CHAPTER NO. 3 (MOTION AND FORCE)

Question 3.1:- What is the difference between uniform and variable velocity? From the explanation of variable velocity, define acceleration. Give SI units of velocity and acceleration.

Answer:- Uniform Velocity:- If an object covers equal displacements in equal intervals of time, the velocity is said to be uniform.

Variable Velocity:- If an object covers unequal displacements in equal intervals of time, velocity is said to be non-uniform or variable.

Acceleration:- The rate of change of velocity with respect to time is called acceleration. Mathematically, $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t}$.

SI unit of velocity is m s^{-1} while SI unit of acceleration is m s^{-2}.

Question 3.2:- An object is thrown vertically upward. Discuss the sign of acceleration due to gravity, relative to velocity, while the object is in air.

Answer:- When an object is thrown vertically upwards, the direction of initial velocity is taken as positive. Acceleration due to gravity is directed downwards, opposite to initial velocity, its sign is considered as negative.

Question 3.3:- Can the velocity of an object reverse the direction when acceleration is constant? If so, give an example.

Answer:- Yes, an object can reverse the direction of its velocity when acceleration is constant. When an object is thrown vertically upwards, the direction of its velocity is reversed at the highest point but the acceleration is always constant and is equal to acceleration due to gravity i.e. a = -g.

Question 3.4:- Specify the correct statements.

Answer:- a. An object can have a constant velocity even its speed is changing. **(False)**

b. An object can have constant speed even its velocity is changing. **(True)**

c. An object can have a zero velocity even its acceleration is not zero. **(True)**

d. An object subjected to a constant acceleration can reverse its velocity. **(True)**

Question 3.5:- A man standing on the top of a tower throws a ball straight up with initial velocity v_i and at the same time throws a ball straight downward with the same velocity. Which ball will have larger speed when it strikes the ground? Ignore air friction.

Answer:- Both balls will hit the ground with same velocity. The ball which is thrown upwards, will cross the point of projection with the same velocity v_i

during its downward journey. Hence, both balls will hit the ground with same velocity.

Question 3.6:- Explain the circumstances in which velocity v and acceleration a of a car are (i) Parallel (ii) Anti-parallel (iii) Perpendicular to each other (iv) v is zero but a is not zero (v) a is zero but v is not zero.

Answer:- (i) When velocity of a car increases, acceleration is positive and both are parallel.

(ii) When velocity of a car decreases, acceleration is negative and both are Anti-parallel.

(iii) When a car is moving along a circular track, acceleration and velocity are perpendicular to each other.

(iv) When a car stops suddenly, **v** is zero but **a** is not zero (negative).

(v) When car is moving with uniform velocity, **a** is zero but **v** is not zero.

Question 3.7:- Motion with constant velocity is a special case of motion with constant acceleration. Is this statement true? Discuss.

Answer:- Yes, the statement is true. When an object performs projectile motion, its horizontal velocity and total acceleration remain constant throughout its trajectory.

(Discussion:- It has been pointed out in several notes that when an object moves with uniform velocity, its acceleration is zero and zero is a constant quantity. Actually, this is not a special case, this is just a general case. Special case is when some phenomenon takes place at a certain time or certain location only.**)**

Question 3.8:- Find the change in momentum for an object subjected to a given force for a given interval of time and state law of motion in terms of momentum.

Answer:- Suppose an object is moving at a certain velocity $\mathbf{v_i}$ at time $t_1 = 0$. It is subjected to a force **F** and after an interval $t_2 = t$, its velocity becomes $\mathbf{v_f}$.

We know that $\vec{a} = \frac{\vec{F}}{m}$. Further, $\vec{a} = \frac{\vec{v}_f - \vec{v_i}}{t_2 - t_1}$

Equating both equations, $\frac{\vec{F}}{m} = \frac{\vec{v}_f - \vec{v_i}}{t_2 - t_1}$, $\vec{F}\ x\ t = \text{m}\ (\vec{v}_f - \vec{v_i})$ = Change in momentum = Force x Time

Further, $\vec{F} = \text{m}\frac{\overrightarrow{(v}_f - \overrightarrow{v_i)}}{t_2 - t_1}$, $\vec{F} = \frac{\overrightarrow{\Delta P}}{\Delta t}$

The rate of change of momentum with respect to time is equal to the applied force. This is statement of Newton's second law of motion in terms of momentum.

Question 3.9:- Define impulse and show that how it is related to linear momentum.

Answer:- When a large force acts on an object for a very short interval of time, the product of force and time is called impulse. Mathematically, Impulse = Force x Time = $\vec{F}\ x\ t$.

We can define force as time rate of change of momentum and mathematically write it as:-

$\vec{F} = \frac{m\vec{v_f} - m\vec{v_i}}{t}$.

Impulse = $\vec{F}\ x\ t = \frac{m\vec{v_f} - m\vec{v_i}}{t}$ x t = $m\vec{v_f} - m\vec{v_i}$ = Change in momentum

Question 3.10:- State the law of conservation of linear momentum, pointing out the importance of isolated system. Explain, why under certain conditions, the law is useful even though the system is not completely isolated.

Answer:- According to law of conservation of linear momentum, the total linear momentum of an isolated system always remains constant.

An isolated system is the one, on which no external force acts.

Sometimes, the system is not completely isolated but external force is so small relative to internal interactions of the objects of the system that it can be neglected and this law can be applied to a good approximation. For example, force of gravity on molecules of an ideal gas enclosed in a cylinder is negligible.

Question 3.11:- Explain the difference between elastic and inelastic collisions. Explain how would a bouncing ball behave in each case. Give plausible reasons for the fact that K.E. is not conserved in most cases.

Answer:- Elastic Collision:- A collision in which both momentum and kinetic energy are conserved, is called elastic collision. A bouncing ball will bounce back to same height after an elastic collision.

Inelastic Collision:- A collision in which momentum is conserved but kinetic energy is not conserved, is called inelastic collision. A bouncing ball will not bounce up to same height after an inelastic collision.

In most cases where two or more objects collide, a portion of their kinetic energies is converted to heat, sound and work done against friction. Hence, K.E. is not conserved in most cases.

Question 3.12:- Explain what is meant by projectile motion. Derive expressions for a. the time of flight b. the range of projectile. Show that the range of projectile is maximum when projectile is thrown at an angle of 45° with the horizontal.

Answer:- Two dimensional motion under constant acceleration due to gravity is called projectile motion.

Time of Flight:- The time taken by a projectile to cover the distance from its point of projection to its point of landing at the same level is called time of flight.

This can be obtained by taking S = h = 0. We know that $S = v_i t + \frac{1}{2} a t^2$,

Put S = 0, $v_{iy} = v_i \sin\theta$ and a = -g.

$0 = v_i \sin\theta\, t - \frac{1}{2} g t^2$

$t = \frac{2 v_i \sin\theta}{g}$

Range of Projectile:- Maximum distance which a projectile covers in the horizontal direction is called the range of the projectile.

This can be obtained by using the relation S = v t

Put S = R, $v_{ix} = v_i \cos\theta$ and $t = \frac{2 v_i \sin\theta}{g}$

$R = (v_i \cos\theta)\left(\frac{2 v_i \sin\theta}{g}\right)$

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

Maximum Range:- Range is maximum when the factor sin 2θ = 1.

$2\theta = \sin^{-1}(1) = 90^\circ$

$\theta = 45^\circ$

Hence proved that range of the projectile is maximum when its angle of projection is 45° w.r.t. horizontal.

Question 3.13:- At what point or points in its path does a projectile have its minimum speed, its maximum speed?

Answer:- The speed of projectile is maximum at the point of projection and its point of landing.

The speed of projectile is minimum at maximum height because its vertical velocity is reduced to zero at maximum height.

Question 3.14:- Each of the following questions is followed by four answers, one of which is correct answer. Identify that answer.

i. What is meant by a ballistic trajectory?

a. The path followed by an un-powered and unguided projectile. **(True)**

b. The path followed by the powered and unguided projectile. **(False)**

c. The path followed by un-powered but guided missile. **(False)**

d. The path followed by powered and guided projectile. **(False)**

ii. What happens when a system of two bodies undergoes an elastic collision.

a. The momentum of the system changes. **(False)**

b. The momentum of the system does not change. **(True)**

c. The bodies come to rest after collision. **(False)**

d. The energy conservation law is violated. **(False)**