FORCE AND MOTION
PART - 1
6th term 1
Unit 2 Forces and Motion

Introduction

We had studied in our earlier classes that push or pull results in some motion of the object. When we open the door, kick a football, lift our school bag, all involve motion and there is some push or pull.

Motion and Rest
What is rest? What is motion?

Suppose there is a book on your table right in the middle. Is the book moving? You will say "it is not moving; it is at rest". If you push the book to one side of the table to clear space for keeping your notebook, then you will say the book is moving.

When the book was at the same place with respect to the table, you say the book was at rest; but when it was pushed from one place on the table to another place, you say it was moving.

When there is a change of position of an object with respect to time, then it is called motion, if it remains stationary it is called rest.

Is Mohan in motion?

We can readily observe that both Reka and Babu are correct. From the point of view of Babu, Mohan along with the bus is in motion; but for Reka who is sitting beside him, he is at one place; therefore stationary. So, according to

Babu, Mohan is in motion; Mohan is at rest from Reka's observation. Can you think any other examples?

Hi! Please answer honey by observing the situation in the picture

Event 1: The man in the boat is moving with respect to the bank of river. He is at rest with respect to the boat.

Event 2:
The girl on the swing is _______with respect to the seat of the swing. She is with respect to   the garden.

Event 3: Nisha is going to her grandmother's house by bicycle. The girl on the bicycle   is __________ with respect to the road. She is _______with respect to the bicycle.

Take the case of a book on a table at rest. Is it really without any motion? We know that Earth is rotating on its axis; therefore the table along with the book must be rotating. Is it not? We are also moving along with the earth. Therefore, from the point of view of ground on which we stand, the book is at 'rest'. Similarly, while travelling in a speeding bus, we feel that the poles and trees seem to move backwards, and the things inside the bus are stationary.

An object may appear to be stationary for one observer and appear to be moving for another. An object is at rest in relation to a certain set of objects and moving in relation to another set of objects. This implies that rest and motion are relative.

Aryabatta, an ancient Indian astronomer, said that like the banks of the river appear to move back to a person in a boat floating gently in a river, the night sky studded with stars appear to move from east to west while Earth rotates from west to east. Learn more by asking others and reading up on your own.

How things move?

When we kick a ball it moves. When we push the book on the table, it moves. When a bullock pulls the cart moves. Motion occurs when the object is pulled or pushed by an agency.

In daily life, we pulled out water from the well, with bucket or "the animal pulls a bullock cart". It is a person or animal, that is an animate agency that does the pushing or pulling.
Sometimes we see a tall grass in the meadow dancing in the wind, a piece of wood is moving down a stream. What pushes or pulls them? We know that blowing wind and flowing water is the cause. Sometimes the push or pull can be due to the inanimate agency.

Forces are push or pull by an animate or inanimate agency.

Contact, Non-Contact Forces

In all the above cases, the force is executed by touching the body. so, these type of force is called Contact Force. Mysteriously ripen coconut falls to the ground. What pulls it to the ground? We would have heard of the 'force of gravity' of Earth. Gravity pulls the ripen coconut from the tree to the ground.

Bring a magnet near the small iron nail. Suddenly the nail jumps into the air and sticks with the magnet. Observe that the magnet and the nail did not touch each other. Still, there was a pulling force that made the nail to jump towards the magnet. In these two examples, the force is applied without touching the object. Such forces are known as "non-contact forces"

Forces can be classified into two major types; contact and non-contact forces. Wind is making a fag flutter, a cart pulled by a bullock are contact forces. Magnetism, gravity are some examples of non-contact forces.

What happens when we apply a force on an object?

What happens when you apply a force on an object? Say you push a book on the table. The book moves. Application of force in an object results in motion from a state of rest.

What happens when a batsman hit a ball? The ball is already in motion, but with the strike, the speed of the ball increases. Moreover the direction of the ball changes. Application of force on object results in a change in its speed and change in its direction.

Crush a balloon, apply force on roti dough, pull a rubber band. In these cases the shape of the object change on application of force.   Application of force in object results in expansion or contraction.

Look at this picture. The person is applying force to stop the cart from moving. When the force is applied against the direction of the motion, the speed can be reduced, or even the motion stopped completely. Break in a speeding bicycle.
In a nutshell, the applied force is an interaction of one object on another that causes the second object to move from rest, or speed up, slow down, stop the motion, change the direction, compress or expand.
Forces can

Change the states of body from rest to motion or motion to rest.
Either change the speed or direction or both of the body.
Change the shape of the body.

That is its motion was 'rotational' and then 'circular' 'straight line or linear' and later 'oscillatory'.

Throw paper aeroplanes or paper dart. Watch its f ight path when you throw it at an angle. The path curves i.e the paper f ight is moving ahead but direction is changing while moving such paths are called curvilinear.

Periodic and non- periodic motions

A fly buzzing around the room is a combination of all these and flight path is zigzag.

You can classify the motion according to the path taken by the object.
Linear- moving in a straight line, like a person walking on a straight path, free fall.
Curvilinear - moving ahead but changing direction, like a throwing ball.
Circular -moving in a circle, swirling stone tied to the rope.
Rotatory -The movement of a body about its own axis, like a rotating top.
Oscillatory -coming back to the same position after a fixed time interval, like a pendulum.
Zigzag (irregular)- like the motion of a bee or people walking in a

crowded street.

Oscillations at Greater Speed

Ask your friend to hold the two ends of a stretched rubber band. Strike it in the middle. Do you see it oscillates very fast? When the oscillation is very swift, it is called as vibration

Fast oscillations are referred to as vibrations.

Speed Vs Slow?

Take the case of the hour-hand of a clock. In one day it makes two rounds. Look at a bouncing ball. It bounces a certain number of times for a given time interval or period. Look at the water waves, in a given period that is a time interval; a fixed number of waves hit the shore.

Motion repeated in equal intervals of time is called as periodic motion.
Let us take the example of sabing swing in wind. This motion is not in uniform interval. Such Motions are called non-periodic motion.

Revolution of the moon around the earth is periodic but not oscillatory. However, the children playing in a swing is both periodic and oscillatory.
Look at the tall tree. When the wind is gentle, its branches are dancing slowly; but if the gentle wind becomes strong, the branches shake violently, and if the speed increases further, the branch may even break and fall. That is the motion can be slow or fast.

Can we say a motion is slow or fast without comparing anything?
Compared to walking, cycling is fast, but a bus is faster than a cycle. The aeroplane is much faster than a bus. So, slow or fast is a relative concept which depends upon the motions we are comparing.

Then how to we say a body moves in a particular Speed?

How do we say? Let us calculate how long they travelled in One Hour?
Distance travelled by the Car in One Hour = ____ 80____ Km (160/2)
Distance travelled by the Bus in One Hour = __________ Km
Distance travelled by the Truck in One Hour = ________ Km

Have you found out? say now.
Fastest _______ , Slowest __________
Have you noticed that saying who is fast and slow? is easy when we calculate the distance they travelled in one hour.

The distance travelled by an object in unit time is called average speed of the object.
If an object travelled a distance (d) in time (t) then its Average speed (s) is = distance travelled / time taken = d/t.

In other words, you divide the distance travelled by the time taken to get the speed.

Suppose a car travels 300 km in one hour. Then we say the speed of the car is '300 kmph' (we read it as 'three hundred kilometres per hour').
If an object travelled 10 metre in 2 seconds, then

Average speed (s)

= distance travelled (d) / time taken (t)
= 10 metre/ 2 second
= 5 metre / second

bus takes three hours to cover this distance of 180 kilometres. Then its Average speed is

Average speed (s)

= distance travelled (d) / time taken (t)
= 180 kilometre/ 3 hour
= 60 kilometre / hour

Please note that metre/second or kilometre/hour comes next to our answer for average speed. What is it? Observe the formula for average speed. If we denote the distance in metre and time by seconds then the unit of average speed is metre/second.

If we denote the distance in kilometre and time in hour then the unit of average speed is kilometre/hour. Sometimes we use units like centimetre/second. In science we generally use SI units. In SI units the unit of distance is metre and the unit of time is second. So, the SI unit of average speed is metre/second.

Let us Calculate

A cat travelled 150 metres in 10 seconds, what is its average speed?
Priya ride her bicycle 40 km in two hours. What is her average speed?

Our Speed...

Let us play a small game. Go to the playground with your friends. Mark 100 metre distance for a race. Conduct a friendly running race and calculate the time they taken to complete the distance by stopwatch. Now fill up the following table.

S. No	Name of the student	distance	Time taken (in seconds)	average speed = distance travelled/ time taken	average speed (m/s)
1	Murugesan	100 m	12 sec	100 metre / 12 sec	8.3 m/s
2		100 m			
3		100 m			
4		100 m			
5		100 m			

If you know the speed and the time taken by the object travelled, then we can compute how much distance it had travelled?

Speed = distance travelled / time taken (s = d/t)

s = d/t or st = d

therefore the distance travelled is speed × time.

If a ship travelled at a speed of 50 kmph and it sailed for five hours, how much distance it had travelled.

s = 50 kmph; t = 5 therefore
s × t = 50 kmph × 5 h = 250 km

If we know the speed and distance travelled we can compute the time taken.
s = d/t that is t = d/s time taken = distance travelled / speed

Suppose a bus travels at a speed of 50 kmph and has to cover a distance of 300 km. How much time will it take?
t = d/s that is 300 km/50 kmph = 6 h.

Compute the following Numerical Problems.

If you travel 10 kilometres in 2 hours, your speed is ______ km per hour.
If you travel 15 kilometres in 1/2 hour, you would travel   km in one hour, and your speed is______ km per hour.
If you run fast at 20 kilometres per hour for 2 hours, you will cover ________ km

A cheetah is the fastest land animal running with an average speed of 112 km/h

Uniform and non-uniform motion

Suppose a train leaves Thiruchirapalli and arrives at Madurai. Is the train travelled in an uniform speed? First, the train was stationary. When the train left the station, the motion was slow and only after it left some distance that it gathered speed. After that it slowed down while crossing bridges and stop at intermediate stations for passengers. Finally, as the train approached Madurai, again, it slowed and finally came to a halt. That is the speed was not same all through the journey time. That is the speed was non-uniform. This motion is said to be non-uniform motion.

In a nutshell, we can classify the motion in terms a) path b) if it is periodic or not c) if the speed is uniform or not. However, in real life, the motions are combinations many types.		
Motion		
Based on PATH	**Based on DUEATION**	**Based on SPEED**
Linear Motion	Periodic Motion	Uniform Motion
Curvilinear Motion	Non- Periodic Motion	Non Uniform Motion
Circular Motion		
Rotatory Motion		
Oscillatory Motion		
Zigzag (Irregular) Motion		

However, in between the journey, there may have a stretch where in the train might have been going at a constant speed. During that interval the train was moving at uniform speed, that is uniform motion.

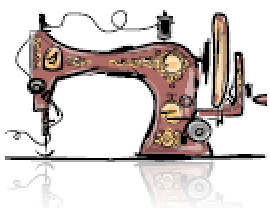
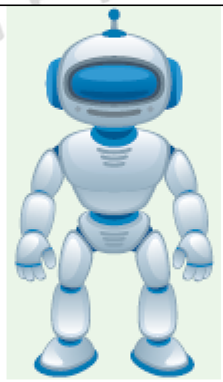
If an object covers uniform distances in uniform intervals then the motion of the object is called Uniform Motion. Otherwise the Motion is called Non-Uniform Motion.

Many motions we see in our day to day life are non-uniform. We will learn more about uniform and non-uniform motion in later classes.

Multiple Motions.

Look at the bicycle. What type of motion does the wheel perform? What type of motion does the cycle in total perform?

The tyres rotate and make a rotatory motion, but the cycle as such moves forward in a linear path.

Multiple Motion in a sewing Machine  Motion of the needle _________ _______ Motion of the Wheel __________________ Motion of footrest ________________	 **A bipedal humanoid robot.**

Robots are automatic machines. Some robots can perform mechanical and repetitive jobs faster, more accurately than people. Robots can also handle dangerous materials and explore distant planets. The term comes from a Czech word, ‘robota’ meaning ‘forced labour’. Robotics is the science and study of robots.

What Can Robots Do?

Robots can sense and respond to their surroundings. They can handle delicate objects or apply great force-for example, to perform eye operations guided by a human surgeon, or to assemble a car. With artificial intelligence, robots will also be able to make decisions for themselves.

How Do Robots Sense?

The quadruped al military robot

Electronic sensors are a robot’s eyes and ears. Twin video cameras give the robot a 3-D view of the world. Microphones detect sounds. Pressure sensors give the robot a sense of touch, to judge how hard to grip an egg. Heavy luggage built-in computers send and receive information with radio waves.

Artificial Intelligence

Artificial intelligence attempts to create computer programs that think like human brains. Current research has not achieved this, but some computers can be programmed to recognize faces in a crowd.

Can Robots Think?

Articulated welding robots (Industrial) Robots can think. They can play complex games, such as chess, better than human beings. But will a robot ever know that it is thinking? Humans are conscious-we know we are thinking-but we don’t know how consciousness works. We don’t know if Robots can ever be conscious.

Nano robotics

Future of Nano robotics
Nano-robots or Nano bots are robots scaled down to microscopic size in order to put them into very small spaces to perform a function. Future Nano bots could be placed in the blood stream to perform surgical procedures that are too delicate

or too difficult for standard surgery. Imagine if a Nano bot could target cancer cells and destroy them without touching healthy cells nearby.

7^{TH} TERM 1
UNIT 2. Force and Motion

Introduction

As shown in the above picture, Kavitha can reach her school in two ways. Can you tell, by choosing which path she could reach the school early.

Road A
Road B

Look at the nearby picture

Uma and Priya are friends studying in the same school. After school hours, they go to the nearby playground, play games and return back home. Oneday Uma told that she would reach the playground after visiting her grandmother's house . The path in which they took reached the playground is shown here.

Take a twine and measure the length of the two paths (A & B). Which is the longest path among the two? ________________________.

From the above examples, we could conclude that when an object travel from one place to another, it will reach faster if it travels along the straight line path. The straight line path is the shortest distance between two points.

Distance and Displacement

Distance - The total length of a path taken by an object to reach one place from the other is called distance.

Displacement – The shortest distance from the initial to the final position of an object.
Both the distance and displacement posses the same unit. The SI unit is meter (m).

He travels 10 km in first path. In the second path, he travels 7 km.

The distance between A and B via first path is 10 km. In the second path the distance is 7 km. The shortest distance between the two places is 5 km represented as 2. So the displacement is 5 km. (In east direction)

The path of an object travelling from A to B is shown in figure. Total distance travelled by the object is 120 m. The displacement of the object is 40 m (south-east direction)

The path in which a rabbit ran is shown in figure. Find the distance and displacement of it in the two figures. Let us consider that each square is in an unit of one square meter. The rabbit starts from point A and reaches the point B.

When will the distance and displacement be equal. Explain. But the starting and finishing points should be different.

When we represent the displacement, we use a positive or negative sign depending on the direction with which it travels.
A ___________________B
Here we can consider the starting point as A and while the object moves from A to B the displacement is considered to be positive and from B to A it is negative.

Answer the following questions:

Subha goes to the nearby playground from her home.
1. What is the distance she travelled?
2. What is her displacement?

The distance travelled by an object is 15 km and its displacement is 15 km. What do you infer from this?

The distance of a person is 30 km and his displacement is 0 km. What do you infer from this?

Do you know?
Nautical mile
Nautical mile is the unit for measuring the distance in the field of aviation and sea transportation. One nautical mile is 1.852 km.
The unit for measuring the speed of aeroplanes and ships is knot. One knot is the speed taken to travel one nautical mile in hour.

Speed - Velocity
Speed
Recapitulation

In sixth standard we already studied about the speed in detail.

Do you know?
1 km/h = 5/18 m/s
How we got this ?
1 km = 1000 m
1 h = 3600 s
1 km / h = 1000 m / 3600 s = 5/ 18 m /s

Speed is the rate of change of distance .
Speed = distance /time
Unit is metre/second (m/s)
We can classify speed into two types.

Uniform speed

If a body in motion covers equal distances in equal intervals of time, then the body is said to be in uniform speed.

Non- uniform speed

If a body covers unequal distances in equal intervals of time, the body is said to be in non-uniform speed.
Average speed = total distance travelled / time taken to travel the distance.

Velocity

Velocity is the rate of change in displacement.
Velocity (v) = displacement / time
SI unit of velocity is meter / second (m/s).

1 km/h = 5/18 m/s

How we got this ?
1 km = 1000 m
1 h = 3600 s

1 km / h = 1000 m / 3600 s = 5/ 18 m /s

If an athlete in the diagram takes 25 s to complete a 200 m sprint event. Find her speed and velocity.

Speed = distance / time

= 200 / 25
= 8 m/s

velocity = displacement /time

= 50 / 25
= 2 m/s

Uniform velocity

A body has uniform velocity, if it covers equal displacement in the same direction in equal intervals of time. E.g. light travels through vacuum.

Non uniform velocity

If either speed or direction changes, the velocity is non uniform. E.g. a train starting and moving out of the station.

Average velocity

Average velocity = total displacement / total time taken
E.g. Figure shows a car that travels 5 km due east and makes a U – turn to travel another 7 km. If the time taken for the whole journey is 0.2 h. Calculate the average velocity of the car.
Average velocity = total displacement/time taken. (taking the direction due east of point O as positive)

= (5 – 7) / 0.2
= –2 / 0.2
= –10 km/h (or) –10 × 5/18 = 25/9
= –0.28 m / s

The triangle method can help you to recall the relationship between velocity (v), displacement (d), and time(t).
v = d / t , t = d / v, d = v × t

Answer the following questions:

Calculate the velocity of a car travelling with a uniform velocity covering 100 m distance in 4 seconds.
Usain Bolt covers 100 m distance in 9.58 seconds. Calculate his speed. Who will be the winner if Usain Bolt comepetes with a Cheetah running at a speed of 30 m/s?
You are walking along east covering a distance of 4 m, then 2 m towards south, then 4 m towards west and at last 2 m towards north. You cover the total distance in 21 seconds, what is your average speed and average velocity?

Acceleration

Acceleration (a)

Acceleration is the rate of change in velocity. In other words if a body changes its speed or dirction then it is said to be accelerated.

Acceleration = change in velocity/ time
= [final velocity (v) – intial velocity (u)] / time (t)

a = (v–u) / t

SI unit of acceleration is m/s2
In other words, the object undergoes acceleration when its speed and/or direction change(s).

The distance travelled by train	Initial velocity (u) m/s	Final velocity (v) m/s	Change in velocity (v – u) m/s	Time taken (t) s	Acceleration = change in velocity / time a = (v – u) / t m / s^2
A-B	0	6	6	10	0.6
B-C					
C-D					
D-E					
E-F					

The velocity at different times of a train departing direction is given in the figure. Analyse this and complete the table.

A car at rest starts to travel in a straight path. It reaches a velocity of 12 m/s in 4 s . What is its acceleration. Assuming that it accelerates uniformly? Initial velocity u = 0 m/s (since the car starts from rest)

Final velocity (v) = 12 m /s
Time taken (t) = 4 s acceleration (a)

$= (v - u) / t$
$= (12 - 0) / 4$
$= 3 \text{ m} / s^2$

Tell me

From the above information, can you calculate the acceleration of the cheetah?

Positive acceleration

If the velocity of an object increases with respect to time, then the object is said to be in positive acceleration or just acceleration.

Negative acceleration or deceleration or retardation

If the velocity of an object decreases with respect to time, then the object is said to be in negative acceleration or deceleration or retardation.

The velocity of a golf ball rolling in a straight line changes from 8 m/s to 2 m/s in 10 s. What is its deceleration, assuming that it is decelerating uniformly?

Initial velocity (u) = 8 m/s
Final velocity (v) = 2 m/s
Time taken(t) = 10 s
Acceleration (a) = (v – u)/t
= (2 – 8)/10
= –0.6 m/s²
The deceleration is –0.6 m/s²

Uniform acceleration

An object undergoes uniform acceleration when the change (increase or decrease) in its velocity for every unit of time is the same. Table shows a moving bus with uniform acceleration.

Time (s)	1	2	3	4	5
Velocity (m/s)	20+20	40+20	60+20	80+20	100 + 20
	(acceleration)				
	100 – 20	80-20	60-20	40-20	20-20
	(deceleration)				

When the velocity of the object is increasing by 20 m/s the acceleration is 20 m/s^2. When the velocity of the object is decreasing by 20 m/s the deceleration is 20 m/s^2.

Non – uniform acceleration

An object undergoes non uniform acceleration if the change in its velocity for every unit of time is not the same.

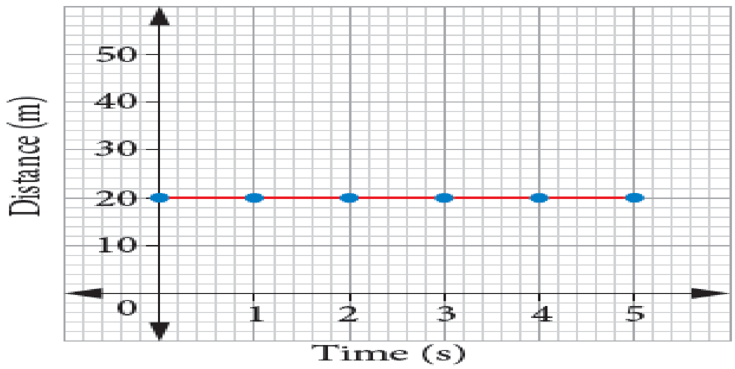
Time(s)	0	1	2	3	4	5
Change in Velocity(m/s)	0	10	30	20	10	20

Note that the change in velocity is not the same for every second. The moving object is undergoing non uniform acceleration.

Distance – Time Graphs

Figure shows a car travelling along a straight line away from the starting point O. The distance of the car is measured for every second. The distance and time are recorded and a graph is plotted using the data. The results for four possible journeys are shown below.

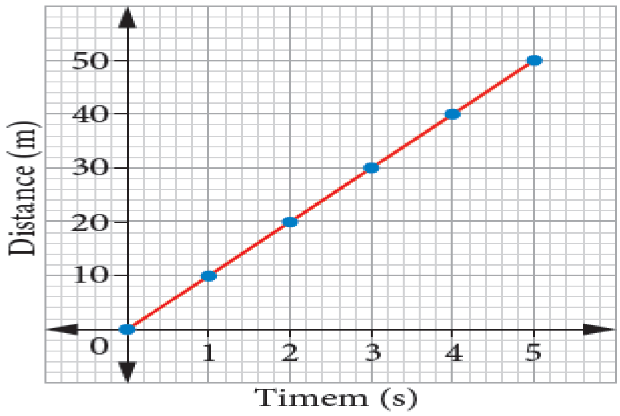
Time (s)	0	1	2	3	4	5
Distance(m)	20	20	20	20	20	20



The graph has zero gradient. The distance is a constant for every second.

(b) Car travelling at uniform speed of 10 m s^{-1}

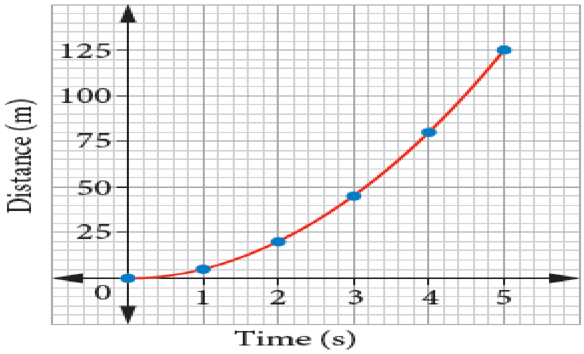
Time (s)	0	1	2	3	4	5
Distance (m)	0	10	20	30	40	50



The graph has a zero constant gradient. The distance increases 10 m every second.

(C) Car travelling at increasing speed

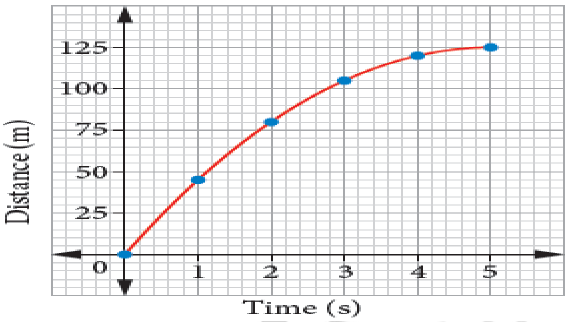
Time (s)	0	1	2	3	4	5
Distance(m)	0	5	20	45	80	125



The graph has an increasing gradient. The speed increases The instantaneous speed of the car at t = 3 s is given by the gradient of the tangent at the point.

(D) Car travelling at decreasing speed

Time (s)	0	1	2	3	4	5
Distance	0	45	80	105	120	125

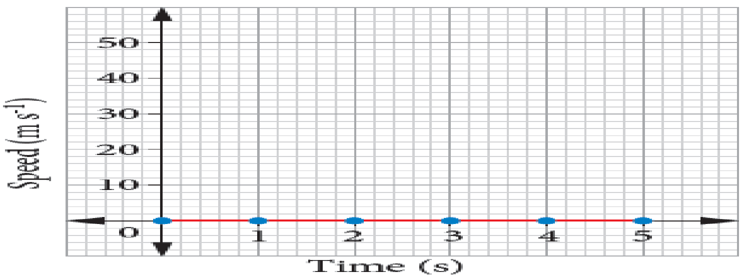


Speed – time graphs

Let us consider a bus travelling from Thanjavur to Trichy. The speed of the bus is measured for every second. The speed and time are recorded and a graph is plotted using the data. The results for four possible journeys are shown.

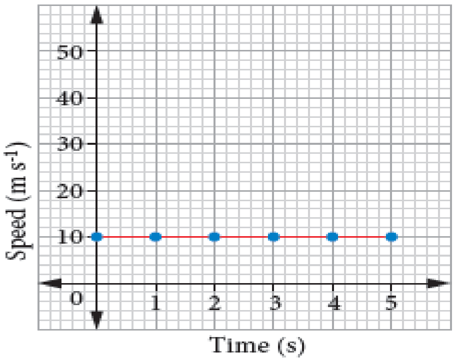
1. Bus at rest

Time (s)	0	1	2	3	4	5
Speed(ms^{-1})	0	0	0	0	0	0



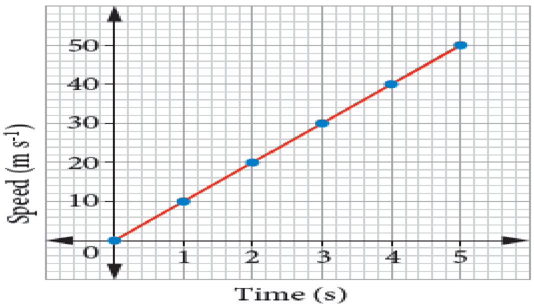
2. Bus travelling at uniform speed of m/s

Time(s)	0	1	2	3	4	5
Speed(m s^{-1})	10	10	10	10	10	10



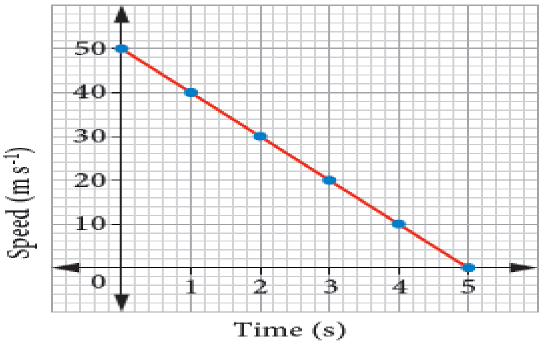
3. Bus travelling with uniform acceleration

Time	0	1	2	3	4	5
Speed (m s^{-1})	10	10	20	30	40	50



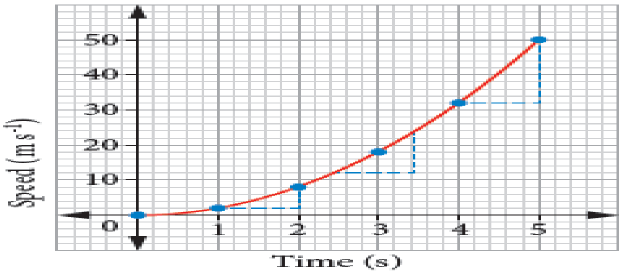
4. Bus travelling with uniform deceleration

Time (s)	0	1	2	3	4	5
Speed ms-1)	50	40	30	20	10	0



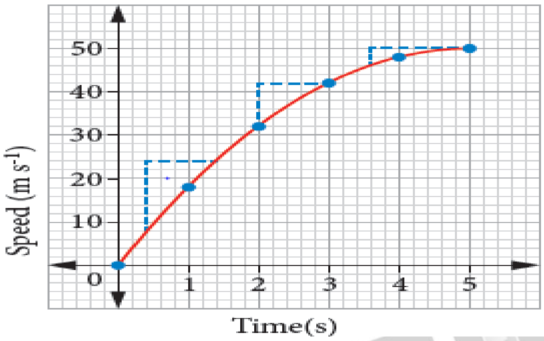
5. Bus travelling with increasing acceleration (non – uniform acceleration)

Time(s)	0	1	2	3	4	5
Speed (ms^{-1})	0	2	8	18	32	50



6. Bus travelling with decreasing acceleration (non – uniform acceleration)

Time (s)	0	1	2	3	4	5
Speed (ms^{-1})	0	18	32	42	48	50



Comparisons between distance – time and speed – time graphs

Speed – time graphs and Distance – time graphs look very similar, but they give different information. We can differentiate them by looking at the labels.

From A to B	**From B to C**	**From C to D**
Car accelerates uniformly from rest.	Car moves at constant speed.	Car decelerates uniformly to a stop.

Centre of Gravity and Stabilty
Centre of gravity

Try to balance a cardboard on your figure tip. What do we observe. We observe there is only one point which the cardboard is balanced. The point which the cardboard is balanced is called the cenre of gravity of the cardboard.

Centre of gravity: The centre of gravity of an object is the point through which the entire weight of the object appears to act.
How to we find the centre of gravity of a object?

Centre of gravity for Regular – shaped objects

Generally the centre of gravity of the geometrical shaped object lie on the geometric centre of the object.
Examples of centre of gravity for Regular-shaped objects. 1. Weight of Card,
2. Weight of Triangle, 3. Weight of Disc, 4. Weight of Ring.

What about irregular shaped objects?

Apparatus: Irregularly shaped card, string, pendulum bob, stand
1. Make three holes in the lamina.
2. Suspend the lamina from the optical pin through one of the holes as shown.
3. Suspend the plumbline from the pin and mark the position of the plumbline on
the lamina.
4. Draw lines on the lamina representing the positions of the plumbline.
5. Repeat the above steps for the holes.
6. Label the intersection of the three lines as X, the position of the centre of gravity of
the lamina.

Meter Rule

The ruler is in equilibrium when supported at its centre of gravity.
For a regular object such as a uniform meter rule, the centre of gravity is at the centre of the object. When the object is supported at that point, it will be balanced. If it is supported at any other point, it will topple.

Stability

Stability is a measure of the body's ability to maintain its original position.
The three types of stability are
(a) Stable equilibrium
(b) Unstable equilibrium
(c) Neutral equilibrium

Stable Equilibrium

The frustum can be tilted through quite a big angle without toppling.
Its centre of gravity is raised when it is displaced.

The vertical line through its centre of gravity still falls within its base.
So it can return to its orginal positionl.

Unstable Equilibrium

The frustum will topple with the slightest tilting. Its centre of gravity is lowered when it is displaced.

Neutral Equilibrium

(d) It causes frustum to topple.
(e) The frustum will rolls about but does not topple.
(f) Its centre of gravity remains at the same height when it is displaced.
(g) The body will stay in any position to which it has been displaced.

Condition for Stability

To make a body more stable.
Lower its centre of gravity.
Increase the area of its base.
This box is at the point of tipping over.
A heavy base lowers at the centre of gravity So the box does not tip over.
A brode base makes the box more difficult to tip over

The Thanjavur Doll

It is s type of traditional Indian toy made of terracotta material. The centre of gravity and the total weight of the doll is concentrated at its bottom most point, generating a dance-like continuous movement with slow oscillations.

Real Life Applications of Centre of Gravity

It is for the reasons of stability that the luggage compartment of a tour bus is located at the bottom and not on the roof. Extra passengers are not allowed on the upper deck of a crowded double decker bus. Racing cars are built low and broad for stability. Table lamps and fans are designed with large heavy bases to make them stable.

Science Today Typical Speeds

Tortoise 0.1 m/s
Person walking 1.4 m / s
Falling raindrop 9-10 m / s
Cat running 14 m/s
Cycling 20-25 km/h
Cheetah running 31 m/s
Bowling speed of fast bowlers 90-100 miles /h
Badminton smash 80-90 m/s Passenger jet 180 m/s

8^{TH} TERM 1

Unit-2 Forces and Pressure

Introduction

Every day you can observe bodies around you. When you are coming to school, you can notice that some of them are moving, some of them are at rest. What pushes or pulls them? What brings the moving bodies to rest? What is the effect of these pulls or pushes?

All the above questions can be answered by saying just one word, which is "Force".

FORCE

Observe the following actions in day to day life:

Opening up a pen, opening a door, kicking a football, striking a carrom coin, making of chapattis etc., all these actions need a force.

Force is an 'action of push or pull', which makes the bodies to move or brings the moving bodies to rest. It even changes the shape and size of certain bodies.

The group of students who pull the rope with a greater force will definitely win. The winners are applying a greater amount of force. Hence, the rope moves in the direction of the greater force.

Definition of force

Force is that which changes or tends to change: i) the state of rest or ii) the state of uniform motion of a body or iii) the direction of a moving body or iv) the shape of a body.

Pushes and pulls are forms of forces. The direction of a force is in the direction in which a push or a pull is applied. Thus, force is a vector quantity, which has magnitude and direction. It is measured with a unit called "newton (N)".

Factors on which a force depends

You have studied the effects of force so far. Now, you are going to study the factors on which the effect of a force actually depends.

When you play any game, the greater the force you apply on a body, greater will be its effect on it. Just observe the strokes of the bat by a batsman. If he wants to hit the cricket ball to the boundary, the striking force on the ball must be greater.

Now, the question before you is does it depend on the area of impact?

Inference: It is a wonderful sight to see that the balloon will not burst. How is this possible?

Reason: If you prick the blown up balloon with a single pin it will burst. But, this did not happen even though many more pins were pricking the balloon.

A single pin produces a large pressure over a small area. But, when a large number of pins prick a body, each pin exerts very little pressure on the balloon, as the applied force gets distributed over a larger surface of the body. So, the balloon will not burst.

We conclude that the effect of a force depends on the magnitude of the force and the area over which it acts.

Thrust

It is a force acting perpendicularly on any given surface area of a body. It is measured by the unit newton.

Pressure

The effect of force can be measured using a physical quantity called pressure. It can be defined as the amount of force or thrust acting perpendicularly on a surface of area one square meter of a body. Unit of pressure is pascal (Pa) or N m^{-2}.

Pressure =**Error! Objects cannot be created from editing field codes.**, P = F A. The SI unit of pressure is pascal (named after the French scientist Blaise Pascal). 1 pascal = 1 N m^{-2}

Pressure exerted by a force depends on the magnitude of the force and the area of

SOLVED PROBLEM:

Calculate the pressure exerted by the foot of an elephant using the following data. Average weight of an elephant is 4000 N. Surface area of the sole of its foot is 0.1m2 .

Solution:

Average weight of the elephant = 4000 N
Weight of one leg = force exerted by one leg = 4000/4 = 1000 N
Area of the sole of one foot = 0.1 m^2.

Pressure= **Error! Objects cannot be created from editing field codes.**
= 10000 **Error! Objects cannot be created from editing field codes.** = 10^4 N m^{-2}
Pressure exerted by one leg of the elephant is 10,000 newton on one square metre.

Increasing pressure:

The effect of pressure can be increased by increasing the thrust or by decreasing the area of the surface of the body experiencing the thrust.

Examples:

The axe, nail, knife, injection needle, bullet etc., all these are having sharp fine edges so as to exert a larger pressure on a smaller area of the body; in order to get the maximum effect from them.

It is very difficult to walk on sand. But, camels can walk easily on it because they have large padded feet, which increase the area of contact with the sandy ground. This reduces the pressure and enables them to walk easily on the sand.

Examples:

More number of wheels are provided for a heavy goods-carrier for decreasing the pressure; thereby increasing the area of contact on the road.
Broader straps are provided on a back-pack for giving a lower pressure on the shoulders by providing a larger area of contact with the shoulder.
It is difficult to drive an automobile, which has flattened tyres.

PRESSURE EXERTED BY AIR - ATMOSPHERIC PRESSURE

You all know very well that air fills the space all around us. This envelope of air is called as atmosphere. It extends up to many kilometres above the surface of the Earth. All objects on the surface of the Earth experience the thrust or force due to this atmosphere.

The amount of force or weight of the atmospheric air that acts downward on unit surface area of the surface of the Earth is known as atmospheric pressure. It can be measured using the device called barometer. The barometer was invented by "Torricelli".

Atmospheric pressure decreases with altitude from the surface of the Earth.

Atmospheric pressure can be measured by the height of the mercury column in a barometer. The height of the mercury column denotes the atmospheric pressure at that place at a given time in 'millimetre of mercury'.

Even if you tilt the tube at various angles, you will see that the level of mercury will not vary. At sea level, the height of the mercury column is around 76 cm or 760 mm. The pressure exerted by this mercury column is considered as the pressure of magnitude 'one atmosphere' (1atm).

1atmospheric peressure =1at = pressure exerted by the mercury column of height 76 cm in the barometer = 1.01×10^5 N $m^{-2.}$
In the SI system 1 atm = 1,00,000 pascal (approximately).
SI unit of atmospheric pressure is Nm^{-2} or pascal.
To realise the effect of atmospheric pressure:

FORCES IN LIQUIDS

Buoyant force of a liquid

An upward force is exerted by water on a floating or a partly submerged body. This upward force is called buoyant force. The phenomenon is known as "buoyancy". This force is not only exerted by liquids, but also by gases. Liquids and gases together are called fluids.

This upward force decides whether an object will sink or float. If the weight of the object is less than the upward force, then the object will float. If not, it will sink.

A body floats if the buoyant force > its weight; A body sinks if its weight > buoyant force.

Pressure exerted by liquids

Liquids do not have a definite shape. The force acting on unit area of the surface, on which the liquid is placed, is called the static pressure of the liquid. Liquids exert a pressure not only on the base of their container/vessel, but also on its side walls. The pressure exerted by a liquid depends upon the depth of the point of observation considered in it.

An instrument used to measure the difference in the liquid pressure is called a "manometer". You can measure the pressure of fluids enclosed in a definite container using the manometer.

a) Pressure exerted by a liquid on the base of a container depends upon the height of the liquid column:

You have already studied that the atmospheric pressure is measured in terms of the height of the mercury column in a barometer.

b) Liquids exert the same pressure in all directions at a given depth:
c) Liquid pressure varies with the depth:

Home Assignments

1. Ask your family doctor how blood pressure is to be measured?
2. Read the life history of Blasie Pascal.

Pascal's law:

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

Application of Pascal's law:

Some of the following examples highlight their working according to Pascal's law.

In an automobile service station, the vehicles are lifted upward using the hydraulic lift, which works as per Pascal's law.
The automobile brake system works according to Pascal's law.
The hydraulic press is used to make the compressed bundles of cotton or cloth so as to occupy less space.

All the above questions have an answer, i.e., "due to surface tension".
Surface tension is the property of a liquid. The molecules of a liquid experience a force, which contracts the extent of their surface area as much as possible, so as to have the minimum value. Thus, the amount of force acting per unit length, on the surface of a liquid is called surface tension. It has the unit N m^{1}.

Application of surface tension:

Water molecules rise up due to surface tension. Xylem tissues are very narrow vessels present in plants. Water molecules are absorbed by the roots and these vessels help the water to rise upward due to "capillarity action" (you will study this topic in the forth-coming classes), which is caused by the surface tension of water.

For a given volume, the surface area of a sphere is the minimum. This is the reason for the liquid drops to acquire a spherical shape.

Water strider insect slides on the water surface easily due to the surface tension of water.
During a heavy storm, sailors pour soap powder or oil into the sea near their ship to decrease the surface tension of sea water. This process reduces the impact of the violent water current against the all of ship.

VISCOUS FORCE OR VISCOSITY

Definition:

When a liquid is flowing, there is a frictional force between the successive layers of the liquid. This force which acts in order to oppose the relative motion of the layer is known as viscous force. Such a property of a liquid is called viscosity.

Viscosity force is measured by the unit called poise in CGS and kg m^{-1} s^{-1} or N s m^{-2} in SI.

Friction

Reason: Ram's brother falls down due to the lack of friction between his feet and the banana peels.

You have studied that forces are classified into two types: contact force and non-contact force. Now, you are going to study one of the contact forces, i.e., friction.

It is easy to hold a tumbler due to the friction between the surfaces of your palm and the tumbler. But, when oil is applied to your palm, the contact force between your fingers and the tumbler is reduced. So, the friction is reduced. Hence, it is difficult to hold it with an oily hand.

Origin of friction

Frictional force or friction arises when two or more bodies in contact move or tend to move, relative to each other. It acts always in the opposite direction of the moving body. This force is produced due to the geometrical dissimilarities of the surface of the bodies, which are in relative motion.

Effects of friction:

Friction can produce the following effects:

a) Friction opposes motion.
b) Friction causes wear and tear of the surfaces in contact.
c) Friction produces heat.

Types of friction:

Friction can be classified into two basic types: static friction and kinetic friction.

Static friction: The friction experienced by the bodies, which are at rest is called static friction. (E.g.: all the objects rigidly placed to be at rest on the Earth, a knot in a thread.)

Kinetic friction: Friction existing during the motion of bodies is called kinetic friction.
Further, kinetic friction can be classified into two: sliding friction and rolling friction.

Sliding friction: When a body slides over the surface of another body, the friction acting between the surfaces in contact is called sliding friction.

Rolling friction: When a body rolls over another surface, the friction acting between the surfaces in contact is called rolling friction.

Rolling friction is less than sliding friction. That is why wheels are provided in vehicles, trolleys, suitcases etc.

Reason: When you push the book, the pencils roll in the direction of the applied force. They prevent the contact of the book with the rough surface. Rolling pencils offer the least amount of friction. So, it is easy to displace the book in comparison with sliding it on the table.

This method is often used in moving heavy wood from one place to another.

Factors affecting friction
a) Nature of a surface:
b) Weight of the body:

It is easy to pedal your cycle without any load on its carrier. With a load placed on its carrier, it is difficult to move it because the weight on the carrier increases the friction between the surface of the tyre and the road.

c) Area of contact:

For a given weight, the friction is directly related to the area of contact between the two surfaces. If the area of contact is greater, then, the friction will be greater too.

A road roller has a broad base, so it offers more friction on the road. But, a cycle has the least friction, since the area of contact of the tyre with the surface of the road is less.

Advantages of friction

Friction is a necessity in most of our day to day activities. It is desirable in most situations of our daily life.

We can hold any object in our hand due to friction.
We can walk on the road because of friction. The footwear and the ground help us to walk without slipping.

Writing easily with a pen on paper is due to friction.
Automobiles can move safely due to friction between the tyres and the road. Brakes can be applied due to frictional resistance on brake shoes.
We are able to light a matchstick, sew clothes, tie a knot or fix a nail in the wall because of friction.

Though it is giving a negative effect, in most of our day to day life friction helps us to make our life easy. So, it is called as “necessary evil”.

Disadvantages of friction

Friction wears out the surfaces rubbing with each other, like screws and gears in machines or soles of shoes.
To overcome the friction an excess amount of effort has to be given to operate a machine. This leads to wastage of energy.
Friction produces heat, which causes physical damage to the machines.

Increasing and decreasing friction

a) Area of contact:

Friction can be increased by increasing the area of the surfaces in contact. Have you seen the sole of a shoe, which has grooves? It is done to provide the shoes a better grip with the floor, so that you can walk safely. Treaded tyres (tyres with slots and projections) are used to increase the friction.

Brake shoes in a cycle have to be adjusted so that they are as close as possible to the rim of the wheel, in order to increase the friction.

E.g.: Sumo players, Kabbadi players rub their hand with mud, to get a better grip. Football shoes are having soles with many projections, for providing a stronger grip with the ground.

b) Using lubricants:

A substance, which reduces the frictional force, is called a lubricant. E.g.: grease, coconut oil, graphite, castor oil, etc.
The lubricants fill up the gaps in the irregular surfaces between the bodies in contact. This provides a smooth layer thus preventing a direct contact between their rough surfaces.

c) Using ball bearing:

Since, the rolling friction is smaller than sliding friction, sliding is replaced by rolling with the usage of ball bearings. You can see lead shots in the bearing of a cycle hub.

9TH LESSON
UNIT 2- MOTION

Introduction

Every object undergoes motion, even stationary objects move along with the speed of earth. Hence it becomes necessary to study the state of an object at any instant of time. An object under the influence of forces may either be at rest or in motion.

Rest and Motion

In physics, the objects which do not change their position are said to be at rest, while those which change their position are said to be in motion. Example: A book lying on a table, the walls of a room (at rest) Cars and buses running on the road, birds and aeroplanes flying in air (in motion). Motion is a relative phenomenon. This means that an object appearing to be in motion to one person can appear to be at rest as viewed by another person. For example, trees on roadside would appear to move backward for a person travelling in a car while the same tree would appear to be at rest for a person standing on road side.

Types of Motion

In physics, motion can be classified under the following types for ease of understanding.

Linear motion - where the object moves along a straight line.
Circular motion - where the object moves along a circular path.
Oscillatory motion - where an object describes a repetitive to and fro movement retracing its original path.
Uniform motion - where an object travels equal distance in equal intervals of time.
Random motion - where the motion of the object does not fall in any of the above categories.

Uniform and Non Uniform Motion

Uniform motion

An object is said to be in uniform motion if it covers equal distances in equal intervals of time how so ever big or small these time intervals may be.

For example, suppose a car covers 60 km in first hour, another 60 km in second hour, and again 60 km in the third hour and so on. The motion of the car is uniform. Let us now understand the meaning of the words "how so ever small the time interval may be" used in the definition. In this example, the car travels a distance of 60 km in each hour. In the striker sense, the car should travel 30 km in each half an hour, 15 km in every 15 minutes, 10 km in every 10 minutes, 5 km in every 5 minutes and 1 km in every 1 minute. Only then the motion of the car can be said to be uniform.

Non uniform motion

An object is said to be in non-uniform motion if it covers unequal distances in equal intervals of time. Consider a bus starting from one stop. It proceeds slowly when it passes crowded area of the road. Suppose, it manages to travel merely 100 m in 5 minutes due to heavy traffic, when it gets out and the road is clear, it speeds up and is able to travel about 2 km in 5 minutes.

We say, the motion of the bus is non-uniform i.e. it travels unequal distances in equal intervals of time.

Distance and Displacement

Distance

The actual length of the path travelled by a moving body irrespective of the direction is called the distance travelled by the body. It is measured in metre in SI system. It is a scalar quantity having magnitude only.

Displacement

It is defined as the change in position of a moving body in a particular direction. It is Vector quantity having both magnitude and direction. It is also measured in metre in SI system.

Speed Velocity and Acceleration

Speed

Speed is the rate of change of distance or the distance travelled in unit time. It is a scalar quantity. The SI unit of speed is ms-1. Thus,
Speed = Distance travelled / time taken

Velocity

Velocity is the rate of change of displacement. It is the displacement in unit time. It is a vector quantity. The SI unit of velocity is ms-1. Thus, Velocity = Displacement / time taken

Acceleration

Acceleration is the rate of change of velocity or it is the change of velocity in unit time. It is a vector quantity. The SI unit of acceleration is ms-2.

Acceleration = Change in velocity/time
= (Final velocity - initial velocity)/time
a = (v-u)/t

Consider a situation in which a body moves in a straight line without reversing its direction.

Case 1: From the above equation if v > u, i.e. if final velocity is greater than initial velocity, the velocity increases with time and the value of acceleration is positive.
Case 2: If v < u, i.e. if final velocity is less than initial velocity the velocity decreases with time and the value of acceleration is negative. It is called negative acceleration. If the acceleration has a value of -2 ms"2 when we say that the retardation is 2 ms"2 or deceleration is 2 ms"2.

Case 3: If v = u, then a = 0. This means that the acceleration is zero when the final velocity is equal to initial velocity

Graphical Representation of Motion along a Straight Line

Plotting the distance/displacement or speed/velocity on a graph helps us visually understand certain things about time and position.

The distance - time graph for uniform motion

The following Table shows the distance walked by Surya at different times.

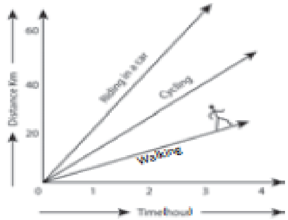
Time (minute)	**Distance (metre)**
0	0
5	500
10	1000
15	1500
20	2000
25	2500

A graph is drawn by taking time along X-axis and distance along Y-axis. The graph is known as distance - time graph. When we look at the distance - time graph of Surya's walk, we notice certain things. First, it is a straight line. We also notice that Surya covers equal distances in equal intervals of time. We can therefore conclude that Surya walked at a constant speed. Can you find the speed at which Surya walked, from the graph? Yes, you can. The parameter is referred to as the slope of the line.

Speed at which Surya walked = distance covered / time taken
= BC/AC (From the graph)
= slope of the straight line
= 500/5
= 100 ms^{-1}

Steeper the slope (in other words the larger value) the greater is the speed.

Let us take a look at the distance-time graphs of three different people - Surya walking, Monica cycling and Hari going in a car, along the same path. We know that cycling can be faster than walking and a car can go faster than a cycle. The distance -time graph of the three would be as given in the following graph. The slope of the line on the distance - time graph becomes steeper and steeper as the speed increases.



The distance time graph for non-uniform motion

We can also plot the distance - time graph for accelerated motion (non-uniform motion). Table given below shows the distance travelled by a car in a time interval of two second.

Note that the graph is not a straight line as we got in the case of uniform motion. This nature of the graph shows non - linear variation of the distance travelled by the car with time. Thus, the graph represents motion with non-uniform speed.

Velocity - Time graph

The variation in velocity of an object with time can be represented by velocity - time graph. In the graph, time is represented along the X - axis and the velocity is represented along the Y - axis. If the object moves at uniform velocity, a straight line parallel to X-axis is obtained. This Graph shows the velocity - time graph for a car moving with uniform velocity of 40 km/hour.

We know that the product of velocity and time gives displacement of an object moving with uniform velocity. The area under the velocity - time graph is equal to the magnitude of the displacement. So the distance (displacement) S covered by the car in a time interval of t can be expressed as

S = AC × CD
S = Area of the rectangle ABCD
(shaded portion in the graph)

We can also study about uniformly accelerated motion by plotting its velocity - time graph. Consider a car being driven along a straight road for testing its engine. Suppose a person sitting next to the driver records its velocity for every 5 seconds from the speedometer of the car. The velocity of the car in ms-1 at different instants of time is shown in the Table below.

Time (Second)	**Velocity of the Car (ms^{-1})**
0	0
5	9
10	18
15	27
20	36
25	45
30	54

In this case, the velocity – time graph for the motion of the car is shown in graph (straight line). The nature of the graph shows that the velocity changes by equal amounts in equal intervals of time. Thus, for all uniformly accelerated motion, the velocity – time graph is a straight line.

One can also determine the distance moved by the car from its velocity – time graph. The area under the velocity – time graph gives the distance (magnitude of displacement) moved by the car in a given interval of time.

Since the magnitude of the velocity of the car is changing due to acceleration, the distance S travelled by the car will be given by the area ABCDE under the velocity – time graph. That is

S = area ABCDE
= area of the rectangle ABCD + area of the triangle ADE
S = (AB × BC) + ½ (AD × DE)

The area ABCDE can also be calculated by considering the shape as trapezium. Area of the quadrangle ABCDE can also be calculated by calculating the area of trapezium ABCDE. It means

S = area of trapezium ABCDE
= ½ × sum of length of parallel sides × distance between parallel sides
S = ½ × (AB + CE) × BC

The case of non-uniformly accelerated motion, distance – time graph, velocity – time graphs can have any shape as shown in Figure below:

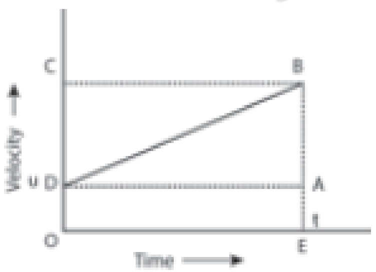
The magnitude of instantaneous velocity is to the instantaneous speed at the given instant. The speedometer of an automobile measures the instantaneous speed of the automobile. In a uniform motion in dimension, the average velocity = instantaneous velocity. Instantaneous velocity is also called velocity and instantaneous speed also called simply speed.

Equations of Motion

Newton studied the motion of an object and gave a set of three equations of motion. These equations relate the displacement, velocity, acceleration and time of an object under motion. An object is in motion with initial velocity u attains a final velocity v in time t due to acceleration a, with displacement s. The three equations of motion can be written as,

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

Let us try to derive these equations by graphical method.
Equations of motion from velocity - time graph:



Graph shows the change in velocity with time for an uniformly accelerated object. The object starts from the point D in the graph with velocity u. Its velocity keeps increasing and after time t it reaches the point B on the graph.
The initial velocity of the object = u = OD = EA
The final velocity of the object = v = OC = EB
Time = t = OE = DA
Also from the graph we know that, AB = DC

First equation of motion

By definition, acceleration = change in velocity / time
= (final velocity – initial velocity)/time
= (OC - OD) / OE
= DC/OE
a = DC/t
DC = AB = at
From the graph EB = EA + AB

$$\boxed{v = u + at}$$

This is first equation of motion. (1)

Second equation of motion

From the graph the distance covered by the object during time t is given by the area of quadrangle DOEB

s = area of the quadrangle DOEB
= area of the rectangle DOEA + area of the triangle DAB
= (AE x OE) + (1/2 x AB x DA)

$$\boxed{S = ut + \tfrac{1}{2} at^2}$$

This is second equation of motion. (2)

Third equation of motion

From the graph the distance covered by the object during time t is given by the area of the quadrangle DOEB. Here DOEB is a trapezium. Then

S = area of trapezium DOEB
=½ x sum of length of parallel side x distance between parallel sides
= V ½ x (OD + BE) x OE
S = V ½ x (u + v) x t
since a = (v - u) /1 or t = (v - u)/a
Therefore s = ½ x (v + u) x (v - u)/a
2 as = $v^2 - u^2$

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

This is third equation of motion (3)

Motion of objects under the influence of gravitational force of the earth - Freely falling body:

In activity , both the stone and the eraser have reached the surface of the earth almost at the same time but in activity 8, the eraser reaches first, the sheet of paper reaches later. In activity 9, the paper crumpled into a ball reaches ground first and plain sheet of paper reaches later, although they have equal mass. Do you know the reason? When all these objects are dropped in the absence of air medium (vacuum), all would have reached the ground at the same time. In air medium, due to friction, air offers resistance to the motion of free falling objects.

The resistance offered by air is negligibly small when compared to the gravitational pull acting on the stone and rubber (in activity). Hence, they reach the ground at the same time. But, in activity 8, the air resistance exerted on the sheet of paper is much higher than that on the eraser. Again in activity 9, the air resistance offered to the plain sheet of paper is much higher than that offered to the paper ball. This is because the magnitude of air resistance depends on the area of objects exposed to air. If we do experiment in a tall glass jar from which air has been sucked out, both the paper and the eraser would fall at the same rate. Galileo dropped different objects from the top of the Leaning Tower of Pisa in Italy to prove the same. We know that an object experiences acceleration during free fall. This acceleration experienced by an object is independent of mass. This means that all objects hollow or solid, big or small, should fall at the same rate.

Can a body have zero velocity and finite acceleration?
Yes, when a body is thrown vertically upwards in space, at the highest point, the body has zero velocity and acceleration to the acceleration due to the gravity.

The equation of motion for a freely falling body can be obtained by replacing ‘a’ in equations 1 to 3 with g, the acceleration due to gravity. For an object falling freely, its initial velocity u = 0. Thus we get the following equations

$$\boxed{v = gt,\ s = \tfrac{1}{2} gt^2,\ v^2 = 2gh}$$

when we through an object vertically upwards, it moves against the acceleration due to gravity. Hence g is taken to be –g in such cases.

If you carefully observe, on being released the stone moves along a straight line tangential to the circular path. This is because once the stone is released, it continues to move along the direction it has been moving at that instant. This shows that the direction of motion changed at every point when the stone was moving along the circular path. When an object moves with constant speed along a circular path, the motion is called uniform circular motion. When an object is moving with a constant speed along a circular path, the velocity changes due to the change in direction. Hence it is an accelerated motion.

Examples of uniform circular motion.

Revolution of earth around the sun.
Revolution of moon around the earth.
The tip of the second's hand of a clock.
If an object, moving along a circular path of radius r, takes time T to come back to its starting position, the speed v is given by,

Speed = circumference/time taken $V = 2\pi r/T$

Giant Wheel moves in a vertical circular path.

2. Centripetal Acceleration and Centripetal Force

A body is said to be accelerated, if the velocity of the body changes either in magnitude or in direction. Hence the motion of a stone in circular path with constant speed and continuous changes of direction is an accelerated motion. There must be an acceleration acting along the string directed inwards, which makes the stone to move in circular path.

This acceleration is known as centripetal acceleration and the force is known as centripetal force. Since the centripetal acceleration is directed radially towards the centre of the circle, the centripetal force must act on the object radially towards the centre.

Let us consider an object of mass m, moving along a circular path of radius r, with a velocity v, its centripetal acceleration is given by

$$\boxed{a = v^2/r}$$

Hence, the magnitude of centripetal force is given by,

F = mass x centripetal acceleration $F = mv^2/r$

In this activity, a pulling force that acts away from the centre is experienced. This is called as centrifugal force.

Centrifugal Force

Force acting on a body away from the centre of circular path is called centrifugal force. Thus centrifugal force is in a direction opposite to the direction of centripetal force. Its magnitude is same as that of centripetal force. The dryer in a washing machine is an example for the application of centrifugal force.

How do we separate cream from milk?

A separator is a high speed spinner. It acts on the same principle of centrifuge machines. The bowl spins at very high speed causing the heavier contents of milk to move outward in the bowl pushing the lighter contents inward towards the spinning axis. Cream is lighter than other components in milk. Therefore, skimmed milk which is denser than cream is collected at outer wall of the bowl. The lighter part of cream is pushed towards the centre from where it is collected through pipe.

When you go for a ride in a merry-go-round in amusement parks, what force do you experience?

We experience an outward pull as merry-go round rotates about vertical axis. This is due to centrifugal force.

Spin dryer - centrifugal force

1 - rotating metal drum
2 & 3 - wet cloth
4 - water droplet
5 - let out of droplets

A spin dryer removes excess water from clothing by rotating a perforated drum at high speed. The water is thrown out through the holes. The clothes keep moving in a circle because the contact force of the drum provides centrifugal force.

Points to Remember
™ Motion is a change of position, which can be described in terms of the distance moved or the displacement. ™™ Motion of an object could be uniform or non-uniform depending on its velocity. ™™ Speed of an object is the distance covered per unit time and velocity is the displacement per unit time. ™™ The acceleration of an object is the change in velocity per unit time. ™™ The motion of an object at uniform acceleration can be described with the help of three equations, namely: v = u + at; s = ut + ½ at2; v2 = u2 + 2as ™™ For a freely falling body, the acceleration, a is replaced by g. ™™ An object under uniform circular motion experiences centripetal force. ™™ Centrifugal force acts in a direction which is opposite to the direction of the centripetal force

9^{TH} LESSSON
UNIT – 3 FLUIDS

Introduction

A small iron nail sinks in water, whereas a huge ship of heavy mass floats on sea water. Astronauts have to wear a special suit while traveling in space. All these have a common reason called 'pressure'. If the pressure increases in a solid, based on its inherent properties, it experiences tension and ultimately deforms or breaks. In the case of fluids it causes them to flow rather than to deform. Although liquids and gases share some common characteristics, they have many distinctive characteristics on their own. It is easy to compress a gas whereas liquids are incompressible. Learning of all these facts helps us to understand pressure better. In this lesson you will study about pressure in fluids, density of fluids and their application in practical life.

Thrust and Pressure

Pushing a pin into a board by its head is difficult. But pushing it by the pointed end is easy. Why? Have you ever wondered why a camel can run in a desert easily? Why a truck or a motorbus has wider tyre? Why cutting tools have sharp edges? In order to answer these questions and understand the phenomena involved, we need to learn about two interrelated physical concepts called thrust and pressure.

In both the cases of the above activity, the force exerted on the sand is the weight of your body which is the same. This force acting perpendicular to the surface is called thrust. When you stand on loose sand, the force is acting on an area equal to the area of your feet. When you lie down, the same force acts on an area of your whole body, which is larger than the area of your feet. Therefore, the effect of thrust, depends on the area on which it acts

The effect of thrust on sand is larger while standing than while lying.
The force per unit area acting on an object concerned is called pressure. Thus, we can say thrust on an unit area is pressure.

$$\text{Pressure} = \frac{Thrust}{Area\ of contact}$$

For the same given force, if the area is large pressure is low and vice versa. This is shown in Figure

In SI units, the unit of thrust is newton (denoted as N). The unit of pressure is newton per square metre or newton metre–2 (denoted as Nm–2). In the honour of the great French scientist, Blaise Pascal, 1 newton per square metre is called as 1 pascal denoted as Pa. 1 Pa = 1 N m–2

If a single nail pricks our body it is very painful. How is it possible for people to lie down on a bed of nails, still remain unhurt? It is because, area of contact is more.

Pressure in Fluids

All the flowing substances, both liquids and gases are called fluids. Like solids, fluids also have weight and therefore exert pressure. When filled in a container, the pressure of the fluid is exerted in all directions and at all points of the fluid. Since the molecules of a fluid are in constant, rapid motion, particles are likely to move equally in any direction. Therefore, the pressure exerted by the fluid acts on an object from all directions. It is shown in Figure 3.2. Pressure in fluids is calculated as shown below.

$$\text{Fluid Pressure} = \frac{Total\ force\ exerted\ by\ the\ fluid}{Area\ over\ which\ the\ force\ is\ exerted} = \frac{F}{A}$$

We shall first learn about the pressure exerted by liquids and then learn about the pressure exerted by gases.

Pressure due to liquids

The force exerted due to the pressure of a liquid on a body submerged in it and on the walls of the container is always perpendicular to the surface. In Figure 3.3(a), we can see the pressure acting on all sides of the vessel.

When an air filled balloon is immersed inside the water in a vessel it immediately comes up and floats on water. This shows that water (or liquid) exerts pressure in the upward direction. It is shown in Figure 3.3(b).

Similarly, liquid pressure acts in lateral sides also. When a bottle having water is pierced on the sides we can see water coming out with a speed as in Figure 3.3(c). This is because liquid exerts lateral pressure on the walls the container.

Factors determining liquid pressure in liquids

Pressure exerted by a liquid at a point is determined by,
(i) depth (h)
(ii) density of the liquid (ρ)
(iii) acceleration due to gravity (g).

From this activity we can infer that pressure varies as depth increases. But, it is same at a particular depth independent of the direction.

Pressure due to a liquid column

A tall beaker is filled with liquid so that it forms a liquid column. The area of cross section at the bottom is A. The density of the liquid is ρ. The height of the liquid column is h. In other words the depth of the water from the top level surface is 'h' as shown in Figure in 3.4

We know that, thrust at the bottom of the column (F) = weight of the liquid.

Therefore, F = mg (1)

We can get the mass of the liquid by multiplying the volume of the liquid and its density.

Mass, m = ρ V (2)
Volume of the liquid column, V
= Area of cross section (A) × Height (h) = Ah (3)

Substituting (3) in (2)
Mass, m = ρAh (4)
Substituting (4) in (1)

Force = mg = ρAhg

Pressure, P = $\frac{Thrust\,(F)}{Area\,(A)} = \frac{mg}{A} = \frac{p(Ah)g}{A}$ = ρhg

Pressure due to a liquid column, P = hρg

This expression shows that pressure in aliquid column is determined by depth, density of the liquid and the acceleration due to gravity. Interestingly, the final expression for pressure does not have the term area A in it. Thus, pressure in liquid depends on depth only.

Atmospheric pressure

Earth is surrounded by a layer of air up to certain height (nearly 300 km) and this layer of air around the earth is called atmosphere of the earth. Since air occupies space and has weight, it also exerts pressure. This pressure is called atmospheric pressure. The atmospheric pressure we normally refer is the air pressure at sea level.

Figure 3.5 shows that air gets 'thinner' with increasing altitude. Hence, the atmospheric pressure decreases as we go up in mountains. On the other hand air gets heavier as we go down below sea level like mines.

Human lung is well adapted to breathe at a pressure of sea level (101.3 k Pa). As the pressure falls at greater altitudes, mountain climbers need special breathing equipments with oxygen cylinders. Similar special equipments are used by people who work in mines where the pressure is greater than that of sea level.

Measurement of atmospheric pressure

The instrument used to measure atmospheric pressure is called barometer. A mercury barometer, first designed by an Italian Physicist Torricelli, consists of a long glass tube (closed at one end, open at the other) filled with mercury and turned upside down into a container of mercury. This is done by closing the open end of the mercury filled tube with the thumb and then opening it after immersing it in to a trough of mercury

The barometer works by balancing the mercury in the glass tube against the outside air pressure. If the air pressure increases, it pushes more of the mercury up into the tub and if the air pressure decreases, more of the mercury drains from the tube. As there is no air trapped in the space between mercury and the closed end, there is vacuum in that space. Vacuum cannot exert any pressure. So the level of mercury in the tube provides a precise measure of air pressure which is called atmospheric pressure. This type of instrument can be used in a lab or weather station.

On a typical day at sea level, the height of the mercury column is 760 mm. Let us calculate the pressure due to the mercury column of 760 mm which is equal to the atmospheric pressure. The density of mercury is 13600 kg m–3.

Pressure, $P = h\rho g$
$= (760 \times 10^{-3} m) \times (13600\ kgm^{-3}) \times (9.8\ ms^{-2}) = 1.013 \times 10^{5}$ Pa.

This pressure is called one atmospheric pressure (atm). There is also another unit called (bar) that is also used to express such high values of pressure.

1 atm = 1.013 × 105 Pa.
1 bar = 1 × 105 Pa.
Hence, 1 atm = 1.013 bar.

Expressing the value in kilopascal gives 101.3 k Pa. This means that, on each 1 m2 of surface, the force acting is 1.013 k N.

Gauge pressure and absolute pressure

Our daily activities are happening in the atmospheric pressure. We are so used to it that we do not even realise. When tyre pressure and blood pressure are measured using instruments (gauges) they show the pressure, over the atmospheric pressure. Hence, absolute pressure is zero-referenced against a perfect vacuum and gauge pressure is zeroreferenced against atmospheric pressure.

For pressures higher than atmospheric pressure,
absolute pressure = atmospheric pressure +
gauge pressure

For pressures lower than atmospheric pressure,
absolute pressure = atmospheric pressure –
gauge pressure

We have seen that liquid column exerts pressure. So the pressure inside the sea will be more. This is more than twice the atmospheric pressure. Parts of our body, especially blood vessels and soft tissues cannot withstand such high pressure. Hence, scuba divers always wear special suits and equipment to protect them.

In petrol bunks, the tyre pressure of vehicles is measured in a unit called psi. It stands for pascal per inch, an old system of unit for measuring pressure.

Pascal's Law

Pascal's principle is named after Blaise Pascal (1623-1662), a French mathematician and physicist. The law states that the external pressure applied on an incompressible liquid is transmitted uniformly throughout the liquid. Pascal's law can be demonstrated with the help of a glass vessel having holes all over its surface. Fill it with water. Push the piston. The water rushes out of the holes in the vessel with the same pressure. The force applied on the piston exerts pressure on water. This pressure is transmitted equally throughout the liquid in all directions (Fig. 3.8). This principle is applied in various machines used in our daily life.

Hydraulic press Pascal's law became the basis for one of the important machines ever developed, the hydraulic press. It consists of two cylinders of different cross-sectional areas as shown in Figure 3.9. They are fitted with pistons of cross-sectional areas "a" and 'A'. The object to be lifted is placed over the piston of large cross-sectional area A. The force F1 is applied on the piston of small cross-sectional area 'a'. The pressure P produced by small piston is transmitted equally to large piston and a force F2 acts on A which is much larger than F_1.

Pressure on piston of small area 'a' is given by,

$P=\frac{f1}{A1}$ (1)

Applying Pascal's law, the pressure on large piston of area A will be the same as that on small piston. Therefore, $P=\frac{f2}{A2}$ (2)

Comparing equations (1) and (2),we get

$\frac{F1}{A1}=\frac{F2}{A2}$.or $F2=F1\times\frac{A2}{A1}$

Since, the ratio $\frac{A2}{A1}$is greater than 1, the force F2 that acts on the larger piston is greater than the force F1 acting on the smaller piston. Hydraulic systems working in this way are known as force multipliers.

To understand density better, let us assume that the mass of the flask be 80 g. So, the mass of the flask filled with water is 330 g and the mass of flask filled with kerosene is 280 g. Mass of water only is 250 g and kerosene only is 200 g. Mass per unit volume of water is 250/250 cm3. This is 1g/cm3. Mass per unit volume of kerosene is 200 g/250 cm3. This is 0.8 g/cm3. The result 1 g/cm3 and 0.8 gcm3 are the densities of water and kerosene respectively. Therefore, the density of a substance is the mass per unit volume of a given substance.
The SI unit of density is kilogram per meter cubic (kg/m3) also gram per centimeter cubic (g/cm3). The symbol for density is rho (ρ).

Relative Density

We can compare the densities of two substances by finding their masses. But, generally density of a substance is compared with the density of water at 4 °C because density of water at that temperature is 1g/cm3. Density of any other substance with respect to the density of
water at 4 °C is called the relative density. Thus relative density of a substance is defined as ratio of density of the substance to density of water at 4 °C. Mathematically, relative density (R.D),

$$= \frac{Density\ of\ the\ substance}{Density\ of\ water\ at\ 4\ °c}$$

We know that, Density $\frac{Mass}{volume}$

∴ Relative density

$$= \frac{mass\ of\ the\ substance/volume of\ the\ sunstance}{mass\ of\ water/volume\ of\ water}$$

Since the volume of the substance is equal to the volume of water,

Relative density

$$= \frac{mass\ of\ certain/volume of\ the\ sunstance}{mass\ of\ equal/volume\ of\ water\ at\ 4\ °c}$$

Thus, the ratio of the mass of a given volume of a substance to the mass of an equal volume of water at 4°C also denotes relative density.

Measurement of relative density

Relative density can be measured using Pycnometer also called density bottle. It consists of ground glass stopper with a fine hole through it. The function of the hole in a stopper is that, when the bottle is filled and the stopper is inserted, the excess liquid rises through the hole and runs down outside the bottle. By this way the bottle will always contain the same volume of whatever the liquid is filled in, provided the temperature remains constant. Thus, the density of a given volume of a substance to the density of equal volume of referenced substance is called relative density or specific gravity of the given substance. If the referenced substance is water then the term specific gravity is used.

Floating and sinking

Whether an object will sink or float in a liquid is determined by the density of the object compared to the density of the liquid. If the density of a substance is less than the density of the liquid it will float. For example a piece of wood which is less dense than water will float on it. Any substance having more density than water (for example, a stone), will sink into it.

Application of principle of flotation

Hydrometer

A direct-reading instrument used for measuring the density or relative density of the liquid is called hydrometer. Hydrometer is based on the principle of flotation, i.e., the weight of the liquid displaced by the immersed portion of the hydrometer is equal to the weight of the hydrometer.

Hydrometer consists of a cylindrical stem having a spherical bulb at its lower end and a narrow tube at its upper end. The lower spherical bulb is partially filled with lead shots or mercury. This helps hydrometer to float or stand vertically in liquids. The narrow tube has markings so that relative density of a liquid can be read directly.

The liquid to be tested is poured into the glass jar. The hydrometer is gently lowered in to the liquid until it floats freely. The reading against the level of liquid touching the tube gives the relative density of the liquid.

Hydrometers may be calibrated for different uses such as lactometers for measuring the density (creaminess) of milk, saccharometer for measuring the density of sugar in a liquid and alcoholometer for measuring higher levels of alcohol in spirits.

Lactometer

One form of hydrometer is a lactometer, an instrument used to check the purity of milk. The lactometer works on the principle of gravity of milk.
The lactometer consists of a long graduated test tube with a cylindrical bulb with the graduation ranging from 15 at the top to 45 at the bottom. The test tube is filled with air. This air chamber causes the instrument to float. The spherical bulb is filled with mercury to cause the lactometer to sink up to the proper level and to float in an upright position in the milk.

Inside the lactometer there may be a thermometer extending from the bulb up into the upper part of the test tube where the scale is located. The correct lactometer reading is obtained only at the temperature of 60 °F. A lactometer measures the cream content of milk. More the cream, lower the lactometer floats in the milk. The average reading of normal milk is 32. Lactometers are used at milk processing units and dairies.

Buoyancy

We already saw that a body experiences an upward force due to the fluid surrounding, when it is partially or fully immersed in to it. We also know that pressure is more at the bottom and less at the top of the liquid. This pressure difference causes a force on the object and pushes it upward. This force is called buoyant force and the phenomenon is called buoyancy (Fig.3.11).

Most buoyant objects are those with a relatively high volume and low density. If the object weighs less than the amount of water it has displaced (density is less), buoyant force will be more and it will float (such object is known as positively buoyant). But, if the object weighs more than the amount of water it has displaced (density is more), buoyant force is less and the object will sink (such object is known as negatively buoyant).

Salt water provides more buoyant force than fresh water, because, buoyant force depends as much on the density of fluids as on the volume displaced.

Cartesian diver

Cartesian diver is an experiment that demonstrates the principle of buoyancy. It is a pen cap with clay. The Cartesian diver contains just enough liquid that it barely floats in a bath of the liquid; its remaining volume is filled with air. When pressing the bath, the additional water enters the diver, thus increasing the average density of the diver, and thus it sinks

Archimedes Priciple

Archimedes principle is the consequence of Pascal's law. According to legend, Archimedes devised the principle of the 'hydrostatic balance' after he noticed his own apparent loss in weight while sitting in his bath. The story goes that he was so enthused with his discovery that he jumped out of his bath and ran through the town, shouting 'eureka'. Archimedes principle states that 'a body immersed in a fluid experiences a vertical upward buoyant force equal to the weight of the fluid it displaces'.

When a body is partially or completely immersed in a fluid at rest, it experiences an upthrust which is equal to the weight of the fluid displaced by it. Due to the upthrust acting on the body, it apparently loses a part of its weight and the apparent loss of weight is equal to the upthrust.

Thus, for a body either partially or completely immersed in a fluid,
Upthrust = Weight of the fluid displaced = Apparent loss of weight of the body.

Apparent weight of an object
= True weight of an object in air – Upthrust (weight of water displaced)

Laws of flotation

Laws of flotation are:
1. The weight of a floating body in a fluid is equal to the weight of the fluid displaced by the body.

2. The centre of gravity of the floating body and the centre of buoyancy are in the same vertical line.

The point through which the force of buoyancy is supposed to act is known as centre of buoyancy. It is shown in Figure

Flotation therapy uses water that contains Epsom salts rich in magnesium. As a floater relaxes, he or she is absorbing this magnesium through the skin. Magnesium helps the body to process insulin, which lowers a person's risk of developing Type 2 Diabetes.

Points to Remember

The force which produces compression is called thrust. Its S.I. unit is newton.

Thrust acting normally to a unit area of a surface is called pressure. Its S.I. unit is pascal.

The pressure exerted by the atmospheric gases on its surroundings and on the surface of the earth is called atmospheric pressure. 1 atm is the pressure exerted by a vertical column of mercury of 76 cm height.

Barometer is an instrument used to measure atmospheric pressure.

The upward force experienced by a body when partly or fully immersed in a fluid is called upthrust or buoyant force.

Cartesian diver is an experiment which demonstrates the principle of buoyancy and the ideal gas law.

Pascal's law states that an increase in pressure at any point inside a liquid at rest is transmitted equally and without any change, in all directions to every other point in the liquid.

Archimedes' principle states that when a body is partially or wholly immersed in a fluid, it experiences an up thrust or apparent lose of weight, which is equal to the weight of the fluid displaced by the immersed part of the body.

Density is known as mass per unit volume of a body. Its S.I. unit is kg m–3.

Relative density is the ratio between the density of a substance and density of water. Relative density of a body is a pure number and has no unit.

Hydrometer is a device used to measure the relative density of liquids based on the Archimedes' principle.

Lactometer is a device used to check the purity of milk by measuring its density using Archimedes' principle.