv}{f-v}$, $f = \frac{uv}{u-v}$

These equations are used for solving problems.

- When an object is placed at a distance of 15 cm from a convex lens, a real image is formed at a distance of 30 cm. What is the focal length of the lens?

  $u = -15$ cm, $v = +30$ cm,

  $$f = \frac{uv}{u-v} = \frac{-15 \times {}^{+}30}{-15 - {}^{+}30} = \frac{-15 \times 30}{-45} = +10\,\text{cm}$$

- The focal length of a concave lens is 20 cm. If an object is kept at a distance of 30 cm from the lens, find out the distance of the image formed.

  $$u = -30\,\text{cm}, f = -20\,\text{cm}, v = \frac{uf}{u+f} = \frac{-30 \times -20}{-30 + -20} = \frac{+600}{-50} = -12\,\text{cm}$$

Is there any relation between the height of an object and the height of its image?

Can it be related to the ratio between the distance to the object and that to the image ?

Magnification

Magnification is the ratio of the height of the image to the height of the object. It shows how many times the image is as large as the object.

$$\text{Magnification} = \frac{\text{Height of the image}}{\text{Height of the object}} = \frac{IM}{OB} = \frac{h_i}{h_o}$$

Mathematically, this can be found out in another way. If the distance of object is taken as u and that of the image as v,

magnification $m = \frac{v}{u}$

- Calculate the magnification of the image formed in Fig. 5.28.
- When an object of height 3 cm is placed at a distance of 30 cm from a lens, a real image is formed at a distance of 60 cm. Find out the height of the image.

  $u = -30$ cm, $v = +60$ cm

  $h_o = 3$ cm, $h_i = ?$

  $$m = \left(\frac{v}{u}\right)$$

Magnification

Magnification is a mere number. The positive and the negative signs of the number indicate the nature of the image. If magnification is negative, the image will be real and inverted. An erect and virtual image indicates that the magnification is positive because from the principal axis, the measurement above is positive and that below is negative.

$$= \frac{+60}{-30} = -2$$

$$m = \frac{h_i}{3}, \; -2 = \frac{h_i}{3}$$

$$h_i = -6 \text{ cm.}$$

The negative sign shows that the image is real.

We have now understood the different types of lenses and the characteristics of images formed by them.

- Find out the uses of lenses in our day to day life and record them in the science dairy.
  - In telescope
  - In spectacles
  - In camera

Eye and vision

Spectacles are used to rectify the defects of the eye. Lenses in the spectacles help to rectify them.

In order to understand this we must know about the structure of the eye. Observe Fig 5.29.

The image is formed by the convex lens of the eye. When this falls on the retina of the eye we see the object.

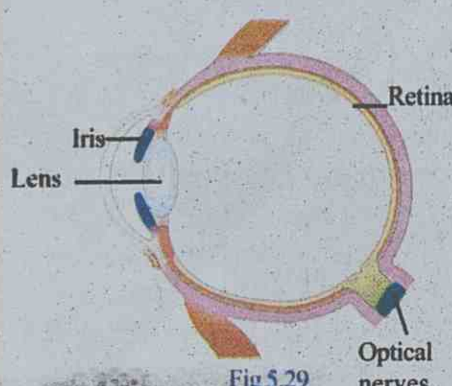


Fig 5.29

- Can we see very near/ far objects clearly?

Try to read a book that touches the end of your nose.

- Can you read it clearly? What if you start moving the book away from you slowly?
- At what distance from the eye can you read clearly?

This is the minimum distance for clear vision.

Nearpoint is the nearest point at which you can see an object clearly. The nearpoint of healthy vision is 25 cm.

- When lenses are used to form images, we have to adjust the position of the screen along with the position of the object for getting a clear image.

  Even when objects are at different distances from the eye, how are clear images formed on the retina?

- What arrangement is there in the eye for this? Write down your conclusions.

As the position of objects changes, the focal length of the lens in the eye also gets adjusted by changing the curvature of the lens with the help of ciliary muscles.

The ability of the eye to form an image on the retina by adjusting the focal length of the lens in the eye, by varying the curvature of the lens whatever be the position of the object, is the power of accommodation.

Given below are the ray diagrams of image formation in the eye.

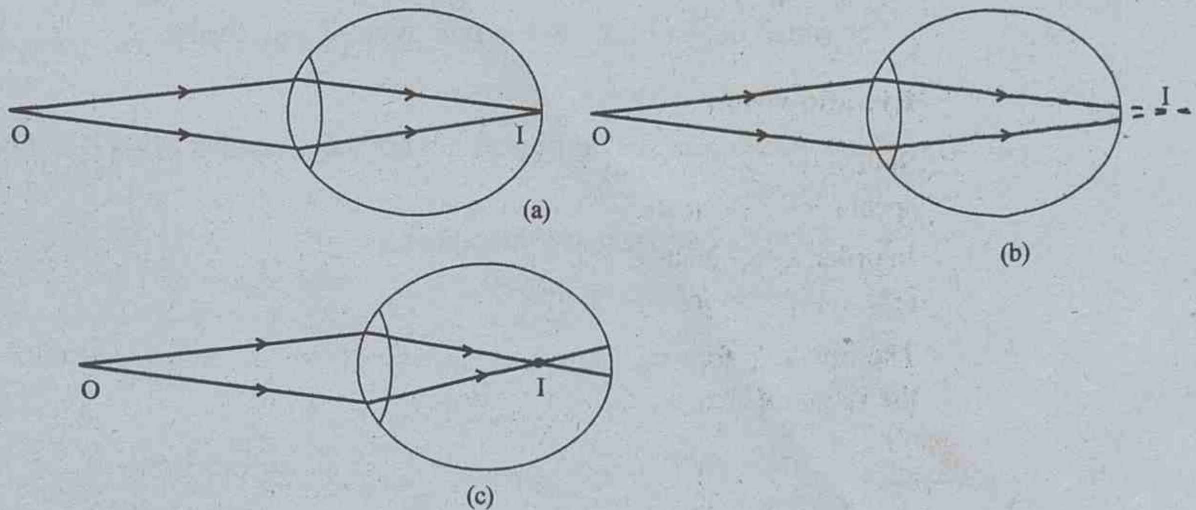


Fig 5.30

- Are all the images formed in the same manner?
- In which case is the image formed on the retina itself?
- In the other cases the image is not formed on the retina. Why?
    - Change of power of the lens of the eye.
    - Change of the size of the eye ball.

In such cases, will vision be affected? Write down your inferences. What is the solution?

Power of a lens

The prescription shows the power of the lens suggested by a doctor for rectifying the defects of the eye.

- What has the doctor indicated in the prescription?

Power is a term related to the focal length of a lens.

Power of a lens is the reciprocal of focal length expressed in metres. Power $p = \frac{1}{f}$. Unit of power is diopter. It is represented by D.

The power of a convex lens is positive and that of a concave lens is negative.

- Calculate the power of a lens of focal length +20 cm.
- The powers of the lenses in the prescription of the doctor are +1.50 D and +1 D? What is the focal length of these lenses? What type of lenses are they?

For which defect of the eye is this type of lens used?

Hypermetropia or far sightedness

Some people can see far objects but not those nearby. What could be the reason?

- The eye ball is shorter than normal
- The lens has less power

Observe Fig. 5.31

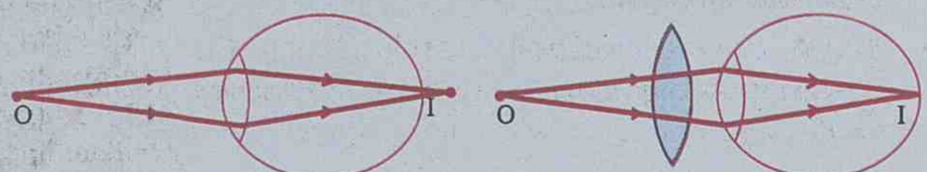


Fig 5.31

If the eye is as shown in Fig. 5.31(a), will a clear image be formed on the retina?

Since the image is formed behind the retina, instead of being formed at the retina, even though distant objects are clearly seen, nearer objects cannot be seen. This defect of the eye is the farsightedness.

This can be remedied by using a convex lens of appropriate power.

Myopia or near sightedness

For some people the eye ball may be long. For some others, even though the eyeball is normal in size, power of the lens may be more.

Where is the image formed in these cases? Write down the answer analysing Fig. 5.32.

- Why can't objects at a distance be seen?
- What is the solution?

If the image is formed in front of the retina instead of being formed on the retina, even though nearby objects can be seen clearly, distant objects cannot be seen. This defect is the nearsightedness.

This can be overcome by using concave lenses of appropriate focal length.

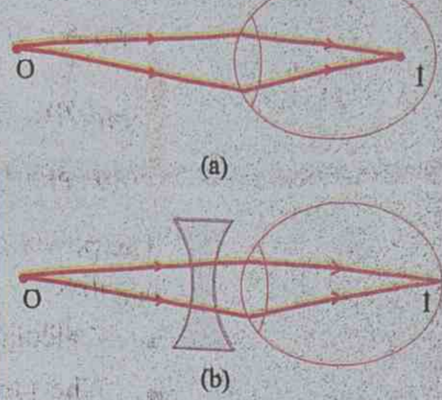


Fig 5.32

Now you must have understood for which defect of the eye, the doctors' prescription was for.

What happens if there is a change in the curvature of the lens?

Astigmatism

The defect of the eye caused due to the curvature of the vertical surface of the eye lens being greater than that of the horizontal surface or vice versa is the astigmatism. This defect can be overcome using cylindrical lens of appropriate power and objects can be seen clearly.

- Haven't you seen elderly people reading the newspaper, holding the paper at a distance? What may be the reason?

Presbyopia

- For a healthy vision what is the distance to the near point?

For elderly people the near point is greater than 25 cm. This is due to the diminishing ability of the ciliary muscles. For such people the power of accommodation will be less. This is presbyopia.

This can be overcome using convex lens of appropriate focal length.

We know that the eyes as windows to the world play an important role. Have you thought about those who have lost their sight? What are the things we can do for them?

3D Vision

Is a single eye not sufficient for vision? Why do we need two eyes?

Vision becomes perfect only when both the eyes are used. When one eye alone is used, only a two dimensional view within an angular width of 150° is possible. When we look at an apple keeping one eye closed, it will appear to be flat. When an object is viewed using both the eyes, a three dimensional and wide vision with an angular span of 180° is possible. It is the brain that creates the perception of the distance of the object, by unifying the visions of the two eyes.

Eye donation

We can bring at least some people who are not having eye sight to the world of light through eye donation. Any person of any age can donate eyes. Exception is the cornea of those people having certain peculiar diseases. The cornea of the donor should be harvested within 6 hours of death. Eye donation helps to fill the life of others with light by those who close their eyes forever.

Conduct activities with your friends to increase awareness and encourage people to donate their eyes.

Significant Learning Outcomes

The learner can

- explain what refraction is and find out suitable examples of it in nature.
- illustrate diagrammatically the refraction through a glass slab and explain angle of incidence and angle of refraction.
- find out how optical density influences refraction and explain it.
- solve problems using equation for refractive index.
- explain the phenomena related to total internal reflection and find out examples from daily life.
- draw the images formed by the lens and explain the characteristics.
- apply New Cartesian sign conventions in certain contexts as required.
- solve numerical problems related to lens.
- explain magnification produced by lenses.
- explain the defects of the eyes and the way in which they are rectified.

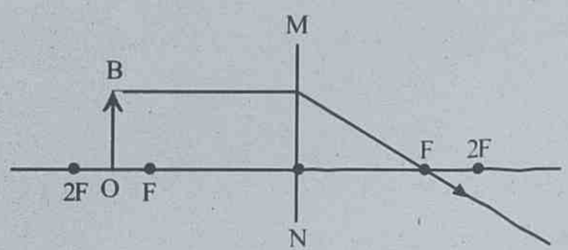
Let us assess

1. Refractive indices of different materials are given. Find out through which medium light passes with maximum speed.

Medium	Refractive index
Glass	1.52
Glycerine	1.47
Sunflower oil	1.47
Water	1.33
Flint glass	1.62

2. The nature of images formed by two lenses are given.
   (i) An erect and magnified virtual image
   (ii) An erect and diminished virtual image
   (a) What type of lens is used in each case?
   (b) On using which of these lenses will we get an image having the same size as the object? What is the position of the object?

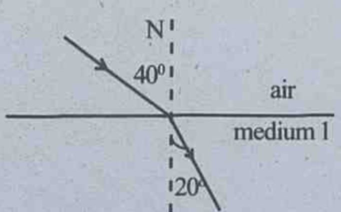
3.

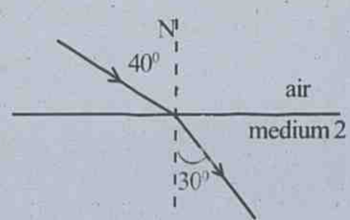


   (a) MN represents a lens. What type of lens is this?
   (b) What are the characteristics of the image?
   (c) Copy the ray diagrams in the science diary and complete it.

4. What do you mean by power of a lens? What is the SI unit of the power of a lens? Calculate the power of a concave lens of focal length 25 cm.

5. Observe the figure. Light falling on two different media are shown.





(a) Which medium has greater optical density?

(b) Why?

(c) Which medium has greater refractive index?

6. An object of height 3 cm is placed in front of a convex lens of focal length 10 cm at a distance of 15 cm.

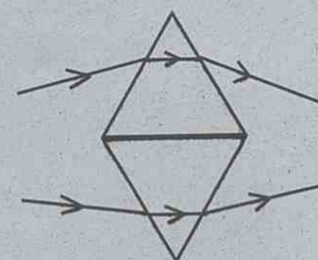
(a) What is the distance of the image formed?

(b) What is the nature of the image?

(c) What is the height of the image?

Extended activities

1. Observe the refraction taking place when two prisms are kept together. Analysing the figure, prove that lens is a combination of prisms.



Notes

Notes

Notes

Notes

While using electricity...

Electricity has become an indispensable part of our day-to-day life. Its consumption has increased and hence the hazards due to this have also increased. Of all the electrical hazards reported in India 10 per cent are from our state. Hence there is no need for specific mentioning to ensure the importance of precautionary measures from electricity related hazards.

Safety measures to be adopted:

- Do not operate switches with wet fingers.
- Do not dry hair using a table fan.
- Do not touch the inner part of the adaptor of a TV. Ensure that the adaptor has a cap which is a non-conductor.
- Do not touch on broken electric wires.
- Do not fly kites near electrical lines.
- Do not use metallic pipes or iron hooks carelessly near electric lines.
- Do not lean against electric posts or stay wires. Cattle should not be tied to them. Do not allow plants or creepers grow on them.
- Switch off the main switch in case of fire on electric appliances or on their vicinity.
- Do not pour water over electric lines or appliances to put out fire. Instead, use dry sand or dry powder type fire extinguishers.
- Use only the electric appliances carrying ISI mark.
- Do not use plastic wires for temporary connections to decorations.
- If a person succumbs to electric shock, he/she should be touched only after disconnecting the electrical contact.
- Detach the victim from the electric connection using dry wooden planks or some dry material which is not a conductor.
- Switch off the main switch immediately, in case electric shock is noted.

Electricity saved is equivalent to electricity generated

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