UNIT 2
MOTION AND FORCE

Question 1

Q1. WHAT IS MEANT BY MOTION?

Answer

Q2. WHAT IS MEANT BY REFERENCE POINT? ILLUSTRATE WITH A SUITABLE EXAMPLE.

Answer

Q3. WHAT IS MEANT BY REST?

Answer

Q4. WHAT IS MEANT BY MOTION?

Answer

Q5. WHAT IS MEANT BY REST?

Answer

Q6. WHAT IS MEANT BY MOTION?

Answer

Question 2

Q1. WHAT IS MEANT BY DISTANCE?

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Q2. WHAT IS MEANT BY DISPLACEMENT?

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Q3. WHAT IS MEANT BY DISTANCE?

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Question 3

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Answer

EXERCISE

Select the correct answer from the following choices.

1) A car takes 1 hour to travel 100 km along a main road and then 1/2 hour to travel 20 km along a side road.

What is the average speed of the car for the whole journey?

a. 40 km h^{-1} b. 70 km h^{-1}

c. 80 km h^{-1} d. 100 km h^{-1}

2) How is the motion of a body affected by balanced and unbalanced forces acting on it?

	Balanced forces	Unbalanced forces
a.	Velocity constant	Velocity constant
b.	Velocity changes	Velocity constant
c.	Velocity constant	Velocity changes
d.	Velocity changes	Velocity changes

3. When a block of wood of mass 2 kg is pushed along a horizontal flat surface of a bench, the force of friction is 4N. When the block is pushed along the bench with a force of 10 N, it moves with a constant.

a. Speed of 3 ms^{-1} b. Speed of 5 ms^{-1}

c. acceleration of 3 ms^{-2} d. Acceleration of 5 ms^{-2}

4. The graph illustrates the motion of an object.

Which features of the graph represent. The distance travelled by the object while moving at a constant speed?

a. Area S b. Area S + area T

c. Area T d. The gradient of point X

5. A body is travelling with a constant acceleration of 10 ms^{-2}. If S_1 is the distance traveled in 1st second and S_2 is the distance traveled in 2nd second, which of the following shows a correct relation between S_1 and S_2.

a. $S_2 = S_1$ b. $S_2 = 3S_1$

c. $S_2 = 3S_1$ d. none

6. The journey of a car is shown in the velocity – time graph. How much distance it traveled?

a. 1250 m b. 2500 m c. 3130 m d. none

7. Two balls travelling in opposite direction slightly of different masses elastically and bounce back. Which of the following correctly show that relative speed of approach is equal to relative speed of separation?

a. $U_1 + U_2 = V_1 + V_2$ b. $U_1 - U_2 = V_1 - V_2$

c. $U_1 + V_1 = V_2 + U_2$ d. $V_1 - U_1 = U_2 - V_2$

8. A projectile is thrown so that it travels a maximum range of 1000m. How high will it rise?

a. 500 m b. 250 m c. 400 m d. none

9. What does not change when force is applied on a body?

a. mass b. Velocity c. Position d. acceleration

Answers:

1.	(b)	**2.**	(c)	**3.**	(b)	**4.**	(d)	**5.**	(d)
6.	(d)	**7.**	(d)	**8.**	(b)	**9.**	(d)	-	-

Write the short answers of the following:

Q.1 Can the velocity of a body reverse the direction, when acceleration is constant? If you think so, give an example?

Answer

Yes, it can be possible i.e. when a body is thrown vertically upward, its velocity goes on decreasing due to gravity and become zero at the maximum height.

After that it reverses its direction, its velocity goes on increasing, but throughout the motion acceleration due to gravity is constant.

Q.2 A man standing on the top of a tower throws a ball straight up with initial velocity V. at the same time throws a second ball straight downward with the same speed. Which ball will hit the ground with higher speed?

Answer.

Both the balls hit the ground with same speed, because the ball which is thrown vertically up with velocity 'v' will have same velocity 'v' when it reaches back of the top of the tower. So, the two balls have same downward velocity. Hence, they hit the ground with same final velocity.

Q.3 Motion with constant velocity is a special case of motion with constant acceleration. Is this statement true? Discuss.

Answer

The statement is not true because if a body is moving with constant velocity then according to Newton's first law there will be no acceleration i.e. a = 0, but if a body is moving with constant acceleration then it means equal change in velocity occur in equal interval of time. So, motion with constant velocity is not a special case of motion with constant acceleration.

Q.4 Define and explain impulse and show that how it is related to linear momentum?

Answer

Definition: When a large force acts on a body for short interval of time then the product of average force and the time over which force acts is called impulse and the force is called impulsive force.

Explanation

In many situations in which momentum of a body suddenly changed such as collision of fast-moving vehicles and striking a ball with a bat. In these cases, force act for very short interval of time and hence are not constant. Also, these forces varying over wide limits and instantaneously not measurable. It is convenient to measure a physical quantity known as impulse.

$$F_{av} = \frac{\Delta P}{\Delta t}$$

$$\Delta P = F_{av} \times \Delta t \quad \text{———(1)}$$

In equation (1) change in momentum is equal to the time over which force acts. Thus, change in momentum is called impulse represented by J.

$$J = F_{av} \times \Delta t \quad \text{———(2)}$$

From Equation (2) it is clear that gradual change in momentum requires small force and long interval of time, and sudden change in momentum requires large force and short interval of time.

The principal is used in the design of automobile safety devices such as air bags and helmet etc. These devices extend the time of collision and decrease the net force, so little change of injury will be there.

Q.5 What is head on collision? Explain with an example.

Answer

If there are only two objects involved in the collision, then the momentum change of the individual objects are equal in magnitude and opposite in direction. Certain collisions are referred to as elastic collisions.

Q.6 For any specific velocity of projection, the range of a projectile cannot exceed from a value equal to four times of the corresponding height.

Answer

According to the given condition.

Let $R = 4H$

$\Rightarrow \frac{u^2 \sin 2\alpha}{g} = \frac{u^2 \sin^2\alpha}{2g}$

$\Rightarrow 2\cos\alpha\sin\alpha = \sin^2\alpha$

$\Rightarrow \frac{\cos\alpha}{\sin\alpha} = 1$

$\Rightarrow \cot\alpha = 1$

$\Rightarrow \alpha = \tan^{-1}(1)$

$\Rightarrow \alpha = 45^\circ$

Since range of projectile is maximum for $\theta = 45^\circ$ therefore, range cannot exceed from a value equal to our times of the maximum corresponding height.

Q.7 What is the angel of projection for which the maximum height reached and corresponding range are equal?

Answer

Since $R = \frac{u^2 \sin 2\alpha}{g} \quad \text{———(1)}$

& $H = \frac{u^2 \sin^2\alpha}{2g} \quad \text{———(2)}$

According to the given condition

$R = H$

$\Rightarrow \frac{u^2 \sin 2\alpha}{g} = \frac{u^2 \sin^2\alpha}{2g}$

$\Rightarrow 2\cos\alpha\sin\alpha = \sin^2\alpha$

$\Rightarrow 2\cos\alpha = \frac{\sin^2\alpha}{\sin\alpha}$

$\Rightarrow 4 = \frac{\sin\alpha}{\cos\alpha}$

$\Rightarrow \tan\alpha = 4$

$\Rightarrow \alpha = \tan^{-1}(4)$

$\Rightarrow \boxed{\alpha = 76.4}$

Q.8 An airplane while horizontally drops a bomb when reaches exactly above the target but missed it. Explain?

Answer

The airplane while horizontally drops a bomb when reaches exactly above the target, the target is missed because the bomb follows the parabolic path. Also, the bomb has the horizontal motion at the point of drop due to which it moves ahead.

Since acceleration is equal to slope of the graph i.e.

Slope = a = tanθ

$a = \tan(60^\circ) \qquad \Rightarrow \theta = 60^\circ$

$\boxed{a = \sqrt{3}\,ms^{-2}}$

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Numerical Problems

1. An object travels 40 m in first 2 sec. Then keeps uniform motion for next 10 sec. It decelerates in the last 10 sec of the journey and comes to rest.

Find a) Maximum speed 'v' b) Total distance travelled by the object d=?

Solution

(a) As the object moves with uniform speed up to 9 sec. So,

$$v = \frac{\text{Total distance}}{\text{Total time taken}}$$

$$v = \frac{40}{2}$$

$$v = 20\,m/s$$

b) Total distance d = ?

i) Distance covered by the object 1st 2 sec

$d_1 = 20\,m$

(I know in 1st2 sec, it decelerates and come to rest. So

$v_i = 20\,m/s$

$v_f = 0\,m/s$

$t = 2\,sec$

$2ad_1 = v_f^2 - v_i^2$

$d_1 = \frac{v_f^2 - v_i^2}{2a}$ ..... (1)

To find 'a' using 1st equation of motion

$v_f = v_i + at$

$0 = 20 + a\,(2)$

Putting values in equation (a)

$d_1 = \frac{0 - 20^2}{2(-10)}$

$d_1 = 20\,m$

$d_2 = 80\,m$

2. An object is travelling with constant acceleration of 10m/s². How much distance will it travelled in the 2ᵗʰ second of journey?

Data

Acceleration of the object $a = 10\,m/s^2$

Distance travelled by the object in 2ᵗʰ sec of journey $d = ?$

Solution

Let S_2 is the distance travelled by the object in 1ˢᵗ second and $S_1 + 2$ sec.

Using 2nd equation of motion we get

$S_1 = ut + \frac{1}{2}at^2$

Putting values

$S_1 = 0 \times t + \frac{1}{2} \times 10 \times t^2$

$S_1 = 5\,t^2$ ..... (1)

Now let S_2 is the distance travelled by the object after time

$S_2 = 2\,sec$

Using 2nd equation of motion we get

$S_2 = 0 \times 2 + \frac{1}{2} \times 10 \times 4$

$S_2 = 20\,m$ ..... (2)

Let S_3 is the distance travelled by the object after time $S_1 + 2$ sec i.e.

$S_3 = S_1 + 2$

$S_3 = 5 \times 3 = S_1 + 10$ ..... (3)

$S_3 = 45\,m$ ..... (3)

The distance travelled by the object in 2ᵗʰ second of journey will be

$d = S_3 - S_2$

$= 30$

$d = 45\,m - 20\,m$

$d = 25\,m$

3. A ball rolls in a revolving vertically at a speed of 19 m/s. What is its of a height of 156.8 m above the ground, a stone is dropped. How long does the stone take to reach the ground?

Data

- Initial velocity of the helicopter $v_i = 19\,m/s$
- Initial velocity of the stone relative to helicopter $u_i = 19\,m/s$
- Height at which the stone is dropped $h = 156.8\,m$
- Time taken by the stone to reach the ground $t = ?$

Acceleration due to gravity $g = 9.8\,m/s^2$

Solution

Using second equation of motion

$$h = ut + \frac{1}{2}g \qquad \text{.....(1)}$$

Putting values we get

$$156.8 = 19\,t + \frac{1}{2} \times 9.8\,t^2$$

or $4.9\,t^2 - 19\,t - 156.8 = 0$

Let $t = 4.9$, $b = 19$ & $c = 156.8$

Using quadratic formula i.e. $t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Putting values in Equation (1)

$$t = \frac{-19 \pm \sqrt{19^2 - 4 \times 4.9 \times 156.8}}{2 \times 4.9}$$

$$t = \frac{-19 \pm \sqrt{361 + 3136}}{9.8} \quad t = \frac{-19 \pm \sqrt{3497.6}}{9.8}$$

$$t = \frac{-19}{9.8} \pm \frac{59.1}{9.8} \quad t = -1.94 \pm 6.03$$

Since time cannot be negative so the required time taken by the stone to reach the ground is $t = 4.09\,sec$

4. Using the following data, draw velocity time graph for short journey on a straight road of a motor bike.

Velocity	0	10	20	20	20	20	0
Time	0	30	60	90	120	150	180

Use the graph to calculate

a) Initial acceleration a = ?

b) Final acceleration a = ?

c) Total distance travelled d = ?

Solution

Using the above data the draw velocity time graph. Time is taken along x-axis and velocity is taken along y-axis.

(a) From the graph velocity of motor bike increases from 0 m/s to 20 m/s in time interval 30 sec. i.e. E to A

Since acceleration is equal to the slope of the graph i.e.

$$\text{Slope} = \frac{\Delta v}{\Delta t}$$

or $a_i = \frac{20 - 0\,m/s}{30\,sec}$

$a_i = 0.66\,m/s^2$

(b) From point A to B velocity is constant and from B to C the magnitude of velocity decreases at point E final velocity is zero.

Using graph

$$a_f = \frac{0\,m/s - 20\,m/s}{30\,sec}$$

$a_f = -0.66\,m/s^2$ negative sign shows retardation.

(c) The total distance covered by motor bike is numerically equal to the area under the velocity time graph. From the graph.

= area of ΔABC + Area of rectangle

$= ABCD = \text{area of } \Delta BDE$

OR $= \frac{1}{2} \times DC \times AC + CD \times BD + \frac{1}{2} \times DE \times BD$

$d = 1 \times 60 + 20 \times 90 + 20 \times 1 \times 90 \times 20$

$d = 2700\,m$

5. A proton moving with a speed of 1.5 × 10⁷ m/s passes through a 0.020 cm thick sheet of paper and emerges with a speed of 2.0 × 10⁶ m/s. Assuming uniform deceleration, find retardation and time taken to pass through the paper.

Data

Initial speed of the proton $v_i = 1.5 \times 10^7\,m/s$

Final speed of the proton $v_f = 2.0 \times 10^6\,m/s$

Thickness of the sheet $x = 0.020\,cm = 2 \times 10^{-4}$

i) Retardation of Proton $a = ?$

ii) Time taken by the proton to pass through the paper $T = ?$

Solution

i) Using 3rd equation of motion i.e

$2ax = v_f^2 - v_i^2$

$2 \times a \times (2 \times 10^{-4}) = (2 \times 10^6)^2 - (1.5 \times 10^7)^2$

$a = \frac{4 \times 10^{12} - 2.25 \times 10^{14}}{4 \times 10^{-4}}$

$a = -5.4 \times 10^{21}\,m/s^2$

ii) To find time taken by proton using first equation of motion i.e

$v_f = v_i + at$

$t = \frac{v_f - v_i}{a}$

$t = \frac{2 \times 10^6 - 1.5 \times 10^7}{-5.4 \times 10^{21}}$

$t = 2.5 \times 10^{-14}\,sec$

6. A constant force 'F' changes the speed of an 80 kg sprinter from 3m/s to 4 m/s in 0.5 sec. Calculate the acceleration of the sprinter?

Data

Mass of the sprinter $m = 80\,kg$

Initial speed of the sprinter $v_i = 3\,m/s$

Final speed of the sprinter $v_f = 4\,m/s$

Time taken by the sprinter $t = 0.5\,sec$

Acceleration of the sprinter $a = ?$ Solution

Solution

$a = \frac{v_f - v_i}{t}$

Putting values we get

$a = \frac{4\,m/s - 3\,m/s}{0.5\,s}$

$a = 2\,m/s^2$

7. A 4kg ball travelling with the speed of 2m/s strikes a rigid wall and rebounds elastically. If the ball is in contact with the wall for 0.005 s, what is

i). Momentum imparted to the wall?

ii. The average force exerted on the wall=?

Data

Mass of the ball $m = 4\,kg$

Initial speed of the ball $v_i = 2\,m/s$

time of contact of ball with wall = 0.005sec

Solution

(i) Momentum imparted to the wall

$\Delta P = 2\,m/s$

$= 2 \times 4 = 8$

$\Delta P = 8\,kg\,m/s$

(ii) The average force exerted on the wall

$F = \frac{\Delta P}{\Delta t}$

$F = \frac{8}{0.005}$

$F = 1600$

8. A projectile is thrown with a speed of 100 m/s at 30° with the horizontal.

Find

a) Time of flight

b) Maximum height if attained

c) The range travelled.

Data

Initial speed $v_i = 100\,m/s$

Angle of projection $\theta = 30°$

Acceleration due to gravity $g = 9.8\,m/s^2$

(a) $t_f = \frac{2v_i \sin\theta}{g}$

$t_f = \frac{2 \times 100 \times \sin 30°}{9.8}$

$t_f = 10.2\,sec$

(b) Maximum height $H = ?$

Since $H = \frac{v_i^2 \sin^2\theta}{2g}$

$H = \frac{(100)^2 \times \sin 30°}{2 \times 9.8}$

$H = 127.5$

(c) Range $R = ?$

$R = \frac{v_i^2 \sin 2\theta}{g}$

$R = \frac{(100)^2 \times \sin 60°}{9.8}$

$R = 882.6\,m$

9. The maximum height gained by a projectile is 300 m. If it travels a range of 600m. Find the displacement of summit point from the point of project.

Data

Maximum height gained by the projectile $H = 300m$

Range of the projectile $R = 600m$

Displacement of summit point from the point of projection "x" = ?

Solution

Consider in the fig the summit point C

and AD = R = 600m

DC = 300m

DC = y = 0

from triangle ACD

$(AC)^2 = (AD)^2 - (DC)^2$

$x = \sqrt{(R)^2 - (H)^2}$

Putting values we get

$x = \sqrt{(600)^2 - (300)^2}$

$x = 519.6\,m$

10. Calculate the angle of project of which R.E at the highest point of its trajectory is equal to one by fo R.E at point of project.

Data

Kinetic energy at the point of projection = E_i = ?

Kinetic energy at maximum height $K.E = \frac{1}{2}K.E$

Angle of projection $\theta = ?$

Solution

According to the given condition

$K.E_{max} = \frac{1}{2}K.E_i$

$\cos\theta = \frac{1}{2}$

$\cos\theta = \frac{1}{2}$

$\theta = \cos^{-1}\left(\frac{1}{2}\right)$

$\theta = 60°$

Objective Type Questions & Answers

Select the correct answer from the following choices:

1) The change in position of a body from its initial position to final position is called.

a. speed b. velocity c. acceleration d. displacement

2) A body moving with uniform velocity has acceleration.

a. zero b. positive c. negative d. Infinite

3) The velocity-time graph is parallel to time axis; the acceleration of the moving body is.

a. maximum b. negative c. positive d. zero

4) If a car moves with uniform acceleration, then the area between the velocity time graph and the time axis is equal to.

a. force b. velocity c. acceleration d. distance covered

5) When the value of average velocity and instantaneous velocity are equal, then the body is said to be moving with,

a. average acceleration b. uniform acceleration

c. negative acceleration d. positive acceleration

6) Acceleration of bodies of different masses, allowed to fall freely is,

a. variable b. the same

c. different for different heights d. different for different bodies

7) Distance covered by freely falling body in 2 seconds is,

a. 4.9 m b. 19.6m c. 39.2 m d. 44.1 m

8) The property of the body due to which it opposes its state of rest or of uniform motion is called.

a. momentum b. torque c. weight d. inertia

9) Pull of earth on a mass of 20 kg on the surface of Earth is,

a. 19.6 N b. 196N c. 392N d. 1960 N

10) A force of 500 N acts on a body for 10 seconds. What will be the change in momentum?

a. 250 N b. 500 N c. 750 N d. 1000 N

11) A body is thrown vertically upward with an initial velocity 9.8 ms^{-2}. It will reach the height.

a. 4.9 m b. 9.8 m c. 19 8 m d. 29.4 m

12) The path of the projectile is,

a. straight line b. circle c. parabola d. hyperbola

13) Motion of the projectile is,

a. one dimensional b. two dimensional

c. three dimensional d. four dimensional

14) A bomber drops its bomb when it is vertically above the target. It misses the target due to,

a. horizontal component b. vertical component of the velocity

c. air resistance d. pull of gravity

15) The time of flight of a projectile is,

a. $\frac{v_i^2 \sin^2\theta}{g}$ b. $\frac{v_i^2 \cos^2\theta}{g}$ c. $\frac{v_i^2 \sin^2\theta}{2g}$ d. $\frac{2v_i \sin^2\theta}{g}$

16) The horizontal range of the projectile is maximum when it is projected at an angle of,

a. 30° b. 45° c. 60° d. 90°

17) The maximum vertical height is,

a. $\frac{v_i^2 \sin^2\theta}{g}$ b. $\frac{v_i \sin\theta}{2g}$ c. $\frac{v_i^2 \cos^2\theta}{g}$ d. $\frac{v_i^2 \sin^2\theta}{2g}$

18) To improve the span of the jump, one should jump at an angle of,

a. 30° b. 45° c. 60° d 90°

19) The horizontal component of a projectile moving with initial velocity 500 ms^{-1} at an angle of 60° with x-axis is equal to,

a. zero b. 250 ms^{-1} c. 500 ms^{-1} d. 1000 ms^{-1}

20) In a projectile motion, the horizontal range depends upon,

a. initial velocity b. angle of projection

c. both initial velocity and angle of projection d. none of these

21) Dimensions of impulse is unguided missile is called a,

a. work b. force c. torque d. momentum

22) An unpowered and unguided missile is called a,

a. simple missile b. plastic missile

c. ballistic missile d. unguided missile

23) The ballistic missiles are used only for,

a. long ranges b. short ranges c. medium ranges d. none of these

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