2. Motion and Laws of Motion

Let us assess

1. Question

Observe the figures given below. Answer the following questions.


a) When the card is suddenly struck off, what happens to the coin? Explain.

b) What is the law to which this property is related?

c) How is the property related to the mass of the object?

Answer

The figures given below tells about the impact of forces, the left figure tells the moment before the force is applied and the right hand side figure tells us about the moment after force has been applied. The force applied is fast, that is the force was applied within a very short interval of time (IMPULSE).

(a). When the card is suddenly(short interval of time) struck off from it's rest position, that is force was applied on card, not on coin,

The coins remains at the same position, and does not changes it's position unlike the card but falls from it's original position where it was kept and it falls simply vertically, also there is no change in it's position in horizontal way. The coin falls freely.

The coin falls as if it was dropped from it's same position.

The reason behind this type of behavior of the coin is due to INERTIA which depends upon mass.

This type of inertia is called inertia of rest which means that when a body is at rest it remains at rest.

So that's what the coin does.

(b). This property inertia(rest) is related to Newton's first law of motion which tells us that " When a body is at motion it remains in motion in one direction and with constant velocity and when a body is at rest it remains at rest until there is an external force applied on the body. " .

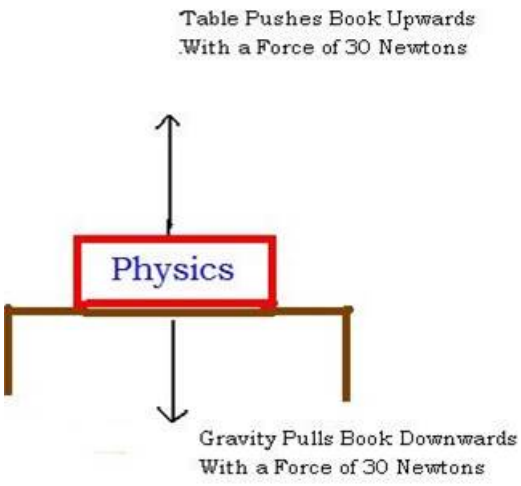
(c). The property INERTIA is directly proportional to the mass of the object, that is the body having large mass will have large inertia and the body having small mass will have small inertia.

2. Question

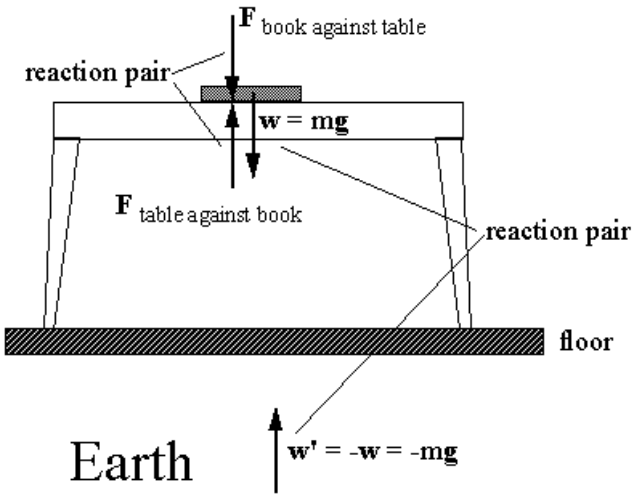
What are the balanced forces acting on a book at rest on a table?

Answer

When a book is kept on a table at rest, it is in state of inertia of rest , and the forces acting on the book are the weight of the book which acts downwards on the table and the normal reaction force which acts upwards on the book back by the table(by Newton's third law of motion which is action = reaction) and counter balances the weight force.



Hence Net Force acting on the book is 0N when it is kept on a table at rest.



3. Question

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

Answer

There is same principle in this case which is about inertia which is that the sand particles are at rest along with the carpet and are resting on carpet , as soon as we hit the carpet with a stick we apply a force very fast and within a short interval of time which does not affect the sand particles because they are at inertia of rest but the force acts on the carpet which moves the carpet and the dust particles fall down because they do not move with the carpet.

As we apply force on carpet it is no longer in inertia, so the only thing possessing inertia in this question is dust particles.

4. Question

A car and a bus are travelling with the same velocity. Which has grater momentum? Why?

Answer

As the momentum is the product of mass and velocity , or we can also say it that it is the amount of motion contained in the body.

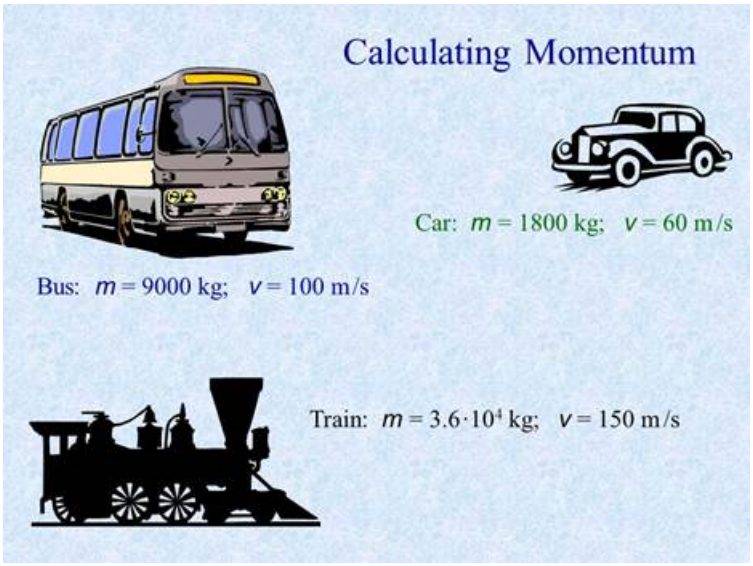
Mathematically,

$p = m \times v$

WherWhere,s momemomentum;s massmass;s velocity.

The car and the bus are travelling with the same velocity, and as we know that bus has larger mass than that

of car, so, as the momentum is the product of mass and velocity.



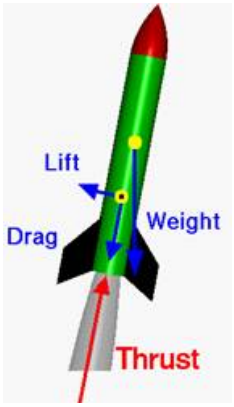
Therefore, bus will have larger momentum than car due to it's larger weight than that of car.

5. Question

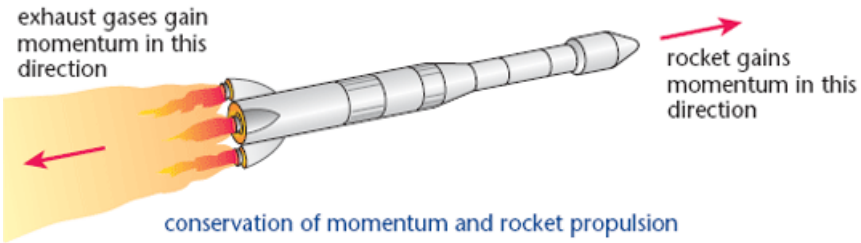
On the basis of Newton's third law of motion, explain the source of force that helps to propel a rocket upward.

Answer

We know that a rocket has excess of fuel in it and the fuel is burned and the gases are released from the bottom of the rocket where we see fire. As the action done by the rocket is to release the gases with high speed in downward direction and the reaction given by the gases is to move the rocket in upward direction which is the thrust force , according to Newton's third law of motion action done by the rocket by releasing gases(downward) gives the rocket reaction(upwards) by the gases which is equal and opposite.



Therefore, the source of force that propels the rocket to move upwards is the reaction force given by the burned gases when they are released by the rocket, the force is called thrust force.



The rocket also moves with the principle of law of conservation of momentum because when it burns the fuel and exhaust the gases it actually releases the mass from the bottom tip of it and hence gets an upward thrust to conserve the momentum.

6. Question

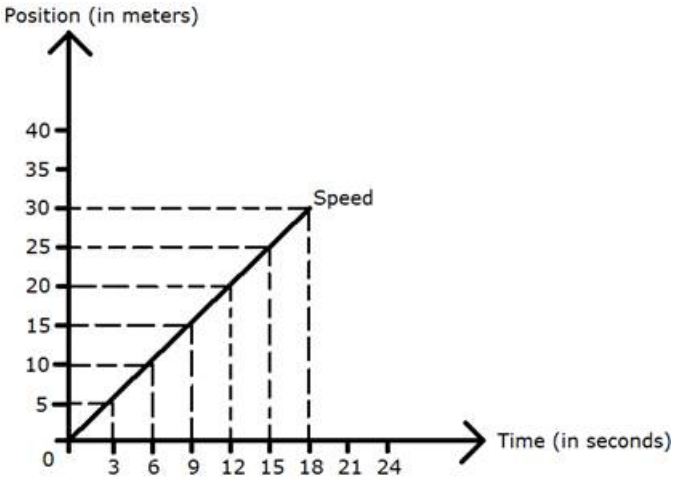
Draw the position-time graph with the given data.

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

Answer

The graph is drawn in this manner because it has all points with same difference and hence it would not matter if we draw all points on the axis of position and time that is 1,2,3,.....

Then also the curve of the graph obtained will be straight line.



Always remember – The curve of the graph between position(Y-axis) and time(X-axis) represents Speed or velocity.

Mathematically,

$$v = \frac{d}{t}$$

Where, v is velocity; d is displacement; t is time.

The straight line of the graph represents that the speed is constant and acceleration is zero(0). Velocity is the rate of change of displacement with respect to time whereas speed is the rate of change of distance with respect to time(time interval in which the change of distance or displacement took place).

7. Question

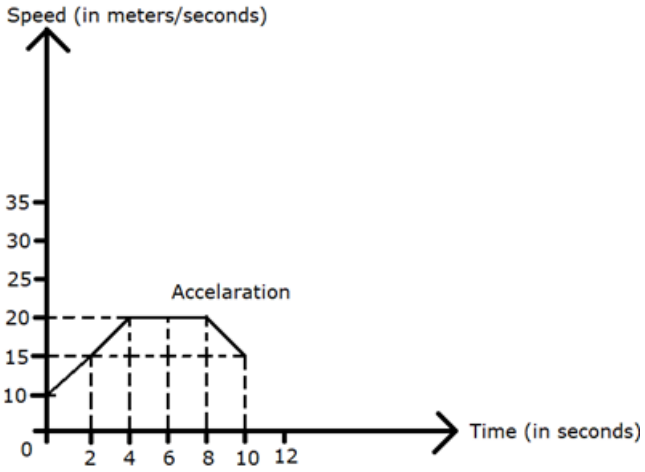
Draw a speed-time graph using the given data.

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

Answer

The graph is drawn in this manner because it has all points with same difference and hence it would not matter if we draw all points on the axis of position and time that is 1,2,3,.....

Then also the curve of the graph obtained will be straight line.



Always remember – The curve of the graph between speed or velocity(Y-axis) and time(X-axis) represents Acceleration.

Mathematically,

$$a = \frac{v}{t}$$

Where, a is acceleration; v is velocity; t is time.

The straight portion parallel to time axis and perpendicular to speed axis shows that in that time interval the speed was constant and acceleration was zero (0).

The rest of the straight lines of the graph shows that the acceleration is constant and uniform which means velocity will increase uniformly. Acceleration is the rate of change of velocity with respect to time(time interval in which the change of velocity took place).

8. Question

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

Answer

We know that the momentum is the product of mass and velocity of an object or it is the amount of motion contained in the body.

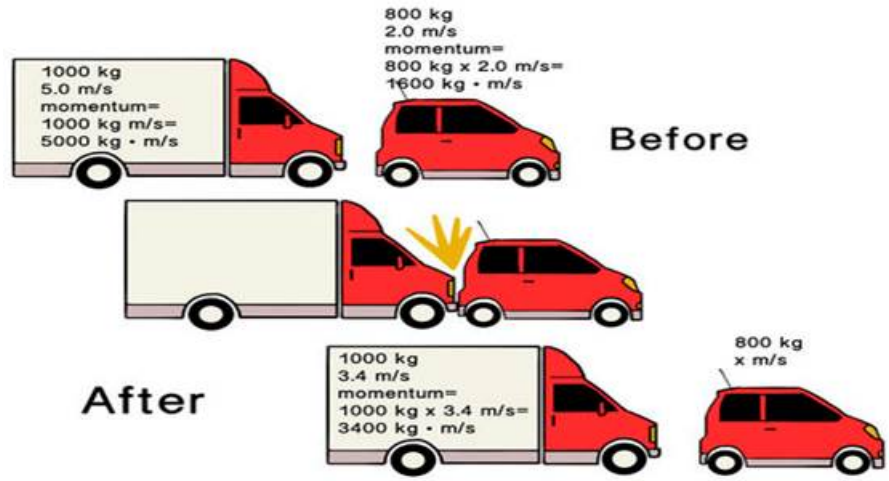
Mathematically ,

P = m × v

Where, p is momentum; v is velocity; m is the mass of the object.

Now we are given with the velocity of the object which is 15 m/s

and the total mass of the object which is 1000 kg , and we have to find the momentum of the car .



First I want you all to know that in this question we will consider car a system and all the things inside the car

have same velocity respectively and the mass of the objects inside the car will get added to the mass of the car in order to get the total mass of the system of which we have to calculate the momentum.

So by putting values in the above formula, we get,

P = m × v = 1000 × 15 =15000 kg m/s

The units of momentum are kg m/s.

Therefore, the momentum of the car is 15000 kg m/s.

9 A. Question

Find out the reasons:

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

Answer

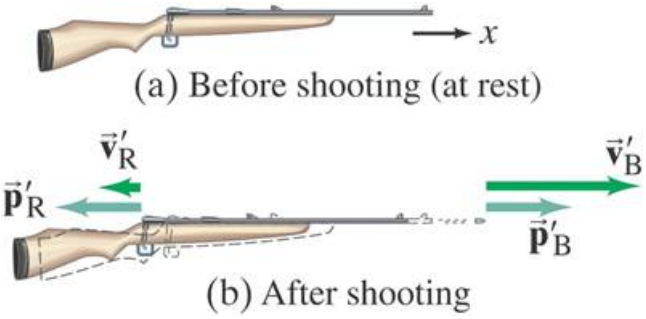
REMEMBER ONE THING – THE MOVEMENT OF SOME BODY AT REST OR THE CHANGE OF SPEED OF ANY OBJECT HAVE NO CONCERN WITH INTERNAL FORCES BUT ARE ALWAYS CONCERNED WITH EXTERNAL FORCES , AND NOT ONLY FORCES THE NET FORCE IS THE ONE WHICH BRING OUT CHANGES , SO , ALWAYS REMEMBER.

Well in these types of problems first we need to consider some system related to the question on which we will apply the laws.

In this question we will consider the gun , the bullet , and the person shooting , all these objects as one system.

<u>As we know that the momentum of a system is always conserved when no external force is applied on it , by law of conservation of momentum and in the context of Newton's third law we will solve the problem.</u>

As the bullet possesses some mass and the gun also has mass which is much larger than that of bullet , so as the bullet leaves the barrel(the long straight hollow rod from where bullet leaves) of the gun it has large velocity and so the momentum of the bullet increases hence as to conserve the momentum as by law of conservation of momentum the gun should have some velocity as calculated mathematically and in the opposite direction of that of the bullet.



Mathematically,

$$0 = mb \times vb + mg \times vg$$

$$vg = \frac{-mb \, X \, vb}{mg}$$

As you can see the velocity of the gun(v_g) comes out in the negative direction or opposite direction of that of the bullet(v_b) , so , that is why the gun recoils.

ADDITIONAL INFORMATION – The bullet in the gun is driven by the gases formed inside the gun , as gases expand due to less space so they exert equal amount of force on the gun also hence the gun recoils and the bullet travels faster due to mass differences.

By Newton’s third law the action is the gases act on gun so we experience recoil and the reaction is our stability or to absorb the thrust of the gun.

9 B. Question

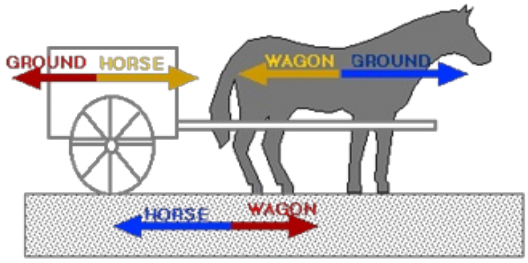
Find out the reasons:

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

Answer

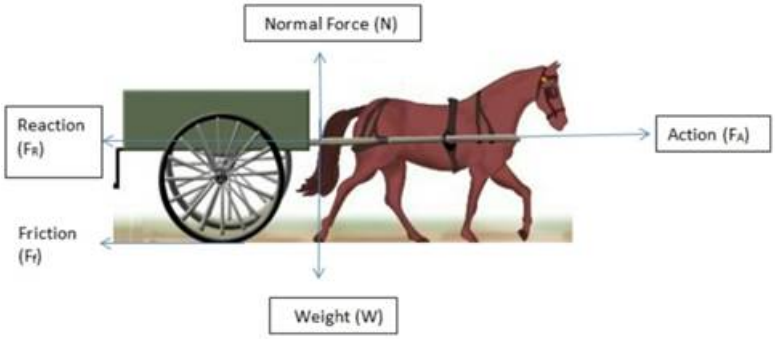
First we need to understand the mechanism and free body diagram of the horse cart system.

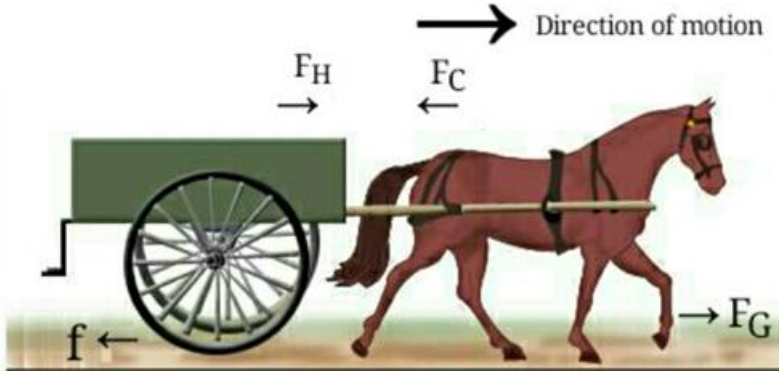
When the horse is tied with the cart , he pushes the ground with his feet in backward direction and due to friction the horse gets reaction and it moves in forward direction , as the horse moves in forward direction he pulls the cart with him , when the horse pulls the cart he does action and the cart pulls him towards it and that is reaction but the horse adjusts it’s muscular power to not to get pulled by cart but to pull the cart. The friction acting on the wheels of the cart makes the wheels roll and hence the cart moves.



Note that the action reaction pair of weight and normal force are canceled out because they are equal and opposite by Newton’s third law.

Actually the simple reason is that the horse moves with suitable force in order to pull the cart with it and not to struggle by applying less force. The main action reaction pair is between that of horse and cart due to the rope attaching them both. The tension in the rope is exerted on the cart in rightward direction and on the horse the tension is exerted in the leftward direction along with the friction force which acts in rightward direction.





To understand this completely we should simplify our system by considering cart at one time and horse at another time independently

CART ALONE – The only driving force on the cart is the tension which acts rightward or forward , hence the net force is also tension , so by Newton’s second law through the ropes the cart moves.

HORSE ALONE – There are two forces acting on the horse which are not cancelled by each other the one is tension in the ropes which pull the horse backwards and the friction force from the ground which makes the horse moves forward.

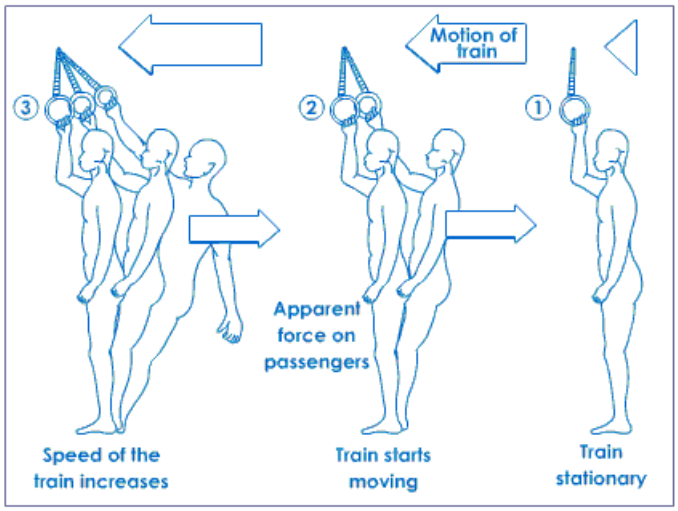
9 C. Question

Find out the reasons:

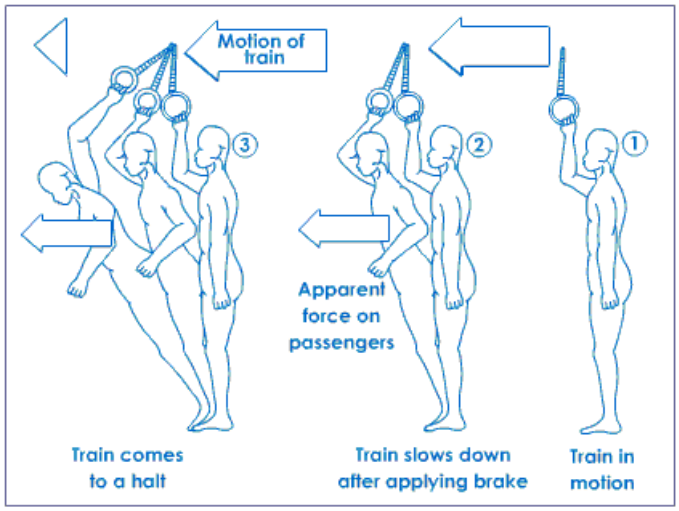
When a bus at rest suddenly moves forward, the passengers, standing in the bus, fall backward.

Answer

When the bus is at rest the passengers standing in the bus are also at rest but the passengers possess inertia of rest also, as we know that when a person is in a bus it will travel with the same velocity as that of the bus. So when a bus is suddenly moves forward from rest , it possesses some force to move it from rest and this force is applied to bus not passengers , the lower part of human body is in contact with the bus but the upper half part of human body possesses more inertia of rest than lower half part because it is more heavy(mass) , hence our lower part moves with the bus easily than the upper part because upper part has more inertia of rest , so it is likely that the upper part will remain at rest . Actually the passengers do not move backward but their lower part is carried in forward direction with the bus and the upper part wants to stay at it's position due to inertia of rest.



The same can be done for brakes and deceleration or retardation.



ADDITIONAL INFORMATION – We can do same experiment with a long rod placed vertically on a wooden plank. When we try to slide the plank with considerable force the lower part of the rod will move with the plank but the upper part remains where it was initially placed. Hence due to inertia of rest.

9 D. Question

Find out the reasons:

We slip on a mossy surface.

Answer

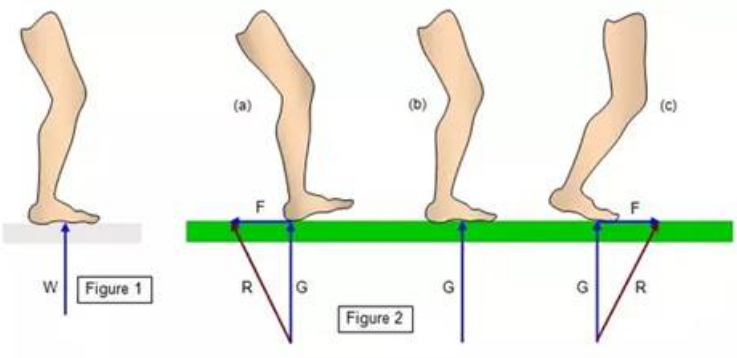
First we need to understand that what is moss ,

MOSS – A small flowerless green plant which lacks true roots, growing in low carpets or rounded cushions in damp habitats.

So it contains very less friction as it is damp.

As the friction is less so it is difficult to walk on it.

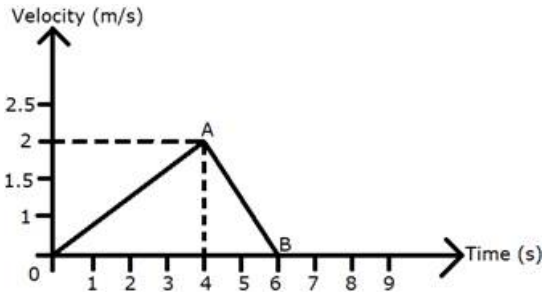
REMEMBER – WHEN WE WALK , THE DRIVING FORCE IS THE FRICTION FORCE WHICH IS THE REACTION FORCE WHICH COMES DUE TO ACTION DONE BY US WHICH IS WHEN WE PUSH THE GROUND BACKWARD BY OUR MUSCULAR FORCE.



The person walking on the mossy surface slips because there is very less friction not enough to make us walk and hence when we push the ground backward we do not get much reaction due to which our feet gets backward and backward in order to get suitable reaction so we can move forward but after certain point our feet slips. The resultant net force also makes our feet to moves some extra backward on a mossy surface than a more friction surface like roads.

10. Question

Examine the graph and answer the following questions:



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

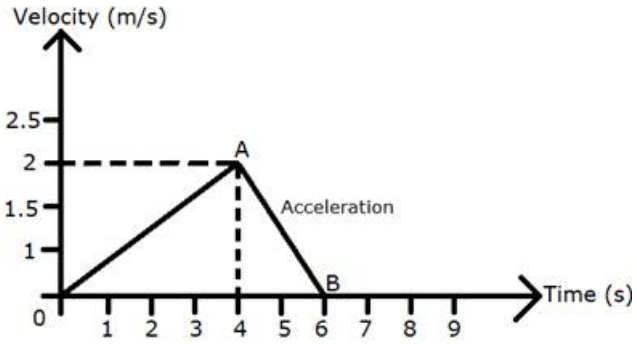
b) From time 0 up to the point A, is the object in uniform acceleration? What about that from A to B?

Answer

First we need to understand that what is Uniform and Non-uniform motion , that is ,

Uniform motion – When a body travels equal distance in equal intervals of time then it is called uniform motion which simply means that the velocity of the object must remain constant in this type of motion.

Non Uniform motion – When a body travels unequal distance in equal intervals of time then the motion traced by the body is called non-uniform motion which simply means that the body possesses some constant acceleration or at extreme cases it changes it's acceleration with time.



a). If we consider the full motion of the object that is from t=0s to t=6s , then we can say that the motion of the object is non uniform motion , even if we choose some portions of the graph then also it is non-uniform motion because there is no point where the velocity of the object is constant. Hence full motion is non-uniform.

b). UNIFORMLY ACCELERATED MOTION – It means that when body changes equal amounts of velocity in equal intervals of time then it is called uniformly accelerated motion which simply means that the acceleration of the body should remain constant.

If we divide the full motion into two parts and then look at them one at a time , the parts should be first from t=0s to t=4s(point A) and second the rest from point A to point B , Then the two motions are called uniformly accelerated motions. So , yes from t=0s till point A the object is in uniformly accelerated motion.

Hence from point A to point B the object now also follows uniformly accelerated motion but with different magnitude of acceleration which was in t=0s till point A. Hence this time it has deceleration or retardation which means negative of acceleration simply which reduces velocity and at the end Point B the object is at rest.

Extended activities

1. Question

Prepare and present an experiment to illustrate inertia of rest.

Answer

INERTIA OF REST – It is the inherent property of the body at rest to remain at rest until and unless an external force is applied to it and vice versa for other types of inertias.

Mass is a measure of body's inertia , higher the mass higher the inertia and vice versa.

With a quick pull, a table cloth can be removed from a dining table without disturbing dishes on it due to the Inertia of rest. The inertia of rest of the dishes keeps them where they are.

We can do this experiment at home also, by putting a table cloth or handkerchief on the table and putting one at a time object of different masses , we will start by lighter objects and will do this experiment till we reach some heavy objects.

But keep this one thing in mind that there should be quick pull not a slow pull that is there should be an impulsive action of pull within an instant , and do not choose very long cloths.

After doing this experiment you will observe and learn

many things like :–

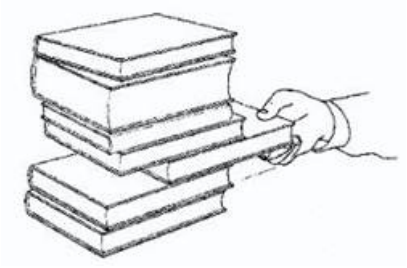
1. Inertia of rest in objects.

2. Inertia depends upon mass of the objects.

3. Newton's first law application.

So kindly do this experiment at home.

More examples on inertia of rest are :-



When we pick a book suddenly(not slowly) the books above does’nt get disturbed.

When we snatch the cloth from the table suddenly the bottle does’nt fall.

Same in the case of dishes.

When we strike quickly with great force on a card on which a coin is placed then the coin falls vertically straight.

2. Question

Find out situations from our daily life to explain the law of conservation of momentum and note them down.

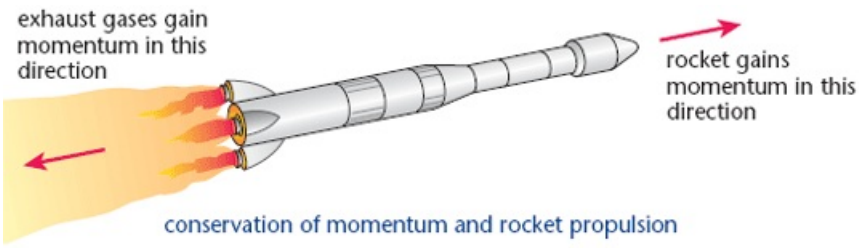
Answer

Before writing the situations first, we need to understand the meaning of law of conservation of momentum.

LAW OF CONSERVATION OF MOMENTUM – It states that when no external force is applied on a system then the momentum of the system does not changes, that is final momentum is equal to initial momentum. Also internal forces have no impact on momentum of the system.

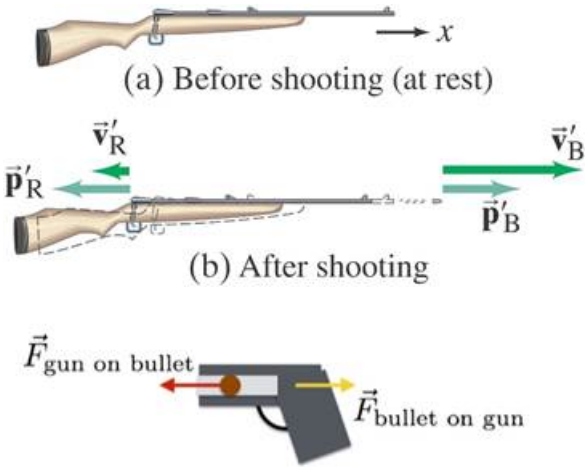
1) Motion of rockets and jet engines

Rockets and jet engines also work on the law of conservation of momentum. In these hot gases produced by burning of fuel rush out with a large momentum, Due to this, these machines gain an equal and opposite momentum. This momentum enables the rockets and jet engines with very high velocities.



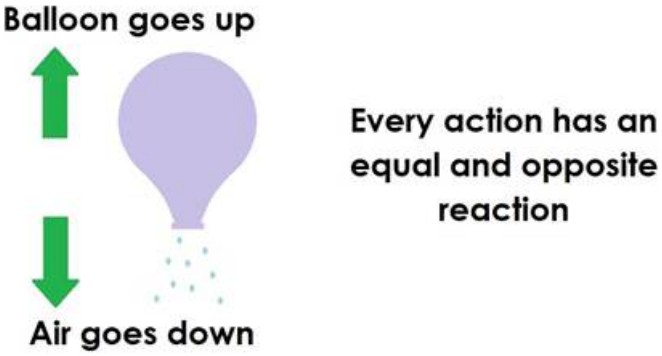
The system of gun and bullet

Before firing both gun and bullet are at rest, therefore momentum of the system is zero. When the bullet is fired the bullet moves forward and gun recoils back. The mass of the gun is very large as compared to the mass of the bullet, therefore the recoils velocity is very small as compared the velocity of the bullet.



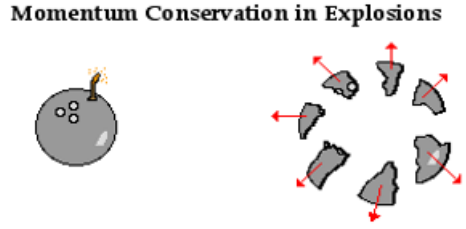
2) Air filled balloons

In the air-filled balloon, balloon, and air inside form a kind of system. Initially when the system is at rest, so the momentum of the system is also zero. As soon as the balloon is set free air escapes out with some great velocity, balloon moves forward in the direction opposite to air rushing out.



3. Diwali crackers

When we lighten a cracker it is at rest so the initial momentum is zero but as soon as the firecracker bursts it gets divided into small pieces and each piece has different velocity and different mass but if we add every piece's momentum it comes out to be zero.



4. Person Stuck on Ice Surface

When a person is in middle of ice surface it can get out by using it's thing by throwing each one of it's things in different direction with most velocity it can achieve as the initial momentum is zero hence to make the

final momentum zero the person will get some momentum by achieving some velocity.

5. Pushing a person

When we push a person, we experience some force on us due to newton’s third law of motion but the velocity due to force is gained by the momentum that we obtained from the person while pushing him as the initial momentum was zero when both the person was still and when one pushes he imparts some momentum to other person so by law of conservation of momentum he will have to suffer the consequences.

- Principle of conservation of momentum doesn`t apply only to collisions.

When the skaters stand facing each other, both skaters have zero momentum, so the total momentum of both skaters is zero.

When the skaters push away from each other, their momentum is equal but opposite, so the total momentum is still zero.