

PHYSICS

Standard IX

Part-1



**Government of Kerala
Department of General Education**

**State Council of Educational Research and Training (SCERT) Kerala
2019**

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.

State Council of Educational Research and Training (SCERT)

Poojappura, Thiruvananthapuram 695012, Kerala

Website : www.scertkerala.gov.in, e-mail : scertkerala@gmail.com

Phone : 0471 - 2341883, Fax : 0471 - 2341869

Typesetting and Layout : SCERT

Printed at : KBPS, Kakkanad, Kochi-30

© Department of Education, Government of Kerala

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.

'Samagra', the education portal and technology enabled QR Code printed textbooks would definitely make your learning activity in classrooms easy and joyful. The National Skills Qualifications Framework, the current relevance of Disaster Management and the possibilities of ICT have also been considered while modifying the textbook.

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

Make learning a joyful experience.

Regards,

Dr. J. Prasad
Director, SCERT

CONSTITUTION OF INDIA

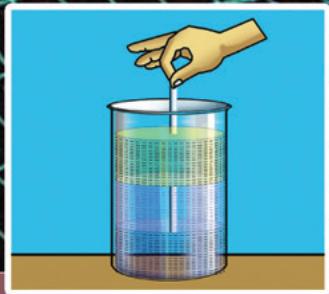
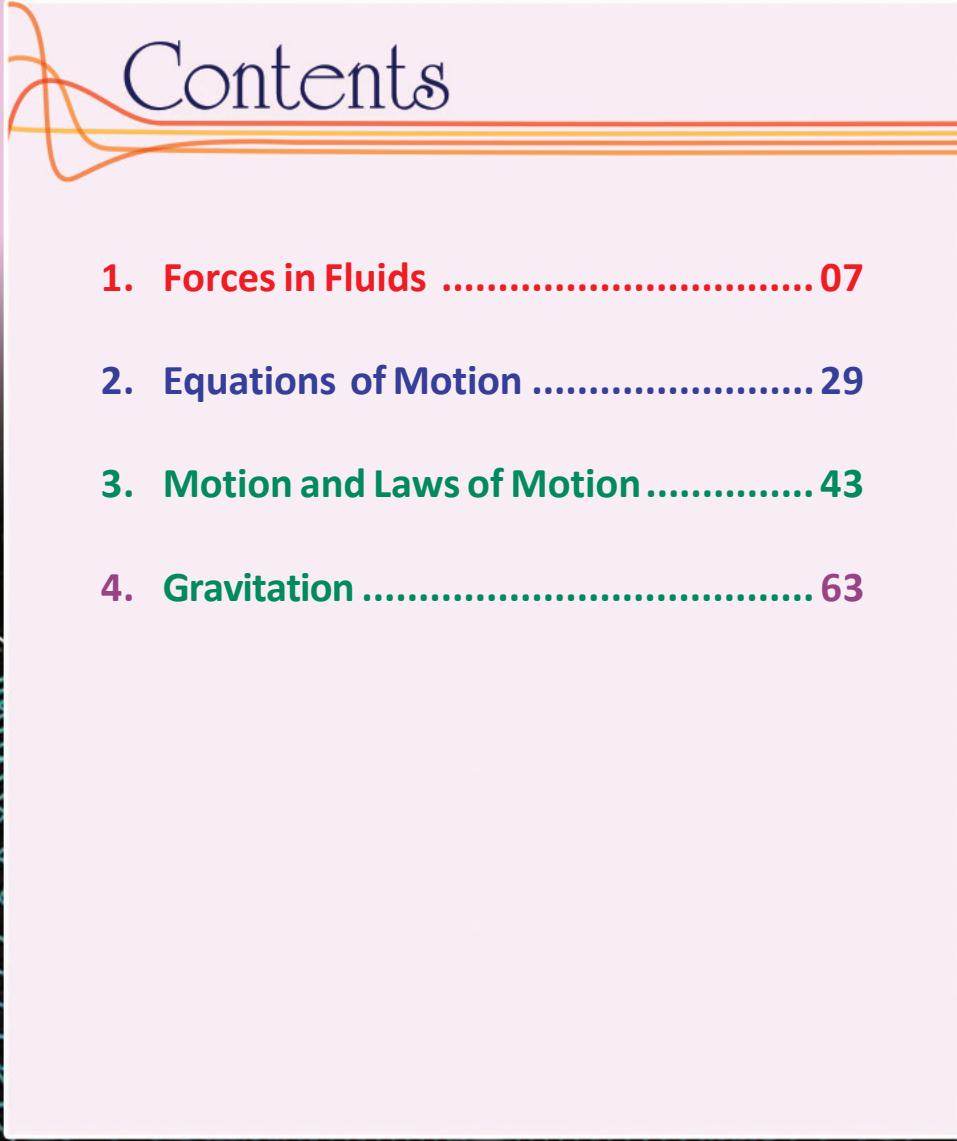
Part IV A

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.



Certain icons are used in this textbook for convenience



*For further reading
(Evaluation not required)*



ICT possibilities for making concepts clear



Let us assess



Extended activities



NSQF

1

Forces in Fluids



Why does a ship remain afloat on water? Is it due to the same reason that a razor blade also floats on water?

But then, 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 empty plastic bottle on it. What do you observe?

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

Just take off your hand from the bottle after it has been immersed into the water. What do you observe?

Why does it rise to the surface of the water?

- Shouldn't the heavy substances be going down?
- Why did the bottle experience an upward force greater than its own weight?
- Will it be possible for liquids to exert an upward force?



Fig. 1.1



Fig.1.2 (a)



Fig.1.2 (b)

Let's consider another situation.

When an immersed object is lifted up within water, its weight appears to be less than that in air. What may be the reason? Write down your inference.

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 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 fluid, the fluid exerts an upward force on the body. This force is known as buoyancy.

Tabulate some situations in your daily life in which you've experienced buoyancy 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 in Table 1.1.

Why did the stone and the metal piece experience loss of weight in water?

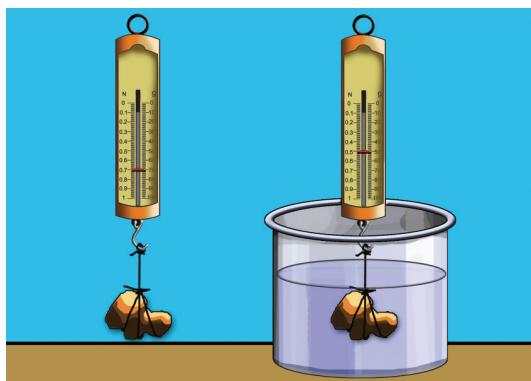


Fig 1.3

| Object | Weight in air (w_1) | Weight in water (w_2) | Loss of weight = ($w_1 - w_2$) |
|----------------|----------------------------|---------------------------|-------------------------------------|
| Stone | _____ N | _____ N | _____ N |
| Piece of metal | _____ N | _____ N | _____ N |

Table 1.1

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

This means that in order to calculate the buoyancy experienced by a substance immersed in a fluid, it is enough to find out the loss of weight of the substance in that fluid.

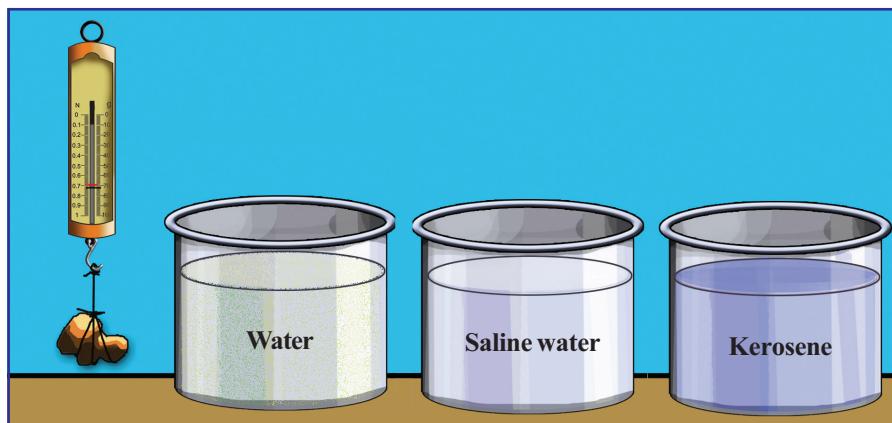
Does the same substance experience the same buoyancy in all liquids?



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 exerted on a piece of stone by each of these liquids and tabulate.



See 'Buoyancy' in
PhET, IT @ School
Edubuntu

Fig 1.4

Weight of stone in air = N

| Liquid | Weight of stone (in liquids) | 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 (approximately) |

Table 1.3

If so, is there any relation between a liquid's density 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 freshwater lake from the ocean sink more or rise more? Justify your answer.

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.



Iron block



Copper block

Fig 1.5

| 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?

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

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.

Archimedes' Principle

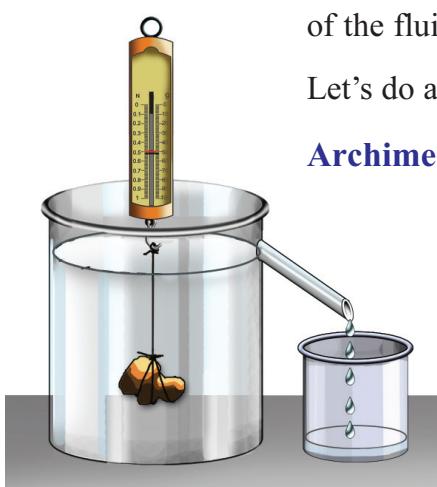


Fig 1.6

Find out the buoyancy on a stone and an iron block in water. Using an overflowing jar, find out the volume of water they have displaced. Using a spring balance find out the weight of water overflowed. 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 (buoyancy) 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 called Archimedes Principle.

Archimedes principle

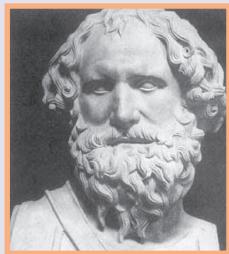
When an object is immersed partially or completely in a fluid, the buoyancy experienced by it will be equal to the weight of the fluid displaced by it.

Floatation

Let's do an activity.

Make a small vessel using an 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 aluminium foil. Fold it many times till it becomes a small piece. Then put it on water. What do you observe?

Archimedes



Archimedes was born in 287 BC at Syracuse, a port city in Italy. He lived during the rule of Hiero II. King Hiero commissioned a goldsmith to fabricate a crown. He commanded Archimedes to find out whether there was any impurity in the crown. Archimedes was perplexed. 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 it. 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 Second Punic War. This happened when he was engaged in the complicated mathematical activities related to circles.

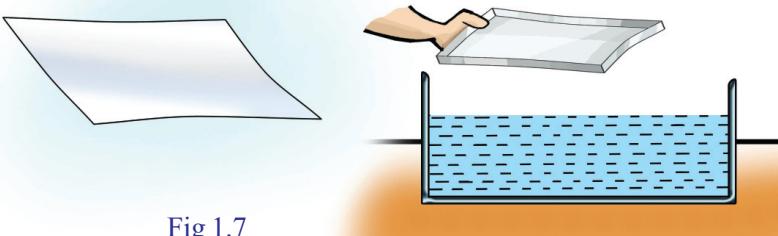


Fig 1.7

- 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?
-
- What about its volume? Will there be any change in its density then?
-

Why does aluminium foil vessel float and the folded foil sink?

Let's examine the reason for this by means of an experiment. Put a piece of stone, wood, rubber, cork, etc., one by one into water. Which among them floats 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 water displaced |
|---------|------|---------------|-----------------|----------|---------------------------|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |

Table 1.6

- Analyse Table 1.6. Find out the inter relationship of the weight of the body, the buoyancy and the weight of the water displaced by each object.
-
- Write down the situation when a body will float on a liquid.
-

Principle of floatation

Weight of a floating body is equal to the weight of the fluid displaced by it. When a body is fully immersed in a fluid the volume of the displaced fluid will be equal to the volume of the body.



Identify the reasons for the following based on what you have learnt.

- A piece of stone experiences a loss of weight while inside water.
- Though an egg sinks in pure water, it will float on salt water.
- Kerosene floats on water.
- A ship floats on water.
- When a body was placed in a liquid it remained in the same position.

Relative density

When kerosene and water are taken in the same vessel, kerosene will be seen floating on water. You know that this is because the density of kerosene is less than that of water.

Write down in Table 1.7 examples for liquids of density greater and lower than that of water.

| Density greater than that of water | Density lower than that of water |
|--|---|
| <ul style="list-style-type: none"> • Honey • | <ul style="list-style-type: none"> • Kerosene • |

Table 1.7

Density of water is 1000 kg/m^3 . Densities of other substances are often stated in relation to the density of water. Relative density of a substance denotes how many times the density of water is the density of the substance. Kerosene's density is less than that of water. How many times the density of water is the density of kerosene? Shall we find this out?

For this, all that is to be done is 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?

$$\begin{aligned}\text{Relative density of kerosene} &= \frac{\text{Density of kerosene}}{\text{Density of water}} \\ &= \frac{810 \text{ kg/m}^3}{1000 \text{ kg/m}^3} = 0.81\end{aligned}$$

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

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

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

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

You might have studied in your lower classes how to make a lactometer. A hydrometer can be made in the same manner. The working of both devices is based on the principle of flotation.

Using the hydrometer you have made, find out liquids of greater and lower density 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 a hydrometer is dipped in a liquid of density greater than that of water. Will the liquid surface be above or below the marking '1'?
- In which will the hydrometer sink deeper? In liquids of greater density or lower density?
- Why do the markings on the hydrometer increase towards the bottom?

Have you seen how the quantity of water in milk is measured?

Lactometer is an instrument used for this purpose.

Lactometer, which is a device to test the purity of milk, is basically a hydrometer. Adulteration of milk is an offence.

Adulterated milk harms our health.



Hydrometer
Fig. 1.8



Lactometer
Fig 1.9



Fig 1.10

Pascal's Law

Razing hills and filling up of paddy fields with an excavator is a common sight.



Excavators are meant to help in environmental protection & disaster management. But are they becoming moving forces behind the ruin of environment?

Arrange a debate in your class on this, based on the trends seen in your surroundings.

Fig 1.11

Such activities which are harmful to the environment and biodiversity need to be controlled. Before the introduction of the excavator, earth moving was a strenuous job. But it became easy when the excavator came into 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 toothpaste 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.



Fig 1.12



Fig 1.13

- Does water come out from all the holes?

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

Let's do another activity.



Blaise Pascal

Blaise Pascal was born in France on 19th 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 initiating 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.

Take a plastic bag without holes and fill it with water. Tie its mouth tightly so that no air gets inside. Make holes on different parts of 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 throughout the 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.

Can we reduce the volume of a liquid by applying pressure?

- Fill a syringe with water, close its end and press the piston. Is there any change in the volume of water?

Volume of a liquid cannot be changed using pressure. This is the basis of Pascal's Law.

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
-

Let's do an activity to understand how heavy loads are lifted using hydraulic jacks.

Fill two identical syringes with water. Connect them with a plastic tube. Then arrange them as shown in Fig.1.14.

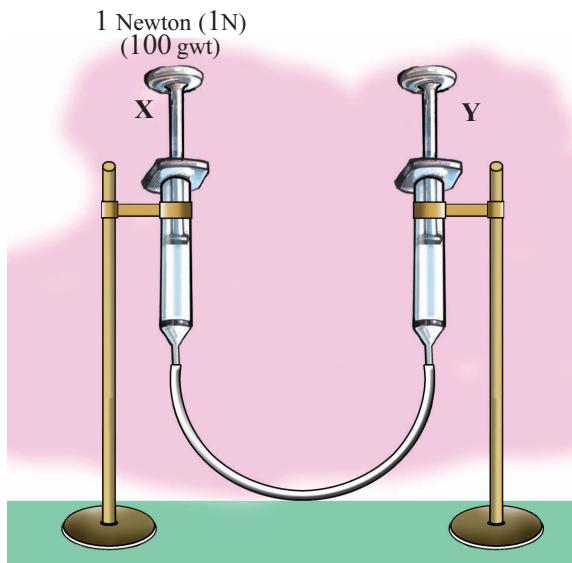


Fig 1.14

- 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 a weight of 1N at the end Y as well. What do you observe now? Then replace the syringe X with one having slightly smaller diameter and repeat the activity.
- Are you able to balance with 1N (100 gwt) 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 the figure.

It is the figure of a hydraulic jack. Two cylinders of different area of cross section, filled with water, are connected using a pipe.

A_1 is the area of cross section of the smaller piston and A_2 , that of the bigger one.

When a force F_1 is applied on the piston X, a force F_2 will be experienced on the piston Y. Then according to Pascal's Law, pressure applied on the side X will be equal to the pressure experienced on the side Y.

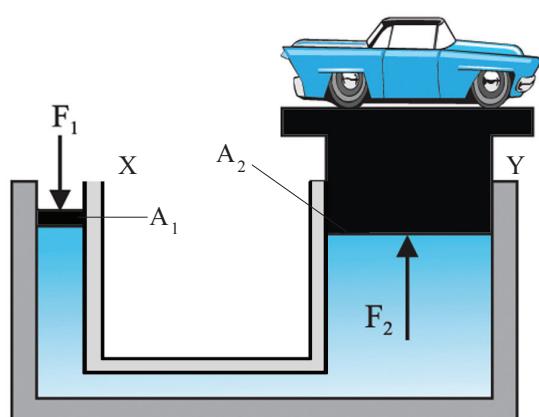
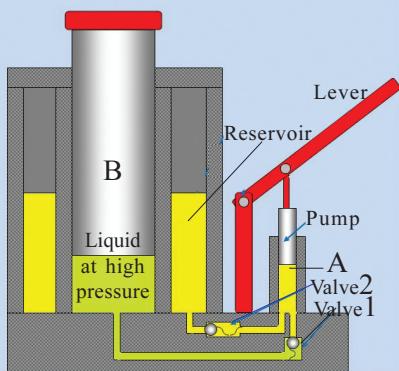


Fig. 1.15



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 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 will be lifted



$$\text{So } P_x = P_y$$

$$\text{since } P = \frac{F}{A}$$

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

$$F_2 = \left[\frac{A_2}{A_1} \right] F_1$$

If the area of cross section of the second piston is 100 times that of the first piston

$$A_2 = 100A_1 \text{ Therefore } \frac{A_2}{A_1} = 100 \quad F_2 = 100F_1$$

That means, the large piston will experience a force of 100 N when a force of 1N is applied on the small piston. The amount of work done on the two sides of the tube is equal. Therfore if the section Y is to be raised by 1 cm, the section X has to be lowered by 100 cm. Isn't it so?

How is it useful?

List down some devices constructed on the basis of Pascal's Law. Explain them on the basis of the above principle and write it in your science diary.

Let's try to solve a problem related to Pascal's Law.

- Two tubes of different area of cross section filled with a liquid are connected. The area of cross section of small pipe is 0.0001256 m^2 (4 cm in diameter) and that of the large one is 0.020096 m^2 (16 cm in diameter). Calculate the pressure experienced on the large piston if a force of 10 N is applied on the small piston.

If the pressure is transmitted without any loss.

$$\text{According to Pascal's Law, } F_2 = \frac{A_2}{A_1} \times F_1$$

$$\therefore F_2 = \frac{0.020096}{0.001256} \times 10 \\ = 16 \times 10 = 160 \text{ N}$$

Construct a simple model of hydraulic jack using syringes of different sizes and exhibit it in the classroom.

Do you think a liquid will rise only when an external force is applied?

Examine the situations given below.

- A piece of chalk is used to blot ink.
- In a kerosene lamp, kerosene rises through the wick.
- In rainy season dampness spreads on walls.
- Cotton cloth absorbs sweat.

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

Capillarity

Take two boiling tubes, one containing water, and the other, mercury. Dip a capillary tube into each.

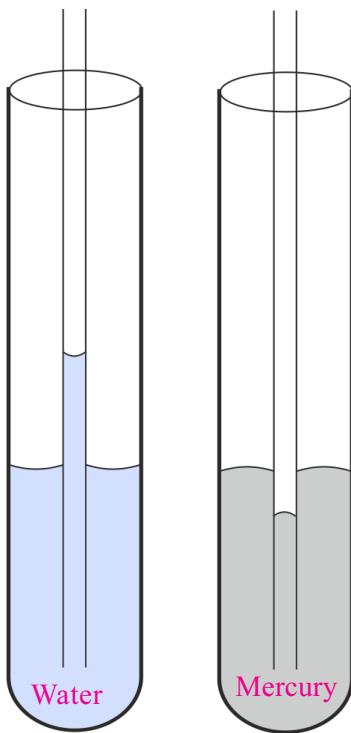


Fig 1.16

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 is known as 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 phenomena of capillary rise and depression?

Observe the figures



Fig. 1.18

- Why are some insects able to move along the surface of water?
- Why does a paper clip remain afloat on the liquid surface?
- Is the liquid surface stretched like a membrane?

Due to the mutual attraction of the molecules on the surface of water, the surface is stretched like a membrane. The force responsible for this is called surface tension.

Aren't all the above due to surface tension?

Place a razor blade afloat on the surface of water as shown in Fig.1.19. If we touch the water surface with a piece of soap, what will happen? How will you explain the change that has taken place?

When the soap touched the water surface, the surface tension decreased and the blade had moved to one side.

Place two drops of mercury side by side on a glass paper. Using a pencil, bring them close to each other. What do you observe?

- Aren't the molecules of the two drops of the same substance?
- The two liquid drops coalesce to form a single drop due to the attraction between the molecules of the same substance.

The attraction between the molecules of the same type is called cohesive force.

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.

In all these situations, why do two substances stick to each other?

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

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

Write down in your science diary more examples of adhesive and cohesive forces from your day to day life.

Observe the molecules on the surface of the water in Fig. 1.20.

- What are the different types of forces acting on the water molecules in contact with the sides of the vessel?
- What about the forces acting between molecules on the water surface?
- Why did the molecules of water in contact with the sides of the vessel rise slightly higher than the others?



Fig 1.19



9SRDS9

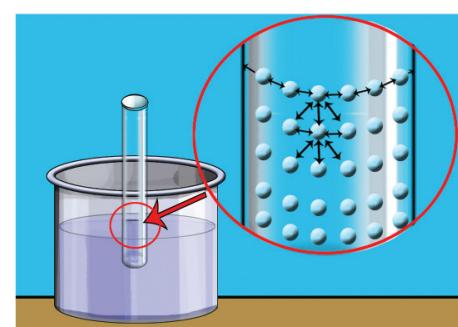


Fig. 1.20

- What will be the direction of the resultant force on a molecule in the water surface?
- What is the reason for the water surface to behave like an elastic membrane?
- Which attractive force between the molecules is responsible for the surface tension that causes the water 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 cardboard piece as shown in the figure. Dip the capillary tubes in water. Compare the capillary rise in the tubes.

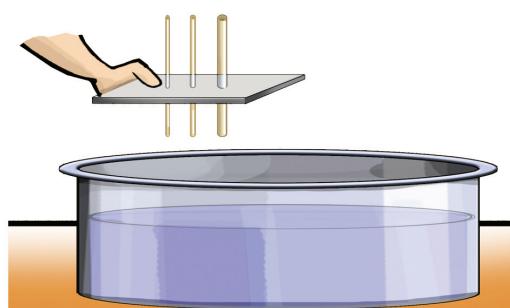


Fig. 1.21

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

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 surfaces it comes into contact with. 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 inside the tube.

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?

Viscous force

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

Place one drop each of kerosene, water, glycerin and honey at various points along a straight 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.

- Water flows faster than honey.
-

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

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

Observe the figure.



Fig. 1.22

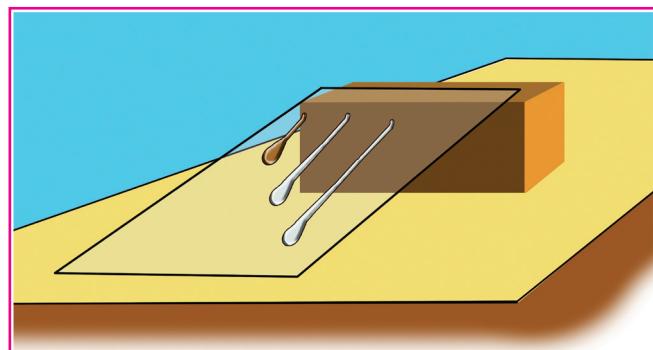


Fig. 1.23

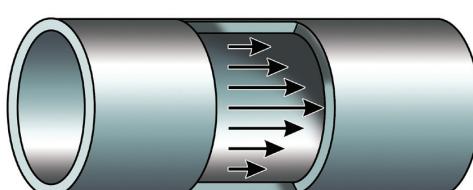


Fig. 1.24 (a)
Water flowing through a pipe

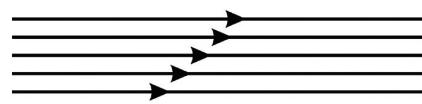


Fig. 1.24 (b)
Water flowing through a plane surface

The variation in speed between the layers of liquid is because every layer of liquid opposes the flow of the layer in contact with it.

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 oppose the relative motion between its different layers.

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

| Greater viscosity | Lower viscosity |
|---|--|
| <ul style="list-style-type: none"> • Honey | <ul style="list-style-type: none"> • Kerosene |

Table 1.8

Liquids of greater viscosity are the viscous liquids, and those of very lower 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 the body of the person.

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

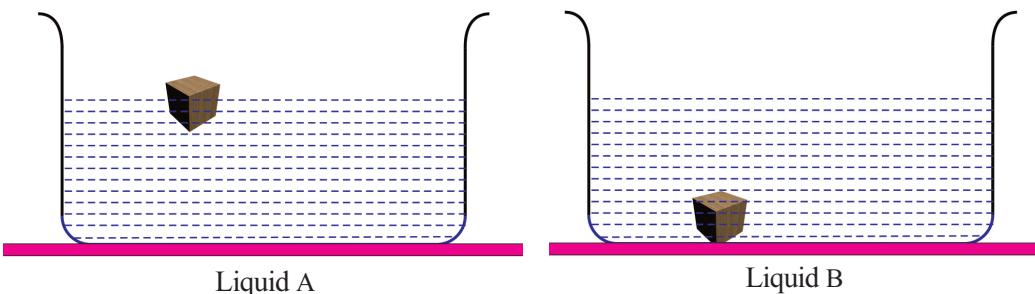
When temperature increases, the viscosity of a liquid decreases.

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 reverts to normal level. The person thus overcomes the dangerous situation.



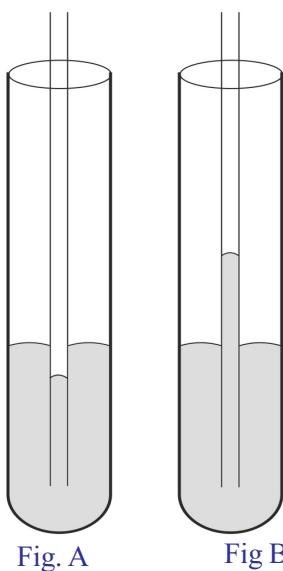
Let us assess

- 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.
- A body, which floated in water, sank when put in kerosene. Why did it happen?
- Observe the figures of an object placed in different liquids.



- Compare the gravitational force and the buoyancy acting on the body when it is in the liquids A and B.
- Among A and B, which is the liquid whose density is greater than that of the object? Why?
- A body of weight 1000 N sinks in water. The weight of the liquid overflowed is 250 N.
 - What will be the weight of the body in water?
 - 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?
- 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 was 20000 N. What was the force applied on the liquid at the first end?
- Write down the reason for the following:
 - Ink can be blotted with chalk.
 - Sweat can be blotted with tissue paper.

7. Identify the correct figure. Give the reason.



8. A hydraulic lift has been constructed to lift vehicles of maximum 3000kg weight. The area of crosssection of the piston's platform on which the vehicles are lifted is 580sq cm. Calculate the maximum pressure experienced on the small piston.



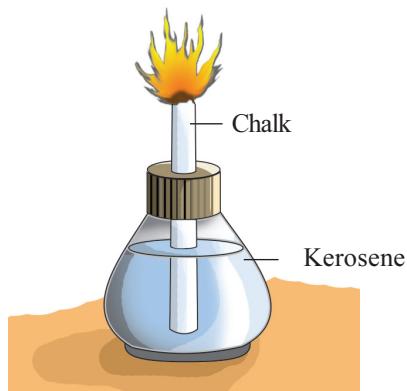
Extended activities

1. Prepare a table of substances of less density than that of water.
2. Place a sewing needle in such a way that it floats 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 whether the liquids are adulterated.
5. Using syringes and rubber tubes of different sizes, make models of hydraulic lifts and exhibit them.
6. Collect capillary tubes of different diameters. Find the capillary rise and depression of different liquids and record them.
7. Collect different types of soil and find out their water absorbing capacity. Record your findings.

8. An egg is placed in water. Will it be possible to retain it at the same place? Find out through an activity.
9. We light lamps using wicks made of cotton cloth. How does the oil rise up along the wick?

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

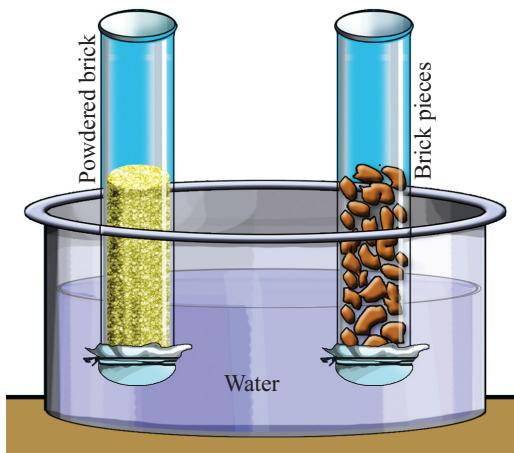
Make a kerosene lamp as shown in the figure and light it up.



10. Why is the land ploughed before the beginning of summer?

Does it have any relation to capillary rise?

Let's do an activity.



Take two glass tubes of diameter 4 cm each. 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 small pieces of the brick. Dip these glass tubes in a trough of water. Observe what happens after sometime.

- 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 put into practical use.



2

Equations of Motion



Can you clear the doubt raised by the girl?

Lets try.

Fig 2.1 depicts the velocity of a freely falling stone at each second.

What information do you get from the table regarding the motion of the freely falling stone?

(For the sake of convenience, the change in velocity of a freely falling stone is approximated to 10 m/s^2 instead of 9.8 m/s^2)

Complete the table using the data given in fig. 2.1.

| | | | | |
|--------------|---|----|--|--|
| Time s | 0 | 1 | | |
| Velocity m/s | 0 | 10 | | |

Table 2.1

| Time | Velocity |
|------|----------|
| 0 s | 0 m/s |
| 1 s | 10 m/s |
| 2 s | 20 m/s |
| 3 s | 30 m/s |
| 4 s | 40 m/s |

Fig 2.1

How much is the initial velocity (u) of the stone here?

What about its final velocity (v) ?

Can you find out the acceleration of the stone in 4 s ?

$$\text{Acceleration (a)} = \frac{\text{Change in velocity}}{\text{time}}$$

$$\text{i.e. } a = \frac{v-u}{t}$$

Find out the acceleration and write it in your science diary.

Formulate the equation for final velocity v from the equation for acceleration.

$$\text{Final velocity } v = u + at$$

This is known as the **First equation of motion.**

Here we have made use of a figure to show the data related to the motion of a stone. Mention any other methods that are employed to show the relationship between various data.

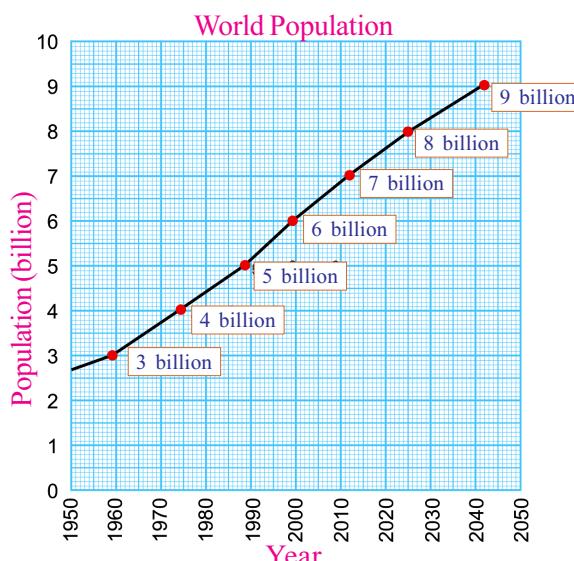
Observe the graphs given below. One is related to the increase in population and the other performance of a cricket team. [fig 2.2(a), fig 2.2(b)]

What are the information linked in each graph?

Graph-1 → population, year

Graph 2 →

What all information do you decipher from each graph?



Graph (1)

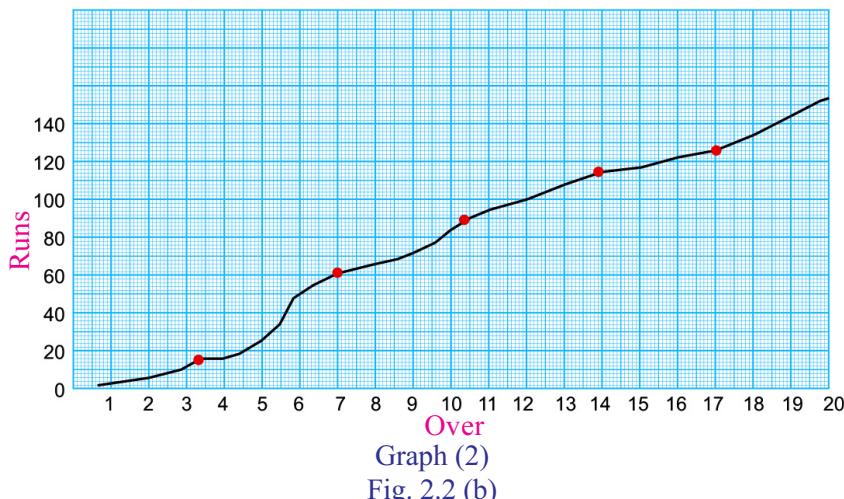
Fig 2.2 (a)

For eg. from the Graph (2) we can understand several things like how many runs the team scored in each over and which is the best over.

Similarly write down in your science diary the information you get from the Graph (1).

Motion - Graphic representation

In the same way can we represent information related to the motion of an object through a graph? For this we should know some basic facts about graphs.



What is a graph?

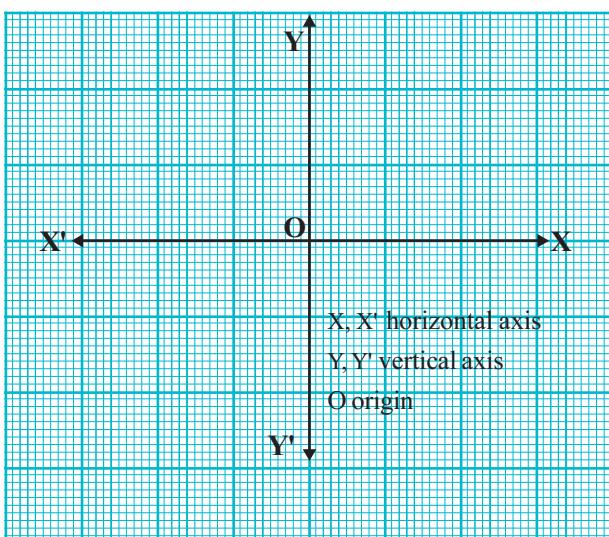


Fig. 2.3

This is a two dimensional diagram. It can be depicted connecting two values. A graph will have 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 the positive X axis (OX) and to the left is the negative X axis (OX'). In a similar way OY and OY' are considered as positive and negative axes respectively in the Y axis.

What is the use of a graph?

We can depict the relation between quantities using a graph. Based on this, equations connecting them can be formulated. Gaining information using a graph is more simple than obtaining it by mathematical calculation. How can these uses be made practical?

Position time graph

On a graph paper draw the axes X'OX and Y'OY. Here X axis can be used for marking time and Y axis for position. Mark the values given in Table 2.2 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 2.2

This graph is known as position - time graph. While naming a graph, value on the Y axis will be given first and the value on the X axis, second, connected with a hyphen.

- Using the data given draw a position – time graph



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

Table 2.3

From a position-time graph, how will you find out the position of an object at a particular time?

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

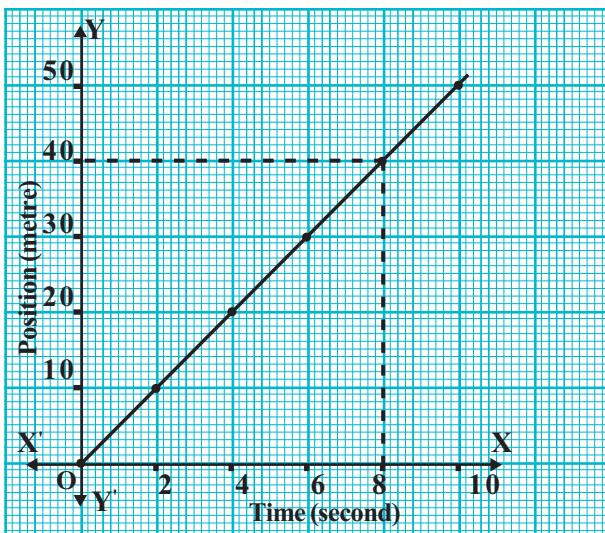


Fig. 2.4

- Draw a perpendicular to the position – time graph at the eighth second. Doesn't this meet the graph at a point? From the point where the perpendicular meets the graph, draw another perpendicular to the Y. The value represented by the point at which this perpendicular meets the Y-axis is the displacement. Can we find the distance from the graph?

The distance covered by the car in 8 second = _____ m

- Complete Table 2.4 using the data from the following position-time graph related to the motion of a car.

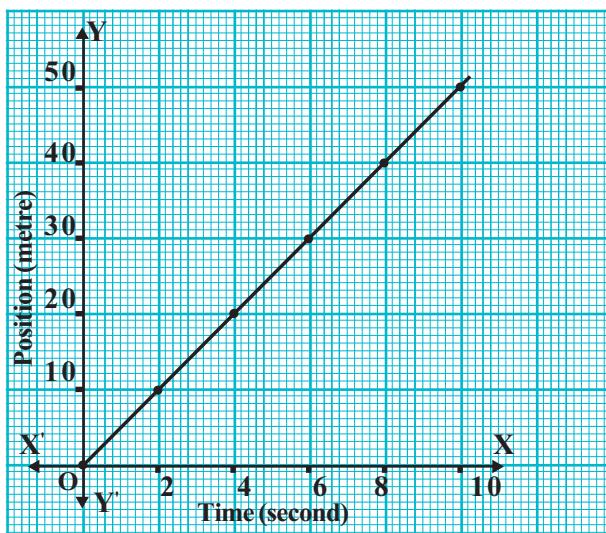


Fig. 2.5

| | | | | | | |
|----------------|---|----|----|---|---|--|
| Position (m) | 0 | 2 | - | 6 | 8 | |
| Velocity (m/s) | 0 | 10 | 20 | - | - | |

Table 2.3

Change the scale used in the graph in fig. 2.5 and draw another graph in the graph in fig. 2.6.

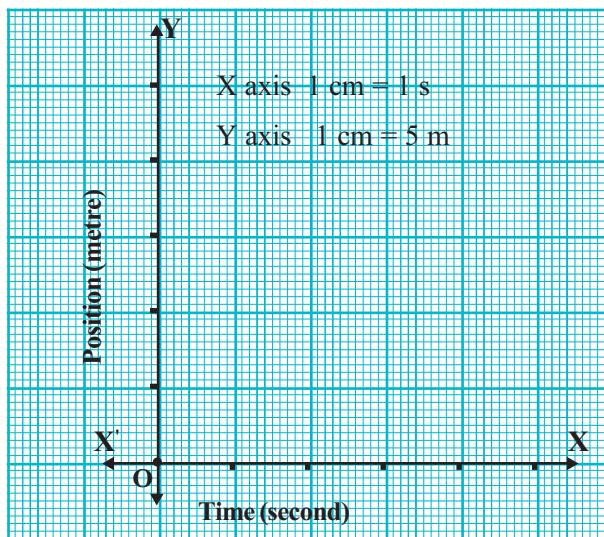


Fig. 2.6

Compare the graph drawn in fig. 2.6 with the graph in fig. 2.5. What change do you see?

From each graph, find out the displacement of the body in 5 s. Is there any change in the values?

We use scales while drawing a graph, to contain the given measurements on a graph paper. The size of the graph decreases as we increase the scale considered. But the value doesn't change.

Motion of a car is shown below using a diagram.

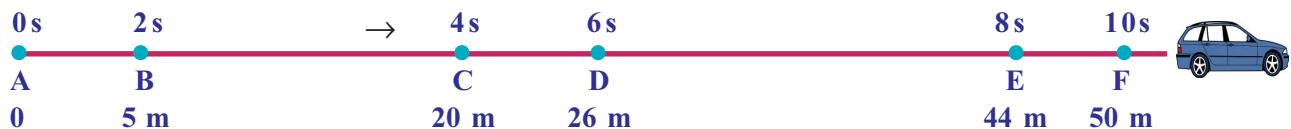


Fig. 2.7

Complete the table with the help of the figure.

| | | | | | | |
|--------------|---|---|------|------|------|------|
| Time (s) | 0 | 2 | 4 | 6 | 8 | 10 |
| Position (m) | 0 | 5 | | | | |

Table 2.5

Complete the position- time graph of the moving car on the basis of the table.

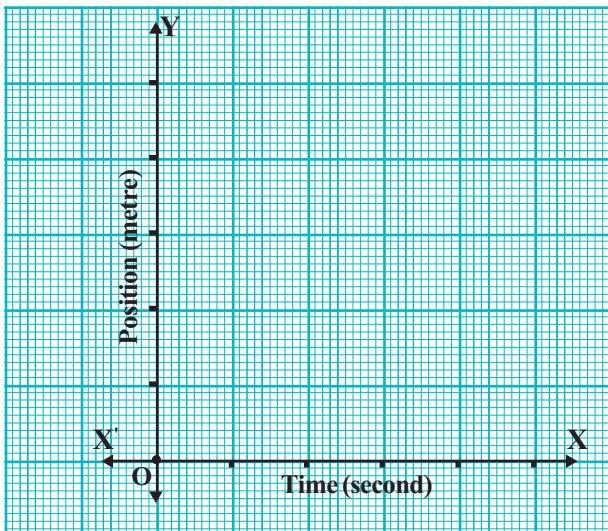


Fig. 2.8

The graph you got from Fig 2.8 and the graph you have drawn using Table 2.2 are position -time graphs. Is there any difference between these two graphs?

Position - time graph of a body moving with uniform speed will be a straight line. The body will be moving with non uniform speed when the graph is not in a straight line.

- Using the graph find out the displacement of the car in 3 s
- From the graph find out the time taken by the car to travel a distance of 45 m.

Velocity – time graph

| | | | | | | |
|----------------|----|----|----|----|----|----|
| Time(s) | 0 | 2 | 4 | 6 | 8 | 10 |
| Velocity (m/s) | 10 | 10 | 10 | 10 | 10 | 10 |

Table 2.6

With the given data in the table, draw a velocity-time graph.

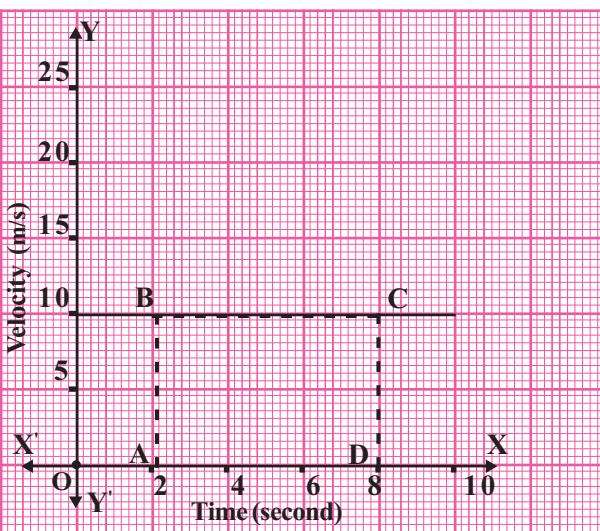


Fig. 2.9

Can you find out from the graph the displacement of the object between the 2nd and 8th second?

$$\text{We know that, Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

Therefore displacement = velocity \times time

In the graph it is equal to AB \times AD (area of ABCD). This is equal to the area of the portion under the part BC, of the graph.

Displacement of a body within a definite interval of time is equal to the area of the portion under velocity-time graph.

You might have understood that displacement, velocity etc can be found out from a graph.

Another use of graph is derivation of equations. Let's try to understand how equations of motions can be derived from a graph.

Draw a velocity-time graph with the completed Table 2.1, based on the motion of a freely falling stone.

Equations of motion

The velocity – time graph of an object travelling with uniform acceleration (freely falling stone) is given below.

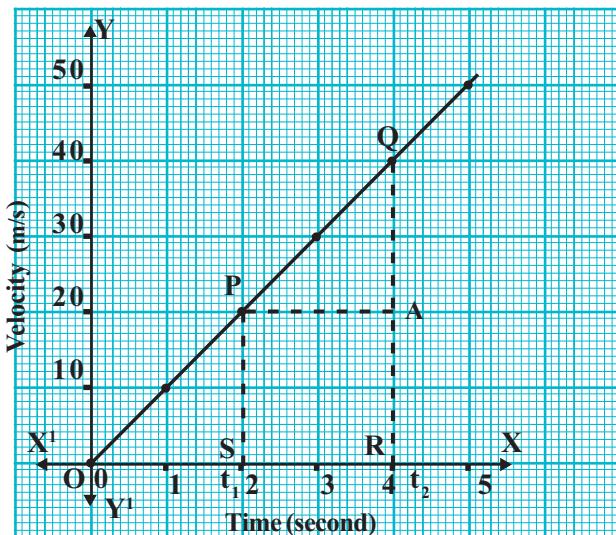


Fig. 2.10

- Draw perpendiculars from t_1 and t_2 to the graph. They meet at points P and Q respectively.
- Draw another perpendicular to QR from P. It meets at A. Consider the trapezium PQRS.

Let u be the velocity of the body at time t_1 , and v be that at time t_2 . In the graph the points P and Q correspond to u and v respectively.

$$PS = AR = u$$

$$QR = v$$

$$SR = t = t_2 - t_1$$

$$\begin{aligned} AQ &= QR - AR \\ &= v - u \end{aligned}$$

Equation showing velocity – time relation

How do we find acceleration from a graph?

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

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{time}}$$

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

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

$$\text{Then acceleration } a = \frac{v-u}{t}$$

$$\text{So } at = v - u$$

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

Equation showing Position -Time relation

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 2.11 is one such quadrilateral obtained.

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

Quadrilateral 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.

$$\begin{aligned}\text{Displacement} &= \text{area of trapezium PQRS} \\ &= \frac{1}{2} SR (PS + QR)\end{aligned}$$

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

$$\begin{aligned}\text{Displacement} &= \frac{1}{2} t (u + v) \\ &= \frac{1}{2} t (u + u + at) \\ &= \frac{1}{2} t [2u + at] \\ &= \frac{1}{2} t \times 2u + \frac{1}{2} t \times at \\ &= ut + \frac{1}{2} at^2\end{aligned}$$

$s = ut + \frac{1}{2} at^2$. This is known as Second Equation of Motion.

Equation showing position – velocity relation

Let's now find out the third equation of motion.

From the given graph, the displacement = The area of the quadrilateral

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

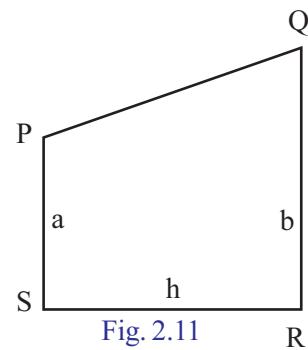


Fig. 2.11

Acceleration of the body $a = \frac{v-u}{t}$ from this, $t = \frac{v-u}{a}$

Substituting this in the above equation

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

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

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

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.

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

Let's now consolidate the equations of motion.

| |
|-----------------------------|
| $v = u + at$ |
| $s = ut + \frac{1}{2} at^2$ |
| $v^2 = u^2 + 2as$ |

These equations are applicable only to uniformly accelerated motion.

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

$$\text{Velocity at the 4th second } u = 20 \text{ m/s}$$

$$\text{Velocity at the 8th second } v = 40 \text{ m/s}$$

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

$$\begin{aligned} \text{Distance travelled } s &= ut + \frac{1}{2} at^2 \\ &= 20 \times 4 + \frac{1}{2} \times 5 \times 4^2 \\ &= 80 + 40 = 120 \text{ m} \end{aligned}$$

- A car came to rest when brake was applied for 4 s to get a retardation of 3 m/s². Calculate how far the car would have travelled after applying the brake.

$$a = -3 \text{ m/s}^2$$

$$t = 4 \text{ s}$$

$$v = 0$$

$$v = u + at$$

$$-u = -3 \times 4 + 0$$

$$u = 12 \text{ m/s}$$

Displacement of the car

$$\begin{aligned}s &= ut + \frac{1}{2} at^2 \\&= (12 \times 4) + \frac{1}{2} (-3) \times 16 \\&= 24 \text{ m}\end{aligned}$$

- If the velocity of a car moving with uniform velocity changes from 20m/s to 40 m/s in 5 s
 - What is the acceleration of the car?
 - What is the displacement by the car during this time interval?
 - $u = 20 \text{ m/s}$, $v = 40 \text{ m/s}$, $t = 5 \text{ s}$

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

Displacement of the car $s = ut + \frac{1}{2} at^2$

$$\begin{aligned}&= 20 \times 5 + \frac{1}{2} \times 4 \times (5)^2 \\&= 150 \text{ m}\end{aligned}$$

- If the velocity of a train starting from rest becomes 72 km/h in 10 minute.
 - What is its acceleration?
 - Calculate the distance travelled by the train within this time interval.

a) Here, $u = 0$, $v = 72 \text{ km/h} = \frac{72 \times 1000}{60 \times 60} = 20 \text{ m/s}$

$$t = 10 \text{ min} = 600 \text{ s}$$

$$\text{Acceleration } a = \frac{v-u}{t} = \frac{20 \text{ m/s} - 0}{600} = \frac{1}{30} \text{ m/s}^2$$

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

$$(20)^2 = 0^2 + 2 \times \frac{1}{30} \times s$$

$$400 = \frac{1}{15} \times s$$

$$s = 400 \times 15 = 6000 \text{ m} = 6 \text{ km}$$

- A car starting from rest travels 100 m in 5 s with uniform acceleration. Find the acceleration of the car.
- An object starting from rest travels with an acceleration of 5 m/s^2 . What will be its velocity after 3 s?

Complete Table 2.7 using the graph (fig 2.10) shown below. Compare displacement and area at different stages.

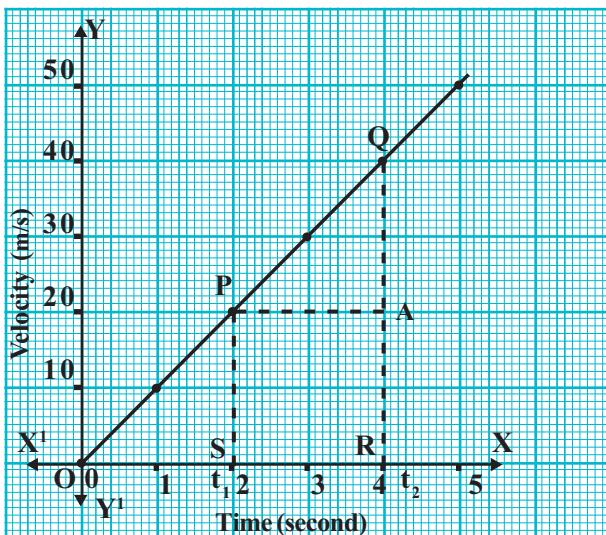


Fig. 2.12

| Displacement | Area |
|---|---|
| Displacement of the object in the first two second. $s = ut + \frac{1}{2} at^2$ $= 0 \times 2 + \frac{1}{2} \times 10 \times 2^2$ $= 20 \text{ m}$ | Area of ΔOSP $= \frac{1}{2} bh = \frac{1}{2} OS \times PS$ $= \frac{1}{2} \times 2 \times 20$ $= 20 \text{ m}$ |
| Displacement of the object in the first four second. $s = ut + \frac{1}{2} at^2$ $= 0 \times 4 + \frac{1}{2} \times 10 \times 4^2 = 80$ | Area of ΔORQ $= \frac{1}{2} bh = \frac{1}{2} OR \times QR$ $= \frac{1}{2} \times 4 \times 40$ $= 80 \text{ m}$ |
| The displacement of the body between the 2 nd and 4 th second. $s = \dots$ $= \dots$ $= \dots$ | Area of trapezium SPQR = Area of SPQR + Area of ΔPAQ $= \dots$ $= \dots$ $= \dots$ |

Table 2.7

In a velocity - time graph when we draw perpendiculars to the graph from the time specified, we get a geometrical shape. The area of this geometrical shape will give displacement in the specified time interval.

Now you must have understood the answer to the problem we raised at the beginning of this chapter. The height of the coconut tree will be equal to the displacement of the coconut. If the time taken by the coconut to reach the ground is 2 second, the height of the coconut tree will be 20 m.



Let us assess

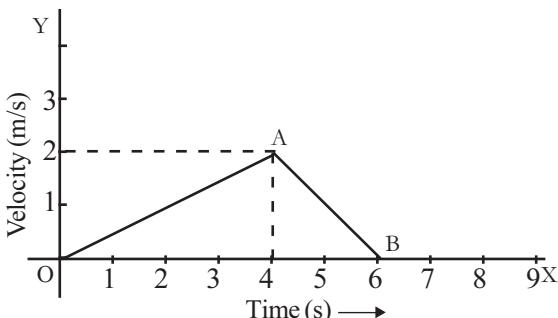
1. Draw position - time graph.

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

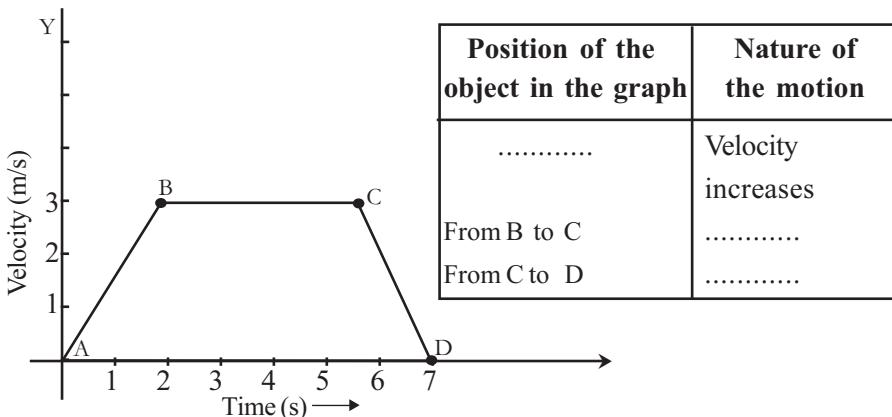
2. Draw speed - time graph

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

3. Examine the graph and answer the following questions.

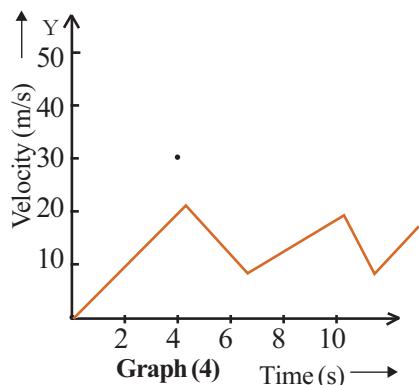
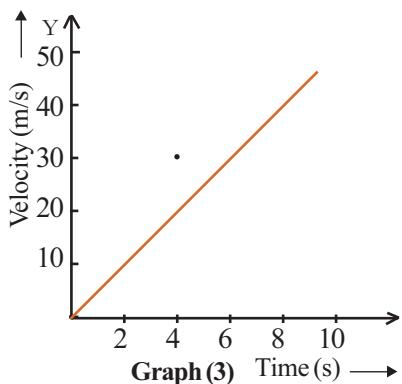
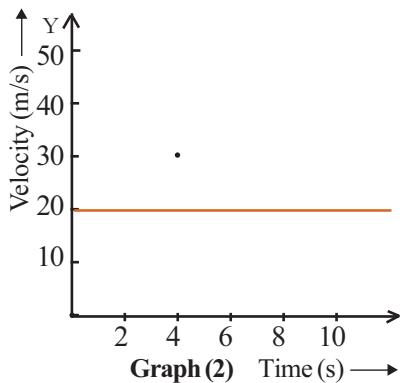
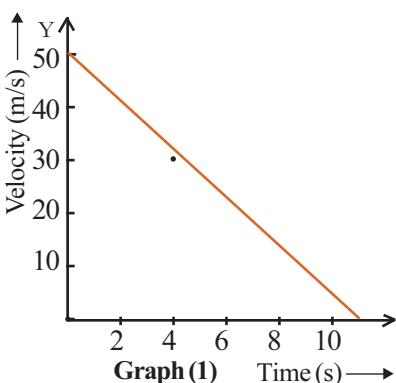


- a) Is the motion of the object uniform/ non uniform?
 b) Say whether the acceleration from O to A is uniform? What about from A to B?
4. Complete the table by analysing the graph.



5. If the velocity of a train which starts from rest is 72 km/h (20 m/s) after 5 minute, find out its acceleration and the distance travelled by the train in this time.
 6. A car attains a velocity of 54 km/h (15m/s) within 5 seconds from an initial velocity of 18 km/h (5m/s). Calculate its acceleration and displacement.

7. Analyse the graphs given below.

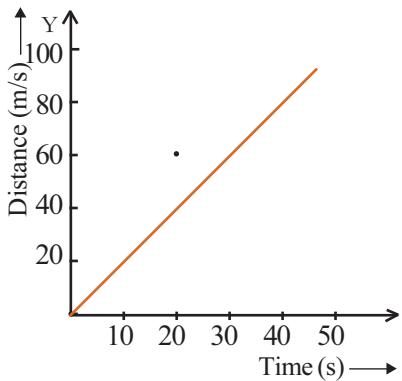


- Which graph indicates uniform velocity?
- Which graph indicates non uniform acceleration?
- Which graph indicates the motion of a freely falling stone?



Extended activities

- Distance-time graph of a moving car from rest is given. Draw the velocity- time graph related to the motion of this car and note down the peculiarities.



3

Motion and Laws of Motion



Observe the movement of the children in the picture. Have you ever thought of the forces causing their motions? Why do the children sliding from a height in the ride go up again? Do all the movements need force? If not, what are the common characteristics of such motions?

Let's find out.

Unbalanced external force and motion

Observe the figures.

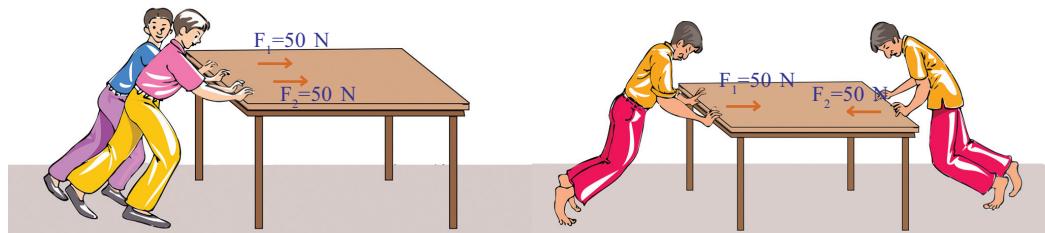


Fig. 3.1

Two boys are pushing a table towards the same direction from the same side.

Fig. 3.2

Two boys are pushing the table from opposite sides with equal force.

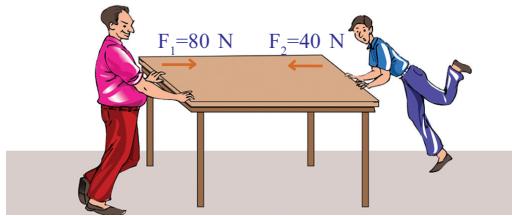


Fig. 3.3
Two persons are pushing the table from opposite sides with unequal force.

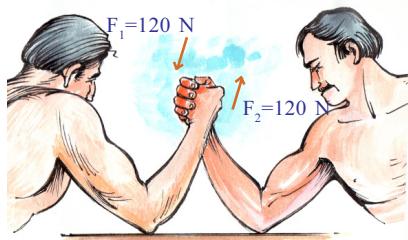


Fig. 3.4
When equal forces are applied in arm wrestling.



Fig. 3.5
When one side wins.

Find the total force acting on the body in each situation above and complete the table. (Force is a vector quantity. So, when force is acting in different directions, force in one definite direction is taken as positive and force in the opposite direction is taken as negative)

| Fig. No. | F_1 newton (N) | F_2 newton (N) | Total Force/ Resultant Force |
|-----------------|--|--|---|
| Fig. 3.1 | 50 | | |
| Fig. 3.2 | 50 | -50 | Zero |
| Fig. 3.3 | | | 40 |
| Fig. 3.4 | 120 | | Zero |
| Fig. 3.5 | | | |

Table 3.1

Examine the table

- In which of the situations depicted in the figures, did the total applied force become zero?
- Does the body move in all these situations?

Such forces are called balanced forces.

If the total force or the resultant force on a body is zero, the applied forces are called balanced forces. Such forces can neither move a body at rest nor stop a body in motion.

- From the table find out the situations where resultant force is not zero?
- Do the objects move in such situations?

Write down your opinion in the science diary. Frame a definition for the unbalanced forces.

.....
.....



Fig 3.6

Observe the activity given below.

Fix two pulleys on either side of a table. Place a wooden block in between the pulleys. Attach two strings on either side of the wooden block. Allow the strings to pass over the pulleys. From the free ends of the strings suspend equal weights. What do you observe as more weights are added? What is your observation about the force and the motion of the wooden block? Write down your observations in the science diary.

- When equal weights are suspended on either sides, is the force on the wooden block balanced or unbalanced?
- Will the wooden block move in the above situation?
- Add more weight to one side. Is the force balanced or unbalanced now? Is there any movement for the wooden block?
- If more weights are added gradually, what will be the change in the speed of motion of the wooden block ? Increases/ decreases.
- By gradually increasing weight to the side having lower weight ,can you change the present direction of motion of the wooden block?

What do you understand from the above observation?

When an unbalanced force is applied on a body, there will be a change in its state of rest or the direction of motion or speed.

So we have seen that unbalanced forces can cause motion. But can all unbalanced forces cause motion? Let's examine.



Fig. 3.7

- What will be the result when a man tries to move a vehicle by pushing it, standing inside the vehicle as in the figure? The vehicle moves/ the vehicle doesn't move

What if the same vehicle is pushed from outside?

- Will it be possible to lift a chair while seated on it? It can be lifted only when we press our feet on the ground.

Haven't you realised that internal force cannot move an object, but only an external unbalanced force can cause its motion? But does a body need unbalanced external force for it to continue in the state of uniform motion along a straight line? The scientist Galileo conducted studies on this topic and explained it based on his experiments and observations.

Observations of Galileo

Two smooth surfaces are arranged with same slopes as shown in the figure. A ball is allowed to roll down from a definite height along the surface A. The ball is seen to attain a definite speed when it reaches the bottom.

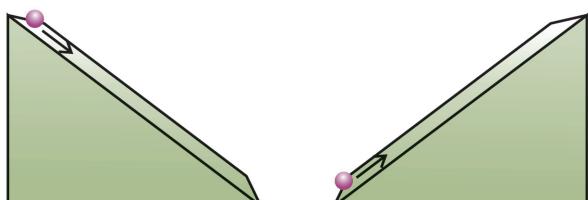


Fig. 3.8 (a)

- What happens to its speed when it rolls upwards along the surface B?
- What do you observe when the slope of this surface is reduced?
- The ball reaches the same height every time the slope is reduced. Doesn't this mean that the ball will have to travel a longer distance as the slope is reduced? See Fig. 3.8(b).
- Doesn't the ball have to move infinitely, when the surface is made horizontal (when the slope is zero)? In that case, wouldn't the motion of the ball continue indefinitely?

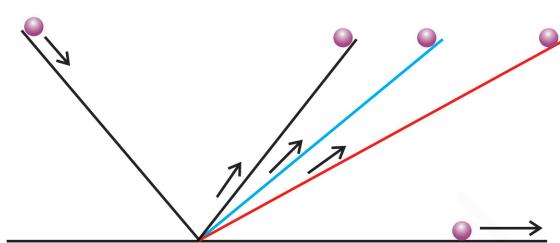


Fig. 3.8 (b)

We can use wiring channels to do this experiment of Galileo. In the experiment it



is seen that the ball comes to rest instead of continuing its state of motion indefinitely. Which is the force responsible for this? In the absence of this force, the ball would have continued indefinitely in its uniform motion along a straight line.

A body in motion doesn't need an external unbalanced force for it to continue in its state of rectilinear uniform motion.

Newton formulated his laws of motion as a continuation of Galileo's observations.

Newton's First Law of Motion

An unbalanced external force is needed to change the state of rest or of motion of an object. If so, wouldn't a body remain in its state of rest or of uniform motion unless an external force acts on it. These inferences led Newton to his First Law of Motion.

Every object continues in its state of rest or of uniform motion along a straight line unless an unbalanced external force acts on it. This is Newton's First Law of Motion.

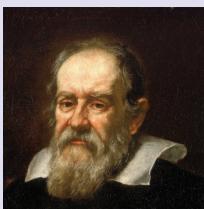
Newton's First Law explains some common tendencies of bodies at rest and in motion. Let's try to understand this through some activities.

Place a bottle filled with water on a thick rough paper as shown in the figure. Pull the paper suddenly to one side. What do you observe?

- Wasn't the bottle at rest before the paper was pulled out?
- When you pull the paper, doesn't the top of the bottle show a tendency to remain at rest?
- Isn't the bottom of the bottle gaining motion because of the friction between the paper and the bottle? If the experiment is repeated with a smooth paper it will be seen that the bottle continues to remain at rest.

Galileo Galilei (1564- 1642)

Galileo was a scientist who proved his mastery in different fields of science. He showed great interest in Mathematics and Natural Science even when he was a child. He joined Pissa University as a medical student to fulfil his father's wish.



He conducted studies on Aristotle's argument that heavier objects will fall down faster. Through his experiment from the Leaning Tower of Pisa he proved that the arguments of Aristotle were wrong. He wrote his first scientific book "The Little Balance" between 1585 and 1592. He proved that the distance travelled by bodies with uniform acceleration is directly proportional to the square of the time. During his time, Galileo's telescope was the most powerful one. He was able to detect the satellites of Jupiter as well as their rotation through continuous observation using his telescope. He used his telescope to observe the rings of Saturn and stars of the Milky Way. His works are 'Starry messenger' about sky observation, 'Discourse on floating bodies' and 'Letters on Sunspots' about Sunspots.



Fig. 3.9

This tendency is known as inertia of rest.

Inertia of rest is the tendency of a body to remain in its state of rest or its inability to change its state of rest by itself.

Do moving objects also have such tendencies? Let's find out.

Place the bottle used in the above experiment on a thick paper with rough surface. Bring the bottle into motion by pulling the paper slowly. Gradually increase the speed of pulling. Stop pulling when the bottle gains a certain speed. What do you observe?

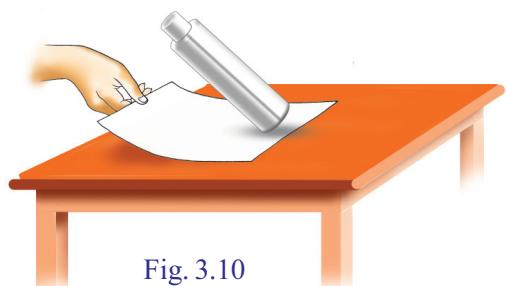


Fig. 3.10

- Wasn't the bottle in a state of motion before you stopped pulling the paper?
- Didn't the top of the bottle show a tendency to continue its motion, when you stopped pulling the paper?
- The bottom of the bottle comes to rest because of friction. The bottle would continue in its state of motion if the experiment is repeated with a paper having smooth surface.

This tendency is known as inertia of motion. Try to define inertia of motion.

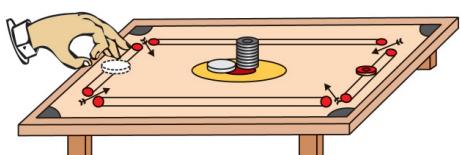


Fig. 3.11

Discuss the following situations and find out the reasons .

- Arrange some carrom board coins one on top of the other. Strike the bottom coin forcefully with a striker. What do you observe? Explain on the basis of inertia.
- When a moving bus is suddenly stopped, the standing passengers tend to fall forward.
- When a bus moves forward suddenly from rest, the standing passengers tend to fall backward.
- Accidents that happen to passengers who do not wear seat belts are more fatal.

Inertia of rest and inertia of motion are generally named as Inertia.

How can we define inertia then?

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

Find out more examples of inertia and complete the table.

| Inertia of rest | Inertia of motion |
|---|--|
| <ul style="list-style-type: none"> When the branch of a mango tree is shaken, mangoes fall just as when the branch starts moving. • | <ul style="list-style-type: none"> A running athlete cannot stop himself abruptly at the finishing line in a race. • |

Table 3.2

Let's try to understand how mass of a body influences the property of inertia.

Mass and Inertia

- It is dangerous for loaded vehicles to negotiate curves in the road without reducing the speed. What may be the reason?

It is more difficult to roll a filled drum of tar 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 the same 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

Take two empty ice cream balls of identical size and shape, and fill one with sand. Fill a wide tray with wet sand. Drop the two ice cream balls from the same height onto this wet sand. It will be seen that two pits are formed on sand.

- They fell down with the same speed. Still which ball formed deeper pit on the sand ? Ball with higher mass/ ball with lower mass.
- Bullets fired from a gun pierce through a target object. If so, does their speed influence the impact they make?

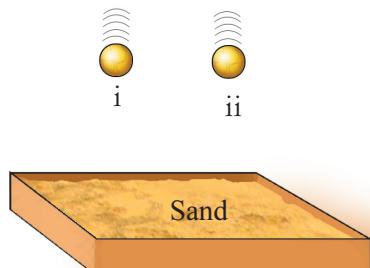


Fig. 3.12

Repeat the experiment by allowing one of the balls to fall from different heights.

- What happens to the velocity of the ball, when it falls from a greater height? Increases/decreases
- What happens to its impact on sand when its velocity increases? increases/decreases.

The more the mass and velocity of moving bodies, the more their impact. This property is called momentum.

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

Momentum is a vector quantity. It is experienced in the direction of velocity.

Momentum = mass \times velocity

What is the unit of momentum? Can you derive it from the equation?

Unit of momentum = Unit of mass \times Unit of velocity

$$= \dots \times \dots$$

$$= \dots$$

- A car of 1000 kg moves with a velocity of 10 m/s. On applying brakes it comes to rest in 5 s. Then what are its initial momentum and final momentum?
- A hockey ball of mass 200 g hits on a hockey stick with a velocity 10 m/s. Calculate the change in momentum if the ball bounces back on the same path with the same speed.
- A loaded lorry of mass 12000 kg moves with a velocity of 12 m/s. Its velocity becomes 10 m/s after 5 s.
 - What is the initial momentum and what is the final momentum ?
 - What is the change in momentum?
 - What is the rate of change of momentum?

You might have seen children taking rides in amusement parks. They would come with high speed from a height and would again move up to another height easily. Now you would have understood the scientific reason behind it. Momentum, the characteristic of moving objects, is made use of here.

Newton's Second Law of Motion

The First Law of Motion defines force and inertia. But how can we measure force? Let's try to understand how Newton's Second Law of Motion helps to measure force. The velocity of a moving body changes from u to v when a force F is applied for t second. Then 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? Guess and write it down.
-
- What if the applied force is reduced?

Haven't you understood that the rate of change of momentum is directly proportional to the applied force? This is 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.

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

$$F \propto ma$$

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

$$F = kma$$

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

$$F = 1 \times ma$$

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

This is the equation to calculate force.

Safety measures while applying brakes



All moving vehicles possess momentum. It is not easy to stop a vehicle that has higher momentum by applying brakes all on a sudden. Even efficient modern braking systems fail on poor quality roads that have less friction. Many accidents occur every day due to over speed and carelessness. For the safest braking, it is essential to keep 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.

Unit of force is Newton

One Newton is the force required to produce an acceleration of 1m/s^2 on a body of mass 1 kg.

$$\text{As } F = kma$$

$$1 = k \times 1 \times 1$$

$$k = 1$$

- A car moving with a speed of 108 km/h comes to rest after 4 s on applying brake.

If the mass of the car including the passengers is 1000 kg, what will be the force applied when brake is applied?

$$\begin{aligned}\text{Initial velocity of the car } u &= 108 \text{ km/h} = 108 \times \frac{1000}{60 \times 60} \\ &= 108 \times \frac{5}{18} = 30 \text{ m/s.}\end{aligned}$$

Final velocity $v = 0$

$$\text{Mass } m = 1000 \text{ kg}$$

$$\text{Time } t = 4 \text{ s}$$

According to newton's second law

$$F = ma$$

$$\begin{aligned}F &= m \frac{(v-u)}{t} = \frac{1000(0-30)}{4} \\ &= -7500 \text{ N}\end{aligned}$$

The negative sign indicates that the applied force is opposite to the direction of motion.

- Velocity of an object of mass 5 kg increases from 3 m/s to 7 m/s on applying a force continuously for 2 s. Find out the force applied. If the duration for which force acts is extended to 5 s, what will be the velocity of the object then?

$$u = 3 \text{ m/s}$$

$$v = 7 \text{ m/s}$$

$$t = 2 \text{ s}$$

$$m = 5 \text{ kg}$$

According to Second Law of Motion

$$F = ma$$

$$= \frac{m(v-u)}{t}$$

$$= \frac{5(7-3)}{2} = 10 \text{ N}$$

$$\text{Acceleration } a = \frac{F}{m} = \frac{10}{5} = 2 \text{ m/s}^2$$

If we substitute the values in the equation $v = u + at$, velocity can be calculated when the time for force is extended to 5 s.

$$v = 3 + (2 \times 5) = 13 \text{ m/s}$$

- Velocity - time graph of an object of mass 20 g, moving along the surface of a long table is given below.

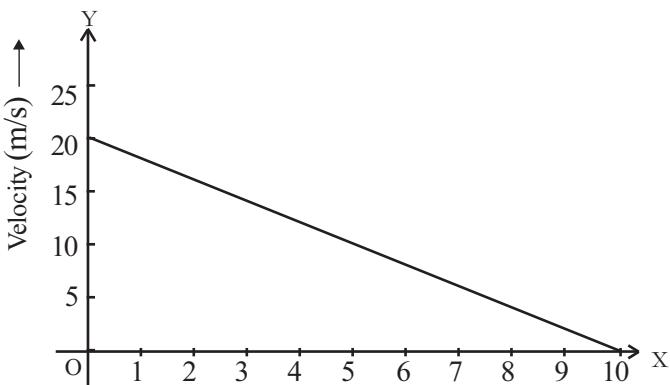


Fig. 3.13

What is the frictional force experienced by the object?

From the graph

Initial velocity $u = 20 \text{ m/s}$

Final velocity $v = 0 \text{ m/s}$

$$t = 10 \text{ s} \quad m = 20 \text{ g} = \frac{20}{1000} \text{ kg}$$

$$F = ma$$

$$\begin{aligned} &= m \frac{(v - u)}{t} \\ &= \frac{20}{1000} \times \frac{(0 - 20)}{10} \\ &= -0.04 \text{ N} \end{aligned}$$

The negative sign shows that the frictional force is acting opposite to the direction of motion of the object.

- 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 system.

Impulse

Impulsive force is a very large force acting for a very short time. Impulse

of force is the product of the force and the time.

$$\text{Impulse} = \text{Force} \times \text{time}$$

What is its unit?

Mathematical representation of the relation between mass, velocity and time based on the Second Law of Motion, when a force is applied will be,

$$F = m \frac{(v - u)}{t}$$

Impulse = $F \times t$. If we substitute the above equation in this,

$$\begin{aligned}\text{Impulse} &= m \frac{(v - u)}{t} \times t \\ &= m(v - u) \\ &= mv - mu\end{aligned}$$

Isn't $(mv - mu)$ change in momentum? This is known as impulse – momentum principle. It states that a change in momentum of an object is equal to the impulse experienced by it.

How will be the ratio between the force and time when same change in momentum occurs? In such cases change of momentum is a constant.

Impulse = change in momentum

Force × time = change of momentum

$F \times t$ = a constant

$$F \propto \frac{1}{t}$$

When the change of momentum is a constant, the force acting on a body will be inversely proportional to the time taken.

Explain the following situations by relating force and time.



Fig. 3.14

- 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.
- Hay or sponges are used while packing glasswares. This helps to avoid breaking of glasswares due to collision.
- Karate experts move their hands with great speed to chop strong bricks.

Newton's Third Law of Motion

Rockets are used for launching artificial satellites. What is the force that makes a rocket shoot up?

Let's make a balloon rocket. Pass a long string through a straw and tie the string between two windows of the classroom as shown in the figure. Paste an inflated balloon on the straw.

- Deflate the balloon and release it suddenly. What do you observe?
- Isn't the motion of the balloon in a direction opposite to the direction of motion of the air?
- Isn't this due to the force produced by the strong release of air? If this force is taken as action, the force that pushes the balloon along the string can be taken as reaction.

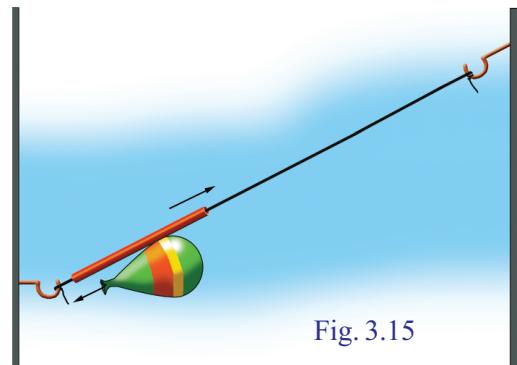


Fig. 3.15

Let's do another experiment.

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

What do you observe?

-
- Is it not due to the force exerted on the cork by the steam from the boiling water?
 - If the force exerted by the steam on the cork is taken as the action, what is the reaction?
-

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

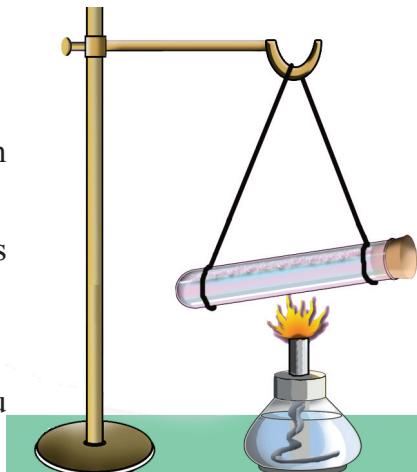


Fig. 3.16

Gas at high pressure is pushed out from the chambers of a rocket. It is the reaction of this force that propels the rocket forward.

- Are action and reaction equal and opposite?

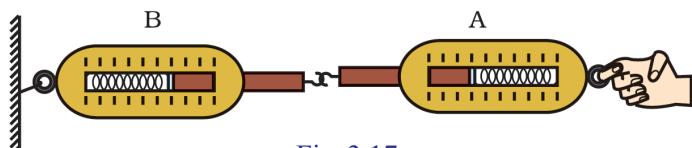


Fig. 3.17

Two digital weighing balances are connected as shown in the figure (fig 3.17)(spring balances can also be used). After fixing the end of balance B strongly, apply a force of 50 N at the free end of balance A. What do you observe?

- What is the reading on balance B ?
- If the applied force is action, which is the reaction?
- How much are the action and reaction?

You have seen that action and reaction are same in this activity.

To every action there is an equal and opposite reaction. This is Newton's Third law.

Consider the following situations and complete the table accordingly.

| Situation | Action | Reaction |
|--|--|--|
| • 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 in opposite direction. The man lands on the shore. |
| • A bullet is fired from a gun | | |
| • A boat is rowed | | |

Table 3.3

Action and Reaction

Action and reaction are forces that are experienced on different objects at the same time. Thus it cannot be said that reaction is the result of action. In other words, when two bodies interact, the force acting on one can be taken as the action and the opposite force acting on the second as the reaction.

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 3.3 and write them 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 3.3. In the first situation, identify the object on which the action takes place? What about reaction?

Examine the other situations too.

Since action and reaction are taking place on two different objects, they do not cancel each other.

According to Newton's Third law of motion, action and reaction are equal and opposite. If so, does the total momentum of a system change if no external force is exerted?

Let's examine.

Law of Conservation of Momentum

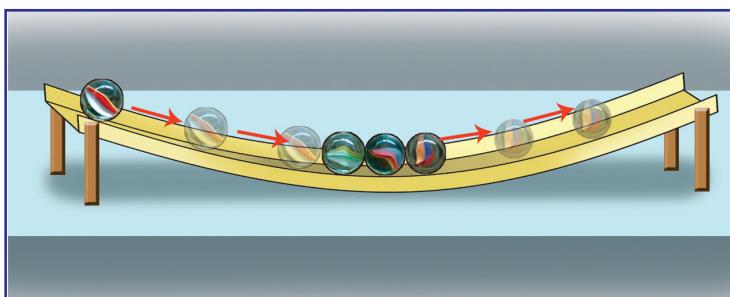


Fig. 3.18

Using wiring channels of 1.5 m length and four marbles, perform the following activities, as shown in the figure.

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

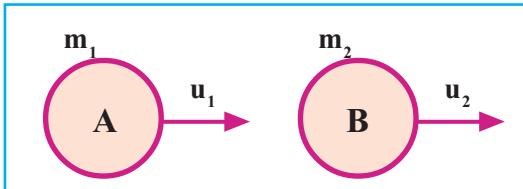
- Bring the two marbles together and let them roll.
What happens?



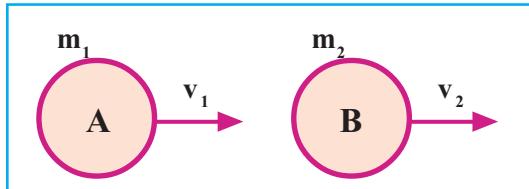
What is your inference?

When an object collides with another, the total momentum of the objects will remain unchanged. Let's verify it by applying the Newton's Third Law of Motion. Consider two bodies A and B of identical size but having

different masses m_1 and m_2 , moving with velocities u_1 and u_2 in the same direction in a straight line(Fig 3.18). If A moves with greater velocity it will bump on to B. After collision if their velocities are changed to v_1 and v_2 respectively let's find out the total momentum of the system.



Before collision
Fig 3.19 (a)



After collision
Fig. 3.19 (b)

According to Newton's Third Law of Motion

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

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 (if time of collision is t)

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

Let's 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. Then how will you find out the force exerted by B on A (F_{AB}) and the force exerted by A on B (F_{BA})?

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

$$F_{BA} = \frac{m_2 v_2 - m_2 u_2}{t}$$

According to the Third Law of Motion

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

$$\frac{m_1 v_1 - m_1 u_1}{t} = -\left(\frac{m_2 v_2 - m_2 u_2}{t} \right)$$

$$m_1 v_1 - m_1 u_1 = -(m_2 v_2 - m_2 u_2)$$

$$m_1 v_1 - m_1 u_1 = -m_2 v_2 + m_2 u_2$$

$$m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2$$

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.

- A bullet is fired with a velocity v from a gun of mass M . What will be the recoil velocity of the gun if the mass of the bullet is m ?

According to law of Conservation of Momentum, total momentum of the gun and the bullet before firing and their total momentum after firing will be equal.

ie, Total momentum before firing = $0 + 0 = 0$

Total momentum after firing = $MV + mv$

According to Law of Conservation of Momentum

$$0 = MV + mv$$

$$MV = -mv$$

$$V = \frac{-mv}{M}$$

The recoil velocity of the gun $V = \frac{-mv}{M}$. The negative sign indicates that the gun moves in the opposite direction of motion of the bullet.

- Suppose a child of mass 40 kg running on a horizontal surface with a velocity of 5m/s jumps on a stationary skating board of

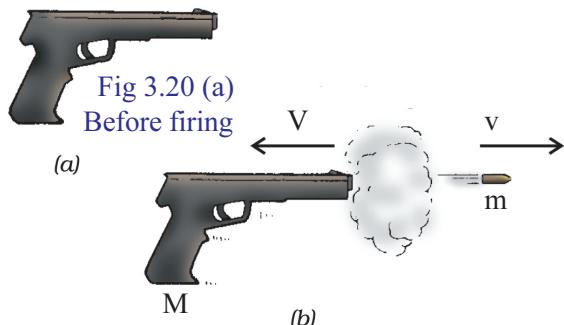


Fig 3.20 (b)
After firing

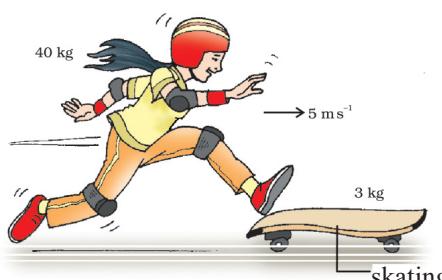


Fig. 3.21

mass 3kg while running as shown in the figure. If there is no other force acting horizontally (assuming the frictional force on the wheels to be zero), calculate the velocity of the combined system of child and the skating board.

Suppose the velocity of the board while moving is u .

Total momentum of the child and the skating board before jumping will be

$$\begin{aligned} &= 40 \text{ kg} \times 5 \text{ m/s} + 3 \text{ kg} \times 0 \text{ m/s} \\ &= 200 \text{ kg m/s} \end{aligned}$$

Total momentum when the system starts moving (boy and skating board)

$$\begin{aligned} &= (40 + 3) \text{ kg} \times u \text{ m/s} \\ &= 43 \times u \text{ kgm/s.} \end{aligned}$$

According to the Law of Conservation of Momentum, Total momentum remains constant.

$$43 u = 200$$

$$u = \frac{200}{43} = +4.65 \text{ m/s}$$

That means the boy and the skating board together will now move in the same direction the boy was running before getting onto it, with a velocity of 4.65 m/s.

You have learned many facts about rectilinear motion. Are all movements that we see in our surroundings rectilinear? Write them down and verify.

- 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 while whirling?

- Rectilinear/circular

Circular motion

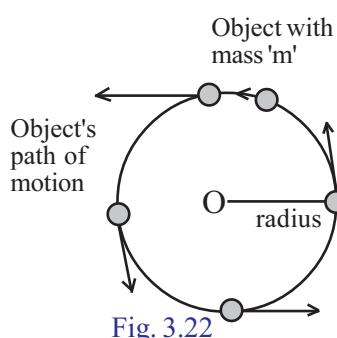


Fig. 3.22

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

The motion of an object along a circular path is known as 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 in velocity produces acceleration. What will be the direction of such an 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? In which direction will be the force?

The force we apply from the centre of the circle reaches the object through the string. Therefore, the acceleration due to this force will also be towards the centre of the circle along the string.

The acceleration experienced by an object in a circular motion, along the radius, towards the centre of the circle, is known as centripetal acceleration. The force that creates a centripetal acceleration is called centripetal force. Centripetal acceleration and centripetal force are directed towards the centre.

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

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

When the stone is subjected to circular motion, the force that the hand exerts through the string becomes the centripetal force.

- What will happen to an object if it loses centripetal force while in circular motion?

Release the string when the stone is moving along the circular path and see what happens. When we release the stone, at a particular point in its circular path, the stone 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 it starts and stops.

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

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



Fig. 3.23

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



Let us assess

1. Observe the figure and answer the following questions.
 - a) When the card is suddenly struck off, what happens to the coin? Why?
 - b) To which law is the observed phenomenon related?
 - c) How is this characteristic related to the mass of the object?

2. What are the balanced forces that act on a book at rest on a table?

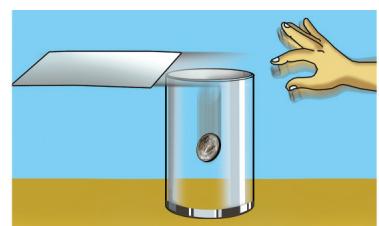
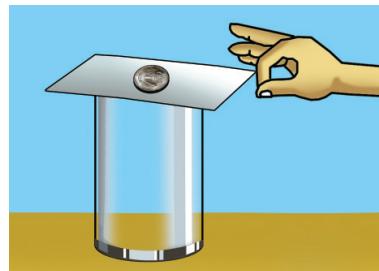
3. To remove the dust from a carpet, it is suspended and hit with a stick. What is the scientific principle behind it?

4. A car and a bus are travelling at the same velocity. Which has greater momentum? Why?

5. On the basis of Newton's Third Law of Motion, explain the force that helps to propel a rocket upward.

6. A car travels at a velocity of 15 m/s. The total mass of the car and the passenger in it is 1000 kg. Find the momentum of the car.

7. Give reasons.
 - a) When a bullet is fired from a gun, the gun recoils.
 - b) When a bus at rest suddenly moves forward, the passengers, standing in the bus, fall backward.
 - c) We slip on a mossy surface.

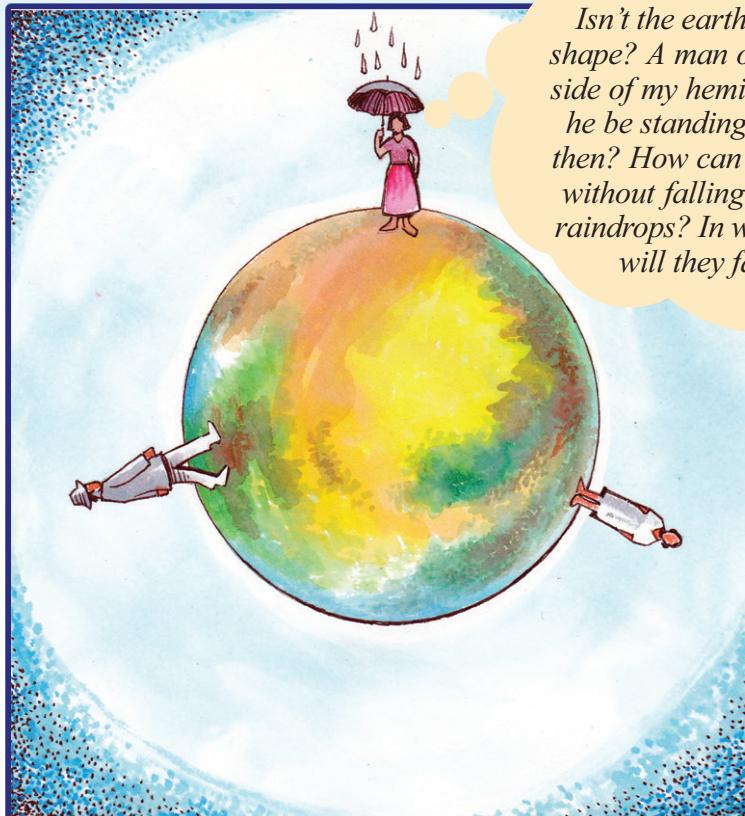


Extended activities

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 write them down.
3. Prepare a poster to create awareness about the accidents due to overspeeding of vehicles.



Gravitation



Have you also felt the same doubts? Let's try to find the answer.

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?

Let's now throw the stone upwards.

- What will happen to the speed of the stone when it is thrown up?
- What about its speed when it falls down?
- Did you apply any force on the stone to bring it down?

Erect and Inverted

Whether an object on earth stands erect or upside down is decided on the basis of the direction of gravity. Since gravity acts towards the centre of the earth, we experience the gravitational pull downwards. Gravitational force is a vector quantity which has got direction. So wherever you stand on earth, the force will be downwards. This is why you feel you are standing erect, irrespective of the place you stand.



- From where did the stone get the force required 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 is 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.
- Artificial satellites revolving around the earth.
-

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 mutual attraction between earth and the body.

From the activities you have done, you would have understood 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 mutual attraction between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

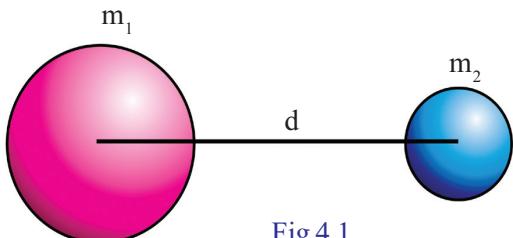


Fig 4.1

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

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

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

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 $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$. It was Henry Cavendish, a scientist, who determined the value of G for the first time through experiments.



Sir Isaac Newton



Isaac Newton
(1642 – 1727)

Sir Isaac Newton was one of the prominent scientists who has contributed much for the progress of science as an astronomer, physicist, mathematician and philosopher. His book 'Principia Mathematica' is considered to be the basic reference book of physics. Newton observed that all celestial bodies and all objects on earth obey the same universal law of motion. He formulated a new branch of mathematics called calculus. He gave theoretical basis to the discoveries of his predecessors like Tycho Brahe, Kepler and Galileo. Newton's Universal Law of Gravitation and Laws of Motion revolutionised the study of physics. In an opinion survey conducted in 2005 by the Royal Society, Sir Isaac Newton was voted as the most influential person of the century. As a mark of respect unit of force has been named after him.

Based on Newton's law of gravitation, complete the table (Table 4.1) given below.

| 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 | $G \times \dots$ |
| 3 | 10 | 20 | 2 | $G \times \dots$ |
| 4 | 5 | 10 | 4 | $G \times \dots$ |
| 5 | 5 | 10 | 1 | $G \times \dots$ |
| 6 | 10 | 20 | 1 | $G \times \dots$ |
| 7 | 5 | 10 | $\frac{1}{2}$ | $G \times \dots$ |

Table 4.1

Observe Table 4.1 and find out the answers to the following questions :

- 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?

Hmm, the force with which I attract Raju must be much greater than the force with which Raju attracts me.

Oh, but isn't the force of attraction between us a mutual force? Shouldn't both of us be attracting each other with the same force?



- 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.

$$m_1 = 40 \text{ kg}$$

$$m_2 = 50 \text{ kg}$$

$$d = 1 \text{ m}$$

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2.$$

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

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

$$\begin{aligned}
 &= 13340 \times 10^{-11} \\
 &= 1.334 \times 10^{-7} \\
 &= 0.000000133 \text{ N}
 \end{aligned}$$

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

Can you now explain why two children sitting close to each other do not come closer in spite of 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?

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$$

There is a mutual force of attraction between us. Then why don't we come closer by ourselves even when the table is removed?



Kepler's Laws

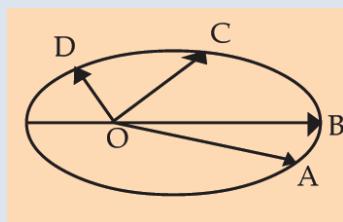
It was on the basis of his predecessor Johannes Kepler's laws of Motion related to planetary motion that Newton explained his Inverse Square Law. Following are the famous three laws of Kepler.

First Law- Planets revolve in elliptical orbits around the Sun. (Observe the figure, 'O' is the position of the Sun).

Second Law- The line joining the planet and the Sun sweep equal areas in equal intervals of time. (Thus, if the time of travel from A to B is the same as that from C to D, then the areas OAB and OCD will be equal).

Third Law- The cube of the mean distance(r) of a planet from the Sun is directly proportional to the square of its orbital period (T)

Or; $r^3 / T^2 = \text{constant}$.



It was based on this that Newton stated The Inverse Square Law. Suppose a planet revolves round the sun in a circular orbit of radius ' r '. If the orbital velocity is v and mass m , then the

centripetal force will be $F = m \frac{v^2}{r}$. Since the mass of the planet is constant $F \propto \frac{v^2}{r}$.

If a planet completes one revolution in time T , the orbital velocity (v) of the planet will be

$$v = \frac{2\pi r}{T} \quad (2\pi r \text{ being the circumference of the orbit.})$$

$$v^2 \propto \frac{r^2}{T^2}$$

$$v^2 \propto \frac{1}{r} \left(\frac{r^3}{T^2} \right)$$

According to Kepler's Third Law $\frac{r^3}{T^2}$ is a constant.

$$\text{Therefore } v^2 \propto \frac{1}{r}$$

when this is substituted in the equation $F = \frac{mv^2}{r}$ the result will be $F \propto \frac{1}{r^2}$

Just like there is a force of attraction between the Earth and the Sun and between the Earth and the Moon, there is a force of attraction between other celestial bodies as well.

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, R its radius and m the mass of an object 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

$$\text{two bodies is } F = G \frac{m_1 m_2}{d^2}$$

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

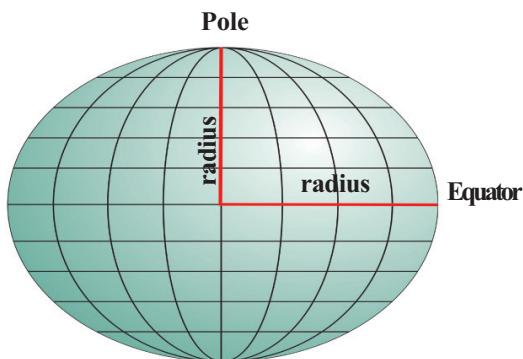


Fig 4.2

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 is a body to be placed to experience the maximum force of attraction ? Where the radius is large/ where the radius is small
- If a body is being continuously raised from the surface of the earth, what happens to the force of attraction?
Increases/decreases
- Imagine that the body is moved from the surface of the earth to its centre. What happens?

Acceleration due to gravity

We know that the force of attraction between 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.

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, $F = ma$

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

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

According to Newton's Law of Gravitation, $F = G \frac{Mm}{R^2}$.

By Newton's Second Law of Motion, $F = ma = mg$

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

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

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



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.

Weight of a body and its 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.

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

- Mass of the earth
-

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

Now let's find out the value of ' g '.

Write down the equation for finding the value of g .

$$G = 6.7 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$$
, mass of the earth $M = 6 \times 10^{24} \text{ kg}$

$$\text{Radius of the earth } R = 6.4 \times 10^6 \text{ m}$$

Now can you find the value of g ?

On substituting the values of G, M and R in the equation $g = G \frac{M}{R^2}$

$$\text{we get } g = \frac{6.7 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2} \times 6 \times 10^{24} \text{ kg}}{(6.4 \times 10^6 \text{ m})^2}$$

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

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

- Will the value of g be the same everywhere on the 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 s to reach the ground. What is the value of g here? Where on the surface of the Earth would this activity have taken place?

$$s = 19.66 \text{ m}, u = 0, t = 2 \text{ s}, a = g = ?$$

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



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

$$19.66 = 2g$$

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

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

- If 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 the ground simultaneously
 - The paper reaches first
 - The stone reaches first

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 vacuum. Sir Isaac Newton could prove this later through the 'feather and coin' experiment.

As shown in Fig 4.3, 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 both 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?

Value of g on moon

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

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

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

$$= 1.62 \text{ m/s}^2$$

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

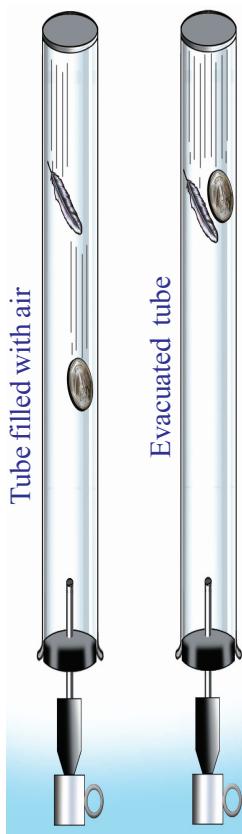


Fig 4.3

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 $a_{\text{earth}} = \frac{F}{M}$ and acceleration of the stone $a_{\text{stone}} = \frac{F}{m}$.

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.

How will the acceleration of the object be, if it falls down due to force of gravity alone?

uniform acceleration / non uniform acceleration

will equations of motion be applicable to objects in uniform acceleration?

Write down the equations of motion

1. _____

2. _____

3. _____

- A stone falls down from the top of a wall in 1 s to the ground ($g = 10 \text{ m/s}^2$)
 - a) What is the speed of the stone just before it touches the ground?
 - b) Calculate the average speed when the stone is falling down
 - c) How much is the height of the wall?
- A ball thrown vertically upward reached a maximum height of 20 m
 - i) What was the velocity of the stone at the instant of throwing up?
 - ii) How much time did the ball take to reach the height 20 m?

Mass and Weight

Observe Fig 4.4. 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

$$\begin{aligned} F &= \frac{GMm}{R^2} \\ &= m \times \frac{GM}{R^2} \end{aligned}$$

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

$$F = mg$$

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. Hence its unit is Newton (N).

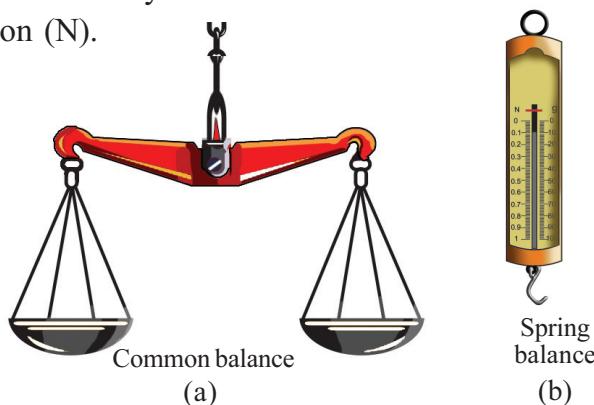


Fig 4.4

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

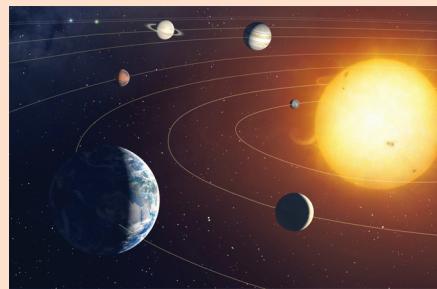
You know how the value of g on Earth changes from place to place. Based on this, find out the answers for the following questions.

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



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 in their orbits of revolution. While the gravitation from the Sun provides the centripetal force for planets, the satellites get the force from the planets.



1 kgwt

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

Since $F = mg$

$$\begin{aligned} 1 \text{ kgwt} &= 1 \text{ kg} \times 9.8 \text{ m/s}^2 \\ &= 9.8 \text{ kg m/s}^2 \\ &= 9.8 \text{ N} \end{aligned}$$

i.e., $1 \text{ kgwt} = 9.8 \text{ N}$

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 reason.
- 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?

$$\begin{aligned}\text{Weight on the Earth} &= mg \\ &= 60 \times 9.8 = 588 \text{ N.} \\ 1 \text{ kgwt} &= 9.8 \text{ N}\end{aligned}$$

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

$$\begin{aligned}\text{Weight on the Moon} &= m \times \text{value of } g \text{ on the Moon} \\ &= 60 \times 1.62 = 97.2 \text{ N} \\ 1 \text{ kgwt} &= 9.8 \text{ N} \\ &= \frac{97.2}{9.8} \text{ kgwt} = 9.918 \text{ kgwt}\end{aligned}$$

- 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 on 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 that place.

Brother, you have jumped up only 4 m. But you would have jumped up to 24 m, if you were on the moon



Free fall

What happens to a pencil when it is let go from a height? Won't it fall down?

- Suppose a spring balance with a body suspended from it is allowed to fall. What will be the reading on the balance?
- While on a giant wheel ride, 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? Why?



Let us assess

1. If the distance between two bodies that attract each other is trebled, how many times more will be their mutual force of attraction?
(9 times, 3 times, $1/3$, $1/9$).
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

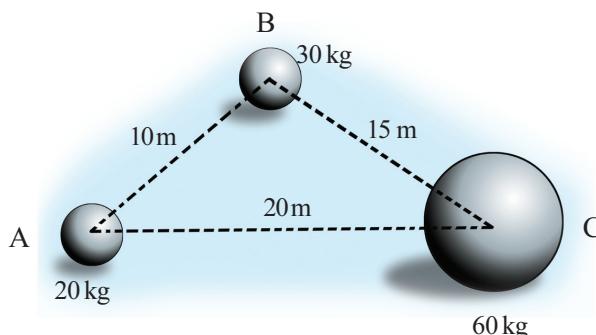
Free fall and weightlessness

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 at all 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. It is the reaction from the surface that is measured as weight.



3. Mass of the Earth is 6×10^{24} kg and that of the Moon is 7.4×10^{22} kg. The distance between Earth and Moon is 3.84×10^5 km. Calculate the force of attraction of Earth on Moon. ($G = 6.7 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$)
4. 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?
($g = 9.8 \text{ m/s}^2$)
- d. What is its weight on the Moon? ($g = 1.62 \text{ m/s}^2$)
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. 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 |



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