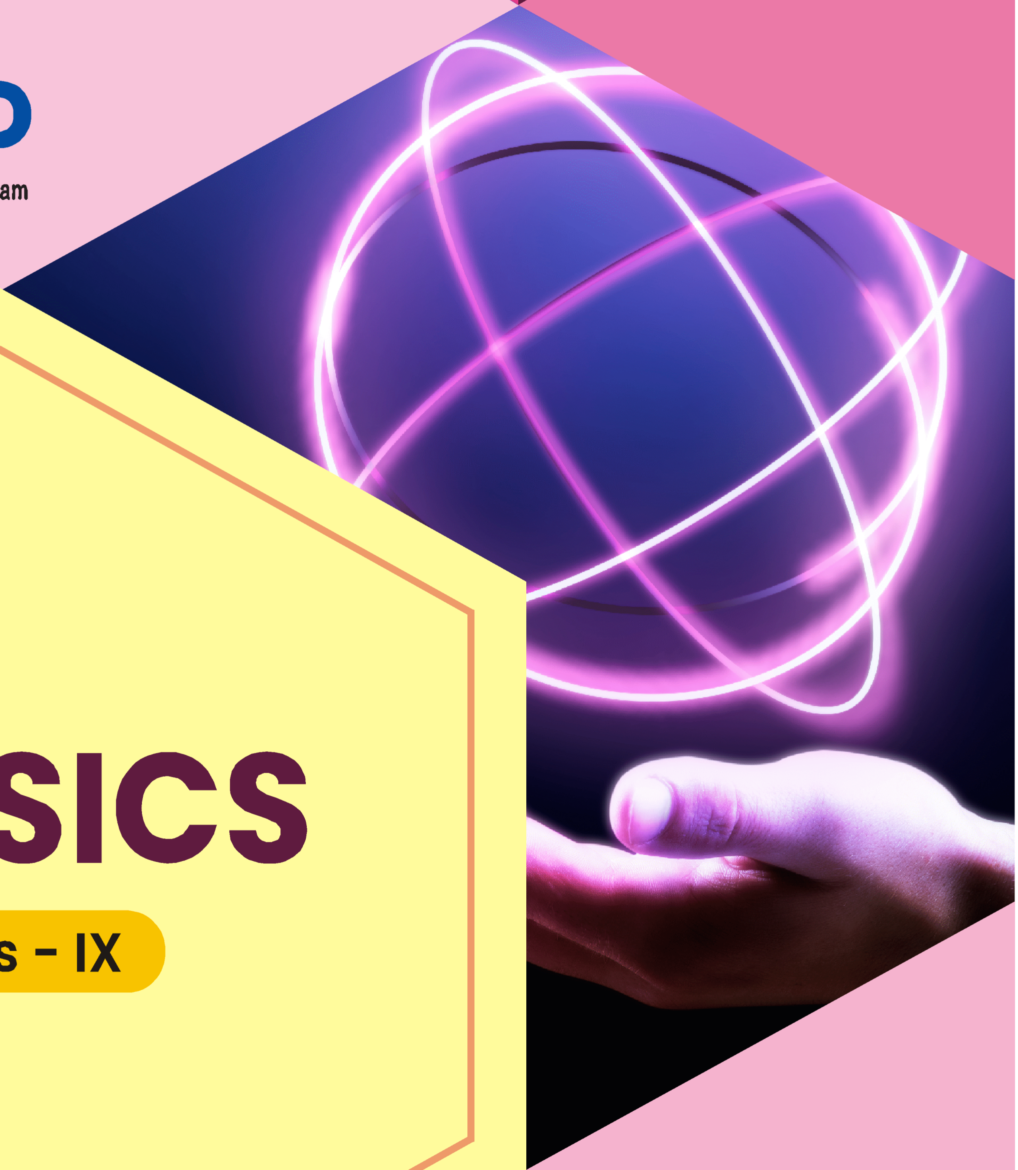
MATRIX OLYMPIAD

The Most Innovative Talent Recognition Exam



PHYSICS

Class - IX

MATRIX

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Few words for the Readers

Dear Reader,

"*Matrix Olympiad is established to encourage school students to go a step further than their regular studies, and get a chance and exposure to competition on a wide scale. It also helps students enhance their learning of basic cognitive skills and deeper knowledge of subjects like Science, Mathematics, English, Mental Ability, Social Studies."Matrix Olympiad helps students nurture their minds for higher targets of tomorrow and enables them to study School for JEE, NEET, CLAT, NDA, Olympiads , NSEJS, NTSE , STSE etc.*"

The above thought has been our guiding principle while designing and collating the study material for **Matrix Olympiad** . And hence, we hope that this particular material will be helpful towards your preparation for **Matrix Olympiad**.

Our team at **MATRIX** has put in their best efforts for making this particular module interesting and relevant for you. Additional efforts have been made to ensure that the content is easy to understand and error free to the extent possible. However, there might remain some inadvertent errors in answer keys and theoretical portion and we would welcome your valuable feedback regarding the same.

If there are any suggestions for corrections, please write to us at **smd@matrixacademy.co.in** and we would be highly grateful.

Finally, we would like to end this message by a famous quote by Ernest Hemingway - "*There is no friend as loyal as a book*." So, please give your study material the time and attention it deserves, and it will surely help you reach newer heights in your fight with competition examinations.

With love and best wishes !

Team MATRIX

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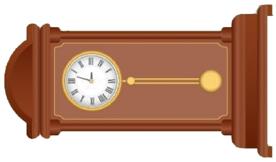
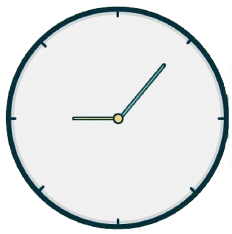
MOTION 1

Concepts



Periodic

Rotational



Circular

Rectilinear

INTRODUCTION

If we look around us, we find that there are number of objects which are in motion like people and vehicles move on roads, trains move on railway track, aeroplanes and birds fly, our teeth go up and down while we eat, the blades of a fan move when the fan is switched on (through the fan remains at the same place), raindrops fall, the sun moves from east to west as seen from the earth, and so on.

In this chapter we shall learn to describe the motion of a small object in mathematical terms. But first let us understand the meaning of motion more precisely.

1. REST AND MOTION

Motion is a combined property of the object and the observer. There is no meaning of rest or motion without the observer. Nothing is in absolute rest or in absolute motion.

An object is said to be in motion with respect to an observer, if its position changes with respect to that observer. It may happen by both ways either observer moves or object moves.

Rest

An object is said to be at rest if it does not change its position w.r.t. its surroundings with the passage of time.

Eg. : The chair, black board, table in the class room are at rest w.r.t. the students.

Motion

A body is said to be in motion if its position changes continuously w.r.t. the surroundings (or with respect to an observer) with the passage of time.

Eg. : A car moving on the road will be in motion w.r.t. to the person standing on the road.

Note : Rest and motion are relative terms, there is nothing like absolute motion or rest.

Eg. : A train is moving on the track, the passengers are seated, will be stationary with respect to each other but in moving condition with respect to station.

Therefore, all the motions are relative. There is nothing like absolute motion.

1.1 CONCEPT OF A POINT OBJECT

In mechanics while studying the motion of an object, sometimes its dimensions are not important and the object may be treated as a point object without much error. When the size of the object is much less in comparison to the distance covered by the object then the object is considered as a point object.

So we can say, A point object (or particle) is one, which has no linear dimensions but possesses mass.

Eg. : Earth can be considered as a point object for studying its motion around the sun. Because length of the path, covered by the earth in one revolution is very large in comparision to the size of earth, so earth can be considered as a point object

2. TYPES OF MOTION

(i) Linear motion (or translatory motion) : When an object moves in straight line than motion is called as linear motion.

Ex. : The motion of a car moving on straight road, a running person, a stone being dropped, motion of a train on a straight track

(ii) Rotational motion : Motion of a body around a fixed axis is called rotational motion.

Ex. : The motion of an electric fan, motion of earth about its own axis.

(iii) Oscillatory motion : The to and fro motion of a body around fixed point is called oscillatory motion.

Ex. : The motion of a simple pendulum, a body suspended from a spring.

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3. SCALAR AND VECTOR QUANTITIES

Physical quantities (i.e. quantities of physics) can be divided into two types :

(i) Scalar quantities

Any physical quantity, which can be completely specified by its magnitude, is known as scalar quantity.

Ex. : Charge, distance, speed, time, temperature, density, volume, work, power, energy, pressure and potential etc.

(ii) Vector quantities

The quantity which can be determined by its magnitude and the direction and also can be added or subracted by vector algebra, is called a vector quantity.

Ex. : Displacement, velocity, acceleration, force, momentum, weight and electric field etc.

4. DISTANCE AND DISPLACEMENT

Distance

The length of the actual path between the initial and the final position of a moving object in the given time interval is known as the distance travelled by the object.

- Distance is a scalar quantity. It is always taken positive.
- Distance is measured by odometer in vehicles.

Unit

In SI system : metre (m).

In CGS system : centimetre (cm).

Displacement

The shortest distance between the initial position and the final position of a moving object in the given interval of time is known as the displacement of the object.

Displacement of an object may also be defined as the change in position of the object in a particular direction.

That is,

Displacement of an object = Final position – Initial position of the object = $x_f - x_i$.

⇒ Displacement is a vector quantity.

⇒ Displacement can be postive, negative or zero.

Units

In SI system : metre (m)

In CGS system : centimetre (cm)

Ex. : Consider a body moving from a point A to a point B along the path shown in figure. Then total length path covered is called distance (path 1). While the length of straight line AB in the direction from A to B is called displacement (path 2).

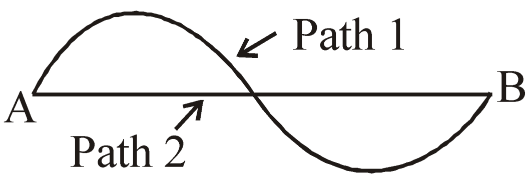

Figure : Distance and displacement

Focus Point

- If a body travels in such a way that it comes back to its starting position, then the displacement is zero. However, distance travelled is never zero in case of moving body.
- In the motion, displacement of an object may be zero but the distance travelled by the object is never zero.
- Distance travelled by an object is either equal to or greater than the magnitude of displacement of the object.

4.1 COMPARISON BETWEEN DISTANCE AND DISPLACEMENT

S.No.	DISTANCE	DISPLACEMENT
1	It is defined as the length of the actual path travelled by a body	It is the shortest distance between two point which the body moves.
2	It is a scalar quantity	It is a vector quantity
3	It is always positive	It can be negative, positive or zero.
4	Distance can be equal to or greater than displaceent	Displacement can be equal to or less than distance.
5	Distance travelled is not a unique path between two points.	Displacement is a unique path between two points.
6	The distance between two points gives full information of the type of path followed by the body.	Displacement between two points does not give full information of the type of path followed by the body.
7	Distance never decreases with time. For a moving body, it is never zero.	Displacement can decrease with time. For a moving body, it can be zero.

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5. MEASURING THE RATE OF MOTION

5.1 SPEED

Speed of a body is the distance travelled by the body per unit time. The rate of change of distance is called speed.

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

If a body covers a distance s in time t then speed,

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

Unit

In SI system : m/s or ms^{-1}

In CGS system : cm/s or cms^{-1}

A commonly used unit of speed is km/h or kmh^{-1}

Speed is a scalar quantity, because it has magnitude but no direction. Speed is always taken positive.

Average speed

The average speed of the body in a given time interval is defined as the total distance travelled, divided by total time taken.

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Instantaneous Speed

The speed of a body at any particular instant of time during its motion is called the instantaneous speed of the body. It is measured by speedometer in vehicles.

Uniform of Constant Speed

When a body covers equal distances in equal intervals of time, the body is to be moving with a uniform speed or constant speed.

Ex. : (i) A train running with a speed of 120 km/h.

(ii) An aeroplane flying with a speed of 600 km/h.

Non Uniform or Variable Speed

When a body covers unequal distances in equal intervals of time, the body is said to be moving with non-uniform speed or variable speed

Ex. : (i) A car running on a busy road.

(ii) An aeroplane landing on a runway.

5.2 VELOCITY

The velocity of a body is the displacement covered by a body per unit time. The rate of change of displacement is called velocity.

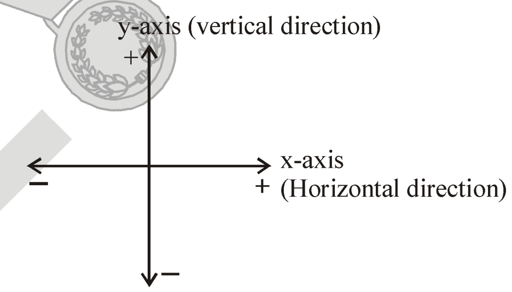

Figure : Sign convention for velocity

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

Velocity is a vector quantity and its direction is in the direction of the displacement of vector.

It can be positive, negative or zero (see fig.)

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Unit

In SI system : m/s or ms^{-1}

In CGS system : cm/s or cms^{-1}

Average Velocity

Total displacement of a particle divided by total time taken is called average velocity.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}} \quad ; \qquad V_{avg} = \frac{x_2 - x_1}{t_2 - t_1}$$

x_2 = Final position of particle ; x_1 = Initial position of particle

$t_2 - t_1$ = Time interval

Focus Point

(a) Average speed is always greater than or equal to magnitude of average velocity.

(b) Average speed is equal to average velocity when particle moves in a straight line without change in direction.

Instantaneous Velocity

The velocity of a body at any particular instant of time during its motion is called the instantaneous velocity of the body.

Uniform or Constant Velocity

(iii) Uniform or Constant Velocity

When a body covers equal displacements in equal intervals of time in a particular direction. The body is said to be moving with a uniform velocity (see fig.)

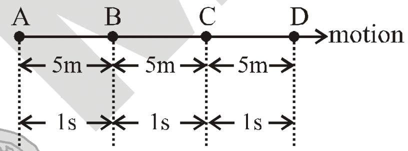

Figure : Body moving with uniform velocity

Conditions for Uniform Velocity

(i) The body must cover equal displacements in equal intervals of time.

(ii) The direction of motion of the body should not change.

Non Uniform or Variable Velocity

(iv) Non Uniform or Variable Velocity

(a) When a body covers unequal dispacements in equal intervals of time, the body is said to be moving with variable velocity (see fig.)

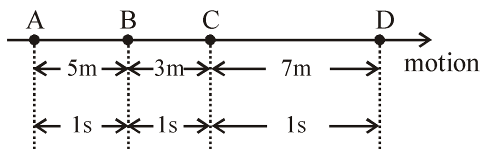

Figure : Body moving with non-uniform velocity

(b) When a body covers equal distances in equal intervals of time, but its direction changes, then the body is said to be moving with variable velocity.

Ex : (i) In circular motion, a particle may have constant speed but its direction changes continuously thus, its velocity is non-uniform (see fig.)

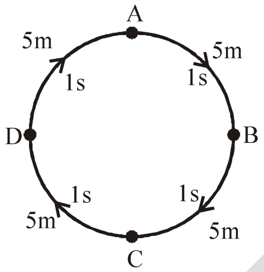

Figure : Body moving with variable velocity

(ii) A car running towards north on a busy road has a variable velocity as the displacement covered by it per unit time changes with change in the road condition.

(iii) The blades of a rotating ceiling fan, a person running around a circular track with constant speed etc. are the examples of variable velocity.

Conditions for Variable Velocity

(i) It should cover unequal displacement in equal intervals of time.

(ii) It should cover equal distances in equal intervals of time but its direction must change.

5.3 COMPARISON BETWEEN SPEED AND VELOCITY

S.No.	SPEED	VELOCITY
1	It is defined as the rate of change of distance	It is defined as the rate of change of displacement
2	It is a scalar quantity	It is a vector quantity
3	It is always positive	It can be negative, positive or zero.
4	Speed is velocity without direction	Velocity is directed speed.
5	Speed in SI unit is measured in ms–1	Velocity in SI unit is measured in ms^{-1}
6	It is rate of change of position of an object	It is rate of change of position of an object in a specific direction.
7	$\text{Speed} = \frac{\text{distance travelled}}{\text{time}}$	$\text{Velocity} = \frac{\text{displacement}}{\text{time}}$
8	For moving body, it will never be zero	It may be zero.

6. ACCELERATION

Mostly the velocity of a moving object changes either in magnitude or in direction or in both when the object moves. The body is then said to have acceleration. So it is the rate of change of velocity i.e. change in velocity in unit time is said to be acceleration.

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

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But change in velocity = final velocity – initial velocity.

$$\text{Acceleration} = \frac{\text{Final velocity(v)} - \text{Initial velocity(u)}}{\text{Time taken for change}}$$

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

Acceleration is a vector quantity and its direction is in the direction of change in velocity.

It can be negative, positive or zero

Unit :

In SI system : m/sec^2 or ms^{-2}

In CGS system : cm/sec^2 or cms^{-2}

When a body moves in a straight line without reversing its direction, then using above equation

(i) **If v > u, a is positive.**

⇒ If final velocity is greater than initial velocity, i.e. if the velocity increases with time, the value of acceleration is positive.

(ii) **If v < u, a is negative.**

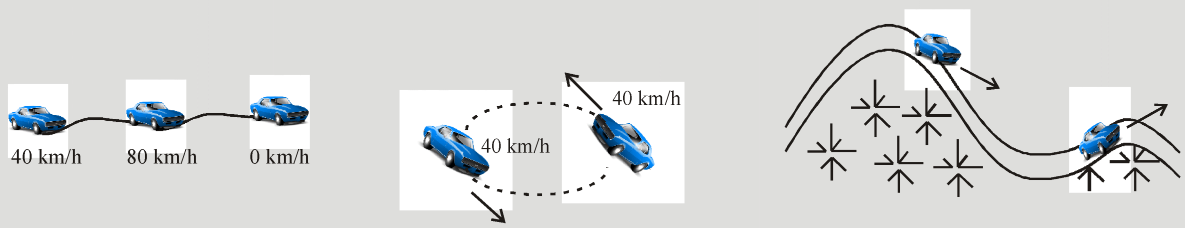
⇒ If final velocity is less than initial velocity, i.e. if the velocity decreases with time, the value of acceleration is negative. Negative acceleration is called retardation or deceleration.

(iii) **If v = u, a = 0,**

⇒ If the final velocity is equal to initial velocity i.e. the body moves with uniform velocity, the value of acceleration is zero.

Focus Point

Acceleration = {Rate of change in velocity} due to {change in speed and/or direction}



Change in speed but not direction | Change in direction but not speed | Change in both speed and direction

Figure : Three ways to accelerate

6.1 UNIFORM OR CONSTANT ACCELERATION

If a body travels in a straight line and its velocity increases in equal amounts in equal intervals of time. Its motion is known as uniformly accelerated motion.

E.g. : –When a body moving in a straight line undergoes equal changes of velocity in equal intervals of time, the body is said to be moving with a uniform acceleration. Also, uniform acceleration means an acceleration having a constant magnitude and a constant direction (see fig.)

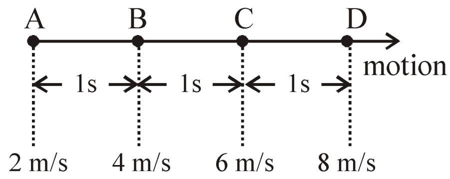


Figure : Uniformly accelerating body

(i) Motion of a ball rolling down on an inclined plane.
(ii) Motion of a freely falling body.

6.2 NON-UNIFORM OR VARIABLE ACCELERATION

If during motion of a body its velocity increases by unequal amounts in equal intervals of time, then its motion is known as non uniform accelerated motion.

E.g. : – When a body undergoes unequal changes of velocity in equal intervals of time, the body is said to be moving with non-uniform acceleration (see fig)

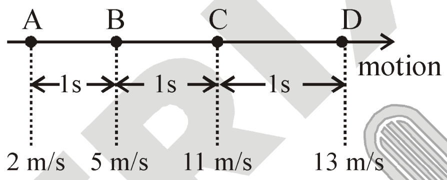


Figure : Non-uniformly accelerating body

(i) The motion of a bus leaving or entering the bus stop.
(ii) A car moving on a busy road has non-uniform acceleration

7. UNIFORM AND NON-UNIFORM MOTION

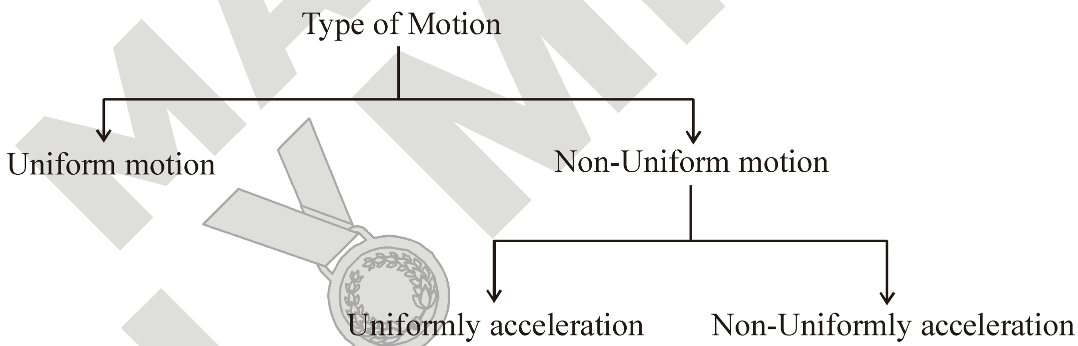


Figure : Type of motion

7.1 UNIFORM MOTION

In uniform motion, the velocity remains constant with time. Thus, the change in velocity for any time interval is zero.

When a body covers equal distances in equal intervals of time, however small may be the time intervals, in a particular direction, the body is said to describe a uniform motion.

Uniform Motion

Time (in second)	0	1	2	3	4	5	6
Distance covered (in metre)	0	10	20	30	40	50	60

⇒ Uniform motion always takes place in a straight line.

Examples of uniform motion

(i) An aeroplane flying at a speed of 600 km/h along north.

(ii) A train running at a speed of 120 km/h along east.

(iii) Light energy travelling at a speed of 3×10^8 m/s in vacuum.

7.2 NON-UNIFORM MOTION

In non-uniform motion, velocity changes with time. Thus, the change in velocity for any time interval has a non zero value. When a body covers unequal distances in equal intervals of time, the body is said to be moving with a non-uniform motion.

Non-Uniform Motion

Time (in second)	0	1	2	3	4
Distance covered (in metre)	0	1	4	9	16

⇒ Any motion along a curved path is always non-uniform motion. Also, any motion in which particle changes its direction is also non-uniform motion.

Examples of non-uniform motion :

(i) An aeroplane running on a runway before taking off.

(ii) A freely falling stone under the action of gravity.

(iii) When the brakes are applied to a moving car.

(iv) A fan rotating with constant speed is also a non-uniform motion.

In non-uniform motion, a new physical quantity called 'acceleration' is used. The rate of change of velocity of a moving body with time is called acceleration. So there are two type of non-uniform motion :

(i) Uniformly accelerated motion (ii) Non-uniformly accelerated motion

8. GRAPHICAL REPRESENTATION OF MOTION

8.1 DISTANCE TIME GRAPH

A moving body changes its position continuously with time. The simplest way to describe the motion of a moving body is to draw its distance-time graph.

The distance-time graphs of a body under the following three conditions are described below :

(A) Distance-time graph for a body at rest

(B) Distance-time graph for a body moving with a uniform speed

(C) Distance-time graph for a body moving with a non-uniform speed

(A) Distance-time graph for a body at rest

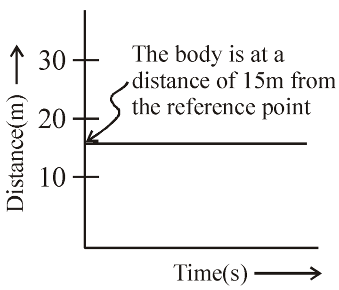


Figure : Distance time graph for a body at rest

The distance-time graph for a body at rest is a straight line parallel to the time axis.

(B) Distance-time graph for a body moving with a uniform speed :

When a body covers equal distances in equal intervals of time, it is said to have uniform speed.

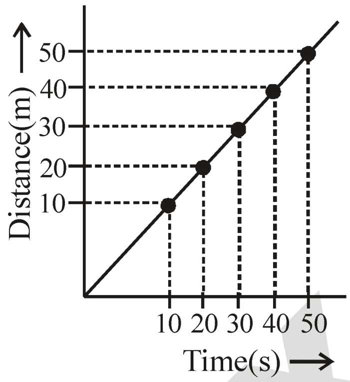


Figure : Distance-time graph for a body moving with a uniform speed

Graph shows that the distance travelled by a body moving with uniform speed is directly proportional to time.

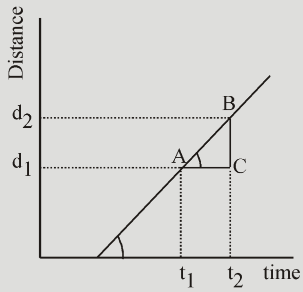
Focus Point

Speed from distance-time graph

Consider an object moving with a uniform speed. The distance-time graph is represented by a straight line as shown in figure. We can calculate the speed of the object from the distance-time graph. As shown in figure, we find that the distance covered till time t_1 is d_1 and till time t_2 it is d_2. Thus, the object covers a distance of $d_2 - d_1$ in the time interval $t_2 - t_1$. The speed of the object is, therefore,

$$\text{Speed} = \frac{d_2 - d_1}{t_2 - t_1} = \frac{BC}{AC}$$

The ratio $\frac{BC}{AC}$ is called the slope of the line.



Thus, if the distance-time graph of an object is a straight line, the speed of the object is equal to the slope of the straight line.

Figure : Distance time graph

The slope of a line show us how steeply it is inclined to the horizontal axis (drawn from left to right). If the line is parallel to the horizontal axis, the slope is zero. As the line gets more and more inclined to this axis, its slope increases. Thus, a more steeply inclined distance-time graph indicated greater speed.

(C) Distance-time graph for a body moving with a non-uniform speed :

A body moving with a non-uniform speed covers unequal distances in equal intervals of time. Therefore, the distance-time graph of a body moving with a non-uniform speed is a curve.

The shape of the distance-time graph for a body moving with non-uniform speed depends upon the way speed of the body changes with time. Two typical cases are described below :

(i) When the speed increases with time : When the speed of a body increases with time, the distance covered by it in one unit of time also increases with time. Therefore, the distance-time graph for a body moving with an increasing non-uniform speed is a curve whose slope increases with time (figure).

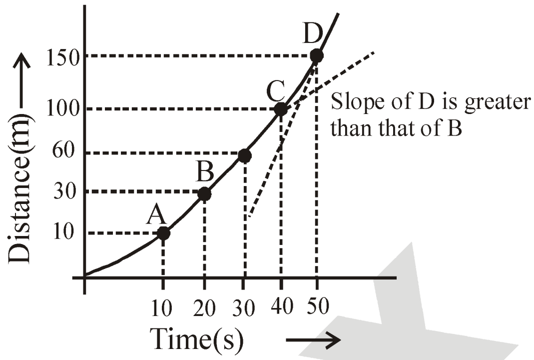


Figure : Distance time graph when speed increases with time

(b) When the speed decreases with time : When the speed of a body decreases with time, the distance covered by it in one unit of time also decreases with time. Therefore, the distance-time graph for a body moving with a decreasing non-uniform speed is a curve whose slope decreases with time (figure).

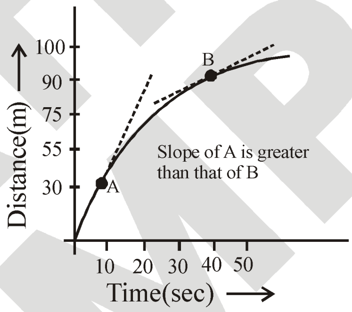


Figure : Distance time graph when speed decreases with time

8.2 DISPLACEMENT-TIME GRAPH

(A) Displacement-time graph for a body at rest :

The position of a body at rest remains unchanged with time. Let us consider a body at a distance 'd' from a reference point in a particular direction. Then from figure.

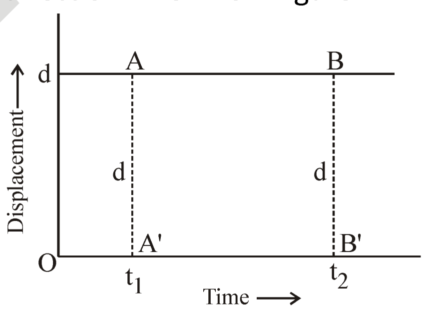


Figure : Displacement-time graph for a body at rest

Graph shows that position of the body does not change w.r.t. time, so that body is said to be in rest. Thus the velocity of a body at rest is zero.

(B) Displacement-time graph for a body moving with uniform velocity :

The displacement-time graph of a body moving with uniform (constant) velocity is a straight line inclined to the time-axis at certain angle.

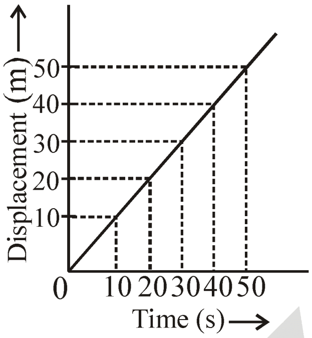


Figure : Displacement-time graph for a body moving with uniform velocity

Focus Point

Velocity from displacement-time graph :

Consider an object moving with a uniform velocity. The displacement-time graph is represented by a straight line as shown in figure. We can calculate the velocity of the object from the displacement-time graph. From the graph shown in figure, we find that the displacement covered till time t_1 is x_1 and till time t_2 it is x_2. Thus, the object covers a displacement of $x_2 - x_1$ in the time interval $t_2 - t_1$. The velocity of the object is, therefore,

$$v = \frac{x_2 - x_1}{t_2 - t_1} = \frac{BC}{AC}$$

The ratio $\frac{BC}{AC}$ is called the slope of the line.

Thus, if the displacement -time graph of an object is a straight line, the velocity of the object is equal to the slope of the straight line.

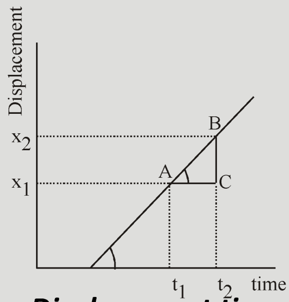


Figure : Displacement time graph

(C) Displacement-time graph for a body moving with increasing non uniform velocity :

(i) When the velocity increases with time : The displacement-time graph of a body moving with an increasing non-uniform velocity is a curve (figure). Here the slope of the curve increases with time. So, i.e., velocity at B > velocity at A

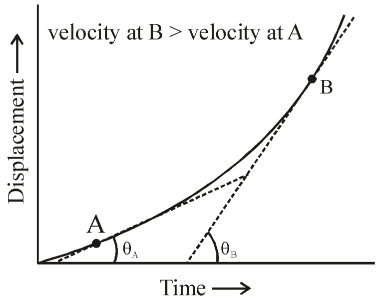


Figure : Displacement time graph when velocity increasing with time

Displacement-time graph for a body moving with decreasing non-uniform velocity.

(ii) When the velocity decreases with time : The displacemen-time graph of a body moving with a decreasing non-uniform velocity is a curve (figure). Here, the slope of the curve decreases with time. So, the velocity of the body decreases with time.

i.e., velocity at B < velocity at A

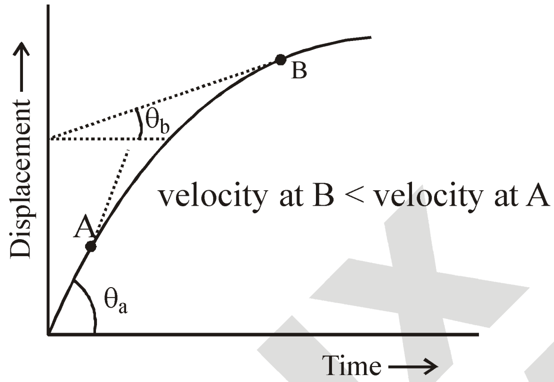


Figure : Displacement time graph when velocity decreasing with time

Note : The slope of a line show us how steeply it is inclined to the horizontal axis (drawn from left to right). If the line is parallel to the horizontal axis, the slope is zero. As the line gets more and more inclined to this axis, its slope increases. Thus, a more steeply inclined displacement -time graph indicated greater velocity.

8.3 SPEED-TIME GRAPH

(A) Speed-time graph for a body moving with constant speed :

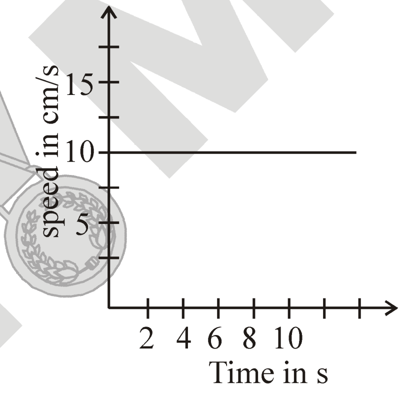


Figure : Speed time graph for constant speed

Figure shows that for any time, the speed has the same value (10 cm/s). Thus it represents an object moving with a constant speed. Whenever an object moves with a constant speed, its speed-time graph is a straight line, parallel to the time-axis.

Focus Point

Distance from speed-time graph :

Suppose an object is moving with a uniform speed v.

The distance covered by this object during a time interval t_1 to t_2 is $s = v(t_2 - t_1)$.

Figure shows the speed-time graph.

We have AD = BC = v and $AB = t_2 - t_1$.

Thus the distance covered is $s = v(t_2 - t_1) = AD \cdot AB$ = area of the rectangle ABCD.

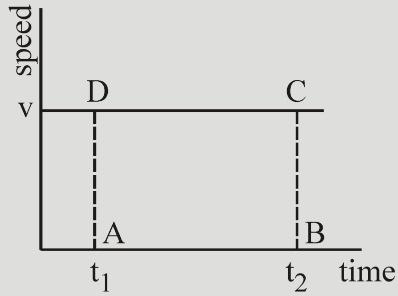


Figure : Speed time graph

The method for finding the distance covered in a time interval t_1 to t_2 using a speed-time graph is as follows.

Draw perpendicular lines to be the time-axis at the points A and B corresponding to t_1 to t_2. The area enclosed by these perpendicular lines, the time-axis and the speed-time graph is equal to the distance covered in the time interval t_1 to t_2.

(B) Speed-time graph for a body moving with non uniform speed

(i) Speed-time graph for a body moving with increases speed at constant rate :

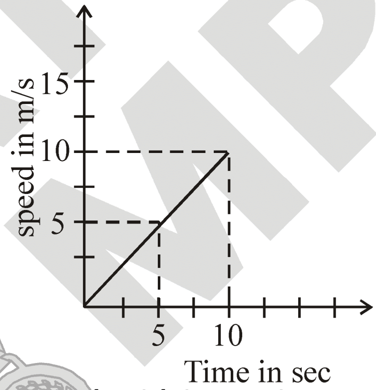


Figure : Speed-time graph with increasing speed at constant rate

Figure shows that the speed continuously increases with time. At time t = 0, the speed is zero. At t = 10 s, it becomes 10 m/s. The straight-line nature of the graph indicates that the speed increases at a constant rate.

(ii) Speed-time graph for a body moving with decrease speed at constant rate :

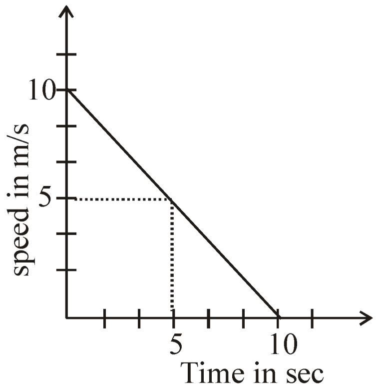


Figure : Speed-time graph with decreasing speed at constant rate

Figure shows that the speed is 10 m/s at t = 0 and gradually decreases as time passes. Thus it represents a decelerating object. Here also the speed changes at constant rate. At t = 10s, the speed become zero.

Note : The method to calculate distance from speed-time graph for object moves with uniform speed is equally applicable for object moves with nonuniform speed. so we can say the distance covered by the body is shown by the area under speed-time graph

Example 1

Find the distance covered by a particle during the time interval t = 0 to t = 20s for which the speed-time graph is shown in figure.

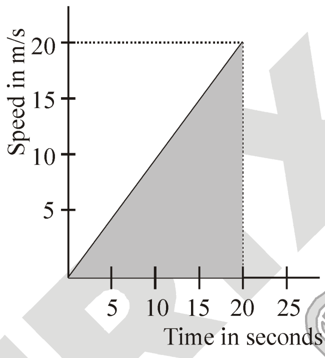


Figure : Speed time graph

Solution :

The distance covered in the time interval 0 to 20 s is equal to the area of the shaded triangle. It is

$\frac{1}{2}$ × base × height

= $\frac{1}{2}\times(20s)\times(20m/s)=200m$

8.4 VELOCITY-TIME GRAPH

Suppose an object moves along a straight line in a fixed direction. That means the object does not turn around during its motion. Taking the direction of motion as the positive direction, the velocity of the object is given by the same value as its speed. Thus the speed - time graph for such an object is also its velocity - time graph.

(A) Velocity time graph for a body moving with constant velocity :

If a graph is plotted taking the velocity of an object moving along a straight line on the vertical axis and time on the horizontal axis, we get a velocity-time graph.

If the particle moves with a constant velocity v, the velocity-time graph will be stratight line parallel to the time-axis, as shown in figure.

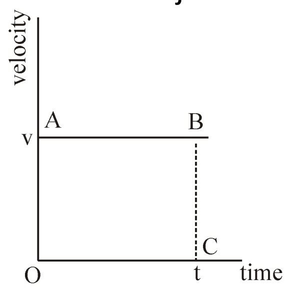


Figure : Velocity time graph for constant velocity

The displacements in time t is given by

s = vt = OA . OC

= area of the rectangle OABC, which is the area under the graph

So, the area under the velocity-time graph of an object gives its displacement.

(B) Velocity-time graph for body moving with nonuniform velocity :

(i) Velocity-time graph for a body moving with increases velocity at constant rate

A ball is dropped from a height is example of body moving with increasing velocity at constant rate. We take the downward direction as positive. As the ball falls, its velocity increases. The velocity of the ball at different instants are given in Table - 1. The velocity versus time graph is shown in figure.

Table 1 : Velocity of the falling ball at different instants :

Time in s	Velocity in m/s
0	0
0.1	1
0.2	2
0.3	3
0.4	4
0.5	5
0.6	6

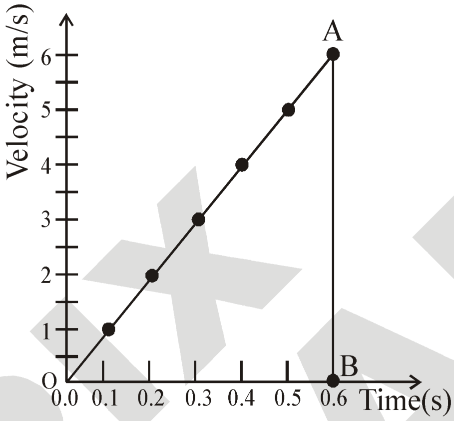


Figure : Velocity-time graph for increasing velocity at constant rate

What is the displacement of the ball in the time interval 0 to 0.6s ? It is equal to the area under the velocity - times graph from t = 0 to t = 0.6s. This area is in the shape of a triangle. The area is

$$\frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2}\ (OB) \times (AB)$$

$$= \frac{1}{2} \times (0.6s) \times (6\ m/s) = 1.8\ m$$

The ball has fallen through 1.8 m in 0.6 s.

(ii) Velocity-time graph for a body moving with decreases velocity at constant rate

A ball is thrown upwards is example of body moving with decreasing velocity at constant rate. We take the upward direction as the positive direction. The velocity decreases as the ball goes up. Table 2 gives the velocity of the ball at different instants.

Table 2 : Velocity of the rising ball at different instants :

Time in s	Velocity in m/s
0	10
0.2	8
0.4	6
0.6	4
0.8	2
1	0

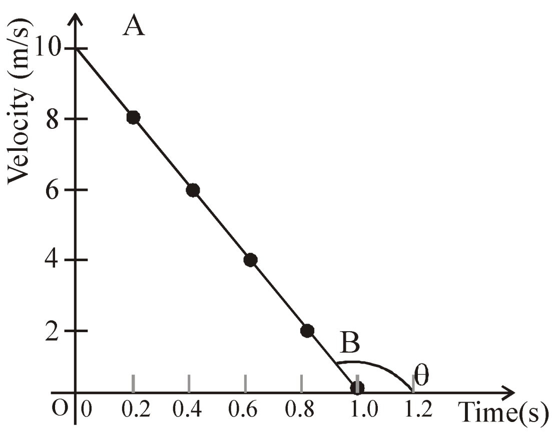


Figure : Velocity-time graph for decreasing velocity at constant rate

Figure shows the velocity - time graph. The plotted points fall on a straight line, AB . At t = 1.0 s, the velocity becomes zero. This means that the ball reaches the highest point at t = 1.0 s.

The displacement of the ball in the time interval 0 to 1sec. is area under the velocity time graph from t = 0 to t = 1 sec. The area under the graph is

$= \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2}\ (OB) \times (OA)$

$= \frac{1}{2} \times (1s) \times (10 m/s) = 5\ m$

The ball has fallen through 5 m in 1s.

NOTE : The area under the speed - time graph gives the distance covered. But for a particle moving in a fixed direction, the distance covered in a time interval has the same value of its displacement in that time interval. So, the area under the velocity-time graph of an object gives its displacement.

Acceleration from velocity-time graph

Suppose a particle moves with a uniform acceleration of 2 m/s^2 along a straight line. This means that the velocity increases by 2 m/s in one second. Also suppose its speed at t = 0 is 10 m/s.

Let us plot the velocity-time graph for this situation, We first find the values of the velocity at certain instants. At t = 0, the velocity is 10 m/s, at t = 1s it will become 10 m/s + 2 m/s = 12 m/s, at t = 2s, it will become 12 m/s + 2 m/s = 14 m/s, at t = 3s, it will become 16 m/s and so on. These value are given in Table 3 and the velocity-time graph is shown in figure.

Table - 3 :

Time in s	Velocity in m/s
0	10
1	12
2	14
3	16
4	18
5	20

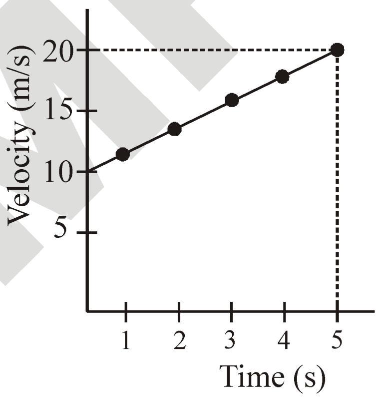


Figure : Velocity time graph

We see that the graph is a straight line. Whenever the acceleration is uniform the velocity-time graph is a straight line. We will now show that the slope of the velocity-time graph of a particle moving along a straight line is as shown in figure. The graph is a straight line. At time t_1, the velocity is v_1, and at time t_2, it is v_2. These values are represented by the points A and B on the graph.

The acceleration of the object is

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{OE - OD}{OG - OF} = \frac{DE}{FG} = \frac{BC}{AC} = \tan\theta$$

were θ is the angle made by the graph with the time-axis.

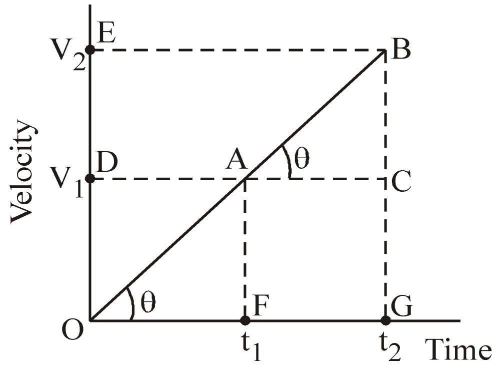


Figure : Velocity time graph

As defined earlier, the ratio $\frac{BC}{AC} = \tan\theta$ is called the slope of the line. Thus, we have the following :

The slope of the velocity-time graphs gives the acceleration for an object moving along a straight line.

9. EQUATIONS FOR UNIFORMLY ACCELERATED MOTION BY GRAPHICAL METHOD

9.1 VELOCITY-TIME EQUATION

First Equation : For uniformly accelerated motion considered velocity-time graph.

v = u + at

It can be derived from v-t graph, as shown in figure

From line PQ, the slope of the line = acceleration

$a = \frac{QR}{RP} = \frac{SP}{SQ}$

$\therefore$ SP = v – u

and RP = t

So $a = \frac{v-u}{t}$

or v = u + at

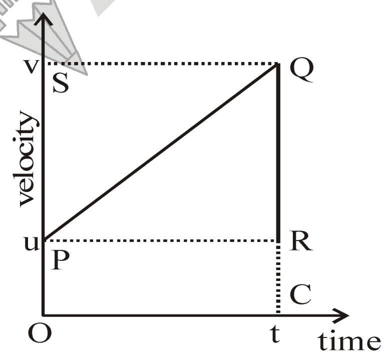


Figure : Velocity time graph

9.2 DISPLACEMENT-TIME EQUATION

Second Equation :

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

It can also be derived from v-t graph as shown in figure.

From relation,

Distance covered = Area under v - t graph

s = Area of trapezium OPQS

= Area of rectangle OPRS + Area of triangle PQR

= OP × PR + $\frac{RQ \times PR}{2}$ Putting values,

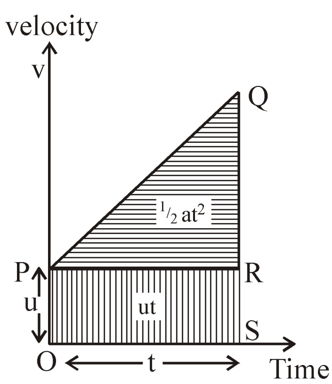


Figure : Velocity time graph

$s = u \times t + \frac{1}{2}(v - u) \times t$ (∵ RQ = v – u & PR = OS = t)

$= u \times t + \frac{1}{2}at \times t$ $(\because v - u = at)$

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

9.3 VELOCITY-DISPLACEMENT EQUATION

Third Equation :

$v^2 = u^2 + 2aS$

From above graph

OP = u, SQ = v, OP + SQ = u + v

$a = \frac{QR}{PR}$

Or $PR = \frac{QR}{a} = \frac{v-u}{a}$

S = Area of trapezium

OPQS = $\frac{OP + SQ}{2} \times PR$

On putting the values,

$S = \frac{u+v}{2} \times \frac{v-u}{a} = \frac{v^2 - u^2}{2a}$

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

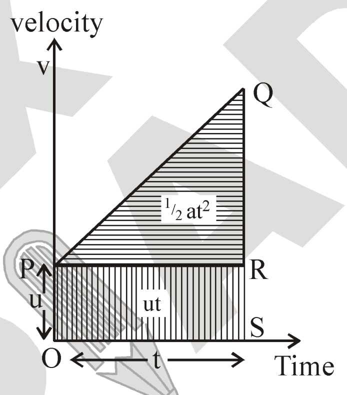


Figure : Velocity time graph

9.4 DISPLACEMENT OF PARTICLE IN NTH SECOND

Displacement travelled in n[th] second = Displacement travelled in n sec. – Displacement travelled in (n–1) sec.

So, $S_{n^{th}} = S_n - S_{(n-1)}$.................... (i)

$= \left(un + \frac{1}{2}an^2\right) - \left[u(n-1) + \frac{1}{2}a(n-1)^2\right]$

[Putting t = n and t = (n – 1) respectively in equation (i)]

$= un + \frac{1}{2}an^2 - un + u - \frac{1}{2}a(n^2 - 2n + 1)$

We have, $S_{n^{th}} = u + \frac{a}{2}(2n - 1)$

$= \left(un + \frac{1}{2}an^2\right) - \left[un - u + \frac{1}{2}a(n^2 - 2n + 1)\right]$ $= \left(un + \frac{1}{2}an^2\right) - \left[un - u + \frac{1}{2}an^2 - an + \frac{1}{2}a\right]$

$= un + \frac{1}{2}an^2 - un + u - \frac{1}{2}an^2 + an - \frac{1}{2}a = u + an - \frac{1}{2}a$

$\therefore S_{n^{th}} = u + \frac{a}{2}(2n-1)$

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10. CIRCULAR MOTION

If an object moves in a circular path with uniform speed, its motion is called uniform circular motion.

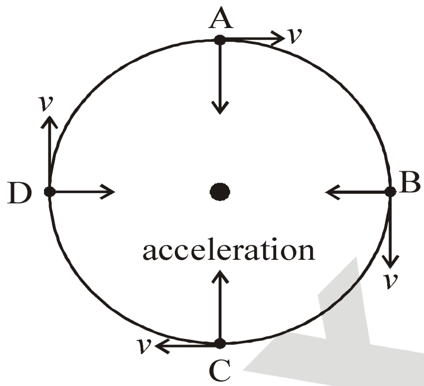

Figure : Uniform circular motion

A circular path can be made up of an indefinite number of small sides, and a body moving along such a circular path changes its direction of motion continuously.

Therefore, if you run on a circular track, you change your direction infinite times in one round. Four arbitrary points on the circular path and the direction of motion of the body at these points are shown. Since the direction of motion changes, circular motion is a case of accelerated motion.

10.1 UNIFORM CIRCULAR MOTION

A uniform circular motion is a motion in which speed remains constant but direction of velocity changes continuously.

Examples of uniform circular motion

(i) An athlete running on a circular track with constant speed.

(ii) Motion of tips of the second hand, minute hand and hour hand of a wrist watch.

10.2 NON-UNIFORM CIRCULAR MOTION

A non uniform circular motion is a motion in which speed of the body changes with time on circular path.

Ex. An athlete running on a circular track with variable speed.

10.3 COMPARISON BETWEEN UNIFORM MOTION AND UNIFORM CIRCULAR MOTION

S.No.	Uniform Linear Motion	Uniform Circular motion
1	The direction of motion does not change.	The direction of motion changes continuously
2	The motion is non-accelerated	The motion is accelerated.

SOLVED EXAMPLES

SE. 1

A car travels 30 km at a uniform speed of 40 km/h and the next 30 km at a uniform speed of 20 km/h. Find its average speed :

Ans. Total distance (d) = 30 + 30 = 60 km

Speed for the first 30 km (v_1) = 40 km/h

To calculate : Average speed (v_{av}) = ?

Formula to be used : $\frac{\text{Total distance(d)}}{\text{Total time}(t)}$

Now in this problem we are not given the total time. So our first step is to find out the total time from the two speeds given to us by using the formula.

Time (t) =

(i) time (t_1) in going from A ot B (in fig.)

$$= \frac{30}{40} = \frac{3h}{4} = 45\,\text{min}$$

(ii) time (t_2) in going from B to C

$$= \frac{30}{20}$$ = 1 hr 30 min = 90 min

Total time t = t_1 + t_2 = 45 + 90 = 135 min

or $t = \frac{135}{60}$ h

Hence, $v_{av} = \frac{60 \times 60}{135} = \frac{80}{3}\,\text{km/h}$

SE. 2

A train travels at 60 km/h for 0.52 hour, 30 km/h for the next 0.24 hour and then 70 km/h for the next 0.71 hour. What is the average speed of the trip ?

Ans. Given :

First speed (v_1) = 60 km/h

Time for this part of the trip (t_1) = 0.52 h

Second speed (v_2) = 30 km/h

Time for second part (t_2) = 0.24 h

Third speed (v_3) = 70 km/h

Time for third part (t_3) = 0.71 h

To calculate : Average speed (v_{av}) = ?

Formula to be used : $\frac{\text{Total distance(d)}}{\text{Total time taken}(t)}$

Now in this case we are not given the total distance travelled, so first of all we will find out the distance covered during the three given intervals by using the formula, distance = speed × time

(i) First part (d_1) = v_1 × t_1 = 60 × 0.52 = $\frac{156}{5}$ km

(ii) Second part (d_2) = v_2×t_2 = 30 × 0.24 = $\frac{36}{5}$ km

(iii) Third part (d_3) $= v_3 \times t_3 = 70 \times 0.71 = \frac{497}{10}\,\text{km}$

Total distance (D) = d_1 + d_2 + d_3

$$= \frac{156}{5} + \frac{36}{5} + \frac{497}{10} = 8.81 \text{ km}$$

Total time (t) = t_1 + t_2 + t_3 = 0.52 + 0.24 + 0.71 = 1.47 h

$$v_{av} = \frac{88.1}{1.47} = 59.93\,\text{km/h}$$

SE. 3

A ship is moving at a speed of 56 km/h. One second later is is moving at 58 km/h. What is its acceleration?

Ans. Given :

Initial speed (u) = 56 km/h

Final speed (v) = 58 km/h

Time taken (t) = $1s = \frac{1}{60 \times 60}h$

To calculate : Acceleration (a) = ?

Formula to be used : $a = \frac{v - u}{t}$

$$a = \frac{58 - 56}{\frac{1}{60 \times 60}} = 7200\,\text{km/h}^2$$

SE. 4

A particle starts from rest with uniform acceleration a. Its velocity after n seconds is v. Find the displacement of the particle in the last two seconds.

Ans. As v = u + at

The velocity after n seconds is

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$\Rightarrow$ v = an ($\because$ u = 0) $\Rightarrow$ $a = \frac{v}{n}$ ....(i)

The displacement of the body in the last two seconds

(Using S = ut + $\frac{1}{2}at^2 = \frac{1}{2}at^2$, as u = 0)

$S_2 = S_n - S_{n-2} = \frac{1}{2}an^2 - \frac{1}{2}a(n-2)^2$

$= \frac{1}{2}a\left[n^2 - (n-2)^2\right]$

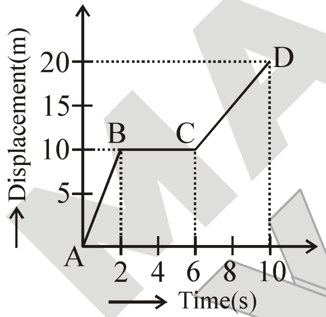
$= \frac{1}{2}a\left[n^2 - n^2 - 4 + 4n\right]$

$S_2 = 2a(n-1)$

From equation (i), $S_2 = \frac{2v(n-1)}{n}$

SE. 5

This figure represents a displacement-time graph of an object moving along a straight line.



(a) Describe the motion of the body during the 10s.
(b) How far did the object travel in the first 2s ?
(c) What was the velocity of the object during the first 2 s ?
(d) What was the velocity during the next 4 s ?
(e) What was it during the last 4 s ?

Ans. (a) For part AB, the object moved with a uniform velocity, for part BC, it was at rest and for part CD, it again moved with some other uniform velocity.
(b) In the first 2s, it covered 10m
(c) Since velocity is given by the slope of the displacement-time graph, i.e.

$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$

Velocity during the first 2s (along AB)

$= \frac{(10-0)}{(2-0)} = 5\text{m/s}$

(d) Velocity during the next 4s (along BC)

$= \frac{(10-10)}{(6-2)} = \frac{0}{3} = 0\text{m/s}$

(e) Velocity during the last 4 s (along CD)

$= = \frac{(20-10)}{(10-6)} = 2.5\text{m/s}$

SE. 6

A body covers half of its journey with speed a m/s and the other half with speed b m/s. Calculate the average speed of the body during the whole journey.

Ans. Given :
Speed (u_1) = a m/s
Speed (u_2) = b m/s
To calculate : Average speed (v_{av}) = ?

Formula to be used : $v_{av} = \frac{\text{Total distance}}{\text{Total time taken}}$

Suppose the total distance covered by the body is 2d, out of which (d) is covered with a speed (a) and the other half (i.e., d) is covered with a speed (b). Let us suppose (t_1) and (t_2) be the times taken for the first and the second half respectively.

$t_1 = \frac{d}{a}$ and $t_2 = \frac{d}{b}$

Total time taken (t) = $t_1 + t_2 = \frac{d}{a} + \frac{d}{b} = d\left(\frac{1}{a} + \frac{1}{b}\right)$

Also, $t_1 + t_2 = \frac{2d}{v_{av}}$ $\quad \therefore \frac{2d}{v_{av}} = d\left(\frac{1}{a} + \frac{1}{b}\right)$

$\Rightarrow \frac{2}{v_{av}} = \left(\frac{a+b}{ab}\right)$

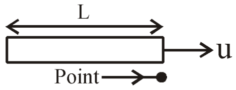
$\Rightarrow v_{av} = \left(\frac{2ab}{a+b}\right)\text{m/s}$

SE. 7

The two ends of a train moving with a constant acceleration pass a certain point with velocities u and v. Find the velocity with which the middle point of the train passes the same point.

Ans. Using $v^2 = u^2 + 2as$

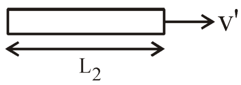
$$L = \frac{v^2 - u^2}{2a} \quad ......(i)$$



$$\frac{L}{2} = \frac{v^2 - u^2}{2a} \quad ....(ii)$$

solving equations (i) and (ii).

$$2 = \frac{v^2 - u^2}{v^2 - u^2}$$



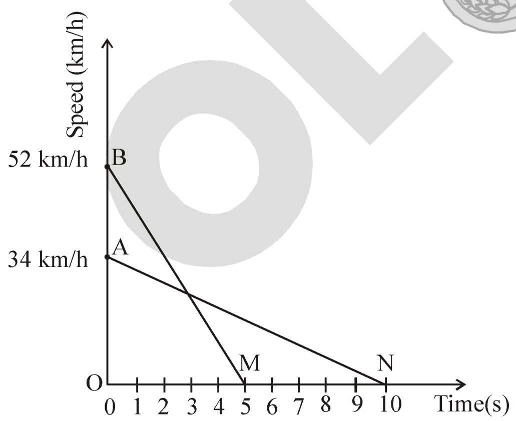
$$2v^2 - 2u^2 = v^2 - u^2$$

$$v' = \sqrt{\frac{u^2 + v^2}{2}}$$

SE. 8

A driver of a car travelling at 52 km h^{-1} applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5s. Another driver going at the speed of 34 km h^{-1} in another car applies his brakes slowly and stops in 10 s. On the same graph paper, plot the speed versus time graph for the two cars. Which of the two cars travelled farther after the brakes were applied ?

Ans.



For car 1,

$$u = 52 \text{ km/h} = 52 \times \frac{5}{18} = 14.4 \text{ m/s}$$

v = 0, t = 5s

For car 2,

$$u = 34 \text{ km h}^{-1} = 34 \times \frac{5}{18} = 9.44 \text{ m/s}$$

v = 0, t = 10 s

Both the graphs are straight lines because the retardation is uniform.

Distance travelled by car 1 = Area of Δ BOM

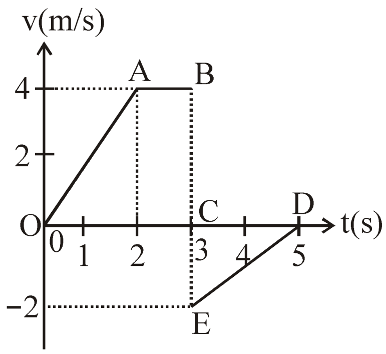
$$= \frac{1}{2} \times 5 \times 14.44 = 36.1\text{m}$$

Distance travelled by car 2 = Area of Δ AON

$$= \frac{1}{2} \times 10 \times 9.44 = 47.2 \text{ m}$$

SE. 9

For a particle moving along x-axis, velocity time graph is shown in figure. Find the distance travelled and displacement of the particle ? Also find the average velocity of the particle in interval 0 to 5 second.



Ans. For a particle moving along x-axis, distance travelled by the particle = sum of areas under v – t graph

Area of trapezium OABC + Area of ΔCDE

$$= \frac{1}{2}(3+1)4 + \frac{1}{2} \times 2 \times 2 = 8 + 2 = 10\text{m}$$

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Displacement of the particle

= area above t-axis – area below t-axis

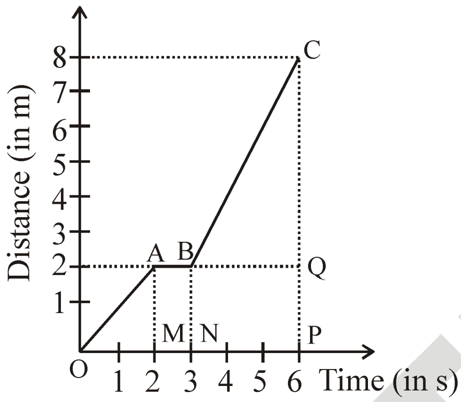
$$=\frac{1}{2}(3+1)4-\frac{1}{2}\times 2\times 2=8-2=6\text{m}$$

Average velocity =

$$\frac{\text{Displacement}}{\text{time}-\text{interval}}=\frac{6}{5}=1.2\text{ m/s}=\ 1.2\text{ m/s}$$

SE. 10

Interpret the distance-time graph



Ans. O to A

When we get a straight line inclined to time axis in a distance-time graph, it is case of constant speed. The speed is the slope of the line.

Speed = $\frac{AM}{OM}=\frac{2m}{2s}=1\,m\,s^{-1}$

A to B

When we get a straight line parallel to time axis in a distance-time graph, the body is at rest

B to C

It is a case of constant speed where

Speed = $\frac{CQ}{BQ}=\frac{6m}{3s}=2\,m\,s^{-1}$

SE. 11

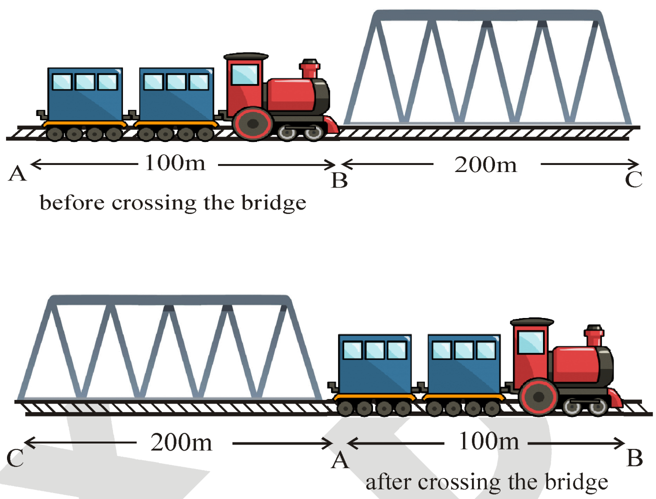
A 100 m long train crosses a bridge of length 200 m in 50 seconds with constant velocity. Find the velocity.

Ans. Distance travelled by the train = BC + AB

= 100m + 200m

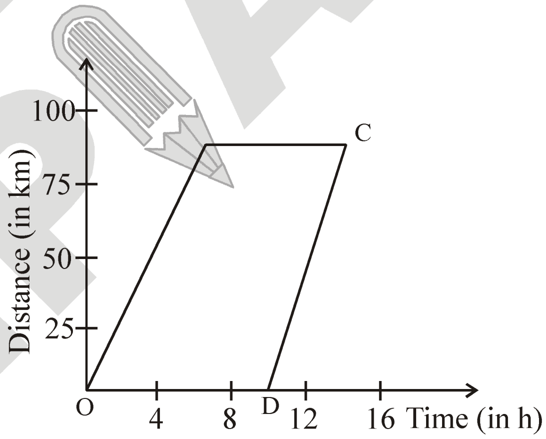
= 300m

$\therefore$ Velocity = $\frac{300}{50}$ = 6 m/s



SE. 12

What is wrong the following graph ?



Distance-time graph for an object

Ans. (a) If we draw a perpendicular on the time-axis at the point corresponding to 12 hours, it cuts the graph at two points. One corresponds to 25 km and the other corresponds to 87 km. Thus, according to the graph, the distance travelled in 12 hours is 25 km as well as 87 km, which is not possible.

(b) The line CD represents time going in reverse direction which is not possible.

SE. 13

A particle moving with an initial velocity of 5.0 m/s is subjected to a uniform acceleration of –2.5 m/s^2. Find the displacement in the next 4.0 s.

Ans. The displacement is

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

$$= \left(5.0\frac{m}{s}\right) \times (4.0s) + \frac{1}{2}\left(-2.5\frac{m}{s^2}\right) \times (4.0s)^2$$

= 20 m – 20 m = 0 m

So, after 4.0 s, the particle will be back at its initial position. Note that the distance traversed is non zero, as the particle moves in the forward direction and then comes back to the initial position.

SE. 14

What can you say about the nature of the motions of the particles for which the velocity-time graphs are given here

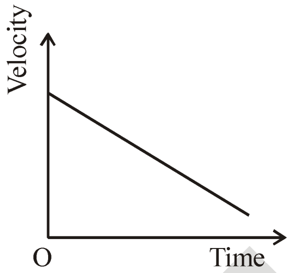


Fig. (a)

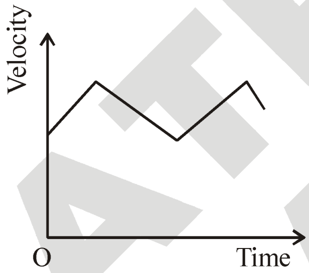


Fig.(b)

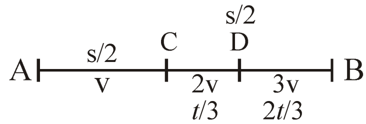
Ans. In case of figure (a), as time passes, the velocity decreases continuously. So the particle is slowing down continuously. We see this type of motion when we throw a ball up. The ball slows down continuously and its velocity becomes zero at the highest point.

In case of figure (b), the velocity increases and decreases alternately. As the velocity remains positive throughout, the particle keeps moving in the same direction. You have this type of motion when a driver drives a car on a straight, busy road. He has to slow down (brake) and speed up (accelerate) alternately for a large part of the drive.

SE. 15

A particle covers half of the total distance with velocity *v*. On the remaining part, it moves with 2*v* for one third of the time and with 3*v* for two third of the time. What is the overall average velocity of the particle ?

Ans.



For AC, $t_1 = \frac{s/2}{v} = \frac{S}{2v}$

$\therefore t_1 = \frac{S}{2v}$

For CB, $\frac{s}{2} = 2v \times \frac{t}{3} + 3v \times \frac{2t}{3} = \frac{2vt}{3} + \frac{6vt}{3}$

$\Rightarrow \frac{S}{2} = \frac{8vt}{3}$

⇒ S × 3 = 2 × 8 vt

$\therefore t = \frac{3}{16}\left(\frac{S}{v}\right)$

$$< v >= \frac{s}{\frac{s}{2v} + \frac{3}{16}\left(\frac{S}{v}\right)} = \frac{16v}{(8+3)} = \frac{16}{11}v$$

SE. 16

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

Ans. Here, t = 5s

Speed, v = 346 ms^{-1}

Distance = ?

Using, distance = speed × time, we get

distance = 346 ms^{-1} × 5 s = 1730 m

Thus, the distance of the location of lightning = 1730m

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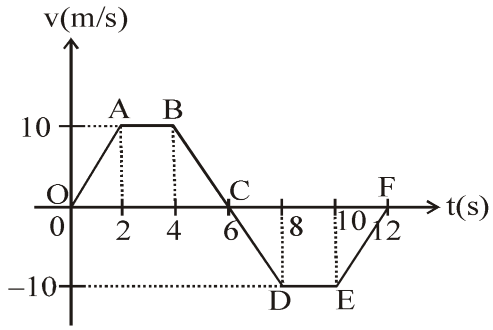
SE. 17

From the velocity-time graph. Find



(i) Average acceleration
t = 0 to t = 2 s, t = 0 to t = 4 s, t = 2 to t = 5 s
(ii) Acceleration at t = 1s, 3s and 5s
(iii) Displacement in 12 seconds
(iv) Distance in 12 seconds
(v) Average velocity and average speed in 12 seconds

Ans. (i) Average acceleration is equal to the slope of the line joining the two points on velocity-time graph.

Time	0-2 s	0-4 s	2s - 5s
$<\vec{a}>$	$\frac{10}{2} = 5\,\text{m s}^{-2}$	$\frac{10}{4} = 2.5\,\text{m s}^{-2}$	$-\frac{5}{3}\,\text{m s}^{-2}$

(ii) Acceleration (or Instantaneous acceleration) is the slope of the tangent on velocity time graph.

Time	t = 1s	t = 3s	t = 5s
Acceleration	$\frac{10}{2}$ = 5 ms^{-2}	0	–5 ms^{-2}

$\therefore$ Area of trapezium = $\frac{1}{2}$ (sum of parallel sides) x h

(iii) Displacement in 12 sec = (Area of trap. OABC) – (Area of trap. CDEF)

$$= \frac{1}{2}(2+6)\times 10 - \frac{1}{2}(2+6)\times 10$$

= 40 – 40 = 0

$\therefore$ Displacement in 12 sec. = 0

(iv) Distance in 12 sec. = (Area of trap. OABC)
+ (Area of trap. CDEF)
= 40 + 40 = 80m

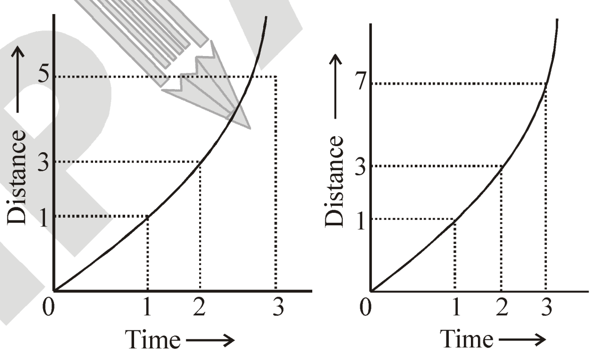
(v) Average velocity

$$= \frac{\text{Total displacement}}{\text{Total time}} = 0$$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{80}{12} = \frac{20}{3}\ \text{m/s}$$

SE. 18

Distance-time graph for the motion of a truck and bus are shown in figure (a) and figure (b) respectively. What can you say about the motion of these vehicles and which of these vehicles is moving fast ?



(a) (b)

Ans. Since both truck and bus are travelling unequal distances in equal intervals of time, therefore, the motion of both the vehicles is non-uniform motion. Slope of distance-time graph = Speed of an object.
Since slope of distance-time graph for the motion of the bus is greater than the slope of distance-time graph for the motion of the truck, therefore, bus is moving faster than the truck.

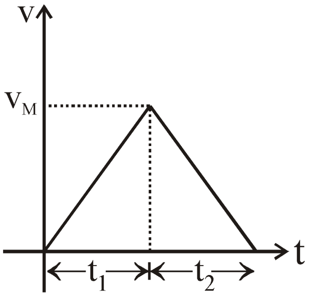
SE. 19

A car accelerates from rest a constant rate α for sometime after which it decelerates at a constant rate β to come to rest. If the total time elapsed is t seconds. Find

(i) The maximum velocity acquired by the car.
(ii) Average velocity
(iii) Average speed.

Ans. (i) The velocity vs time graph will be $\alpha = \frac{v_M}{t_1}, \beta = \frac{v_M}{t_2}$

(ii) $t_1 + t_2 = t$ or $\frac{v_M}{\alpha} + \frac{v_M}{\beta} = t \Rightarrow v_M = \frac{\alpha\beta t}{\alpha + \beta}$



(iii) Displacement = Area = $\frac{1}{2} t_{v_M}$

Average velocity

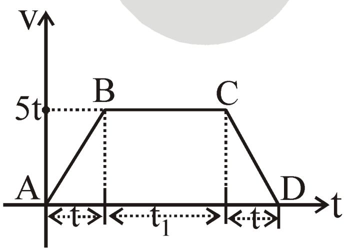
$$= \frac{\text{Total displacement}}{\text{Total time}} = \frac{\text{Area}}{\text{time}} = \frac{\frac{1}{2} t v_M}{t} = \frac{v_M}{2}$$

$$< \vec{v} > = \frac{v_M}{2} = \frac{\alpha\beta t}{2(\alpha + \beta)}$$

SE. 20

A car starts moving with acceleration a = 5 m s^{-2}, then moves uniformly for some time and then decelerates at a = –5 m s^{-2} and comes to a stop. The total time of motion is 25 s. The average velocity is equal to 20 m s^{-1}. Find the time for which the car moves with acceleration, retardation and uniformly.

Ans. Velocity vs time graph for the given data will be



AB = Acceleration, say the time for acceleration is t

BC = Uniform motion, say the time for uniform is t_1

CD = Deceleration, time for deceleration motion will be t

(Time of deceleration will be same as that of acceleration)

$2t + t_1 = 25$s

Area under the velocity vs time curve = Displacement

$\Rightarrow \frac{1}{2} \times 5t \times t + (25 - 2t) \times 5t + \frac{1}{2} \times 5t \times t =$ Disp.

$\Rightarrow \frac{1}{2} 5t^2 + 125t - 10t^2 + \frac{1}{2} 5t^2 =$ Displacement

$\Rightarrow 5t^2 - 10t^2 + 125t =$ Displacement

$\therefore$ Displacement = $125t - 5t^2$

Average velocity = $\frac{\text{Total displacement}}{\text{Total time}}$;

$\Rightarrow 20 = \frac{125t - 5t^2}{25}$

$\Rightarrow 5t^2 - 125t + 500 = 0$

$\therefore$ t = 5 s ($t \neq 20$ since total time is 25 s)

$t_1 = 25 - 2t = 15$ s.

$\therefore$ t_1 = 15sec.

$\therefore$ Car moves with acceleration, for 5 sec.

$\therefore$ Car moves with retardation, for 5 sec.

$\therefore$ Car moves uniformly for 15 sec.

NS. 1

An object has moved through a distance. Can it have zero displacement ? If yes support your answer with an example.

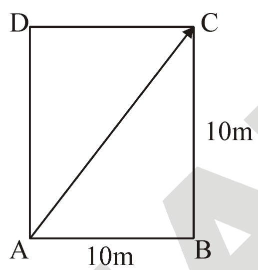
Ans. Yes, the object inspite of moving through a distance can have zero displacment.

Example : If an object travels from point A and returns to the same point A, then its displacement is zero.

NS. 2

A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds ?

Ans. Figure ABCD is a square field of side 10 m.



Time for one round = 40 s

Total time = 2 min 20 s

= (2×60+20) s = 140 s

Number of round completed = $\frac{140}{40}$ = 3.5

If farmer starts from A, it will complete 3 rounds ($A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$) at A. In the last 0.5 round starting from A, he will finish at C.

Displacement of farmer

= AC = $\sqrt{AB^2 + BC^2}$ = $\sqrt{10^2 + 10^2} = 10\sqrt{2}\text{m}$

NS. 3

Which of the following is true for displacement ?

(a) It cannot be zero.

(b) Its magnitude is greater than the distance travelled by the object.

Ans. (a) False (b) False

NS. 4

Distinguish between speed and velocity ?

Speed	Velocity
The distance travelled by a moving body in per unit time is called its speed	The displacement covered by a moving body in a per unit time is called its velocity
It is a scalar quantity	It is a vector quantity

NS. 5

Under what condition(s) is the magnitude of average velocity of an object equal to its average speed ?

Ans. The magnitude of average velocity of an object is equal to its average speed if the object moves in a straight line in a particular direction.

NS. 6

What does the odometer of an automobile measure?

Ans. The odometer of an automobile measures the distance travelled by a vehicle.

NS. 7

What does the path of an object look like when it is in uniform motion ?

Ans. It is a straight line.

NS. 8

During experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station ? The signal travels at the speed of light, that is 3×10^8 m s^{-1} ?

Ans. Time taken = 5 minutes = 5×60s = 300 s

Speed of signal u = 3×10^8 m s^{-1}

distance = ?

$\text{speed} = \frac{\text{distance}}{\text{time}}$ $\therefore$ distance = speed × time

$\therefore$ distance = $3\times10^8 \times 300 = 9 \times 10^{10}$ m

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NS. 9

When will you say a body is in :

(i) Uniform acceleration

(ii) Non-uniform acceleration

Ans. (i) Uniform acceleration : When a body travels with the same acceleration in the given time, then the acceleration is said to be uniform for example.

A body falling under gravity.

(ii) Non-uniform acceleration : When a body moves with unequal velocity acceleration in the equal interval of time, the body is said to be moving with non-uniform acceleration for example : A body in circular motion.

NS. 10

A bus decreases its speed from 80 km h^{-1} to 60 km h^{-1} in 5 s. Find the acceleration of the bus.

Ans. Initial velocity u = 80 km h^{-1}

$= \frac{80 \times 1000}{60 \times 60}$ = m s^{-1} = 22.22 m s^{-1}

Final velocity v = 60 km h^{-1}

$= \frac{60 \times 1000}{60 \times 60}$ = 16.66 km h^{-1}

Time t = 5 s

$\therefore$ a = ?

$$a = \frac{v - u}{t} = \frac{16.66 - 22.22}{5} = -1.11 \, m\, s^{-2}$$

$\therefore$ The acceleration of bus is – 1.11 m s^{-2}.

NS. 11

A racing car has a uniform acceleration of 4 m s^{-2}. What distance will it cover in 10 s after start ?

Ans. a = 4 m s^{-2}

t = 10 s

s = ?

u = 0

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

= 0 × 10 + $\frac{1}{2}$ × 4 × $(10)^2$ = 0+ $\frac{1}{2}$ ×4×100

s = 200 m

The distance covered in 10 s by the car is 200 m.

NS. 12

A stone is thrown in a vertically upward direction with a velocity of 5 m s^{-1}. If the acceleration of the stone during its motion is 10 m s^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there

Ans. u = 5 m s^{-1}

v = 0

a = –10 m s^{-2}

s = ?

t = ?

(i) v = u + at

$\Rightarrow$ 0 = 5 + (–10)t

$\Rightarrow$ –5 = –10t $\therefore$ t = $\frac{5}{10}$ = 0.5 s

(ii) $v^2 - u^2 = 2as$

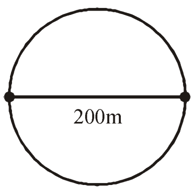
$\Rightarrow (0)^2 - (5)^2 = 2(-10) \times s$

$\Rightarrow$ –25 = –20×s $\therefore$ s = $\frac{25}{20}$ = 1.25 m

NS. 13

An athelete completes one round of a circular track of diameter 200 m in 40 s. What will be the distance covered and the displacement at the end of 2 minutes 20 s ?

Ans.



Diameter = 200m, r = $\frac{d}{2}$ = 100m

Time for one round = 40 s

Distance travelled in 2 minutes and 20 s

(2×60+20 = 140 s) = $\frac{140}{40}$ = 3.5 rounds

Distance travelled = Circumference of the circle × 3.5

$= 2\pi r \times 3.5$

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$= 2 \times \frac{22}{7} \times 100 \times 3.5 = 2200\text{m}$

Displacement after 3.5 revolutions

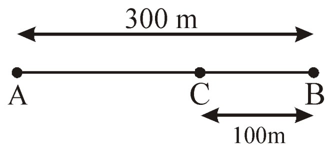
= diameter of the track

= 200 m

NS. 14

Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes 30 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging. (a) from A to B and (b) from A to C ?

Ans. **(a) From A to B.**



Time for A to B = 2 min 30 s

= 2×60+30 = 150 s

$$\text{Average speed} = \frac{\text{total distance}}{\text{time interval}}$$

$$= \frac{300}{150} = 2\,\text{m s}^{-1}$$

$$\text{Average velocity} = \frac{\text{displacement}}{\text{time interval}}$$

$$= \frac{300}{150} = 2\text{m s}^{-1}$$

(b) From A to C,

Time taken (A to B + B to C) = 150 + 60 = 210 s

Displacement = 300 – 100 = 200 m

total distance = 300 + 100 = 400 m

$$\therefore \text{ Average speed} = \frac{\text{total distance}}{\text{time interval}}$$

$$= \frac{400}{210} = 1.9\,\text{m s}^{-1}$$

$$\therefore \text{ Average velocity} = \frac{\text{displacement}}{\text{time interval}}$$

$$= \frac{200}{210} = 0.95\,\text{m s}^{-1}$$

NS. 15

Abdul, while driving to school, computes the average speed for his trip to be 20 km h^{-1}. On his return trip along the same route, there is less traffic and the average speed is 30 km h^{-1}. What is the average speed for Abdul's trip ?

Ans. Let the school be at a distance of x km. If t_1 is time taken to reach the school, then

$$t_1 = \frac{\text{distance}}{\text{average speed}} = \frac{x}{20}$$

If t_2 is time taken to reach back, then

$$t_2 = \frac{\text{distance}}{\text{average speed}} = \frac{x}{30}$$

total time,

$$t = t_1 + t_2 = \frac{x}{20} + \frac{x}{30} = x\left[\frac{1}{20} + \frac{1}{30}\right] = \frac{5x}{60} = \frac{x}{12}$$

total distance x + x = 2x

$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$= \frac{2x}{x/12} = 24\,\text{km h}^{-1}$$

$\therefore$ Average speed for Abdul's trip is 24 km/h

NS. 16

A motorboat starting from rest on a lake accelerates in a straight line at a constant rate of 3.0 m s^{-2} for 8.0 s. How far does the boat travel during this time

Ans. u = 0

a = 3.0 m s^{-2}

t = 8 s

$s = ut + \frac{1}{2}at^2 = 0\times t + \frac{1}{2}(3)(8)^2$

$s = \frac{1}{2}\times 3\times 64 = 96$ m

∴ Boat travelled a distance of 96 m

NS. 17

A driver of a car travelling at 52 km h^{-1} applies the brakes and accelerated uniformly in the opposite direction. The car stops in 5 s. Another driver going at 3 km h^{-1} in another car applies his brakes slowly and stops in 10 s. On the same graph paper plot the speed versus time graphs for the two cars. Which of the two cars travelled farther after the brakes were applied ?

Ans. The date given in this numerical problem are in different units. So, we should first convert km h^{-1} unit into m s^{-1} unit.

For first car :

Initial velocity u = 52 km h^{-1}

$$= \frac{52\,\text{km}}{1\text{h}} = \frac{52\times 1000\text{m}}{1\times 3600\text{s}} = 14.4\,\text{m s}^{-1}$$

Final velocity, v = 0 km h^{-1} = 0.0 m s^{-1}

Time taken, t = 5 s

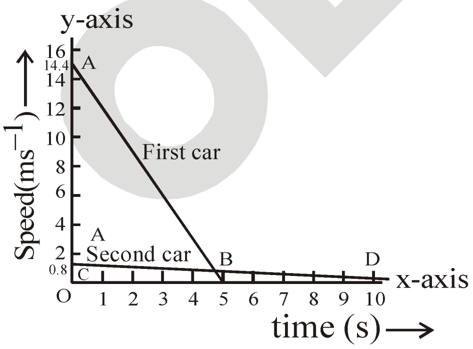
For second car :

Initial velocity, u = 3 km h^{-1}

$$= \frac{3\text{km}}{1\text{h}} = \frac{3\times 1000\text{m}}{1\times 3600\text{s}} = 0.83\,\text{m s}^{-1}$$

Final velocity, v = 0 km h^{-1} = 0.0 m s^{-1}

Time taken, t = 10 s



The distance travelled by a moving body is given by the area under its speed-time graph.

So, distance travelled by the first car = Area of the triangle AOB

$$= \frac{1}{2}\times OB\times AO = \frac{1}{2}\times 5\text{s}\times 14.4\,\text{m s}^{-1}$$

$$= \frac{1}{2}\times 14.4\times 5\text{m} = 36\,\text{m}$$

Similarly,

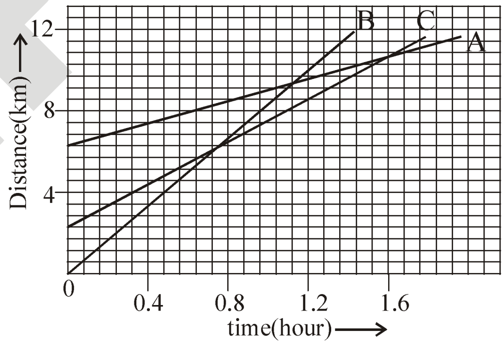
Distance travelled by the second car = Area of triangle COD

$$= \frac{1}{2}\times OD\times CO = \frac{1}{2}\times 10\text{s}\times 0.83\,\text{m s}^{-1}$$

$$= \frac{1}{2}\times 0.83\times 10\,\text{m} = 4.1\,\text{m}$$

NS. 18

Figure given below show the distance-time graph of three objects A, B and C. Study the graph and answer the following questions



(a) Which of the three is trevelling the fastest ?

(b) Will all three ever meet at the same point on the road ?

(c) How far has C travelled when B passes A?

(d) How far has B travelled by the time it passes C

Ans. (a) B is travelling fastest.

(b) As three lines do not meet at any point, the three objects never meet on the road.

(c) B passes A at D (say). At this time, C is at E (say), which corresponds to 9 km. Hence when B crosses A, then C is at 9 km from the origin.

(d) By the time B passes C, it has travelled 6 km.

NS. 19

A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 m s^{-2}, with what velocity will it strike the ground ? After what time will it strike the ground ?

Ans. s = 20 m, u = 0, a = 10 m s^{-2}

We have, $s = ut + \frac{1}{2}at^2$

$\therefore$ $(20) = 0 \times t + \frac{1}{2}(10)t^2$

$\Rightarrow$ $20 = \frac{1}{2} \times 10t^2$

$\frac{20 \times 2}{10} = t^2 \Rightarrow t^2 = 4$

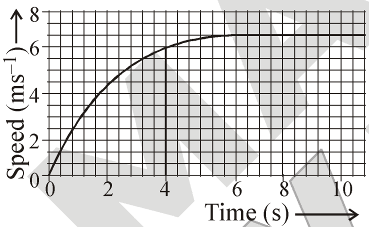
$\therefore$ t = 2 s

v = u + at = 0 + 10 × 2 = 20 m s^{-1}

The ball strikes the ground after 2sec. and velocity of ball when it strike the ground 20ms^{-1} .

NS. 20

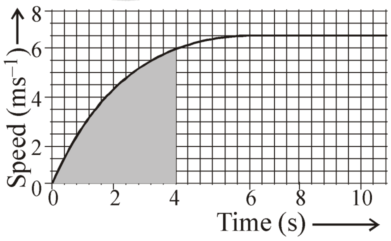
The speed-time graph for a car is shown in the figure.



(a) Find how far does the car travel in the first 4 seconds. Shade the area on the graph that represents the distance travelled by the car during the period.

(b) Which part of the graph represents uniform motion of the car ?

Ans. The motion during first 4 seconds is not uniformly accelerated. So, distance travelled by car in first 4 seconds is calculated by graphical method.



(a) Area of small division on the graph

$= \frac{2}{3}ms^{-1} \times \frac{2}{5}s = \frac{4}{15}m$

Total number of small divisions under the curve up to 4 s = 63

Area under the curve up to 4 s = $\frac{4}{15} \times 63$ =16.8 m

Therefore, the car has covered a distance of 16.8 m in first 4 s.

(b) The limiting flat portion of the curve describes the constant speed of the car, i.e., a speed of 6.0 ms^{-1}. At this stage, the acceleration of the car is zero.

Therefore, portion of the graph beyond 4.2 s describes the uniform motion of the car.

NS. 21

State which of the following situation are possible and give an example for each of these :

(a) an object with a constant acceleration but with zero velocity

(b) an object moving in a certain direction with an acceleration in the perpendicular direction

Ans. (a) free fall due to gravity (at the top point)

(b) object moving in a circular path

NS. 22

An artificial satellite is moving in a circular orbit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth.

Ans. Radius of the orbit = 42250 km

= 42250×1000m

Time taken for one revolution = 24 hours

= 24 × 60 × 60 s

Speed = ?

$\therefore$ Speed

$= \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{\text{time}} = 2 \times \frac{22}{7} \times \frac{42250 \times 1000}{24 \times 60 \times 60}$

Speed = 3073.74 m s^{-1}

= 3.07 km s^{-1}.

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EXERCISE – I

ONLY ONE CORRECT TYPE

1. An object is said to be at rest if its .... does not change with time :
(A) Position (B) Size
(C) Colour (D) Material

2. Which of these is an example of oscillatory motion ?
(A) Motion of an electric fan
(B) Motion of a spinning top
(C) Motion of pendulum of a wall clock
(D) Motion of a stone dropped from a roof

3. Which of the following is not a vector quantity ?
(A) Retardation
(B) Acceleration due to gravity
(C) Average speed
(D) Displacement

4. In which of the following cases of motion, the distance moved and the magnitude of displacement are equal :
(A) If the car is moving on straight road
(B) If the car is moving in circular path
(C) The pendulum is moving to and fro
(D) The earth is revolving around the sun

5. The numberical ratio of displacement to distance for a moving object is :
(A) Always less than 1
(B) Always equal to 1
(C) Always more than 1
(D) Equal or less than 1

6. A particle is moving in a circular path of radius r. The displacement after half a circle would be :
(A) Zero (B) π r
(C) 2 r (D) 2π r

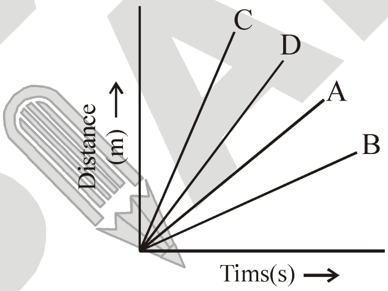
7. A body goes from A to B with a velocity of 20 m/s and comes back from B to A with a velocity of 30 m/s. The average velocity of the body during the whole journey is :
(A) zero (B) 25 m/s
(C) 24 m/s (D) none of these

8. The CGS unit of acceleration is :
(A) cm/s (B) cm/min
(C) cm/s^2 (D) cm/min^2

9. A body is thrown vertically upward with velocity (u). The greatest height h to which it will rise is :
(A) u/g (B) $u^2/2g$
(C) u^2/g (D) u/2g

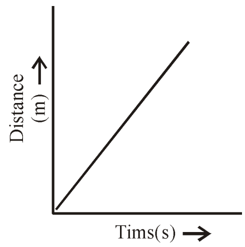
10. If the displacement of an object is proportional to square of time, then the object moves with :
(A) Uniform velocity
(B) Uniform acceleration
(C) Increasing acceleration
(D) Decreasing acceleration

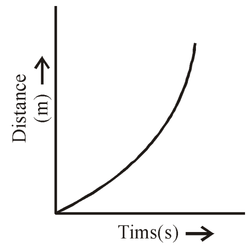
11. Four cars A, B, C and D are moving on a levelled road. Their distance versus time graphs are shown in figure. Choose the correct statement :

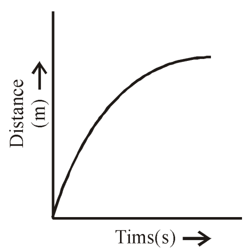


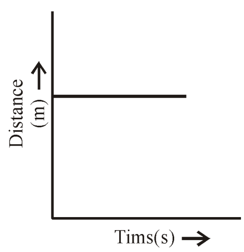
(A) Car A is faster than car D
(B) Car B is the slowest
(C) CarD is faster than car C
(D) Car C is the slowest

12. Which of the following figures represents uniform motion of a moving object correctly :

(A) 

(B) 

(C) 

(D) 

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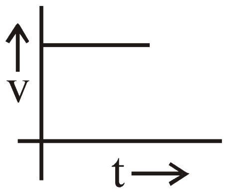
13. From the given v-t graph, it can be inferred that the object is :



(A) in uniform motion
(B) at rest
(C) in non-uniform motion
(D) moving with uniform acceleration

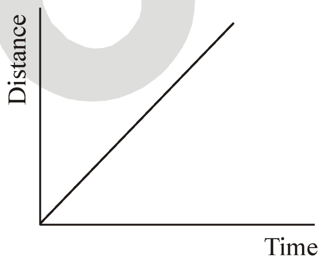
14. A particle is travelling with a constant speed. This means :
(A) Its position remains constant as time passes
(B) It covers equal distances in equal time intervals
(C) Its acceleration is zero
(D) It does not change its direction of motion

15. A particle moves with a uniform velocity
(A) The particle must be at rest.
(B) The particle moves along a curved path
(C) The particle moves along a circle
(D) The particle moves along a straight line

16. A quantity has a value of –6.0 m/s. It may be the :
(A) Speed of a particle
(B) velocity of a particle
(C) acceleration of a particle
(D) position of a particle

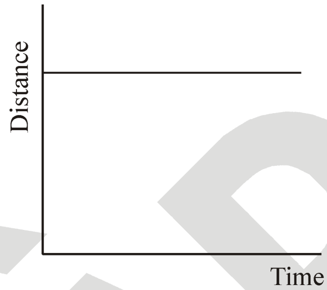
17. The velocity-time graph of a particle is not a straight line. Its acceleration is :
(A) Zero (B) Constant
(C) Negative (D) Variable

18. The distance-time graph of an object moving in a fixed direction is shown in figure



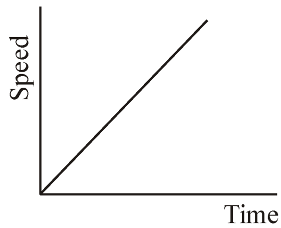
The object
(A) is are rest
(B) moves with a constant velocity
(C) moves with a variable velocity
(D) moves with a constant acceleration

19. The distance-time graph of an object is shown in figure.



The object :
(A) is at rest
(B) moves with a constant speed
(C) moves with a constant velocity
(D) moves with a constant acceleration

20. The speed-time graph of an object moving in a fixed direction is shown in figure



The object :
(A) is at rest
(B) moves with a constant speed
(C) moves with a constant velocity
(D) moves with a constant acceleration

21. In circular motion the :
(A) direction of motion is fixed
(B) direction of motion changes continuously
(C) acceleration is zero
(D) velocity is constant

22. A 100 m long train crosses a bridge of length 200 m in 50 seconds with constant velocity. Find the velocity.
(A) 3 m/s (B) 6 m/s
(C) 9 m/s (D) 12 m/s

23. Rahim, while driving to school, computes the average speed for his trip to be 20 km h^{-1}. On his return trip along the same route, there is less traffic and the average speed is 30 km h^{-1}. What is the average speed for Rahim's trip ?
(A) 12 km/h (B) 24 km/h
(C) 36 km/h (D) 72 km/h

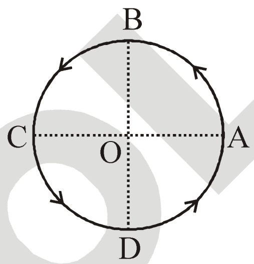
24. On a 100 km road, a car travels the first 50 km at a uniform speed of 30 kmh^{-1}. How fast must the car travel for the next 50 km so as to have an average speed of 45 kmh^{-1} for the entire journey ?
(A) 45 km/h (B) 15 km/h
(C) 90 km/h (D) 30 km/h

25. The brakes applied to a car produce an acceleration of 6 ms^{-2} in the opposite direction to the motion.
If the car takes 2 s to stop after the application of brakes, calculate the distance it travels during this time.
(A) 6 m (B) 12 m
(C) 18 m (D) 24 m

PARAGRAPH TYPE

PARAGRAPH # 1

Distance travelled by an object in a given time is the actual path length covered by an object in the given time and displacement is the shortest distance between the initial and final position of the object in the given time. Speed is equal to distance/time and velocity = displacement/time.



Change in velocity = final velocity – initial velocity.
A particle moves along a circle of radius R. It starts from point A and moves in anticlockwise direction, as shown in figure

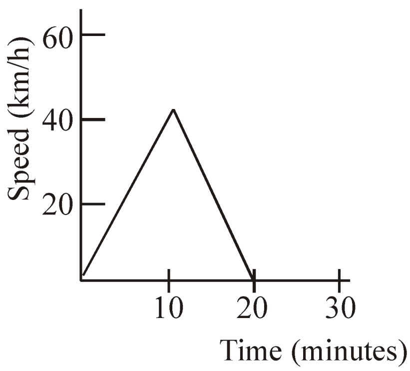
26. The distance travelled and displacement of the particle from A to B is :
(A) $\frac{\pi R}{4}, R$ (B) $\frac{\pi R}{2}, 2R$
(C) $\frac{\pi R}{4}, \sqrt{2}R$ (D) $\frac{\pi R}{2}, \sqrt{2}R$

27. The distance travelled and displacement of the particle from A to C is :
(A) $\frac{\pi R}{2}, 2R$ (B) πR , 2R
(C) $\frac{\pi R}{2}, \frac{\pi R}{2}$ (D) πR , πR

28. If T is the time period of uniform revolution of the particle on the circle, then the speed of the object at B is :
(A) $\frac{2\pi}{2T}$ (B) $\frac{\sqrt{2}R}{T}$
(C) $\frac{2\pi R}{T}$ (D) $\frac{R}{T}$

PARAGRAPH # 2

Figure shows the speed-time graph of a bus.



29. What is the distance covered during its acceleration ?
(A) $\frac{10}{3}km$ (B) $\frac{5}{3}km$
(C) $\frac{15}{3}km$ (D) $\frac{20}{3}km$

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30. What is the distance covered during its deceleration ?

(A) $\frac{20}{3} km$ (B) $\frac{5}{3} km$

(C) $\frac{15}{3} km$ (D) $\frac{10}{3} km$

31. What is the average speed in the entire journey ?

(A) 10 km/h (B) 20 km/h

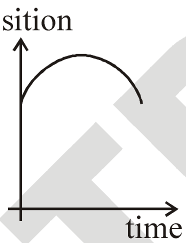
(C) 30 km/h (D) 15 km/h

MATCH THE COLUMN TYPE

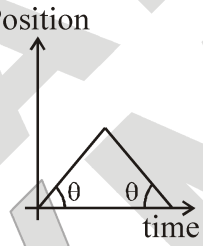
32. Match the situation given in Column-I with the possible curves in Column-II.

Column-I **Column-II**

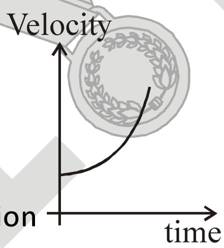
(a) Particle moving with constant speed (p)



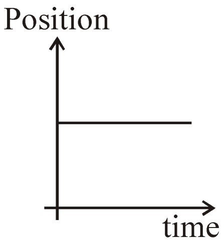
(b) Particle moving with increasing acceleration (q)



(c) Particle moving with constant negative acceleration (r)



(d) Particle is stationary (s)



(A) a-q, b-r, c-p, d-s

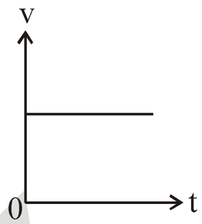
(B) a-r, b-p, c-s, d-q

(C) a-p, b-q, c-r, d-s

(D) a-s, b-r, c-q, d-p

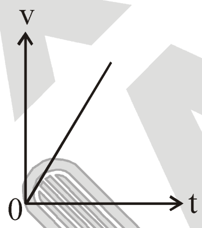
33. Column I **Column II**

(a)



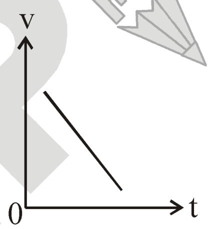
(p) Motion with non uniform acceleration

(b)



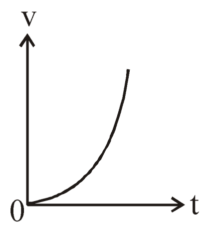
(q) Uniform acceleration

(c)



(r) Constant retardation

(d)



(s) Motion of body covering equal distances

(A) a-q, b-r, c-p, d-s

(B) a-r, b-p, c-s, d-q

(C) a-p, b-q, c-r, d-s

(D) a-s, b-q, c-r, d-p

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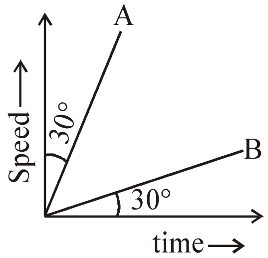
EXERCISE – II

VERY SHORT ANSWER TYPE

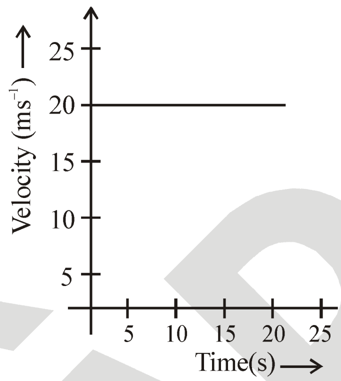
1. Give an example of a motion in which distance is covered
2. Is displacement independent of path ? Explain.
3. Two cars A and B have their s-t graph as shown. Which one has greater velocity ?



4. What is the value of acceleration, if v-t graph is a straight line parallel to the time axis ?
5. Name a physical quantity that (i) varies (ii) remains same, in a uniform circular motion.
6. You are walking towards India Gate. Is India Gate at rest with respect to you or is it moving with respect to you ?
7. Which of the following are scalar quantities ?
   (a) Mass (b) Displacement
   (c) Speed (d) Velocity
8. What is the displacement of a satellite when it makes a complete round along its circular path ?
9. A scooter moves 45 km on one litre of petrol. In a journey, the scooter used up one litre of petrol. Is it necessary that the displacement of the scooter in the journey is 45 km ? Is it possible that the displacement is 45 km ?
10. Can the distance travelled by an object be smaller than the magnitude of its displacement ?

SHORT ANSWER TYPE

1. The displacement of a moving object in a given interval of time is zero. Would the distance travelled by the object also be zero ? Justify your answer.
2. A motorcyclist drives from A to B with a uniform speed of 30 km h^{-1} and returns with a speed of 20 km h^{-1}. Find his average speed.
3. Give two examples each of uniform and nonuniform acceleration.
4. The velocity-time graph given shows the motion of a cyclist. Find (i) its acceleration (ii) its velocity and (iii) the distance covered by the cyclist in 15 seconds.



5. Define uniform speed and velocity

LONG ANSWER TYPE

1. A stone is thrown vertically upward which takes time 't' to reach the maximum heigh 'h'. After next 't' seconds it reaches the ground from the maximum heigh. Draw (i) distance-time graph and (ii) displacement time graph for the motion of the stone.
2. A car is moving on a straight road with uniform acceleration. The following table gives the speed of the car at various instants of time :

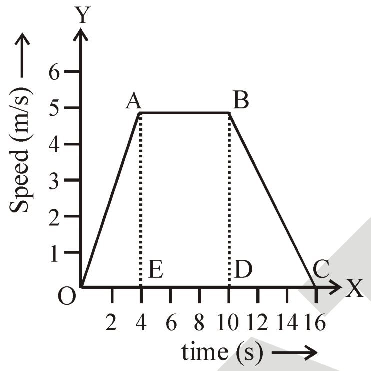
Time (s)	0	10	20	30	40	50
Speed (m/s)	5	10	15	20	25	30

   Draw the speed time graph choosing a convenient scale. Determine from it (i) the acceleration of the car (ii) the distance travelled by the car in 50s.
3. The following is the distance-time table of a moving car.

Time (am)	Distance(km)
10.05	0
10.25	5
10.40	12
10.50	22
11.00	26
11.10	28
11.25	38
11.40	42

(a) Use a graph paper to plot the distance travelled by the car versus the time.
(b) When was the car travelling at the greatest speed
(c) What is the average speed of the car ?
(d) What is the speed between 11.25 am and 11.40 am ?
(e) During a part of the journey, the car was forced to slow down to 12 km/h. At what distance did this happen ?

4. Study the speed time graph of a body shown in figure and answer the following questions :



(a) What type of motion is represented by OA ?
(b) What type of motion is represented by AB ?
(c) What type of motion is represented by BC ?
(d) Find out acceleration of the body.
(e) Find out retardation of the body.
(f) Find out the distance travelled by the body from A to B.

5. State which of the following situations are possible and give an example for each of these :
(a) an object with a constant acceleration but with zero velocity (b) an object moving in a certain direction with an acceleration in the perpendicular direction.

TRUE / FALSE TYPE

1. Motion along a curved line is called rectilinear motion.

2. A quantity which can be represented completely by magnitude only is called a vector quantity.

3. A motion is said to be uniform if a body undergoes equal displacements in equal interval of time.

4. Acceleration is defined as the rate of change of velocity.

5. If A moves with respect to B then B moves with respect to A.

FILL IN THE BLANKS

1. A body is said to be at rest if it does not change its .... with respect to the surroundings.

2. Speed is the ratio of the .... between two points and time.

3. A vector quantity has magnitude as well as ....

4. Distance is a .... quantity as it has no direction.

5. Displacement is a .... quantity.

NUMERICAL PROBLEMS

1. Using following data, draw displacement-time graph for a moving object.

Displacement (m)	0	2	4	4	4	6	4	2	0
Time (s)	0	2	4	6	8	10	12	14	16

Use the graph for find average velocity for first 4s, for next 4s and for last 6s.

2. The odometer of a car reads 2000 km at the start of a trip and 2400 km at the end of the trip. If the trip took 8 h. calculate the average speed of the car in km h^{-1} and ms^{-1}.

3. The table below shows the speed of a moving vehicle with respect to time :

Speed (m/s)	0	2	4	6	8	10
Time (s)	0	1	2	3	4	5

(i) Find the acceleration of the vehicle.
(ii) Calculate the distance covered in above question in 5 seconds.

4. A car moving along a straight highway with a speed of 126 kmph and is brought to a stop within a distance of 200m. What is the acceleration of the car and how long does it take for the car to stop ?

5. A particle is moving around in a circle of radius 1.5m with a constant speed of 2 m/s. Find
(i) the centripetal acceleration
(ii) angular velocity of the particle

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Answer Key

EXERCISE–I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	C	C	A	D	C	A	C	B	B	B	A	A	B	D
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B	D	B	A	D	B	B	B	C	B	D	B	C	A	D
31	32	33												
B	A	D												

EXERCISE – II

TRUE / FALSE

1. F **2.** F **3.** T **4.** T **5.** T

FILL IN THE BLANKS

1. Position **2.** Distance **3.** Direction **4.** Scalar **5.** Vector

NUMERICAL PROBLEMS

1. 1 m/s, 0 m/s and –1 m/s
2. 50 km/h or 13.9 m/s
3. (i) 2 m/s^2 (ii) 25 m
4. –3.06 ms^{-2}, 11.43s
5. (i) 2.67 m/s^2, 1.33 rad/sec

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SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : MOTION)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

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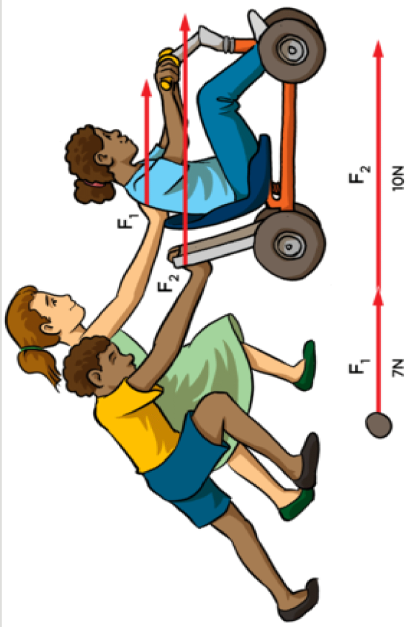
NOTES :

1. In the status, put “completed” only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.

Space for Notes :

FORCE AND ACCELERATION 2

Concepts



INTRODUCTION

When the position of a body does not change with time, we say that it is at rest. If a body moves in such a way that its speed as well as its direction remains the same, it is said to move with a uniform velocity. If the speed of a body or its direction of motion changes, it is said to be accelerated. Thus, if a body at rest starts moving, it is accelerated. If a body is moving and its speed increases or decreases, it is accelerated. If a body is moving and its direction changes then also it is accelerated. How can a body at rest start moving ? How can the speed of a moving body increase or decrease ? How can the direction of a moving body change ? These three questions can be combined into a single question. How can a body be accelerated ? The answer is : A body can be accelerated by applying a force on it. Let us now discuss what a force is.

1. FORCE

A pull or push which changes or tends to change the state of rest or of uniform motion or direction of motion of any object is called force. Force is the interaction between the object and the source (providing the pull or push).

OR

A force can be defined as 'a push or pull exerted on an object that can cause the object to speed up, slow down, or change direction as it moves or it can change its shape and size'.

1.1 EFFECT OF FORCE

(i) A force can distort an object i.e. it can change the shape and size of an object.
(ii) A force can start an object at rest i.e. it can move a stationary object.
(iii) A force can stop a moving object i.e. it can cause a moving object to come to rest.
(iv) A force can change the speed or the magnitude of velocity of an object i.e. it can increase or decrease the speed of an object.
(v) A force can change the direction of a moving object.

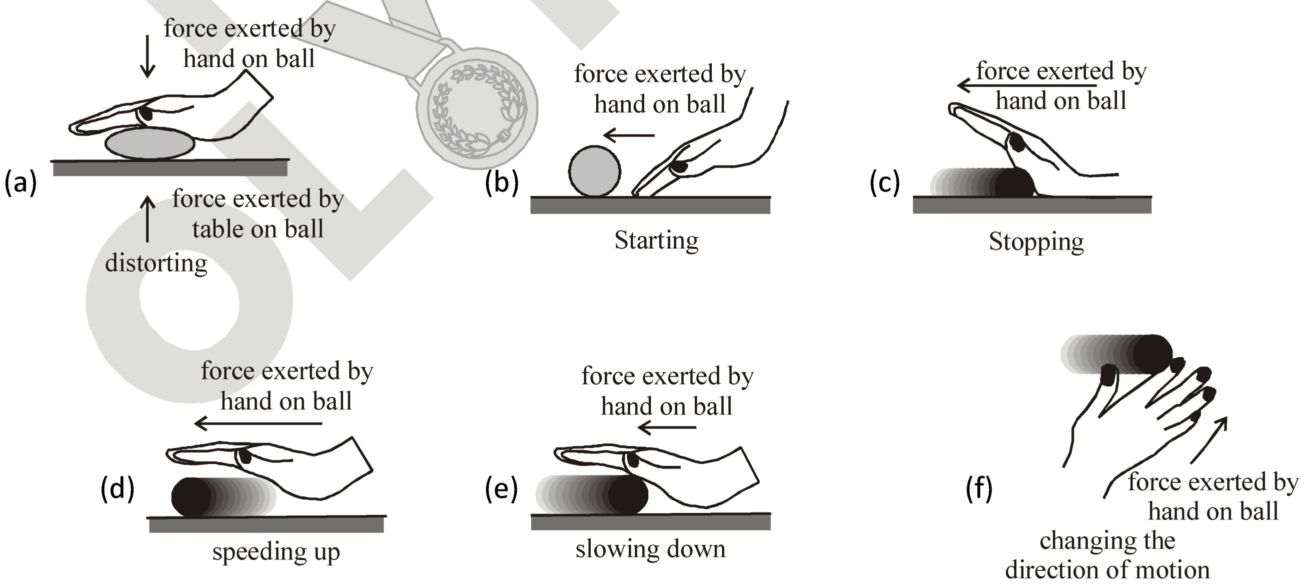


Figure : Effect of Force

1.2 BALANCED AND UNBALANCED FORCES

(a) Balanced Forces : If a number of forces acting on an object does not produce any change in its state of rest or uniform motion or direction of motion then, they are called as balanced forces.

For example :

(i) A person holding briefcase in hand

(ii) A book resting on table

(iii) Squeezing a lemon etc.

(b) Unbalanced Forces : If a number of forces acting on an object produce a change in its state of rest or uniform motion or direction of motion, then they are termed as unbalanced forces.

For example :

(i) A briefcase released from a persons hand.

(ii) A stone dropped etc.

1.3 GALILEO'S EXPERIMENTS

(i) Experiment I : It was observed by Galileo that when a ball is rolled down on an inclined frictionless plane its speed increases, whereas if it rolled up an inclined frictionless plane its speed decreases. If it is rolled on a horizontal frictionless plane the result must be between the cases describe above i.e. the speed should remain constant. It can be explain as :

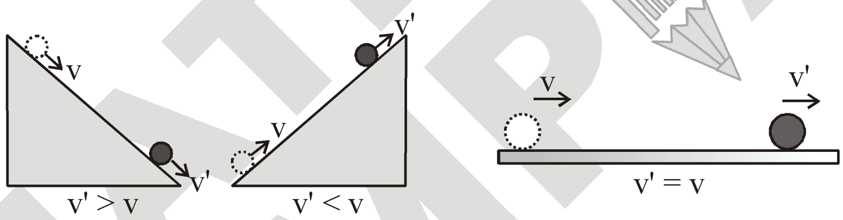


Figure : Galileo's experiments

moving down : speed increases ; moving up : speed decreases ; moving horizontal : speed remains constant

(ii) Experiment II : When a ball is released on the inner surface of a smooth hemisphere, it will move to the other side and reach the same height before coming to rest momentarily. If the hemisphere is replaced by a surface shown in figure (b) in order to reach the same height the ball will have to move a larger distance

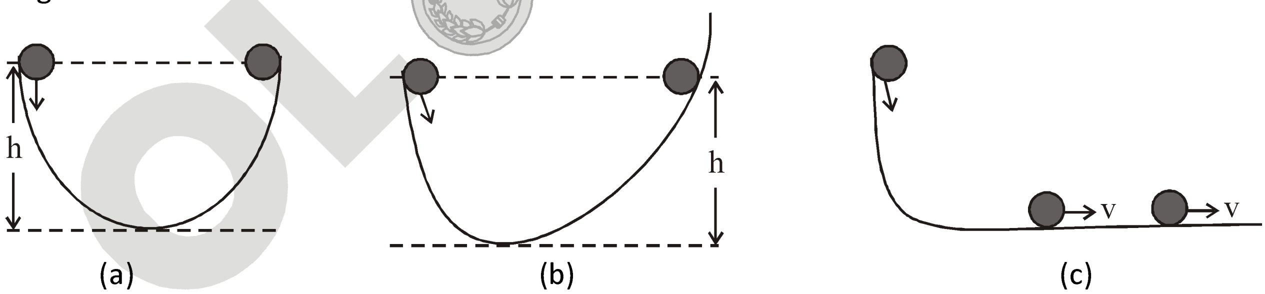


Figure : Galileo's experiments

In the other side is made horizontal, the ball will never stop because it will never be able to reach the same height,it means its speed will not decrease. It will have uniform velocity on the horizontal surface. Thus. if unbalanced forces do not act on a body, the body will either remain at rest or will move with a uniform velocity. It will remain unaccelerated.

2. NEWTON'S LAW OF MOTION

Newton built on Galileo's ideas and laid the foundation of mechanics in terms of three laws of motion that go by his name.

2.1 NEWTON'S FIRST LAW OF MOTION

According to Newton's first law of motion "Every body remain in its state of rest or uniform motion in a straight line unless it is compelled by some external force".

Inertia : Inertia is ' the natural tendency of an object or remain at rest or in motion at a constant speed along a straight line'. In other words, 'the tendency of an object to resist any attempt to change its velocity' is called **inertia**. The mass of an object is a quantitative measure of inertia. More the mass, more will be the inertia of an object and vice-versa.

Inertia of an object can be of three types : (i) Inertia of rest (ii) Inertia of motion (iii) Inertia of direction

Inertia of rest

It is the tendency of an object to remain at rest. This means an object at rest remains at rest until a sufficiently large external force is applied on it.

Examples of inertia of rest :

(i) When you are sitting in a stationary car, if the car starts suddenly i.e., accelerates forward, you feel as if your body is being pushed back against the seat, because your body which was initially at rest resists this change due to inertia. The lower part of body comes in motion as it is in direct contact with the car floor, while the upper portion still remains at rest due to inertia of rest (see figure). If the speed of car increases slowly, you will not feel a push or a jerk because the inertia of motion will get transferred to the whole body.

(ii) When a blanket is given a sudden jerk, the dust particles fall off. This is because the blanket suddenly comes in motion but the dust particles still remain at rest. As a result, the dust particles get separated from the blanket.

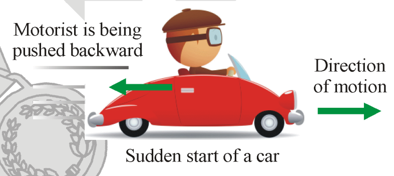


Figure : Example of inertia of rest

Inertia of motion

It is the tendency of an object to remain in the state of uniform motion. This means an object in uniform motion continues to move uniformly until an external force is applied on it.

Examples of inertia of motion :

(i) When you are driving a car and you apply brakes to stop the car suddenly, you feel as if your body is being pushed forward, because your body resists the decrease in speed. The lower part of body comes to rest as it is in direct contact with the car floor, while the upper portion still remains in motion due to inertia of motion (see figure). If you stop the car by decreasing its speed slowly, you will not feel a push or a jerk because the inertia of rest will get transferred to the whole body.

Figure : Example of inertia of motion

(ii) A person jumping out of a moving train has the tendency to fall forward. This is because on jumping, his feet come to rest as they touch the ground.. But his upper body continues to move forward due to inertia of motion (see figure)

(iii) An athlete runs for some distance quickly before taking a long jump. As a result, he takes a longer jump due to inerita of motion (see figure)

Inertia of motion helps a long jumper

Figure : Example of inertia of motion

(iv) When you move a hammer with loose hammerhead in downward motion and suddenly stop it on a floor or a wooden base, the hammerhead gets tightened. This is because the handle of the hammer suddenly comes to rest on hitting the floor, while the hammerhead continues to move downward due to more inertia of motion, and hence gets tightened (see figure). If you move the hammer slowly, the state of rest will get transferred to the hammerhead also, thus, the hammerhead will not get tightened.

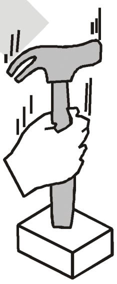


Figure : Tightening of hammerhead

Inertia of direction

It is the tendency of an object to maintain its direction. This means an object moving in a particular direction continues to move in that direction until an external force is applied to change it.

Examples of inertia of direction :

(i) When your motorcar makes a sharp turn at a high speed, you tend to get thrown to one side. You tend to continue in straight-line motion due to inertia of direction (see figure).

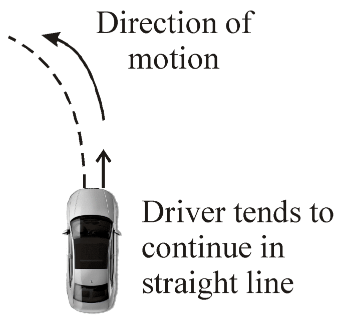


Figure : Inertia of direction

(ii) When a wheel rotates at high speeds, the sand particles on the wheel fly tangentially along a straight line due to inertia of direction (see figure)

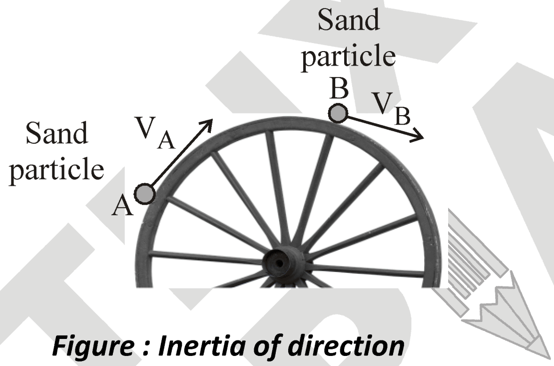


Figure : Inertia of direction

3. MOMENTUM & NEWTON'S 2ND LAW OF MOTION

3.1 LINEAR MOMENTUM

Definition : Momentum of a particle may be defined as the quantity of motion possessed by it and it is measured by the product of mass of the particle and its velocity

Momentum is a vector quantity and it is represented by $\vec{p}$.

$\vec{p} = m\vec{v}$

Unit of momentum

(In C.G.S. system) → p = mv → gram × cm/s = dyne × s

(In M.K.S. system) → p = mv → kg × m/s = Newton × s

3.2 NEWTON'S SECOND LAW OF MOTION

According to the second law of motion, 'the rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts'.

Mathematically, the force, $F \propto \frac{\Delta p}{t}$

Where, Δp = change in momentum, t = time interval.

Mathematical formulation of second law of motion

Let an object of mass 'm' is moving along a straight line with an initial velocity 'u'. It is uniformly accelerated to velocity 'v' in time 't' by the application of a constant force F throughout the time t. The initial and final momentum of object will be, p_1 = mu and p_2 = mv, respectively.

The change in momentum, $\Delta p = p_2 - p_1 = mv - mu = m(v - u)$
The force F is proportional to the rate of change of momentum, that is,

$$F \propto \frac{\Delta p}{t} \text{ or } F \propto \frac{m(v-u)}{t}$$

or $F = k\frac{m(v-u)}{t}$ ....(1) where, k is a constant of proportionality.

Now, acceleration, $a = \frac{(v-u)}{t}$ ....(2)

From eq. (1) & eq. (2), we get, F = k m a ......(3)
The SI units of mass and acceleration are kg and m s^{-2} respectively. The unit of force is so chosen that the value of the constant 'k' becomes one.
That is, 1 unit of force = k × (1 kg) × (1 ms^{-2}) or k = 1
Thus, the value of k becomes 1. Therefore, the eq. (3) reduces to, F = ma

F = ma

Unit of force
SI unit : Newton(N)
Since, F = ma
or 1 N = 1 kg × 1 ms^{-2} = 1 kg m s^{-2}
$\therefore$ C. G. S. unit : Dyne
1 dyne = 1 g cm s^{-2}
1 N = 1000 g × 100 cm s^{-2} = 10^5 g cm s^{-2}, or 1 N = 10^5 dynes

3.3 IMPULSE OF FORCE

A large force acting for a short time to produce a finite change in momentum is called impulsive force.
The product of force and time is called impulse of force.
i.e. Impulse = Force × Time
or Impulse = $F\Delta t$
The S.I. unit of impulse is Newton-second (N-s) and the C.G.S. unit is dyne-second (dyne-s)

(a) Impulse and Momentum :
From Newton's second law of motion

Force, $F = \frac{p_2 - p_1}{\Delta t}$ or $F\Delta t = p_2 - p_1$

i.e., Impulse = Change in momentum
This relation is called impulse equation or momentum-impulse theorem. It has an important application in our everyday life.

(b) Impulse from force-time graph
The important points of force time graph is Area under Force-time graph gives impulse. Impulse gives change in momentum.

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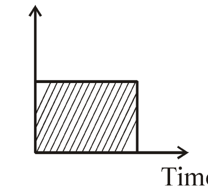


Figure : Impulse from force-time graph

3.4 APPLICATION OF IMPULSE

(i) Catching the ball by a cricketer : While catching a fast moving cricket ball, the player moves his hands backward after catching the ball. By moving his hands, the cricketer increases the time. As a result he has to apply a small force on the ball. In reaction, the ball also applies lesser force and the hands of the player are not injured.

Figure : Catching the ball by a cricketer

(ii) Jumping on a head of sand : If someone jumps from a height on a heap of sand then, his feet move inside the sand very slowly. His momentum changes slowly requiring a lesser force of action from the sand hand the man is not injured.

(iii) Jumping down of a passenger from a moving train or bus : A passenger sitting in a moving train or bus has momentum. When he jumps down and stands on platform or road, his momentum becomes zero. If he jumps down suddenly from the moving train or bus and tries to stand on his feet, his body will fall forward due to inertia of motion. He will be injured.

He is advised to run over some distance on the platform or road along with (in direction of) the train or bus. This will slow down his rate of change of momentum and lesser force will be involved.

(iv) Springs in vehicles : The vehicles are fitted with springs to reduce the hardness of the shocks. When vehicles move over an uneven road, they experience impulses exerted by the road. The springs increase the duration of impulse and hence reduce the force.

(v) Springs in seats : The seats are also fitted with springs to reduce their hardness. When we sit on them all of a sudden, the seat are compressed. The compression increases duration of our coming to rest on the seat. The reaction force of seat becomes negligible.

(vi) Soft material packing : China and glass wares are packed with soft material when transported. They collide during transportation but soft packing material slows down their rate of change of momentum. The force of impact is reduced and the items are not broken.

(vii) Athletes : Athletes are advised to come to stop slowly after finishing a fast race. In general, all changes of momentum must be brought slowly to involve lesser forces of action and reaction to avoid injury.

(viii) Impulse during an impact or collision : The impulsive force acting on the body produces a change in momentum of the body on which it acts. We know Impulse, $F\Delta t = mv - mu$, therefore the maximum force needed to produce a given impulse depends upon time. If time is short, the force required in a given impulse is large and vice-versa.

4. NEWTON'S 3RD LAW OF MOTION

The second law relates the external force on a body to its acceleration. What is the origin of the external force on the body ? What agency provides the external force ? The simple answer is that the external force on a body always arises due to some other body. When two object interact, two forces will always be involved. One force is the action force and the other is the reaction force that means force always exist in pairs.

According to Newton's third law, 'whenever one body exerts a force on a second body, the second body exerts an oppositely directed force of equal magnitude on the first body'.

In other words, '**to every action, there is always an equal and opposite reaction**'.

Demonstration :

(a) When a ball strikes a wall, the following happens :

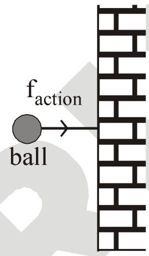


Figure : Newton's 3rd law of motion

F_{action} = action force = force exerted by the ball on the wall

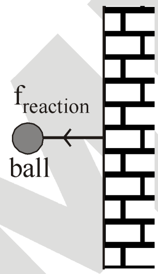


Figure : Newton's 3rd law of motion

$F_{reaction}$ = reaction force = force exerted by the wall on the ball due to reaction force, the ball bounces back.

(b) Two similar spring balances A and B joined by hook as shown in the figure. The other end of the spring balance B is attached to a hook rigidly fixed in a rigid wall.

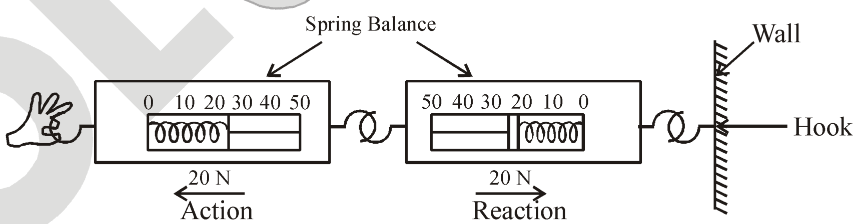


Figure : Demonstration-Newton's third law of motion

The other end of the spring balance A is pulled out to the left. Both balances show the same reading (20 N) for the force. The pulled balance A exerts a force of 20N on the balance B. It acts as action, B pulls the balance A in opposite direction with a force of 20N. This force is known as reaction.

We conclude that action-reaction forces are equal and opposite and act on two different bodies that means "**No Action is possible without Reaction**".

4.1 APPLICATION OF NEWTON'S THIRD LAW

(i) Swimming of a man : The man swims because he pushes water behind (action), water pushes mand forward (reaction).

(ii) Walking of a man : Man pushes the earth behind from right foot (action). Earth pushes the man forward (reaction). Then the man walks.

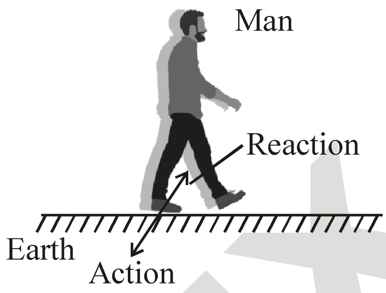


Figure : Walking man

(iii) Flight of jet or rocket : The burnt gases are exhausted from behind with high speed giving the gases backward momentum (action). The exhausted gases impart the jet or rocket a forward momentum (reaction). Then jet or rocket moves.

(vi) Gun and bullet : A loaded gun has a bullet inside it. When the gun's trigger is pressed, the powder inside cartage explodes. A force of action acts on the bullet and makes the light bullet come out of the barrel with a high velocity. The heavy gun moves behind (recoils) with a small velocity due to force of reaction. This is also an example of law of conservation of linear momentum.

(v) Man and boat : A man in a boat a river bank is at rest. To reach the bank, the man pushes the boat behind (action), the boat pushes the man forward (reaction). Then man lands to the bank.

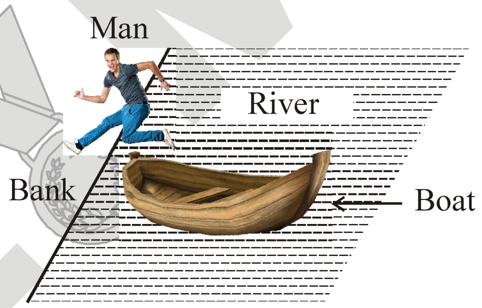


Figure : A man in boat

(vi) Hose pipe : Water rushes out of the hose pipe with a large velocity due to force of action of the compressor from behind. The rushing out jet of water pushes the hose pipe behind due to force of reaction. Then pipe has to be held tightly.

(vii) A nail cannot be fixed on a suspended wooden ball.

(viii) A paper cannot be cut by scissors of single blade.

(ix) A hanging piece of paper cannot be cut by blade.

(x) Writing on a hanging page is impossible.

(xi) Hitting on a piece of sponge does not produce reaction. You do not enjoy hitting.

5. LAW OF CONSERVATION OF LINEAR MOMENTUM

By Newton's second law, the rate of change of momentum is equal to the applied force.

$\frac{\text{Change in momentum}}{\text{time}}$ = Force   Change in momentum = F × t

If F = 0 then,

Change in momentum = 0

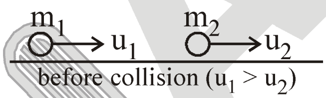
If the force applied on the body is zero then its momentum will be conserved, this law is also applicable on the system. If in a system the momentum of the objects present in the system are P_1, P_2, P_3............ and external force on the system is zero, then :

$P_1 + P_2 + P_3 + \ldots\ldots = \text{Constant}$

Note : If only internal forces are acting on the system then its linear momentum will be conserved.

5.1 LAW OF CONSERVATION OF LINEAR MOMENTUM BY THIRD LAW OF MOTION

Suppose A and B are two objects of masses m_1 and m_2 are moving in the same direction with velocity u_1 and u_2 respectively ($u_1 > u_2$). Object A collides with object B and after time t both move in their original direction with velocity v_1 and v_2 respectively.



The change in momentum of object A = $m_1v_1 - m_1u_1$

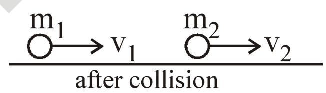
The force on B by A is $F_1 = \frac{\text{Change in momentum}}{\text{time}}$

$F_1 = \frac{m_1v_1 - m_1u_1}{t}$ ....(A)

The change in momentum of object B = $m_2v_2 - m_2u_2$

The force on A by B is

$F_2 = \frac{\text{Change in momentum}}{\text{time}}$



$F_2 = \frac{m_2v_2 - m_2u_2}{t}$ ....(B)

By Newtons third law, $F_1 = -F_2$

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

$= m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Initial momentum = Final momentum ($p_{initial} = p_{final}$)

5.2 APPLICATION ON CONSERVATION OF MOMENTUM

(i) Recoil of gun : A loaded gun (rifle) having bullet inside it forming one system is initially at rest. The system has zero initial momentum.

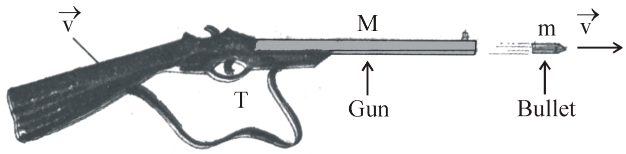


Figure : Recoil of Gun

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When the trigger (T) is pressed, the bullet is fired due to internal force of explosion of powder in cartage inside.

The bullet moves forward with a high velocity and the gun move behind (recoils) with a lesser velocity.

Let the bullet and the gun have masses m and M respectively. Let the bullet move forward with velocity v and the gun recoils with velocity V.

Then final momentum of the gun and bullet is MV + mv

By the law of conservation of momentum :

Initial momentum of the system = Final momentum of the system.

$0 = MV + mv$ or $V = -\frac{mv}{M}$

Hence the recoil velocity of gun = $\frac{mv}{M}$ and the velocity of the gun is = $-\frac{mv}{M}$

(ii) The working of a Rocket : The momentum of a rocket before it is fired is zero. When the rocket is fired, gases are produced. These gases come out of the rear of the rocket with high speed. The direction of the momentum of the gases coming out of the rocket is in the downward direction. Thus, to conserve the momentum of the system i.e. (rocket + gases), the rocket moves upward with a momentum equal to the momentum of the gases. So, the rocket continues to move upward as long as the gases are ejected out of the rocket. Thus a rocket works on the basis of the law of conservation of momentum.

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SOLVED EXAMPLES

SE. 1

A force of 10 N towards the east and an unknown force F balance each other. Find the unknown force.

Ans. If two forces balance each other, they have to be in the opposite directions and their magnitudes have to be equal Thus, F has a magnitude 10 N and acts towards the west.

SE. 2

A force produces an acceleration of 0.5 m/s^2 in a body of mass 3.0 kg. If t he same force acts on a body of mass 1.5 kg, what will be its acceleration?

Ans. The force is

F = ma = (3.0 kg) × (0.5 m/s^2) = 1.5 N.

The acceleration produced in the 1.5 kg body is

$$a = \frac{1.5\,N}{1.5\,kg} = 1.0\ m/s^2.$$

SE. 3

A force produces an acceleration of 5.0 cm/s^2 when it acts on a body of mass 20 g. Find the force in newtons.

Ans. The force is F = ma

$$= (20\ g) \times (5.0\ cm/s^2) = \left(\frac{20}{1000}kg\right)\times\left(\frac{5.0}{100}m/s^2\right)$$

$$= \frac{1}{1000}\ N = 1.0 \times 10^{-3}\ N.$$

SE. 4

A force produces an acceleration of 2.0 m/s^2 in a body A and 5.0 m/s^2 in another body B. Find the ratio of the mass of A to the mass of B.

Ans. Let the mass of the body A be m_A and that of the body B be m_B. We have to find m_A/m_B.

We have

$F = (m_A)\ (2.0\ m/s^2)$

and $F = (m_B)\ (5.0\ m/s^2)$.

Thus, $(m_A)\ (2.0\ m/s^2) = (m_B)\ (5.0\ m/s^2)$

or $\dfrac{m_A}{m_B} = \dfrac{5.0}{2.0} = 2.5.$

SE. 5

A force acts on a particle of mass 200 g. The velocity of the particle changes from 15 m/s to 25 m/s in 2.5 s. Assuming the force to be constant, find its magnitude.

Ans. The acceleration of the particle is

$$a = \frac{\upsilon - u}{t} = \frac{(25\,m/s) - (15\,m/s)}{2.5\,s}$$

$$= \frac{10}{2.5}\ m/s^2 = 4.0\ m/s^2.$$

The force is F = ma

$= (200\ g) \times (4.0\ m/s^2)$

$$= \left(\frac{200}{1000}kg\right) \times (4.0\ m/s^2) = 0.8\ N.$$

SE. 6

A bullet of mass 20 g moving with a speed of 120 m/s hits a thick muddy wall and penetrates into it. It takes 0.03 s to stop in the wall. Find (a) the acceleration of the bullet in the wall, (b) the force exerted by the wall on the bullet, (c) the force exerted by the bullet on the wall, and (d) the distance covered by the bullet in te wall.

Ans. (a) The velocity of the bullet as it hits the wall is u = 120 m/s. The velocity after 0.03 s is υ = 0. So, using $\upsilon = u + at$,

$0 = (120\ m/s) + a(0.03\ s)$

or $a = -\dfrac{120}{0.03}\ m/s^2 = -4000\ m/s^2.$

(b) The force exerted by the wall on the bullet is

F = ma

$= (20\ g)\ (-4000\ m/s^2)$

$$= \left(\frac{20}{1000}kg\right)(-4000\ m/s^2) = -80\ N.$$

The negative sign shows that the force by the wall on the bullet is in a direction opposite to that of the velocity.

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(c) From Newton's third law, the force exerted by the bullet on the wall is also 80 N, in direction of the velocity.

(d) The distance covered by the bullet in the wall is

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

$$= (120\ m/s)(0.03\ s) + \frac{1}{2}(-4000\ m/s^2)(0.0009\ s^2)$$

$$= 3.6\ m - 1.8\ m = 1.8\ m.$$

SE. 7

A particle of mass 0.5 kg is kept at rest. A force of 2.0 N acts on it for 5.0 s. Find the distance moved by the particle in (a) these 5.0 s, and (b) the next 5.0 s.

Ans. (a) The acceleration of the particle is

$$a = \frac{F}{m} = \frac{2.0\ N}{0.5\ kg} = 4.0\ m/s^2.$$

The distance moved by the particle in 5.0 s is

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

$$= 0 + \frac{1}{2} \times (4.0\ m/s^2) \times (5\ s)^2 = 50\ m.$$

(b) The velocity at the end of the first 5.0 s is

$\upsilon = u + at = 0 + (4.0\ m/s^2) \times (5.0\ s) = 20\ m/s.$

After this, the force is withdrawn, and hence, the particle moves with uniform velocity. The distance moved in the next 5.0 s is,

$s = ut = (20\ m/s) \times (5.0\ s) = 100\ m.$

SE. 8

A force of 6.0 N produces an acceleration of 2.0 m/s^2 when it acts on a body A, and 3.0 m/s^2 when it acts on another body B. If the bodies A and B are tied together and a force of 5.0 N is applied, what will be the acceleration ?

Ans. Suppose the mass of the body A is m_A and that of B is m_B. From the question,

$$6.0\ N = (m_A)(2.0\ m/s^2)$$

or $$m_A = \frac{6.0\ N}{2.0\ m/s^2} = 3.0\ kg.$$

Similarly, $6.0\ N = (m_B)(3.0\ m/s^2)$

or $m_B = 2.0$ kg.

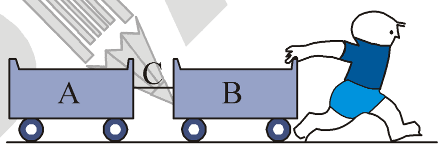
When the bodies are tied together, the combined mass is 3.0 kg + 2.0 kg = 5.0 kg.

When a force of 5.0 N acts on it, the acceleration is

$$a = \frac{5.0\ N}{5.0\ kg} = 1.0\ m/s^2.$$

SE. 9

Two carts A and B of mass 10 kg each are placed on a horizontal track. They are joined tightly by a light but strong rope C. A man holds the cart A and pulls it towards the right with a force of 70 N. The total force of friction by the track and the air on each cart is 15 N, acting towards the left. Find (a) the acceleration of the carts, and (b) the force exerted by the rope on the cart B.



Ans. (a) Consider the cart A, the cart B and rope C together as one body. The man exerts a force of 70 N towards the right on this combined body. The total force of friction is 30 N towards the left. So, the resultant force is (70 N – 30 N = 40 N) towards the right. Using Newton's second law, F = ma, we get

$$a = \frac{F}{m} = \frac{40\ N}{20\ kg} = 2\ m/s^2, \text{ towards the right.}$$

(b) Now, consider the cart B alone. It is also accelerating towards the right with an acceleration of 2 m/s^2. The rope C pulls the cart B towards the right with a force, say F_1. The force of friction on B is 15 N towards the left. So, the resultant force on it is F_1 – 15 N towards the right.

Using F = ma,

$$F_1 - 15\ N = (10\ kg)(2\ m/s^2) = 20\ N$$

or $F_1 = 35$ N.

Thus, the rope exerts a force of 35 N on the cart B.

SE. 10

A force of 12 N starts acting on a body kept at rest. Find the momentum of the body at 1 s, 2 s and 5s after the force starts acting.

Ans. We have $F = \frac{p_2 - p_1}{t_2 - t_1}$.

at t = 0, the momentum is $p_1 = 0$. So, at a time t, its value is given by

$$F = \frac{p_2 - p_1}{t - 0}$$

or $p_2 = p_1 + Ft = Ft$.

The momentum at t = 1 s is

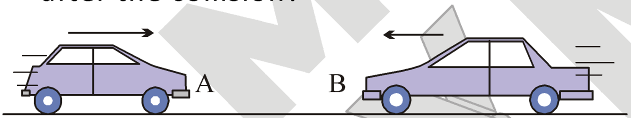
$p_2 = Ft = (12\ N) \times (1\ s) = 12\ N\ s$.

at t = 2 s, it is $p_2 = (12\ N) \times (2\ s) = 24\ N\ s$.

at t = 5 s, it is $p_2 = (12\ N) \times (5\ s) = 60\ N\ s$.

SE. 11

Two toy cars A and B are moving towards each other on a horizontal surface. The car A has mass of 60 g and moves towards the right with a speed of 60 cm/s. The car B has a mass of 100 g and moves towards the left with a speed of 20 cm/s. The two cars collide and get stuck to each other. With what velocity will they move after the collision?



Ans. Let us take the direction towards the right as the positive direction. The linear monentum of A before the collision is

$p_1 = m_1\upsilon_1 = (60\ g)\ (60\ cm/s) = 3600\ g\ cm/s$,

and that of B is

$p_2 = m_2\upsilon_2 = (100\ g)\ (-20\ cm/s) = -2000\ g\ cm/s$.

The total momentum of A and B before the collision is

$p_1 + p_2 = (3600 - 2000)\ g\ cm/s = 1600\ g\ cm/s$.

After the collision, the two cars get stuck to each other and move together. Let the velocity just after the collision be υ. The total momentum of A and B after the collision is $m_1\upsilon + m_2\upsilon = (60\ g)\ \upsilon + (100\ g)\ \upsilon = (160\ g)\ \upsilon$.

As the total linear momentum is the same before and after the collision,

$1600\ g\ cm/s = (160\ g)\upsilon$

or $\upsilon = 10\ cm/s$.

As υ comes out to be positive, the cars move together towards the right.

MATRIX OLYMPIAD

NS. 1

A hockey ball of mass 200g travelling at 10 ms^{-1} is struck by a hockey stick so as to return it along its original path with a velocity of 5 ms^{-1}. Calculate the change of momentum which occurred in the motion of the hockey ball by the force applied by the hockey stick.

Ans. Mass of ball, m = 200g = 0.2kg: initial velocity of ball, u_1 = 10 ms^{-1}; final velocity of ball, u_2 = –5 ms^{-1}.

(Negative sign denotes that ball is moving in opposite direction)

Initial momentum of ball = mu_1 = 0.2 × 10 = 2 Ns

Final momentum of ball = mu_2 = 0.2 × (–5) = –1 Ns

∴ Change in momentum =

Final momentum – initial momentum = (–1) – (2) = – 3 Ns

Negative sign denotes that change in momentum is in the direction opposite to the direction of initial momentum of the ball.

NS. 2

A bullet of mass 10 g travelling horizontally with a velocity of 150 ms^{-1} strikes a stationary wooden block and comes to rest in 0.03s. Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.

Ans. Mass of bullet, m = 10g = 0.01 kg; initial velocity of bullet, u = 150 ms^{-1}; final velocity of bullet, v = 0; time, t = 0.03s; acceleration of bullet, a = ?; force exerted by wooden block, F = ?; distance penetrated by bullet, s = ?

We know, $v = u + at$

or $0 = 150 + a \times 0.03$

or $-a \times 0.03 = 150$

or $a = \frac{-150}{0.03} = -5000\ ms^{-2}$

We know, $s = ut + \frac{1}{2}at^2$

$= 150 \times 0.03 + \frac{1}{2} \times (-5000) \times (0.03)^2$

$= 4.5 - 2.25 = 2.25$ m

We know, F = ma

Force acting on bullet,

F = 0.01 × (–5000) = – 50 N

Negative sign denotes that wooden block exerts force in a direction opposite to the direction of motion of the bullet.

NS. 3

An object of mass 1 kg travelling in a straight line with a velocity of 10 ms^{-1} collides with, and sticks to a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Ans. For object: m_1 = 1kg; u_1 = 10 ms^{-1}

For wooden block; m_2 = 5 kg; u_2 = 0

Momentum just before collision = $m_1u_1 + m_2u_2$ = 1 × 10 + 5 × 0 = 10 kg ms^{-1}

Since, momentum is conserved, momentum before collision = momentum after collision = 10 kg ms^{-1}

Mass after collision = $(m_1 + m_2)$ = 1 + 5 = 6 kg

Let velocity after collision = v

∴ Momentum after collision = 6 × v

Using the law of conservation of momentum, momentum after collision = momentum before collision

∴ $6 \times v = 10$ or $v = \frac{10}{6} = 1.67\ ms^{-1}$

NS. 4

An object of mass 100 kg is accelerated uniformly from a velocity of 5 ms^{-1} to 8 ms^{-1} in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Ans. Mass of object, m = 100 kg; initial velocity, u = 5 ms^{-1}; final velocity, v = 8 ms^{-1}; time, t = 6 s

Initial momentum = mu = 100 × 5 = 500 Ns

Final momentum mv = 100 × 8 = 800 Ns

Force exerted on the object

$F = \frac{mv - mu}{t} = \frac{800 - 500}{6} = \frac{300}{6} = 50$ N

NS. 5

Akhtar, Kiran and Rahul were riding in a motorcar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen, Akhtar and Kiran started pondering over the situation. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result the insect died. Rahul while putting an entirely new explanation said that both the motorcar and the insect experienced the same force and change in their momentum. Comment on these suggestions.

Ans. Kiran's suggestion is not correct because momentum is always conserved i.e. change in momentum of insect must be equal and opposite to that of motorcar.

Akhtar's suggestion is also not correct.

Rahul's suggestion is correct i.e., insect and motorcar experience same force and change in momentum.

However, the insect dies, because it is unable to bear the large force and large change in momentum.

NS. 6

How much momentum will a dumb-bell of mass 10 kg transfer to the floor if it falls from a height of 80 cm and does not rebound? Take its downward acceleration to be 10 ms^{-2}.

Ans. Mass of dumb-bell, m = 10kg; initial velocity, u = 0; final velocity, v = ?; distance, s = 80 cm = 0.8 m; acceleration, a = 10 ms^{-2}

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

$v^2 - (0)^2 = 2 \times 10 \times 0.8$

$v^2 = 16$

$v = \sqrt{16} = 4\ ms^{-1}$

$\therefore$ Momentum of dumb-bell transferred to ground = mv = 10 × 4 = 40 kg ms^{-1}.

NS. 7

The following is the distance-time table of an object in motion

Time	Distance
0	0
1	1
2	8
3	27
4	64
5	125
6	216
7	343

(a) What conclusion can you draw about the acceleration? Is it constant, increasing, decreasing or zero?

(b) What do you infer about the force acting on the object?

Ans. (a) A careful observation of the distance-time table shows that $s \propto t^3$.

It is known that, in uniform motion $s \propto t$, and for motion with uniform acceleration $s \propto t_2$.

In the present case, $s \propto t_3$. Therefore, we conclude in this case that acceleration must be increasing with time.

(b) As F = ma, therefore, $F \propto a$. Hence, the force must also be increasing with time.

NS. 8

Two persons manage to push a motorcar of mass 1200 kg at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of 0.2 ms^{-2}. With what force does each person push the motorcar?

(Assume that all persons push the motorcar with the same muscular effort.)

Ans. As two persons can make the motorcar move with uniform velocity, it is clear that total force applied by them on the motorcar is balanced by the force of friction acting in the opposite direction. It is force of one more person which produces an acceleration of 0.2 ms^{-2}.

$\therefore$ Force of one person = mass × acceleration =1200 × 0.2 = 240 N

NS. 9

A hammer of mass 500 g, moving at 50 ms^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

Ans. The force of nail on the hammer

$$F = \frac{\text{Change in momentum of hammer}}{\text{Time}}$$

$$F = \frac{m(v-u)}{t} = \frac{0.5(0-50)}{0.01} = -2500\ N$$

Negative sign denotes that the force of nail on the hammer is acting in the direction opposite to that of motion of hammer.

NS. 10

A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

Ans. (i) initial velocity of the car, u = 90 km/h

$$= 90\ km/h \times \frac{5}{18} = 25\ ms^{-1}$$

time, t = 4s; acceleration, a = ?

We know, $v = u + at$

$\Rightarrow 5 = 25 + a \times 4$

$\Rightarrow -a \times 4 = 20$

$\therefore\ a = \frac{-20}{4} = -5\ ms^{-2}$

(ii) Change in momentum, $\Delta p = m(v-u)$

$= 1200\ (5-25) = 1200 \times (-20) = -24000$ Ns

(iii) Magnitude of force

$$F = \frac{m(v-u)}{t} = \frac{-24000}{4} = -6000N$$

$\therefore\ F = -6000N$

NS. 11

A large truck and a car, both moving with a velocity of magnitude v, have a head-on collision. If the collision lasts for 1 s,

(a) Which vehicle experiences greater force of impact ?

(b) Which vehicle experiences greater change in momentum?

(c) Which vehicle experiences greater acceleration?

(d) Why is the car likely to suffer more damage than the truck?

Ans. Let mass of truck M; mass of car m; velocity of truck = v; time for which collision lasts, t = 1s; velocity of car = -v (Negative sign for opposite direction of motion).

(a) On collision, both the vehicles experience the same force, as action and reaction are equal.

(b) Change in momentum of truck is equal and opposite to change in momentum of car, i.e., both the vehicles experience the same change in momentum.

(c) As acceleration = force/mass, and force on each vehicle is same, therefore, acceleration $\propto \frac{1}{\text{mass}}$. As mass of car is smaller, therefore, acceleration of car is greater than the acceleration of the truck.

(d) The car is likely to suffer more damage than the truck, as it is lighter. The acceleration i.e. change in velocity/s of car is more than that of the truck.

MATRIX OLYMPIAD

EXERCISE – I

ONLY ONE CORRECT TYPE

1. A field gun of mass 1.5 tonne fires a shell of mass 15 kg with a velocity of 150 m s^{-1}. Calculate the velocity of the recoil of the gun :
(A) 1 m s^{-1} (B) 1.5 m s^{-1}
(C) 3 m s^{-1} (D) 5 m s^{-1}

2. One newton is equal to :
(A) 10^5 dyne (B) 10 kg m s^{-2}
(C) 10^3 dyne (D) 100 kg m s^{-2}

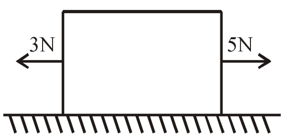
3. Which of the following situations involves a noncontact force ?
(A) Opening a drawer
(B) Kicking a ball
(C) Magnet pulling an iron piece
(D) Closing a door

4. Which of the following statements is not correct for an object moving along a straight path in an accelerated motion ?
(A) Its speed keeps changing
(B) Its velocity always changes
(C) It always goes away from the earth
(D) A force is always acting on it.

5. If a constant force acts on a body initially at rest, the distance moved by the body in time 't' is proportional to :
(A) $\frac{1}{t}$ (B) t
(C) t^2 (D) t^3

6. An object moving at constant velocity must
(A) have a net force on it
(B) eventually stop due to gravity
(C) not have any force of gravity on it
(D) have zero net force on it

7. The block shown moves with constant velocity on a horizontal surface. Two of the forces on it are shown. A frictional force exerted by the surface is the only other horizontal force on the block. The frictional force is :

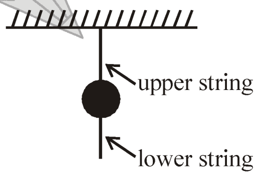


(A) 0
(B) 2N, leftward
(C) 2N, rightward
(D) slightly more than

8. The inertia of an object tends to cause the object :
(A) to increase its speed
(B) to decrease its speed
(C) to resist any change in its state of motion
(D) to decelerate due to friction

9. A water tanker filled up to (2/3)rd of its height is moving with a uniform speed. On sudden application of the brake, the water in the tank would :
(A) move backward (B) move forward
(C) be unaffected (D) rise upwards

10. A heavy ball is suspended as shown. A quick jerk on the lower string will break that string but a slow pull on the lower string will break the upper string. The first result occurs because :



(A) the force is too small to move the ball
(B) action and reaction is operating
(C) the ball has inertia
(D) air friction holds the ball back

11. A passenger sitting in a train with his face in the direction of the moving train, tosses a coin which falls behind him. It means that motion of the train is :
(A) accelerated (B) uniform
(C) retarded (D) along circular tracks

12. A body P has mass 2m and velocity 5v. Another body Q has mass 8m and velocity 1.25 v. The ratio of momentum of P qnd Q is :
(A) 2 : 1 (B) 1 : 1
(C) 1 : 2 (D) 3 : 2

13. Acceleration is always in the direction :
(A) of the displacement
(B) of the initial velocity
(C) of the final velocity
(D) of the net force

14. A goalkeeper in a game of football pulls his hands backwards after holding the ball shot at the goal. This enables the goalkeeper to :
(A) exert larger force on the ball
(B) reduce the force exerted by the ball on hands
(C) increase the rate of change of momentum
(D) decrease the change in momentum

15. Equal forces F act on isolated bodies A and B. The mass of B is three times that of A. The magnitude of the acceleration of A is :
(A) three times that of B
(B) 1/3 that of B
(C) the same as B
(D) nine times that of B

16. An unbalanced force acts on a body. The body :
(A) must remain at rest
(B) must move with uniform velocity
(C) must be accelerated
(D) must move along a circle

17. If a body is not accelerated :
(A) no force acts on it
(B) no unbalanced force acts on it
(C) the resultant force is not zero
(D) a single force acts on it

18. The force of friction between two bodies is :
(A) parallel to the contact surface
(B) perpendicular to the contact surface
(C) inclined at 30° to the contact surface
(D) inclined at 60° to the contact surface

19. Which of the following has the largest inertia ?
(A) A pin (B) An inkpot
(C) Your physics book (D) Your body

20. When a bus starts suddenly, the passengers standing on it lean backwards in the bus. This is an example of :
(A) Newton's first law
(B) Newton's second law
(C) Newton's third law
(D) None of Newton's laws

21. If a constant force acts on a body initially kept at rest, the distance moved by the body in time t is proportional to :
(A) t (B) t^2
(C) t^3 (D) t^4

22. The principle of conservation of linear momentum states that the linear momentum of a system :
(A) cannot be changed
(B) cannot remain constant
(C) can be changed only if internal forces act
(D) can be changed only if external forces act

23. Action-reaction forces :
(A) act on the same body
(B) act on different bodies
(C) act along different lines
(D) act in the same direction

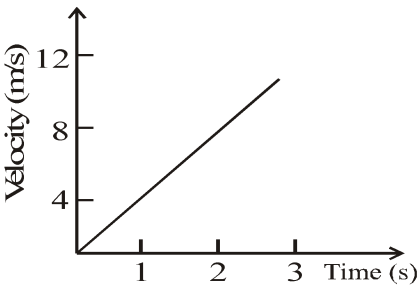
24. A block of mass 120 g moves with a speed of 6.0 m/s on frictionless horizontal surface towards another block of mass 180 g kept at rest. They collide and the first block stops. Find the speed of the other block after the collision.
(A) 2 m/s (B) 4 m/s
(C) 6 m/s (D) 8 m/s

25. A cart of mass 50 kg is moving on a straight track with a speed of 12 m/s. A mass of 10 kg is gently put into the cart. What will be the velocity of the cart after this ?
(A) 10 m/s (B) 20 m/s
(C) 30 m/s (D) 40 m/s

PARAGRAPH TYPE

PARAGRAPH # 1

Figure shows the velocity-time graph for a particle moving in a fixed direction.



26. Find the acceleration of the particle
(A) 2 m/s^2 (B) 4 m/s^2
(C) 6 m/s^2 (D) 8 m/s^2

27. If the mass of the particle is 200 g, what is the force acting on it ?
(A) 0.2 N (B) 0.4 N
(C) 0.6 N (D) 0.8 N

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28. Find displacement of particle at t = 2s.
(A) 4 m (B) 8 m
(C) 12 m (D) 2 m

PARAGRAPH # 2

Your physics book has a mass of 400 g. It is kept on a horizontal table. Taking $g = 10\ m/s^2$, find the force (both magnitude and direction) exerted by :

29. The table on the physics book
(A) 2 N upwards
(B) 2 N downwards
(C) 4 N upwards
(D) 4 N downwards

30. The physics book on the table
(A) 2 N upwards
(B) 2 N downwards
(C) 4 N upwards
(D) 4 N downwards

31. The earth on the physics book
(A) 2 N upwards
(B) 2 N downwards
(C) 4 N upwards
(D) 4 N downwards

MATCH THE COLUMN TYPE

32.

Column I	Column II
(a) Momentum	(p) $m\ s^{-2}$
(b) Impulse	(q) $kg\ m\ s^{-2}$
(c) Acceleration	(r) $kg\ m\ s^{-1}$
(d) Force	(s) newton

(A) a-p,b-q,c-r,d-s
(B) a-s,b-r,c-p,d-q
(C) a-r,b-q,c-p,d-s
(D) a-s,b-r,c-q,d-p

33.

Column I	Column II
(a) Dusting of a carpet	(p) Inertia of direction
(b) Vehicles are provided with mud guards	(q) Inertia of motion
(c) Fan continues to rotate after switching off	(r) Measure of inertia
(d) Mass	(s) Inertia of rest

(A) a-p,b-q,c-r,d-s
(B) a-s,b-r,c-p,d-q
(C) a-r,b-q,c-p,d-s
(D) a-s,b-p,c-q,d-r

Space for Notes :

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EXERCISE – II

VERY SHORT ANSWER TYPE

1. On what factor does inertia of a body depend ?

2. What do you mean by recoil velocity of a gun ?

3. Can you identify the action and reaction forces in the case of an object falling under gravity ? Neglect air resistance.

4. If a ball is moving on a frictionless horizontal surface and no forces are applied on it, will its speed decrease, increase or remain constant ?

5. The earth attracts an apple with a force of 1.5 N. Taking this as an action force, how much is the reaction force ? Who exerts this reaction force ? On which body does this reaction force act ?

6. A coin falls towards the earth because the earth attracts the coin. Does the coin also attract the earth ?

7. Can the internal forces acting among the parts of a system change the linear momentum of the system ?

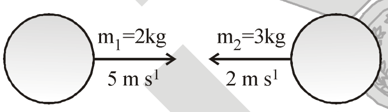
8. How much force is needed to produce an acceleration of 16 cm/s^2 in a body of mass 250 g ?

9. When a carpet is beaten with a stick, dust comes out of it. Explain

10. Why is it advised to tie any luggage kept on the roof of a bus with a rope ?

SHORT ANSWER TYPE

1. Two object m_1 and m_2 are moving in the straight line, approaching each other as shown. After collision these objects stick together. What will be the velocity of the combined object after collision?



2. A hourse continues to apply a force in order to move a horie cart with a constant speed. Explain why ?

3. Is it possible to move in a curved path in the absence of a force ?

4. Two balls of the same size but of different materials, rubber and iron, are kept on the smooth floor of a moving train. The brakes are applied suddenly to stop the train. Will the balls start rolling ? If so, in which direction ? Will they move with the same speed ? Give reason for your answer.

5. A truck of mass M is moved under a force F. If the truck is then loaded with an object a force F. If the truck is then loaded with an object of mass equal to the mass of the truck and the driving force is halved, then how does the acceleration change ?

LONG ANSWER TYPE

1. Define inertia. Explain the 3 kinds of inertia with examples.

2. Prove mathematically, the principal of conservation of linear momentum, using Newton's third law of motion. Two friends on roller-skates are standing 5m apart facing each other. One of them throws a ball of 2 kg towards the other, who catches it. How will this activity affect the position of the two ? Explain your answer.

3. What are the effects a set of forces can produce ?

4. When you pull your arms back while catching a fast-moving cricket ball, the chances of hurting your hand are low. Explain this on the basis of Newton's laws.

5. State Newton's three laws of motion. Give one example each to explain the first and the third laws.

TRUE / FALSE TYPE

1. If there are many forces acting on an object, it must have a non-zero net (unbalanced) force acting on it.

2. If the net external force on a body is zero, its acceleration may not be zero.

3. If the acceleration of an object is zero, it must be at rest.

4. It's possible to have motion in the absence of a force

5. If the net force acting on an object is in the positive x-direction, the object moves only in the positive x-direction.

FILL IN THE BLANKS

1. The gravitational force is a .... force

2. If no net force acts on an object, then the .... of the object remains unchanged.

3. When a boy tries to push a heavy box placed on a rough surface, the box does not move because of an opposing force called ....

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4. If the net force on an object is zero, then the object is in ....
5. Linear momentum is always in the direction of ....

NUMERICAL PROBLEMS

1. A loaded transport truck with a mass of 38000 kg is travelling at 1.20 m/s. What wil be the velocity of a 1400 kg car if it has the same momentum ?
2. Reena is riding a motorised scooter along a straight path. The combined mass of Reena and her scooter is 80 kg. The frictional forces that are acting total to 45 N. What is the magnitude of the driving force being provided by the motor if (a) she is moving with a constant speed of 10 $m\ s^{-1}$?
   (b) she is accelerating at 1.5 $m\ s^{-2}$?
3. A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 $m\ s^{-1}$. How long does the body take to stop ?
4. A constant force acting on a body of mass 3.0 kg changes its speed from 2.0 $m\ s^{-1}$ to 3.5 $m\ s^{-1}$ in 25 s. The direction of motion of the body remains unchanged. What is the magnitude and direction of the force ?
5. The driver of a three-wheeler moving with a speed of 36 km/h sees a child standing in the middle of the road and brings his vehicle to rest in 4.0 s just in time to save the cild. What is the average retarding force on the vehicle ? The mass of the three-wheeler is 400 kg and the mass of the driver is 65 kg.

Space for Notes :

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Answer Key

EXERCISE–I														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	A	C	C	C	D	B	C	B	C	A	B	D	B	A
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C	B	A	D	A	B	D	B	B	A	B	D	B	C	D
31	32	33												
D	C	D												

EXERCISE – II

VERY SHORT ANSWER TYPE

5. 1.5N 8. 0.04N

TRUE / FALSE

1. F 2 F 3. F 4. T 5. F

FILL IN THE BLANKS

1. Non contact force 2. Velocity 3. Friction 4. Equilibrium

5. Velocity

NUMERICAL PROBLEMS

1. 32.57 m/s 2. (a) 45 N (b) 165 N 3. 6s

4. 0.18N, direction of force is in the direction of motion of the body

5. –1162.5 N

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SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : FORCE AND ACCELERATION)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

NOTES :

1. In the status, put "completed" only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.

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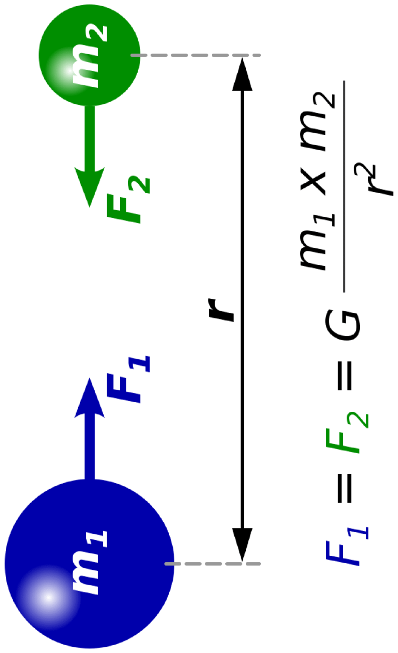
Space for Notes :

GRAVITATION 3

Concepts



INTRODUCTION

Gravitation is the weakest force in nature. It is negligible in the interactions of tiny particles, and thus plays no role in molecules, atoms and nuclei. The gravitational attraction between objects of ordinary size, such as the gravitational force exerted by a building on a car, is too small to be noticed. When we consider very large objects, such as stars, planets, and satellites (moons), gravitation is of primary importance. The gravitational force exerted by the Earth on us and on the objects around us is a fundamental part of our experience. It is gravitation that binds us to the Earth and keeps the Earth and the other planets on course within the solar system. The gravitational force plays an important role in the life history of stars and in the behaviour of galaxies.

1. NEWTON'S UNIVERSAL LAW OF GRAVITATION

The magnitude and the direction of the gravitational force between two particles are given by the universal law of gravitation, which was formulated by Newton.

Universal Law of Gravitation :

The force of attraction between any two particles is directly proportional to the product of the masses of the particles and is inversely proportional to the square of the distance between them.

Mathematical Expression :

The universal law of gravitation states that the magnitude of the force of attraction between the bodies is :

(i) directly proportion to the product of their masses.

(ii) Inversely proportional to the square of the distance between them.

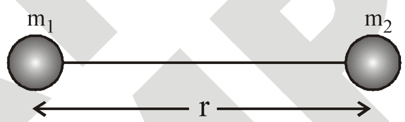


Figure : Law of gravitation

According to law of gravitation

$F \propto m_1 m_2$ ....(i)

$F \propto \frac{1}{r^2}$ ....(ii)

combining (i) and (ii)

$F \propto \frac{m_1 m_2}{r^2} \Rightarrow F = \frac{G m_1 m_2}{r^2}$

where m_1 & m_2 are masses of two bodies and r is the distance between their centres.

When G is proportionality constant and is known as the universal gravitational constant.

Universal Gravitational Constant

(i) Definition :

In relation, $F = \frac{G m_1 m_2}{r^2}$

If $m_1 = m_2 = 1$, r = 1, then F = G. Hence, universal gravitational constant may be defined as the force of attraction between two bodies of unit masses separated by unit distance apart.

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(ii) Unit of G :

$$F = \frac{Gm_1m_2}{r^2}$$

We have, $G = \frac{Fr^2}{m_1m_2}$

In S.I. unit $G \Rightarrow \frac{Nm^2}{kg\,kg} = Nm^2kg^{-2}$

In C.G.S. unit $G \Rightarrow \frac{dyne\,cm^2}{g.g.} = dyne\,cm^2g^{-2}$

(iii) Value of G :

In S.I. unit $G = 6.67\times10^{-11}$ Nm^2 kg^{-2}

In C.G.S. unit $G = 6.67\times10^{-8}$ dyne cm^{2}g^{-2}

1.1 CHARACTERISTICS OF GRAVITATION FORCE

(i) Gravitational force between two bodies from an action and reaction pair i.e. the forces are equal in magnitude but opposite in direction.

(ii) Gravitational force is a central force i.e., it acts along the line joining the centres of the two interacting bodies.

(iii) Gravitational force between two bodies is independent of the nature of the intervening medium.

(iv) Gravitational force between two bodies does not depend upon the presence of other bodies.

(v) Gravitational force is negligible in case of light bodies but becomes appreciable in case of massive bodies like stars and planets.

(vi) Gravitational force is a long range force i.e. gravitational force between two bodies is effective even if their distance of separation is very large. For example, gravitational force between the sun and the earth is of the order of 10^{22} N, although distance between them is 1.5×10^8 km.

(vii) Gravitational force is a conservative force.

(viii) Distance are always measured from the centre of the bodies.

(ix) The gravitational force is always an attractive force

1.2 EXPERIMENTAL SUPPORT FOR LAW OF GRAVITATION

Newton's universal law of gravitation succesfully explained several phenomena which were believed to be unconnected :

(i) The force that binds us to the Earth.

(ii) The motion of the Moon around the Earth.

(iii) The motion of planet around the Sun.

(iv) The tides due to the Moon and ths Sun.

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Focus Point

Why Moon does not fall on Earth directly ?

The motion of Moon is just like the motion of an object in circular motion. The velocity of the Moon is directed tangential to the circle at every point along its path. The acceleration of Moon is directed towards the center of the circle i.e., towards the Earth (the central body) around which it is orbiting. This acceleration is caused by a centripetal force which is supplied by the gravitational force between the Earth and the Moon.If this force was absent, the Moon would continue in motion at the same speed in a direction tangential to the circular path and would have escaped away from the Earth.

If the Moon had no tangential velocity, it would have fallen on Earth due to gravitation. Thus, it is the tangential velocity and the gravitational force that are perpendicular to each other, and cause the Moon to fall around the Earth without actually falling onto it (see figure)

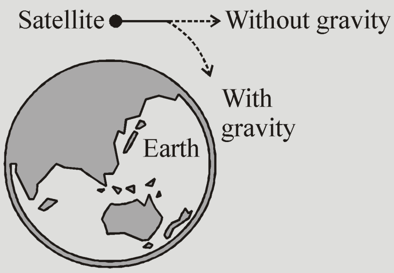

Figure : Building concepts

Focus Point

Which figure best represents the gravitational force acting on you and on Earth. (See figure). Explain ?

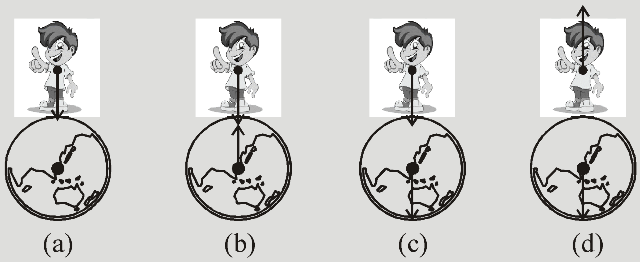

Figure : Building Concepts

Explanation :

The gravitational force exist in action-reaction pair. The force on you should be towards the centre of Earth (or vertically downward). The force on earth will be opposite to that acting on you i.e., it should be away from the centre of Earth (vertically upwards). Thus, figure (b) best represents the gravitational force acting on you and on Earth.

2. GRAVITATIONAL FORCE BETWEEN CELESTIAL OBJECTS

(i) Between Sun and Earth :

Mass of earth, $m_1 = 6\times10^{24}$ kg

Mass of the sun, $m_2 = 2\times10^{30}$ kg

Distance between the sun and the earth,

$r = 1.5\times10^{11}$ m

Gravitational force between the sun and the earth,

$$F = \frac{Gm_1m_2}{r^2}$$

$$F = \frac{6.67\times10^{-11}\,Nm^2kg^{-2}\times6\times10^{24}\,kg\times2\times10^{30}\,kg}{(1.5\times10^{11}\,m)^2} \Rightarrow F = 3.6\times10^{22}\text{ N}$$

The gravitational force between the sun and the earth is very large (i.e. 3.6×10^{22}N). This force keeps the earth bound to the sun.

(ii) Between Moon and Earth :

Mass of the earth, $m_1 = 6\times10^{24}$ kg

Mass of the moon, $m_2 = 7.4\times10^{22}$ kg

Distance between the earth and the moon, $r = 3.8\times10^{8}$ m

$\therefore$ Gravitational force between the earth and the moon,

$$F = \frac{Gm_1m_2}{r^2}$$

$$F = \frac{6.67\times10^{-11}\,Nm^2kg^{-2}\times6\times10^{24}\,kg\times7.4\times10^{22}\,kg}{(3.8\times10^{8}\,m)^2} \Rightarrow F = 2.05\times10^{20}\text{ N}$$

This large gravitational force keeps the moon to move around the earth. This large gravitational force is also responsible for the ocean tides.

3. FORCE OF GRAVITATION OF EARTH (GRAVITY)

Free fall is the motion of an object under the influence of gravity only. An object is in free fall as soon as it is dropped from rest, thrown downward or thrown upward.

Acceleration due to gravity : The constant acceleration of a freely falling body is called the acceleration due to gravity. The acceleration due to gravity is the acceleration of an object in free fall that results from the influence of Earth's gravity. Its magnitude is denoted with the letter 'g'.

3.1 ACCELERATION DUE TO GRAVITY AT THE SURFACE OF EARTH

Let us consider an object of mass m placed on the surface of Earth (see figure) Let the mass of Earth be M and radius of Earth be R. The gravitational force on the object due to Earth is given by F_g. The gravitational force on the object due to Earth is given by,

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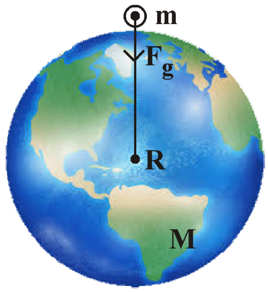

Figure : Acceleration due to gravity on earth surface

$F_g = \frac{GMm}{R^2}$ ....(1)

Let this force produces an acceleration 'a' in the object, then,

F_g = ma.......(2)

From eq. (1) and eq. (2), we get

$ma = \frac{GMm}{R^2}$ or $a = \frac{GM}{R^2}$

This acceleration is called acceleration due to gravity and it is denoted by g i.e., a = g

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

Calculating the value of g on Earth

Mass of the Earth = 6×10^{24} kg ; radius of Earth = 6.4×10^6 m ; G = 6.673×10^{-11} N m^2 kg^{-2}

Now, $g = \frac{GM}{R^2} = \frac{(6.67\times10^{-11})(6\times10^{24})}{(6.4\times10^6)^2}$ = 9.8 ms^{-2}

The acceleration due to gravity g for any planet is (i) directly proportional to the mass of the planet (ii) inversely proportional to the square of the radius of the planet.

Calculating the value of g on Moon

Mass of the Moon = $\frac{M_{Earth}}{100}$ and radius of Moon = $\frac{R_{Earth}}{4}$

Now, $g_{Moon} = \frac{GM_{Moon}}{R^2_{Moon}} = \frac{GM_{Earth}}{R^2_{Earth}} \times \frac{16}{100} \approx \frac{g}{6}$

3.2 VARIATION OF VALUE OF g

(i) Variation of 'g' with Altitude : The value of 'g' decreases with height from the surface of the earth.

(ii) Variation of 'g' with depth : The value of 'g' decreases with depth from the surface of the earth. The value of 'g' is zero at the centre of the earth.

(iii) Variation of 'g' with Latitude : The value of 'g' is depend on the shape of the Earth. It is more at the poles and less at the equator.

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3.3 DIFFERENCE BETWEEN 'g' AND 'G'

Difference between 'g' and 'G'

S.No.	Acceleration due to gravity (g)	Universal gravitational constant (G)
1	The acceleration produced in a body falling freely under the action of gravitational pull of the earth is known as acceleration due to gravity.	The gravitational force between two bodies of unit masses separated by a unit distance is known as universal gravitational constant.
2	The value of 'g' is different at different points on the earth	The value of 'G' is same at every point on the earth
3	The value of 'g' decreases as we go higher from the surface of the earth or as we go deep into the earth.	The value of 'G' does not change with height and depth from the surface of the earth.
4	The value of 'g' at the centre of the earth is zero.	The value of 'G' is not zero at the centre of the earth or anywhere else.
5	The value of 'g' is different on the surfaces of different heavenly bodies like the sun, moon, the planets.	The value of 'G' is same throughout the universe.
6	The value of 'g' on the surface of the earth is 9.8 ms^{-2}.	The value of G = 6.673 × 10^{-1}1 Nm^2 kg^2 throughout the universe.

4. KEPLER'S LAW OF PLANETARY MOTION

Kepler's law of planetary motion. These are :

(i) The law of orbits : All planet move in elliptical orbits with the sun at one focus.

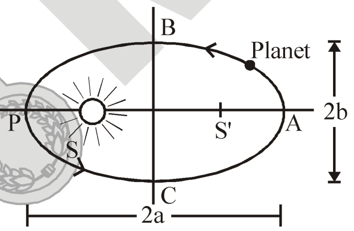

Figure : Kepler's law of orbits

(ii) The law of areal velocity : A line that connects a planet to the sun sweeps out equal areas in equal time i.e., the areal velocity of the planet is always constant.

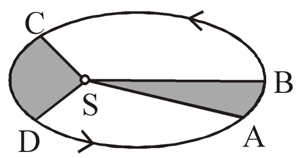

Figure : Kepler's law of areal velocity

(iii) The law of periods : The square of the period of revolution of any planet is proportional to the cube of the semi-major axis of the orbit, i.e. $T^2 \propto r^3$.

Newton showed that these empirical laws followed from his law of gravitation. These laws are found to hold equally well for satellites either natural or artificial orbiting around a planet. [Earth or any other massive central body]

5. MASS AND WEIGHT

Mass

The amount of matter contained in a body is called its mass.

Mass of a body is constant at all places in the universe. It is measured by physical balance. It is a scalar quantity and it is always taken positive.

Unit of mass

SI unit : Kilogram (kg)

CGS unit : Gram (g)

Weight

The gravitational force exerted by the Earth on an object is called is weight. This force is directed towards the centre of the Earth. It is denoted by letter W.

The force with which an object is attracted towards the centre of Earth's called its weight. It is measured by a weighing machine or spring balance.

Weight, W = mg

Where, m = mass of object ; g = acceleration due to gravity

Unit of weight

SI unit : Newton (N)

CGS unit : Dyne

5.1 DIFFERENCE BETWEEN MASS AND WEIGHT

S.No	Mass	Weight
1	Mass is quantity of matter possessed by a body	Weight is the force with which a body is attracted towards the centre of the earth.
2	It is a scalar quantity.	It is a vector quantity
3	The S.I. unit is kilogram (kg).	Its S.I. unit is newton (N).
4	Mass of body remains constant at all places	Weight of the body changes from place to place.
5	Mass of a body is never zero.	Weight of a body becomes zero at the centre of the earth
6	Mass is measured by a beam balance	Weight is measured by a spring balance.

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5.2 VARIATION IN THE WEIGHT OF BODY

Weight of the body is given by,

W = mg

So the weight of a body depends upon (i) the mass of the body and (ii) value of acceleration due to gravity (g) a place. The mass of a body remains the same throughout the universe, but as the value of 'g' is different at different places. Hence, the weight of a body is different at different places.

5.3 WEIGHTLESSNESS

Introduction : When a man stands on weighing machine at rest, his weight compresses its spring down-loads. Due to upward reaction, the machine records the weight of the man. But when the same machine starts falling down freely, there is no reaction so the machine records zero weight. The man falling freely under the action of gravity has become weightless.

Weightlessness of an Astronaut in a Satellite (Space Ship) : A satellite is a freely falling body orbiting round the earth. It tries to reach the earth but its path being parallel to earth's surface. It does not reach the earth. Hence the satellite and all the bodies inside it become weightless. It is due to this situation of weightlessness of astronauts that they are shown floating in spaceship in films on television.

Weightlessness in Satellite : The body feels its weight due to the reaction force and is acted upon by other bodies kept in its contact. If the force of reaction acting on the body becomes zero the weight of the body is not experienced. This is called the state of weightlessness.

A man in a satellite is in a state of weightlessness, because the total gravitational force acting on the satellite acts as the centripetal force necessary to revolves the satellite, so that the force of reaction on each body is zero and the body is in weightlessness.

6. WEIGHT OF AN OBJECT ON MOON

We know that the weight of an object on the Earth is the force with which the earth attracts the object. Similarly, the weight of an object on the Moon is the force with which the Moon attracts that object.

Let us mass of the Moon be M_m and its radius be R_m.

By Newton's universal law of gravitation, the weight of the object on the Moon will be,

$$W_m = \frac{GM_m m}{R_m^2} \quad ......(1)$$

Let weight of the same object on the Earth be W_e. Let the mass of the Earth be M_e and its radius be R_e. Thus, the weight of the object on the Earth will be,

$$W_e = \frac{GM_e m}{R_e^2} \quad ......(2)$$

$$\frac{(1)}{(2)} \Rightarrow \frac{W_m}{W_e} = \frac{\frac{GM_m m}{R_m^2}}{\frac{GM_e m}{R_e^2}} = \frac{M_m R_e^2}{M_e R_m^2} \quad ......(3)$$

Now, mass of Earth is approximately 100 times the mass of Moon and radius of earth is nearly 4 times the radius of Moon i.e.,

$M_e = 100\ M_m$; $R_e^2 = 16R_m^2$ ......(4)

Using (3) and (4), we get

$$\frac{W_m}{W_e} = \frac{M_m(4R_m)^2}{100M_mR_m^2} = \frac{M_m 16R_m^2}{100M_mR_m^2} = \frac{16}{100} \approx \frac{1}{6}$$

or $\frac{W_m}{W_e} = \frac{1}{6}$

i.e., weight of the object on the Moon = (1/6) × its weight on the Earth

Now, $W_m = mg_m$ and $W_e = mg_e$, where g_m and g_e are accelerations due to gravity of Moon and Earth respectively.

$$\therefore \frac{W_m}{W_e} = \frac{mg_m}{mg_e} = \frac{1}{6}$$

or $\frac{g_m}{g_e} = \frac{1}{6}$

7. EQUATIONS OF MOTION OF FREELY FALLING BODY

There are two main assumptions in free fall :

(i) Acceleration due to gravity (g) is constant throughout the motion and it acts vertically downwards.

(ii) Air resistance is negligible.

Newton's equation of motion under gravity

(i) $v = u + gt$

(ii) $s = ut + \frac{1}{2}gt^2$

(iii) $v^2 = u^2 + 2gs$

Sign Conventions of Equations of Motion Under Gravity :

(i) g is taken as positive when it is acting in the same direction as that of motion and g is taken as negative when it is opposing the motion.

(ii) Distance measured upward from the point of projection is taken as positive, while distance measured downward from the point of projection is taken as negative.

(iii) Velocity measured away from the surface of earth (i.e. in upward direction) is taken as positive, while velocity measured towards the surface of the earth is taken as negative.

CASE I : An object thrown vertically upward and it returns after some time. Let us consider an object (figure) thrown vertically upward with an initial velocity u; the acceleration due to gravity g is acting vertically downward on it. Let after a time interval 't', it achieves a height h and final velocity v.

Initial velocity = +u; acceleration, a = –g; distance travelled, s = +h

From first equation of motion, we have, $v = u + at$

or $v = (+u) + (-g)t$ or $v = u - gt$ ......(i)

From second equation of motion, we have, $s = ut + \frac{1}{2}at^2$

or $+h = (+u)t + \frac{1}{2}(-g)t^2$ or $h = ut - \frac{1}{2}gt^2$ ......(ii)

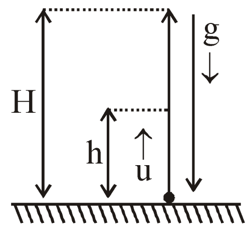

Figure : An object thrown vertically upward from ground

From third equation of motion, we have, $v^2 = u^2 + 2as$

or $v^2 = (+u)^2 + 2(-g)(+h)$ or $v^2 = u^2 - 2gh$ ......(iii)

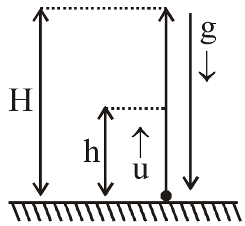

Figure : An object thrown vertically upward from ground

(a) Time taken to reach maximum height

At maximum height, v = 0

From eq. (i), we get, $0 = u - gt$

or $u = gt$ or $t = \frac{u}{g}$

(b) Total time of journey

Since g is constant throughout the motion, time taken to reach maximum height from the ground is equal to time taken to reach ground from the maximum height. That is total time (T) of journey.

$T = 2t = \frac{2u}{g}$ or $T = \frac{2u}{g}$

(c) Maximum height achieved by the object

Let the maximum height achieved be H.

At maximum height, v = 0

From eq. (iii), we get, $(0)^2 = u^2 - 2g(H)$ or $u^2 = 2gH$ or $H = \frac{u^2}{2g}$

(d) Total distance covered :

Here, the total distance covered, $s = 2H = 2\left(\frac{u^2}{2g}\right) = \frac{u^2}{g}$ = while, the total displacement is zero.

CASE II : An object is thrown vertically downward from a certain height H. Let us consider an object as shown in figure thrown vertically downward with an initial velocity u; the acceleration due to gravity g is acting vertically downward on it. Let after a time interval t, it falls through a distance y and achieves a final velocity v.

Initial velocity = –u ; acceleration, a = –g ; displacement ; s = –y ; final velocity = –v

From first equation of motion, we have, $v = u + at$

or $(-v) = (-u) + (-g)t$ or $-v = -u - gt$

or $-v = -(u + gt)$ or $v = u + gt$ .....(i)

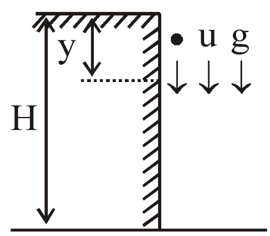

Figure : An object thrown vertically downward from a certain height H

From second equation of motion, we have, $s = ut + \frac{1}{2}at^2$

or $-y = (-u)t + \frac{1}{2}(-g)t^2$ or $-y = -ut - \frac{1}{2}gt^2$

or $-y = -\left(ut + \frac{1}{2}gt^2\right)$ or $y = ut + \frac{1}{2}gt^2$ .....(ii)

From third equation of motion, we have, $v^2 = u^2 + 2as$

or $(-v)^2 = (-u)^2 + 2(-g)(-y)$ or $v^2 = u^2 + 2gy$ ....(iii)

⇒ For numericals, we can assume acceleration due to gravity as +g for downward, while –g for upward motion.

⇒ If an object is dropped from certain height, its initial velocity is taken zero i.e., u = 0. In such case, the equs. (i), (ii), (iii) will be reduced to,

$v = gt$; $y = \frac{1}{2}gt^2$; $v^2 = 2gy$

Example 1

A body falls freely from rest. Find (a) the distance it falls in 3 seconds (b) its speed after falling 20m (c) the time required to reach a speed of 16 m/s (d) time taken to fall 125 m. Take g = 10 m/s^2.

Solution :

Given, Initial velocity, u = 0 ; g = 10 m/s^2

(a) Distance travelled s = ? ; time t = 3 s

Now, $s = ut + \frac{1}{2}gt^2$

or $s = (0)t + \frac{1}{2}(10)(3)^2$ or $s = 45$ m

(b) Speed, v = ? ; s = 20 m

Now, $v^2 = u^2 + 2gs = (0)^2 + 2(10)(20) = 400$

or $v = \sqrt{400}$ or $v = 20$ m/s

(c) Time = ? ; v = 16 m/s

Now, $v = u + gt$

or $16 = 0 + (10)t$ or $t = \frac{16}{10}$ or $t = 1.6$ s

(d) Time = ? ; distance travelled s = 125 m

Now, $s = ut + \frac{1}{2}gt^2$

or $125 = (0)t + \frac{1}{2}(10)t^2$ or $125 = 5t^2$

or $t^2 = 25$ or $t = \sqrt{25}$ or $t = 5$s

Note : To solve numerical problems :

(i) If a body is dropped from a height then its initial velocity u = 0 but has acceleration (acting). If a body starts from rest its initial velocity u = 0.

(ii) If a body comes to rest, its final velocity v = 0 or, if a body reaches the highest point after being thrown upwards its final velocity v = 0 but has acceleration (acting)

(iii) If a body moves with uniform velocity, its acceleration is zero i.e. a = 0

(iv) Motion of a body is called free fall if only force acting on it is gravity (i.e. earth’s attraction).

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SE. 1

Calculate the force of gravitation due to a child of mass 30 kg on his fat mother of mass 80 kg if the distance between their centres is 1 m from each other.

Given G = 20/3 × 10^{-11} $Nm^2\ kg^{-2}$

Ans. Here m_1 = 30 kg ; m_2 = 80 kg ; d = 1 m ;

$$G = \frac{20}{3}\times10^{-11}\ Nm^2\ kg^2$$

Using $F = \frac{Gm_1m_2}{d^2}$

or $F = \frac{20\times10^{-11}\times80\times30}{3\times(1)^2}$

or F = 16,000 × 10^{-11}

or F = 1.6 × 10^{-7} N

SE. 2

Communication satellites move in the orbits of radius 44000 km around the earth. Find the acceleration of such a satellite, assuming that the only force acting on it is that due to the earth. Mass of the earth = 6×10^{24} kg.

Ans. The force on the satellite due to the earth is

$$F = \frac{GM_eM_{sat}}{d^2}$$

where d = 44,400 km is the distance of the satellite from the earth's centre.

Acceleration $a = \frac{F}{M_{sat}}$ = (Using (i))

$$= \frac{6.67\times10^{-11}\times6\times10^{24}}{\left(44400\times10^3\right)^2}\ m\ s^{-2} \approx 0.2\ m\ s^{-2}$$

SE. 3

A body of mass 1 kg is placed at a distance of 2m from another body of mass 10 kg. At what distance from the body of 1 kg, another body of mass 5kg be placed so that the net force of gravitation acting on the body of mass 1 kg is zero ?

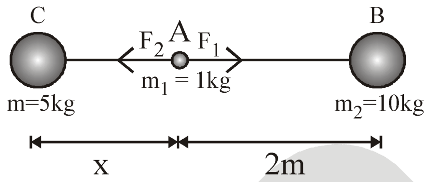
Ans. Here, mass of body A, m_1 = 1kg

mass of body B, m_2 = 10 kg

distance between bodies A and B, r_1 = 2m

mass of another body C, m = 5 kg

Let distance of body C from body A be AC=r_2=x,



As net force of gravitation acting on the body A of mass 1 kg is zero ?

∴ force of attraction of B on A = force of attraction of C on A,

i.e., $F_1 = F_2$

or $\frac{Gm_1m_2}{r_1^2} = \frac{Gm_1m}{r_2^2}$ or $\frac{m_2}{r_1^2} = \frac{m}{r_2^2}$

i.e., $\frac{10}{(2)^2} = \frac{5}{x^2}$ or $x^2 = \frac{5\times2^2}{10} = 2$

or $x = \sqrt{2}m$

SE. 4

A stone is dropped from the edge of the roof.

(a) How long does it take to fall 4.9 m ?

(b) How fast does it move at the end of the fall ?

(c) How fast does it move at the end of 7.9 m ?

(d) What is its acceleration after 1s and after 2s ?

Ans. (a) As the stone is dropped, its initial velocity, u = 0, h = 4.9 m

a = g = 9.8 m s^{-2}, time t = ?

From h = ut + $\frac{1}{2}$$gt^2$,

4.9 = 0 + $\frac{1}{2}$ × 9.8t^2 = 4.9t^2 or $t^2 = \frac{4.9}{4.9} = 1$,

t = $\sqrt{1} = 1s$

(b) Final velocity, v = ? at t = 1s

From v = u + gt, v = 0+9.8×1 = 9.8 m s^{-1}

(c) Let v be final velocity when h = 7.9 m

From $v^2 - u^2 = 2gh$, $v^2 - 0$ = 2 (9.8) 7.9

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or v = $\sqrt{2\times9.8\times7.9}$ = $\sqrt{154.84}$ = 12.4 m s^{-1}

(d) The acceleration of a freely falling body remains the same at all times, i.e.,

a = g = 9.8 m s^{-2}, after 1s and after 2s

SE. 5

A particle is thrown up vertically with a velocity of 50 m/s. (a) What will be its velocity at the highest point of its journey? (b) How high would the particle rise? (c) What time would it take to reach the highest point. (g = 10 ms^{-2})

Ans. (a) At the highest point the velocity will be zero.

(b) Using $v^2 - u^2 = 2as$

$\Rightarrow 0^2 - (50)^2 = 2(-10) \times s$

$\Rightarrow s = \frac{50\times50}{2\times10}$ = 125 m

(c) Considering activity

A to B

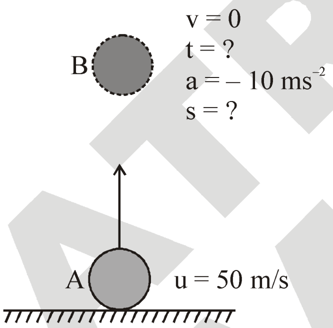
Using v = u + at

$\Rightarrow$ 0 = 50 – 10 × t

$\Rightarrow$ 10t = 50

$\Rightarrow t = \frac{50}{10}$ = 5 s

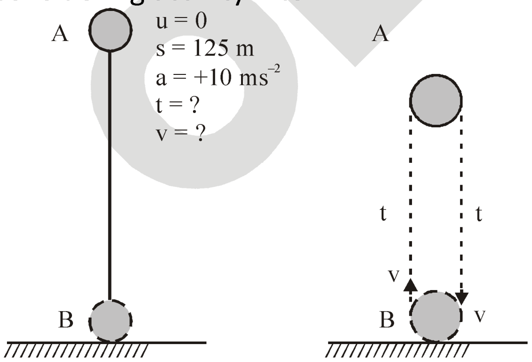
$\therefore$ t = 5 s



SE. 6

With reference to the above sample problem, (a) Find the time the particle takes from the highest point back to the initial point (b) Find the velocity with which the particle reaches the initial point. (g = 10 ms^{-2})

Ans. The data is given in the adjacent figure. Considering activity B to A



(a) Using $v^2 - u^2 = 2as$

$\Rightarrow v^2 - 0^2 = 5(10)(125)$

v = 50 m/s

(b) Also v = u + at

$\Rightarrow$ 50 = 0 + 10 (t)

$\therefore$ t = 5 s

SE. 7

The gravitational force between two objects is F. How will this force change when

(i) distance between them is reduced to half ?

(ii) the mass of each object is quadrupled ?

Ans. (i) According to Newton's law of gravitation, gravitational force F between two objects distance r apart is

$F \propto \frac{1}{r^2}$

When distance between them is reduced to half,

i.e., r' = r/2, the force, $F' \propto \frac{1}{r'^2}$

Thus,

$\frac{F'}{F} = \frac{r^2}{r'^2} = \frac{r^2}{(r/2)^2} = 4$ or F' = 4F

i.e., force becomes 4 times its previous value.

(ii) Again, according to Newton's law of gravitation, the gravitational force F between two'objects of masses m_1 and m_2 is

$F \propto m_1m_2$

When mass of each object is quadrupled,

$m'_1 = 4m_1$

and $m'_2 = 4m_2$

The force, $F' \propto m'_1m'_2$

Thus,

$\frac{F'}{F} = \frac{m'_1m'_2}{m_1m_2} = \frac{(4m_1)(4m_2)}{m_1m_2} = 16$

$\therefore$ F' = 16 F

i.e., force becomes 16 times its previous value.

SE. 8

A ball is dropped from the edge of a roof. It takes 0.1 s to cross a window of height 2.0 m. Find the height of the roof above the top of the window.

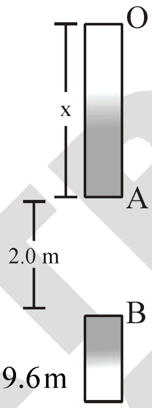
Ans. Let AB be the window, and suppose the roof is at a height x above A. Also,
suppose it takes a time t_1 for the ball to reach A. The velocity of the ball at A is
$v_1 = 0 + gt_1 = (9.8\ m/s^2)t_1$.
Now, consider the motion of the ball from A to B. Here the initial velocity is v_1, the distance covered is 2m, and the time taken is 0.1 s.

We have, $s = ut + \frac{1}{2}gt^2$

$$\Rightarrow 2.0\ m = v_1\ (0.1\ s) + \frac{1}{2} \times (9.8\ m/s^2) \times (0.1\ s)^2$$

$$= (9.8\ m/s^2)t_1\ (0.1\ s) + 0.049\ m$$

$$\Rightarrow 2.0\ m - 0.049\ m = \left(0.98\frac{m}{s}\right)t_1$$



$$\Rightarrow t_1 = \frac{1.951m}{0.98m/s} \approx 2s$$

$\therefore t_1 = 2s$

The height x is

$$x = \frac{1}{2}gt_1^2 = \frac{1}{2}\times(9.8m/s^2)\times(2s)^2 = 19.6m$$

$\therefore x = 19.6m$

The roof is at a height 19.6 m above the top of the window.

SE. 9

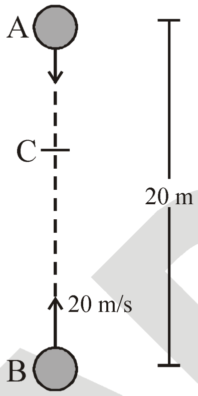
A ball is dropped from a height of 20 m. At the same instant another ball is thrown up from the ground with a speed of 20 m/s. When and where will the balls meet ?

Ans. Suppose the first ball is dropped from the point A and the second is thrown up from the point B as shown in figure. Suppose the balls meet at C at time t.

The ball A starts from rest. So,

$$AC = \frac{1}{2}gt^2 \qquad .....(i)$$

At B, the ball is thrown up with a speed of 20 m/s. The displacement in time t is



$$BC = (20\ m/s)\,t - \frac{1}{2}gt^2 \qquad .....(ii)$$

Adding (i) and (ii),

$AC + BC = (20\ m/s)t$

$\Rightarrow 20m = (20\ m/s)t$

$$\Rightarrow t = \frac{20m}{20m/s} = 1s$$

$\therefore t = 1s$

So, the balls meet at t = 1s after they start moving.

NS. 1

State the universal law of gravitation

Ans. According to universal law of gravitation, every particle in the universe attracts every other particle with a force which is directly proprotional to the product of their masses and inversely proportional to the square of distance between them. The direction of the force is along the line joining the two particles.

NS. 2

What do you mean by free fall ?

Ans. All objects falling towards earth under the action of gravitational force of earth alone are said to be in free fall.

NS. 3

What do you mean by acceleration due to gravity ?

Ans. The acceleration with which an object fall freely towards the earth is known as acceleration due to gravity. It is denoted by g and its value is 9.8 ms^{-2}.

NS. 4

What are the differences between the mass of an object and its weight ?

Ans.

Mass	Weight
Mass of body is the the measure of its inertia.	Weight of the body is force with which it is attracted towards the earth (W = mg).
Its S.I. unit is kg.	Its S.I. unit is newton.
It remains constant the everywhere.	Its value changes from place to place.
It can be measured by common balance.	It is measured by spring balance.

NS. 5

Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.

Ans. The formula for the magnitude of gravitational force between the earth and an object on its surface is

$$F = G\frac{M_e m}{R_e^2}$$

where F is the gravitational force.

G is the gravitational constant.

M_e is the mass of the earth

m is the mass of the object on the surface of the earth.

R_e is the radius of the earth.

NS. 6

Why is the weight of an object on the moon $\frac{1}{6}$th its weight on the earth ?

Ans. The weight of an object depends on the value of acceleration due to gravity g. The value of g on earth is 6 times more than that on the moon because, the mass and radius of the earth is more than the mass and radius of the moon.

We have, $g = \frac{GM}{R^2}$ and W = mg

Weight of a body of mass m on earth is

$$W_e = mg_e = m \times \frac{GM_e}{R_e^2}$$

$$\therefore \; We = \frac{GmM_e}{R_e^2}$$

Weight of a body of mass m on moon is

$$W_m = mg_m = m \times \frac{GM_m}{R_m^2}$$

$$\therefore \; W_m = \frac{GmM_m}{R_m^2}$$

$$\text{Now, } \frac{W_m}{W_e} = \frac{\frac{GmM_m}{R_m^2}}{\frac{GmMe}{R_e^2}} = \frac{M_m}{M_e} \times \frac{R_e^2}{R_m^2}$$

$$\therefore \; \frac{W_m}{W_e} = \frac{1}{6}$$

As mass of moon M_m is $\frac{1}{100}$ times the mass of earth M_e and radius of moon R_m is $\frac{1}{4}$ times the radius of earth R_e.

$$\frac{W_m}{W_e}=\frac{M_m}{M_e}\left(\frac{R_e}{R_m}\right)^2=\frac{1}{100}\times(4)^2=\frac{1}{6}$$

$$\therefore\ \frac{W_m}{W_e}=\frac{1}{6}$$

NS. 7

How does the force of gravitation between two objects change when the distance between them is reduced to half ?

Ans. Force of gravitation,

$$F\propto\frac{1}{R^2}$$

If R is reduced to $\frac{R}{2}$

$$F\propto\frac{1}{\left(\frac{R}{2}\right)^2}\ \text{i.e.,}\ F\propto\frac{4}{R^2}$$

The force of gravitation becomes 4 times.

NS. 8

Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object ?

Ans. Gravitational force acts on all objects in proportion to their masses. But a heavy object does not fall faster than a light object. This is because of the reason that

Acceleration = $\frac{\text{Force}}{\text{Mass}}$ and Force $\propto$ mass

Force = Acceleration × mass

or Acceleration = Constant

NS. 9

What is the magnitude of the gravitational force between the earth and a 1kg object on its surface ? (Mass of the earth is 6×10^{24} kg and radius of the earth is 6.4×10^{6} m)

Ans. The gravitational force between the earth and 1kg body on its surface is given by

$$F=\frac{GM_eM_{body}}{R_e^2}=\frac{6.67\times10^{-11}\times6\times10^{24}\times1}{(6.4\times10^6)^2}$$

This gives, F = 9.8 N

NS. 10

The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth ? Why ?

Ans. The earth attracts the moon with a force equal to the force with which the moon attracts the earth. This is because as per Newton's third law of motion, forces of action and reaction are always equal and opposite.

NS. 11

If the moon attracts the earth, why does the earth not move towards the moon ?

Ans. Both the earth and the moon attract each other with the same force. But according to Newton's second law of motion, accleration produced in a body by any force is inversely proportional to the mass of the body. Since, mass of the earth is much more than that of the moon, the acceleration produced in the earth is negligible. As a result, it appears as if the earth does not move towards the moon.

NS. 12

What happens to the force between two objects, if

(i) the mass of one object is doubled ?

(ii) the distance btween the object is doubled and tripled

(iii) the masses of both the objects are doubled ?

Ans. From the relationship,

$$F=\frac{Gm_1m_2}{R^2}$$

(i) If the mass of one object (say body 1) is doubled, then

$$F'=\frac{G\times(2m_1)m_2}{R}=\frac{2\times Gm_1m_2}{R^2}=2F$$

Thus, the gravitational force between the two object gets doubled.

(ii) If the distance between the two objects becomes doubled.

$$F'' = \frac{Gm_1m_2}{(2R)^2} = \frac{1}{4} \times \frac{Gm_1m_2}{R^2} = \frac{1}{4} \times F = \frac{F}{4}$$

Thus, the gravitational force between the two objects becomes one-fourth.

If the distance between the two objects is tripled, then

$$F''' = \frac{Gm_1m_2}{(3R)^2} = \frac{1}{9} \times \frac{Gm_1m_2}{R^2} = \frac{1}{9} \times F = \frac{F}{9}$$

Thus, the gravitational force between the two objects becomes one- ninth.

(iii) If the masses of both the objects are doubled, then

$$F''' = \frac{G \times (2m_1) \times (2m_2)}{R^2} = \frac{4Gm_1m_2}{R^2} = 4F$$

Thus, the gravitational force between the two objects becomes 4 times.

NS. 13

What is the importance of universal law of gravitation ?

Ans. Universal law of gravitation is important as it accounts,

(a) For the existence of the solar system, i.e., motion of planets around the sun.

(b) for holding the atmosphere near the surface of the earth.

(c) for exitence of life on the earth.

(d) for rainfall and snowfall.

(e) for occurrence of tides.

NS. 14

What is the acceleration of free fall ?

Ans. All objects moving towards earth on account of gravitational force of earth on them are said to be in free fall. This force produces a uniform acceleration in the object. This is acceleration of free fall and its value is 9.8 m s^{-2}.

NS. 15

What do we call the gravitational force between the earth and an object ?

Ans. The gravitational force between the earth and an object is called the force of gravity or simply earth's gravity.

NS. 16

Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought ? If not, why ?

[Hint : The value of g is greater at the poles than at the equator]

Ans. We know that the value of g is greater at the poles than at the equator. So the weight of gold at the equator will be less than the weight of gold at the poles. So it is obvious that the friend at equator will not agree with the weight of gold bought at poles.

NS. 17

Gravitational force on the surface of the moon is only $\frac{1}{6}$ as gravitational force on the earth. What is the weight in newtons of a 10 kg object on the moon and on the earth ?

Ans. Here, m = 10 kg

Mass is the same on earth and moon

Now, weight of the object on earth

$W_e = mg_e = 10 \times 9.8 = 98N$

Weight of the object on moon,

$$W_m = mg_m = \frac{10 \times 9.8}{6} = 16.3N$$

$\therefore W_m = 16.3N$

NS. 18

A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate :

(i) the maximum height to which it rises,

(ii) the total time it takes to return to the surface of the earth

Ans. Initial velocity, u = 49 m/s

Acceleration, a = g = 9.8 m/s^2

Velocity at the highest point, v = 0 m/s

(i) If h is the maximum height reached by the ball, then

$\because 2gs = v^2 - u^2$

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or $s = \frac{v^2 - u^2}{2g} = \frac{(0\,m/s)^2 - (49\,m/s)^2}{2 \times (-9.8\,m/s^2)}$

$= \frac{-49 \times 49 m^2/s^2}{-2 \times 9.8 m/s^2} = 122.5$ m

$\therefore$ s = 122.5 m

Thus, the ball will reach a height of 122.5 m.

(ii) We have, v = u + gt

Here, 0 = 49 – 9.8t

$\Rightarrow$ 9.8t = 49

$\Rightarrow t = \frac{49}{9.8} = 5s$

$\therefore$ t = 5s

Total time = 2t = 2×5s = 10s

So, total time it takes to return in the surface of the earth in 10 sec.

NS. 19

A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.

Ans. Initial velocity, u = 0 m s^{-1}

Final velocity, v = ?

Height of the tower, h = 19.6 m

Acceleration due to gravity, g = 9.8 m s^{-2}

Using the equation, $v^2 - u^2 = 2gs = 2gh$

$v^2 - 0 = 2 \times 9.8\ ms^{-2} \times 19.6$ m

$v^2 = 19.6\ ms^{-2} \times 19.6$ m

$v^2 = (19.6)^2\ m^2\ s^{-2}$

or v = 19.6 m s^{-1}

NS. 20

A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking g = 10 m/s^2, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone ?

Ans. Here, u = 40 m/s,

g = –10 m/s^2, h = ?, v = 0

From $v^2 - u^2 = 2gh$,

$0 - (40)^2 = 2(-10)h$

or $h = \frac{40 \times 40}{20} = 80m$

As final position of the stone coincides with its initial position, net displacement = 0

Total distance covered by the stone

= h + h = 80 m + 80 m = 160 m

NS. 21

Calculate the force of gravitation between the earth and the sun, given that the mass of the earth = 6×10^{24} kg and of the sun = 2×10^{30} kg. The distance between two is 1.5×10^{11} m.

Ans. Mass of the earth, $M_e = 6\times10^{24}$ kg

Mass of the sun, $M_s = 2\times10^{30}$ kg

Distance between the earth and the sun,

R = 1.5×10^{11} m

Then, the gravitation force between the earth and the sun is given by,

$$F = G\frac{M_e \times M_s}{R^2}$$

$$F = \frac{6.67\times10^{-11}\,N\,m^2kg^{-2} \times (6\times10^{24}kg) \times (2\times10^{30}kg)}{(1.5\times10^{11}m)^2}$$

= 3.56×10^{22} N

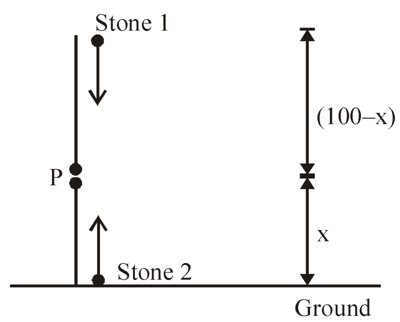
Thus, the earth and the sun attract each other by a gravitational force of 3.56×10^{22} N.

NS. 22

A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.

Ans. Here, h = 100 m

Let the two stones meet after t seconds at a point P which is at a height x above the ground as shown in figure.



For stone 1,
u = 0, h = (100 – x) m,
a = g = 9.8 m/s^2

From s = ut + $\frac{1}{2}$gt^2

$\Rightarrow$ (100 – x) = 0 + $\frac{1}{2}\times 9.8t^2 = 4.9t^2$ ....(i)

For stone 2
u = 25 m/s, h = x, a = g = –9.8 m/s^2

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

$\Rightarrow x = 25t + \frac{1}{2}(-9.8)t^2$

x = 25t – 4.9t^2 .....(ii)

Adding equations (i) and (ii)
100 – x + x = 25t

$\Rightarrow$ t = $\frac{100}{25} = 4s$ .....(iii)

From equation (i),
100 – x = 4.9 × (4)^2 = 78.4
$\Rightarrow$ x = 100 – 78.4 = 21.6 m
$\therefore$ x = 21.6 m

NS. 23

A ball thrown up vertically returns to the thrower after 6 s. Find
(a) the velocity with which it was thrown up,
(b) the maximum height it reaches, and
(c) its position after 4 s.

Ans. Here, time of ascent = time of descent,

$t = \frac{6}{2} = 3s$

(a) u = ?, v = 0, a = –g = –9.8 m/s^2
From v = u + gt,
0 = u – 9.8 × 3 $\Rightarrow$ u = 29.4 m/s
(b) From v^2 – u^2 = 2gs,
0 – (29.4)^2 = 2(–9.8)h

$\Rightarrow$ h = $\frac{29.4\times 29.4}{2\times 9.8} = 44.1$ m

$\therefore$ h = 44.1 m

(c) t = 3s, ball is maximum height.

From, s = ut + $\frac{1}{2}$gt^2,

h = 0 + $\frac{1}{2}\times 9.8(1)^2 = 4.9$

$\therefore$ h = 4.9m (below the top)
So, the position of ball after 4sec will be below the top.

EXERCISE – I

ONLY ONE CORRECT TYPE

1. The universal constant of gravitation G has the unit
(A) N (B) m/s
(C) $(N\ m^2)/kg^2$ (D) J

2. The equation $F = \frac{Gm_1m_2}{r^2}$ is valid for
(A) rectangular bodies
(B) circular bodies
(C) eliptical bodies
(D) spherical bodies

3. The force acting on a ball due to the earth has a magnitude F_b and that acting on the earth due to the ball has a magnitude F_e. Then :
(A) $F_b = F_e$ (B) $F_b > F_e$
(C) $F_b < F_e$ (D) $F_e = 0$

4. A coin and a feather are dropped together in a vacuum.
(A) The coin will reach the ground first.
(B) The feather will reach the ground first.
(C) Both the bodies will reach the ground together.
(D) The feather will not fall down.

5. Law of gravitation gives the gravitational force between
(A) The earth and a point mass only
(B) The earth and sun only
(C) Any two bodies having some mass
(D) Two charged bodies only

6. In the realtion $F = G\ M\ m/r^2$, the quantity G
(A) depends on the value of g at the place of observation
(B) is used only when the earth is one of the two masses
(C) is greatest at the surface of the earth
(D) is universal constant of nature

7. The gravitational force between two objecs is F. If masses of both objects are halved without changing distance between them, then the gravitational force would become :
(A) F/4 (B) F/2
(C) F (D) 2F

8. An apple falls from a tree because of gravitational attraction between the earth and apple. If F_1 is the magnitude of force exerted by the earth on the apple and F_2 is the magnitude of force exerted by apple on earth, then :
(A) F_1 is very much greater than F_2
(B) F_2 is very much greater than F_1
(C) F_1 is only a little greater than F_2
(D) F_1 and F_2 are equal

9. A boy is whirling a stone tied with a string in a horizontal circular path. If the string breaks, the stone
(A) will continue to move in the circular path
(B) will move along a straight line towards the centre of the circular path
(C) will move along a straight line tangential to the circular path
(D) will move along a straight line perpendicular to the circular path away from the boy

10. If 'g' is the acceleration due to gravity on earth, what is the acceleration due to gravity on another planet having mass and radius twice that of earth ?
(A) $\frac{g}{2}$ (B) 2g
(C) $\frac{g}{4}$ (D) 4g

11. Two objects of different masses falling freely from the same height near the surface of moon would
(A) have same velocities at any instant
(B) have different accelerations
(C) experience forces of same magnitude
(D) undergo a change in their inertia

12. If a rock is brought from the surface of the moon,
(A) Its mass will change
(B) Its weight will change but not mass
(C) Both mass and weight will change
(D) Its mass and weight both will remain same

13. The value of acceleration due to gravity :
(A) Is same on equator and poles
(B) Is least on poles
(C) Is least on equator
(D) Increase from pole to equator

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14. An object is thrown vertically upwards with a velocity *u*, the greatest height *h* to which it will rise before falling back is given by :
(A) u / g (B) $u^2 / 2g$
(C) u^2 / g (D) $u / 2g$

15. The mass of moon is about 0.012 times that of earth and its diameter is about 0.25 times that of earth. The value of G on the moon will be :
(A) Less than the on the earth
(B) More than that on the earth
(C) Same as that on the earth
(D) About one-sixth of that on the earth

16. The value of g on the surface of the moon :
(A) Is the same as on the earth
(B) Is less than that on the earth
(C) Is more than that on the earth
(D) Keeps changing day by day

17. The force of attraction between two unit point masses saparated by a unit distance is called :
(A) Gravitational potential
(B) Acceleration due to gravity
(C) Gravitational field strength
(D) Universal gravitational constant

18. The weight of an object at the centre of the earth of radius R is :
(A) Zero
(B) R times the weight at the surface of the earth
(C) Infinite
(D) $1 / R^2$ times the weight at the surface of the earth

19. Two objects of different masses falling freely near the surface of moon would :
(A) Have same velocities at any instant
(B) Have different accelerations
(C) Experience forces of same magnitude
(D) Undergo a change in their inertia

20. The law of gravitation gives the gravitational force between :
(A) The earth and a point mass only
(B) The earth and sun only
(C) Any two bodies having some mass
(D) Any two charged bodies only

21. The value of quantity G in the formula for gravitational force :
(A) Depends on mass of the earth only
(B) Depends on the radius of earth only
(C) Depends on both mass and radius of earth
(D) Depends neither on mass nor on radius of earth

22. Two particles are placed at some distance from each other. If, keeping the distance between them unchanged, the mass of each of the two particles is doubled, the value of gravitational force between them will become.
(A) 1 / 4 times (B) 1 / 2 times
(C) 4 times (D) 2 times

23. The gravitational force of attraction between two objects is x. Keeping the masses of the objects unchanged, if the distance between the objects is halved, then the magnitude of gravitational force between them will become :
(A) x / 4 (B) x / 2
(C) 2x (D) 4x

24. According to one of the Kepler's laws of planetary motion :
(A) $r^2 \propto T^3$ (B) $r \propto T^2$
(C) $r^3 \propto T^2$ (D) $r^3 \propto \frac{1}{T^2}$

25. If mass of a body is M on the earth surface, then the mass of the same body on the moon surface is.
(A) M / 6 (B) Zero
(C) M (D) None of these

PARAGRAPH TYPE

PARAGRAPH # 1

In the solar system, planets move in almost circular orbits around the sun ; and satellites move in circular orbits around the planets. A force (called centripetal force) is needed to make an object move in a circular orbit (or circular path). In the case of plantes moving around the sun, the centripetal force is provided by the gravitional force of the sun. And in the case of satellites moving around the plantes, the centripetal force is provided by the gravitional force of the planets.

MATRIX OLYMPIAD

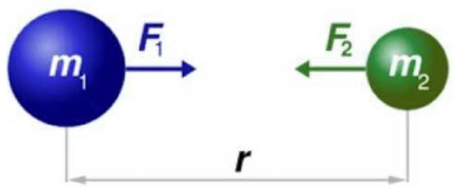
26. In the solar system, planets move around the.
(A) Earth (B) Sun
(C) Moon (D) Mercury

27. A force needed to make an object in a circular path is called.
(A) Friction force (B) Electric force
(C) Centripital force (D) None of these

28. In cash of planets moving around the sun, the centripital force is provided by
(A) Gravitational force (B) Tension force
(C) Friction force (D) None of these

PARAGRAPH # 2

The universal law of gravitation was given by Newton. So, it is also known as Newton's law of gravitation. According to universal law of gravitation : Every body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. The direction of force is along the line joining the centres of the two bodies.



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

29. The universal law of gravitation was given by
(A) Kepler (B) Newton
(C) Einstein (D) Faraday

30. The universal law of gravitation is applicable for
(A) Charged body
(B) Uncharged body
(C) Every body
(D) None of these

31. Grivatational force is
(A) May be attrative
(B) May be repulsive
(C) Always attractive
(D) Always repulsive

MATCH THE COLUMN TYPE

32.

Column I	Column II
(a) A body falling feely	(p) Centripetal acceleration
(b) A satellite moving round the earth in a circular path	(q) Ellipse
(c) Path of a planet around the sun	(r) Does not depend on mass of individual objects
(d) Acceleration due to gravity on earth	(s) Uniformly accelerated motion

(A) a-s, b-p, c-q, d-r
(B) a-p, b-s, c-q, d-r
(C) a-s, b-r, c-q, d-p
(D) a-s, b-q, c-p, d-r

33.

Column I	Column II
(a) Mass	(p) Attraction by earth
(b) Weight	(q) Scalar
(c) Gravity	(r) Kepler's third law
(d) $r^3 \propto T^2$	(s) Vector

(A) a-q, b-s, c-p, d-r
(B) a-p, b-s, c-q, d-r
(C) a-q, b-p, c-s, d-r
(D) a-s, b-p, c-p, d-r

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EXERCISE – II

VERY SHORT ANSWER TYPE

1. Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than light object.
2. You know that the earth attracts you in the vertically downward direction. Do you attract the earth as well ? If yes, in which direction ?
3. Write the units of G and g.
4. A coin and a feather are dropped from the roof of a building. Which will fall to the ground first ?
5. State Kepler's third law of planetary motion.
6. State Universal law of gravitation.
7. The gravitational force between two objects on the earth is 2 N. What will be the gravitational force between these two objects on the surface of the moon ?
8. Name the force which is responsible for the revolution of planet around the sun.
9. Is acceleration due to gravity on the surface of moon less or more than the acceleration due to gravity on the surface of earth ?
10. The weight of a body on the earth is 60 N. What is the mass of the body on the moon ?

SHORT ANSWER TYPE

1. What happens to the force between two objects, if
   (a) the mass of one object is doubled ?
   (b) the distance between the objects is doubled and tripled ?
   (c) the masses of both objects are doubled ?
2. Give the difference between g and G.
3. Calculate the average density of the earth in terms of g, G and R.
4. How does the weight of an object vary with respect to mass and radius of the earth ? In a hypothetical case, if the diameter of the earth becomes half of its present value and its mass becomes four times of its present value, then how would the weight of any object on the surface of the earth be affected ?
5. The weight of any person on the moon is about 1/6 times that on the earth. He can lift a mass of 15 kg on the earth. What will be the maximum mass which can be lifted by the same force applied by the person on the moon ?

LONG ANSWER TYPE

1. Shubham buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought ? If not, why ?
2. If each object in the universe attracts every other object, why don't two books kept on a table come towards each other and collide ?
3. State Newton's law of gravitation. Write a mathematical expression for it. Write its importance.
4. Explain Kepler's laws of planetary motion.
5. What is acceleration due to gravity ? Find an expression for it. How does 'g' change with altitude ?

TRUE / FALSE TYPE

1. The force of gravitation exerted by the earth on a ball is Gm_1m_2 / r^2, where r is the distance of the ball from the earth's surface.
2. Due to gravitational forces, all bodies in the universe attract each other.
3. The value of G on the moon is about one-sixth of its value on the earth.
4. Mass and weight are measured in different units.
5. The value of G depends upon the mass of the two objects.

FILL IN THE BLANKS

1. The force of gravitation exerted on one body by the other is F. If the mass of each body is doubled, the force will become ....
2. If the earth shrinks, thus descreasing its radius, the value of g at its surface will ....
3. The value of Gravitational constant is .... Nm^2/kg^2.
4. If the distance between two bodies is doubled them the force of gravitation acting between them becomes .... times of its initial value.
5. .... of a body changes from place to place but its .... remains constant.

MATRIX OLYMPIAD

NUMERICAL PROBLEMS

1. A stone is thrown upward with an initial velocity of 40 m/s. Taking $g = 10\ m/s^2$, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone ?

2. A ball is thrown vertically upwards with a velocity of 20 ms^{-1} from the top of a multistorey building. The height of the point where the ball is thrown 25 m from the ground ? Take, $g = 10\ ms^{-2}$.

3. A boy on a cliff 49 m high drops a stone. One second later, he throws a second stone after the first. They both hit the ground at the same time. With what speed did he throw the second stone ?
($\sqrt{10}$ =3.162)

4. A man weighs 600 N on the earth. What is his mass ? If he was taken to the moon, his weight would be 100 N. What is his mass on the moon ? What is the acceleration due to gravity on the moon ?
(Take g on earth = 10 m/s^2)

5. A ball thrown up vertically returns after 6s. Find
(a) the velocity with which it was thrown up.
(b) the maximum height it reaches, and
(c) its position after 4 s.

Space for Notes :

MATRIX OLYMPIAD

Answer Key

EXERCISE–I														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C	D	A	C	C	D	A	D	C	A	A	B	C	B	C
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B	D	A	A	C	D	C	D	C	C	B	C	A	B	C
31	32	33												
C	A	A												

EXERCISE – II

VERY SHORT ANSWER TYPE

7. 2N 10. 6kg

TRUE / FALSE

1. F 2. T 3. F 4. T 5. F

FILL IN THE BLANKS

1. 4F 2. Increase 3. 6.67×10^{-11}

4. One fourth 5. Weight, mass

NUMERICAL PROBLEMS

1. H_{max} = 80m, Displacement = 0 and Distance = 160 m
2. t = 5s
3. 12.1 m/s
4. 60 kg, 60 kg, 1.66 m/s^2
5. (a) 29.4 m/s (b) 44.1 m (c) 39.2 m

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SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : GRAVITATION)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

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NOTES :

1. In the status, put "completed" only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.

Space for Notes :