JSR IAS ACADEMY

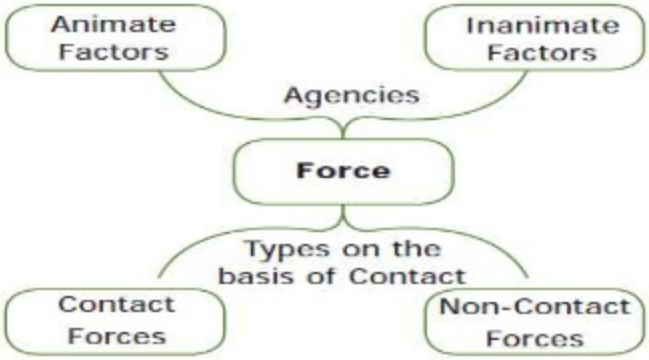
GENERAL SCIENCE

PHYSICS

Force, Pressure and Energy, Everyday application of the basic principles of Mechanics -I

Motion

Motion is the change in the position of an object with respect to its surrounding.



You can classify the motion according to the path taken by the object.

a. Linear- moving in a straight line, like a person walking on a straight path, free fall.
b. Curvilinear - moving ahead but changing direction, like a throwing ball.
c. Circular -moving in a circle, swirling stone tied to the rope.
d. Rotatory -The movement of a body about its own axis, like a rotating top.
e. Oscillatory -coming back to the same position after a fixed time interval, like a pendulum.

f. Zigzag (irregular)- like the motion of a bee or people walking in a crowded street.

Do you notice that all oscillatory motions are periodic, but not all periodic are oscillatory?

Uniform and non-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.

Multiple Motion

❖ 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.

Motion of freely falling body

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

DO YOU KNOW?

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 but it has acceleration due to the gravity.

When we throw an object vertically upwards, it moves against the acceleration due to gravity. Hence, 'a' is taken to be –g and when moving downwards 'a' is taken as +g.

Uniform circular motion

If an object, moving along a circular path of radius, r takes time, T to come back to its starting position, then the speed, v is given by,

Speed = Circumference/Time taken

V = 2pr/T

DO YOU KNOW?

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.

Distance

The actual length of the path travelled by a moving body irrespective of the direction is called the distance travelled by the body.

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

- It is measured in metre in SI system.
- It is a scalar quantity having magnitude only.

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.

Displacement

It is defined as the change in position of a moving body in a particular direction.

The shortest distance from the initial to the final position of an object.

- It is a vector quantity having both magnitude and direction.
- It is also measured in metre in SI system.

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.

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

An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?

Solution:

Total distance travelled by the object = 16 m + 16 m = 32 m

Total time taken = 4s + 2s = 6s

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{32m}{6s} = 5.33\ ms^{-1}$$

Therefore, the average speed of the object is 5.33 ms^{-1}

A sound is heard 5 s later than the lightning is seen in the sky on a rainy day. Find the distance of location of lightning? Given the speed of sound = 346 ms^{-1}

Solution:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Distance = Speed × Time = 346 × 5 = 1730 m

Thus, the distance of location of lightning is 1730 m.

Velocity

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

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)

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

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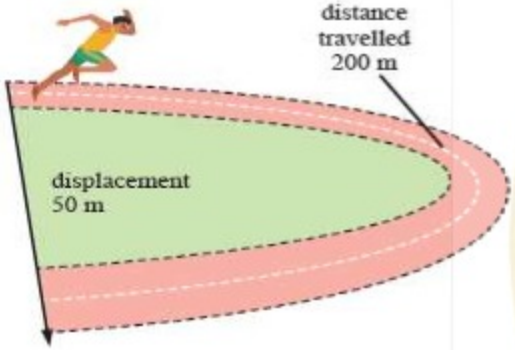


If an athlete in the diagram takes 25 s to complete a 200 m sprint event. Find her speed and velocity?

Speed = distance / time
= 200 / 25
= 8 m/s

velocity = displacement /time
= 50 / 25
= 2 m/s

Usain Bolt crossed 100metre in 9.58 seconds and made a world record. If you have the hope to run in a speed above that speed. Then Olympic Gold Medal is waiting for you.

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

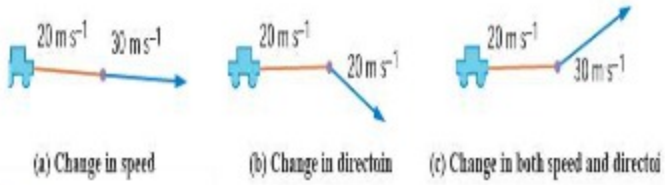
Acceleration (a)

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



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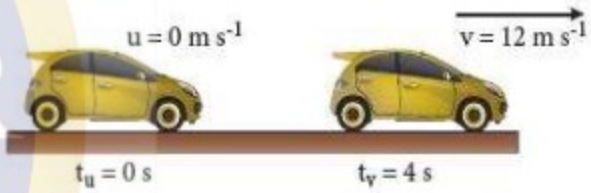
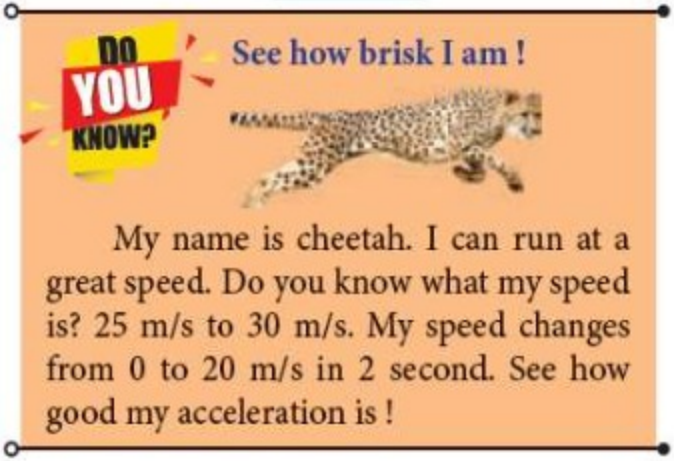
Tell me



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 m / s^2

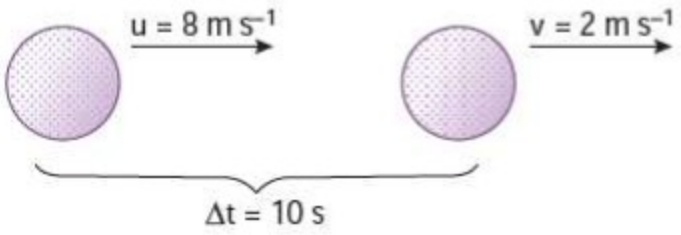


Positive acceleration

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.



Th e 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/s^2
- The deceleration is –0.6 m/s^2

Uniform acceleration

An object undergoes uniform accelcration 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 .

Non – uniform acceleration

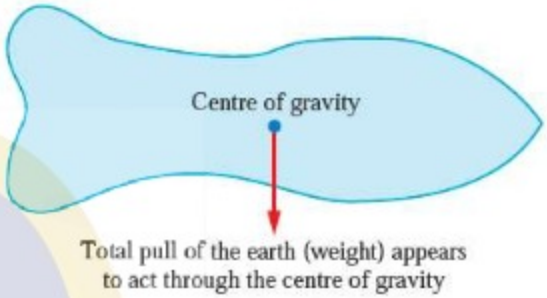
An object undergoes non uniform acceleration if the change in its velocity for every unit of time is not the same.

Time (s)	0	1	2	3	4	5
Velocity (m/s)	0	10	40	60	70	50
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.

Centre of gravity

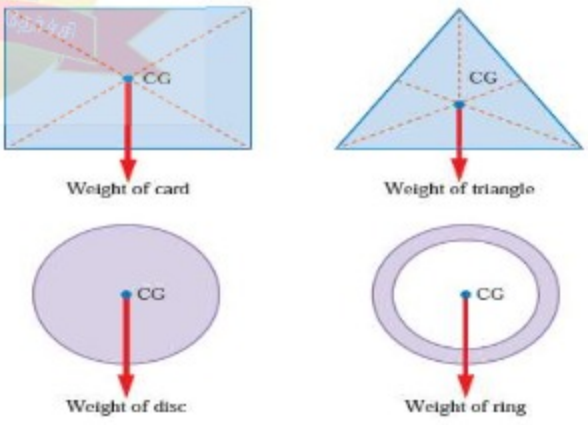
The point which the cardboard is balanced is called the cenre of gravity of the cardboard.



Centre of gravity:

The centre of gravity of an object is the point through which the entire weight of the object appears to act.

Centre of gravity for Regular – shaped objects



Stability

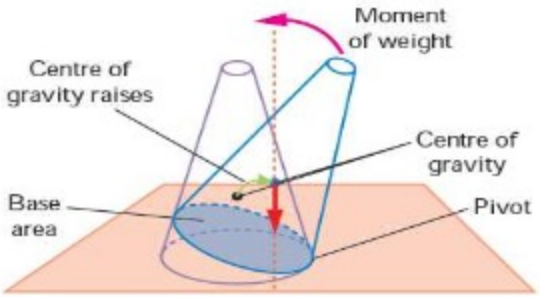
Stability is a measure of the body's ability to maintain its original position.

The three types of stability are

(a) Stable equilibrium
(b) Unstable equilibrium
(c) Neutral equilibrium

Stable Equilibrium

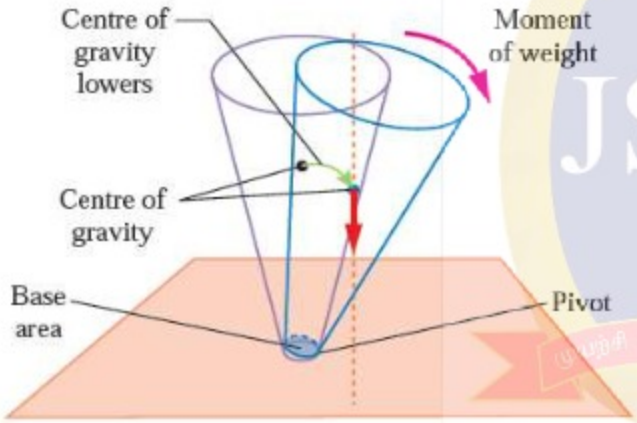
The frustum can be tilted through quite a big angle without toppling.



- 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

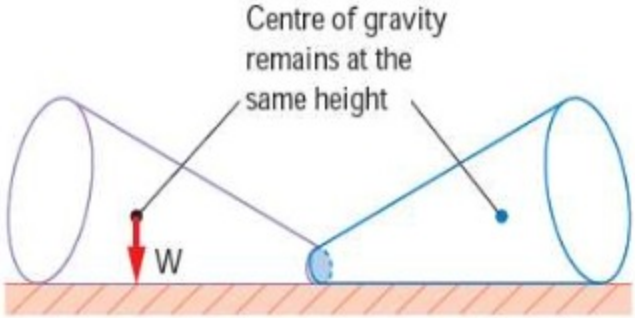
The frustum will topple with the slightest tilting. Its centre of gravity is lowered when it is displaced.



The vertical line through its centre of gravity falls outside its base.

Neutral Equilibrium

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 .

- 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.

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

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.

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.

- 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)".**

When the force is applied against the direction of the motion, the speed can be reduced, or even the motion stopped completely.

Forces can

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

Thrust

It is a force acting perpendicularly on any given surface area of a body.

It is measured by the unit newton.

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.
- So, the motion of a stone in circular path with constant speed and contineous change of direction is an accelerated motion.
- In this case, 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.
- 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 $a = v^2/r$
- The magnitude of centripetal force is given by,
- F = Mass × Centripetal acceleration $F = mv^2/r$

DO YOU KNOW?

Any force like gravitational force, frictional force, magnetic force, electrostatic force etc., may act as a centripetal force.

A 900 kg car moving at 10 ms^{-1} takes a turn around a circle with a radius of 25 m. Determine the acceleration and the net force acting upon the car.

Solution:

When the car turns around circle, it experiences centripetal acceleration, $a = \frac{v^2}{r}$

$$a = \frac{(10)^2}{25} = \frac{100}{25} = 4 \text{ ms}^{-2}$$

Net force acting upon the car,

$$F = m\,a = 900 \times 4 = 3600 \text{ N}$$

Centrifugal Force

- In this activity, a pulling force that acts away from the centre is experienced. This is called as centrifugal force.
- Force acting on a body away from the centre of circular path is called centrifugal force.
- Thus, centrifugal force acts in a direction which is 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.

DO YOU KNOW?

When you go for a ride in a merry-go-round in amusement parks, you will experience an outward pull as merry-go round rotates about vertical axis. This is due to centrifugal force.