Chapter # 03 (Motion and Force)
Important Short Questions

1. Define the terms
(i) Displacement (ii) Velocity (iii) Instantaneous velocity (iv) Average velocity (v) Uniform velocity

(i) Displacement:
The change in position of a body from its initial position to final position is called displacement.

$$\vec{d} = \vec{r}_2 - \vec{r}_1$$

Its unit is meter.

(ii) Velocity
The time rate of change of displacement is called velocity.

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

(iii) Instantaneous velocity
The limiting value of $\frac{\Delta\vec{d}}{\Delta t}$, as time interval Δt approaches to zero is called instantaneous velocity.

$$\vec{v}_{ins} = \lim_{\Delta t \to o} \frac{\Delta\vec{d}}{\Delta t}$$

(iv) Average velocity
The ratio of the total displacement to the total time taken to cover this displacement is called as average velocity.

$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$$

(v) Uniform velocity
If a body covers equal displacement in equal interval of time is called uniform velocity.
Unit: The unit of velocity is ms^{-1}.

2. Define the terms
(i) Acceleration (ii) Instantaneous acceleration (iii) Positive acceleration (iv) Negative Acceleration

(i) Acceleration
The time rate of change of velocity is called acceleration.

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

(ii) Instantaneous acceleration
The limiting value of $\frac{\Delta\vec{v}}{\Delta t}$, as time interval Δt approaches to zero is called instantaneous acceleration.

$$\vec{a}_{ins} = \lim_{\Delta t \to o} \frac{\Delta\vec{v}}{\Delta t}$$

(iiii) Average acceleration

The ratio of the total change in velocity to the total time is called as average acceleration.

$$\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t}$$

(iv) Positive Acceleration

If velocity of the body increases, its acceleration is positive.

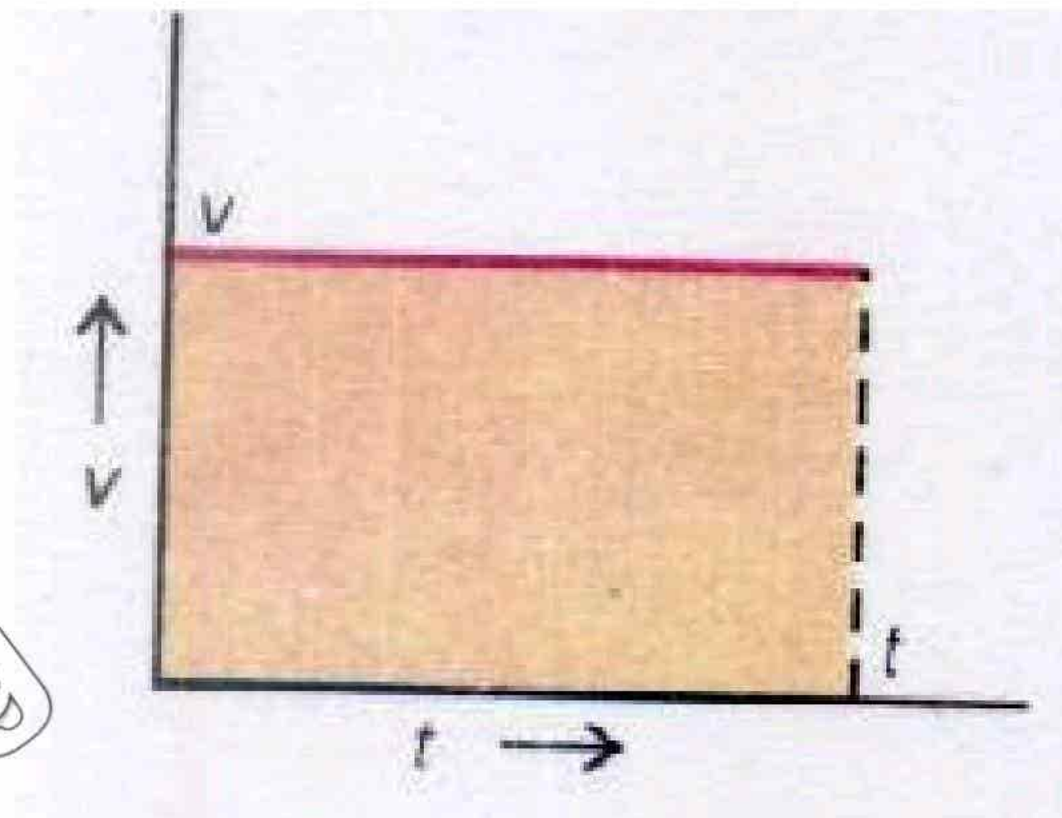
(v) Positive Acceleration

If velocity of the body decreases, its acceleration is negative. It is also called deceleration or retardation.

Unit: The unit of acceleration is ms^{-2}.

3. Show that the area between the velocity time graph is equal to the distance covered by the object.

Ans: Case I:



When the object moves with the uniform velocity, velocity-time graph is a horizontal straight line parallel to time axis.

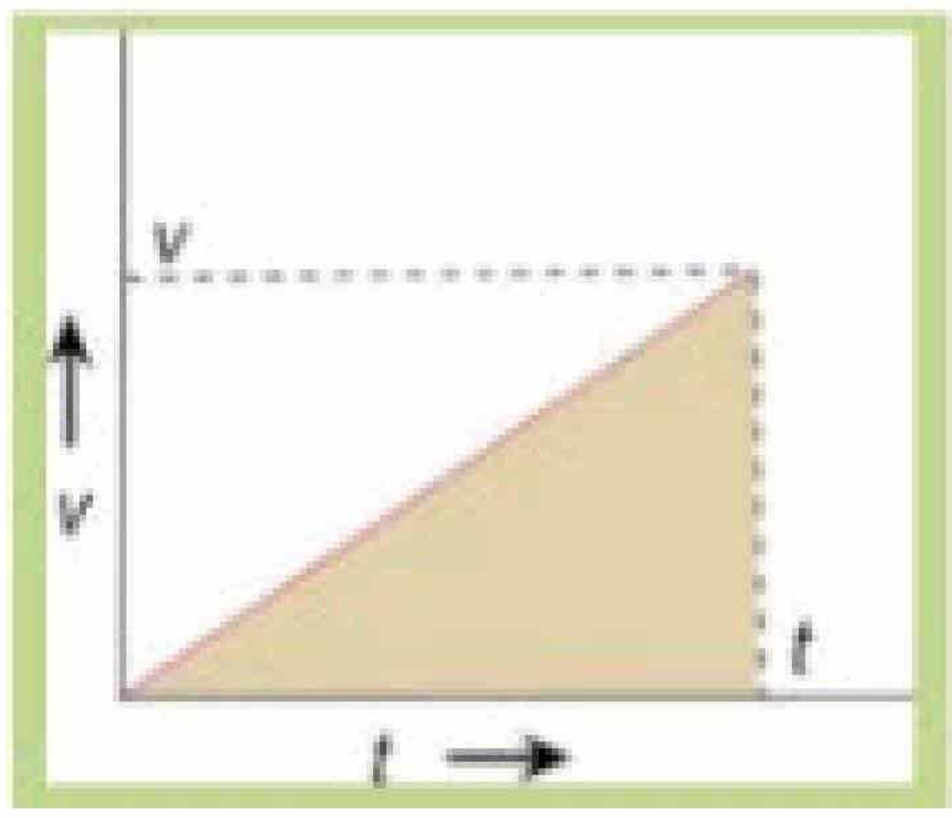
Distance covered by the body = Area of rectangle

= (Length) × (Width)

= vt

= S

Case II:



When the body moves with uniformly increasing velocity (uniform acceleration), the velocity-time graph is an inclined line with time axis.

Distance covered by the body = Area of triangle

$$= \frac{1}{2}(\text{base}) \times (\text{Height})$$

$$= \frac{1}{2}vt$$

$$= V_{av} \times t \quad \left(V_{av} = \frac{0+v}{2} = \frac{1}{2}v\right)$$

= S

4. Define Inertial frame of reference

Ans: Inertial frame of reference

The frame of reference in which Newton's law holds is called inertial frame of reference.

Example:

The Earth is approximately an inertial frame of reference.

5. Define Newton's law.

Ans: Newton's first law of motion:

A body at rest remain at rest and a body moving with uniform velocity will continue to do so, unless unbalanced external force acts on it.

Newton's 2nd Law of motion:

"When a net force acts on a body, it produces acceleration in the body in the direction of the net force. The magnitude of this acceleration is directly proportional to the net force acting on the body and inversely proportional to its mass."

$$a \propto F$$

$$a \propto \frac{1}{m}$$

$$a \propto \frac{F}{m}$$

$$F \propto ma$$

$$F = kma$$

$$F = ma \qquad (K = 1)$$

Newton's 3rd Law of motion

"To every action there is always an equal but opposite reaction."

- Motion of rocket
- Motion of air filled Balloon

6. Define momentum, Write its formula and unit.

Ans: Momentum:

"The product of mass and velocity is called momentum."

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

Its unit is Ns ($Kgms^{-1}$).
It depends upon.

- Mass of the body.
- Velocity of the body

7. Define isolated with suitable example.

Ans: Isolated System:

The system on which no external force acts is called isolated system.

Example:

The molecules of gas enclosed in a glass vessel at a constant temperature.

8. State law of conservation of momentum. Write its formula.

Ans: Statement:

Total linear momentum of an isolated system remains constant.

$$\mathbf{m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}'_1 + m_2\vec{v}'_2}$$

9. Drive the relation for force due to water flow.

Ans: Suppose water from a horizontal pipe strikes a wall normally. Then it exerts a force on the wall. Let initially the velocity of water flow is $\vec{v}$ and on striking the wall, it comes to at rest so final velocity becomes zero.

$$\vec{F} = \frac{m\vec{v}_f - m\vec{v}_i}{t}$$

$$\vec{F} = \frac{0 - m\vec{v}}{t}$$

$$\vec{F} = -\frac{m\vec{v}}{t}$$

According to Newton's 3rd law of motion, a force of reaction exerted by water on the wall is equal but opposite.

$$\vec{F} = -\left(\frac{-m\vec{v}}{t}\right)$$

$$\vec{F} = \frac{m\vec{v}}{t}$$

10. How do you find the momentum of an explosive force? Explain with one example.

Ans: When a shell explodes in mid-air, its fragments fly off in different directions. The total momentum of all its fragments equals the initial momentum of the shell.

Suppose a falling bomb explodes into two pieces. The momentum of the bomb fragments combines by vector addition equal to the original momentum of the falling bomb.

11. When a bullet is fired from a riffle. Why does the riffle move backward?

Ans: When the bullet is fired, the total momentum of bullet and riffle still remains zero. Since no external force has acted on them. Thus if v' is the velocity of riffle.

$$\mathbf{mv + Mv' = 0}$$

$$\mathbf{Mv' = -mv}$$

$$\mathbf{v' = -\frac{mv}{M}}$$

The momentum of the riffle thus equal and opposite to that of the bullet. Since mass of riffle is much greater than the bullet that's why the riffle move backs or recoils.

12. What is principle of rocket propulsion?

Ans: Motion of rocket is based on the law of conservation of momentum and Newton's third law of motion.

Principle of rocket propulsion

Rocket moves up by ejecting burning gasses from its rear part. When fuel is burned, high pressure gasses come out from the engine with high velocity. The rocket gains momentum equal to the momentum expelled gasses but in opposite direction. Rocket continues to gain more and more momentum. So, the speed of rocket goes on increasing as long as engine are operating.

13. Define ballistic missile, ballistic flight and ballistic trajectory.

Ans: Ballistic Missile:

Ballistic missiles are un-powered, unguided and useful only for short range.

Ballistic flight:

When a projectile is given an initial push and is then allowed to move freely due to inertia and under the action of gravity, such a flight is called ballistic missile.

Ballistic trajectory:

The path followed by the ballistic missile is called ballistic trajectory.

14. Why a safety of a motorcycle's is padded?

Ans: A motorcycle's helmet is padded so as to extend the time of any collision to prevent serious injury.

$$\vec{I} = \vec{F} \times \Delta t$$

Through this relation time is inversely proportional to the force so increases the time so decrease the force so this is why safety helmet is padded to prevent the serious injury.

Exercise Short Questions

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.

Ans:

Uniform Velocity	Variable Velocity
• When a body covers **equal** displacement in equal intervals of time then the body moves with **uniform** velocity. • In this case **acceleration** is **zero**.	• When a body covers **unequal** displacement in equal intervals of time then the body moves with **variable** velocity. • In this case **acceleration** is has **some value**.

Acceleration: -

The time rate of change of a body is called acceleration.

If the velocity of a body changes from by an amount $\Delta\vec{V}$ in time Δt .then

$$a_{av} = \frac{\Delta\vec{V}}{\Delta t} = \frac{V_f - V_i}{\Delta t}$$

- The SI unit of velocity is ms^{-1}.
- The SI unit of acceleration is ms^{-2}.

2. An object is thrown vertically upward. Discuss the sign of acceleration due to gravity, relative to velocity, while the object is in air?

Ans: Sign of acceleration due to gravity relative to velocity is **negative.**

Explanation: -

As acceleration due to gravity is directed downward but the velocity is directed upward. Therefore, the sign of acceleration due to gravity relative to velocity is negative and when it moves in the downward direction acceleration and velocity are parallel. So, sign of acceleration will be positive.

3. Can the velocity of an object reverse direction when acceleration is constant? If so, given an example?

Ans: Yes, it is possible.

Example: -

When a body is thrown vertically upward, its velocity decreases because of downward force of gravity and becomes zero at the highest point and the body starts moving downward and reverses its direction of velocity, but the acceleration remains constant during whole flight (i.e. $9.8ms^{-2}$.)

4. Specify the correct statement:

(a) An object can have a constant velocity even its speed is changing.

(b) An object can have a constant velocity even its velocity is changing.

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

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

(a) As when speed changes, velocity also changes so it is not true statement.

(b) When object moves along a circle with constant speed, velocity changes due to change in direction. So, it is true statement.

(c) When a body thrown vertically upward. At the maximum height its velocity becomes zero, but the acceleration is not zero. So, it is true statement.

(d) When an object is thrown vertically up, after reaching its maximum height, its velocity reverses but its acceleration remains same (i.e. $9.8ms^{-2}$.) So, it is also true statement.

5. A man is standing on the top of a tower throws a ball straight up with initial velocity V_i and at the same time throws a second ball straight downward with the same speed. Which bass will have larger speed when it strikes the ground? Ignore air friction.

Ans: Both the balls hit the ground with the same speed.

Explanation: -

The ball which is thrown vertically up with velocity V_i will have same velocity V_i when it reaches back to the top of the tower. So, the two balls have same downward velocity at top of the tower, hence they hit the ground with the same final velocity.

6. Explain the circumstances in which the velocity $\vec{V}$ and acceleration $\vec{a}$ of car are;

(i) Parallel **(ii) Anti-Parallel** **(iii) Perpendicular to one another**

(iv) v is zero but a is not zero **(v) a is zero but v is not zero**

(i) When the velocity of the car is increasing in a Straight line then $\vec{v}$ and $\vec{a}$ are parallel.

(ii) When the velocity of the car is decreasing in a straight line the $\vec{v}$ and $\vec{a}$ are anti-parallel.

(iii) When a car moves in a circle the $\vec{v}$ and $\vec{a}$ are perpendicular to each other.

(iv) When an opposing force is acting. The car slow-downs and at the end point $\vec{v}$ is zero but acceleration $\vec{a}$ is not zero $\vec{a}$.

(v) When a car is moving with uniform velocity then $\vec{a}$ is zero but $\vec{v}$ is not zero.

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

Ans: Yes, this statement is true.

Explanation: -

The acceleration depends upon change in velocity. When a body moves with constant velocity $\Delta\vec{v} = 0, \vec{a} = \frac{\Delta v}{\Delta t} = 0$. It means velocity changes at a constant rate i.e. zero meter per second. Hence acceleration will remain constant (zero) during motion. This is a special case of motion with constant acceleration.

8. Find the change in momentum for an object subjected to a given force for a given time and state law of motion in terms of momentum?

Ans: The time rate of change of momentum of a body is equal to applied force.

Proof: -

Let a force $\vec{F}$ acts on a body of mass m, its velocity changes from $\vec{V}_i$ **to** $\vec{V}_f$ in time t second. Then the acceleration produced is

$$\vec{a} = \frac{\vec{V}_f - \vec{V}_i}{\Delta t}$$

$$\vec{a} = \frac{\vec{F}}{m}$$

$$\frac{\vec{F}}{m} = \frac{\vec{V}_f - \vec{V}_i}{\Delta t}$$

$$\vec{F} = \frac{m\vec{V}_f - m\vec{V}_i}{\Delta t}$$

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

Hence, it is proved.

9. Define impulse and show that how it is related to linear momentum?

Ans: impulse:

When a large force acts on a moving body for a short interval of time then the product of force and time is called impulse.

Relation:

$$\vec{I} = \vec{F} \times t$$

$$\vec{F} = \frac{m\vec{V}_f - m\vec{V}_i}{\Delta t}$$

$$\vec{F} \times t = m\vec{V}_f - m\vec{V}_i$$

$$\vec{I} = m\vec{V}_f - m\vec{V}_i$$

So, the impulse is equal to the change in momentum.

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?

Ans: Statement: -

Total linear momentum of an isolated system always remains constant.

Importance: -

- For an isolated system, total change in linear momentum due to mutually interacting forces is zero.
- Law of conservation of momentum holds only for the isolated system otherwise it is not valid.

Example:

Firing of a bullet from gun.

Application:

When the effect of external force (like frictional and gravitational force) is negligible small as compared to the forces between the interacting objects, then this law becomes applicable.

11. Explain the difference between elastic and inelastic collision. 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?

Ans:

Elastic Collision	Inelastic Collision
• The collision in which the K.E is conserved is called elastic collision. • For example, bouncing of hard ball from marble floor.	• The collision in which the K.E is not conserved is called inelastic collision. • For example, bouncing of hard ball from sandy floor.

But the total linear momentum and total energy of the system remains constant.

Behaviour of bouncing ball:

When a hard ball is dropped from a certain height. If it has elastic collision on striking the floor, it will come at the original height but in case of inelastic collision, ball will lose some part of K.E and will not bounce back at the same height.

Solid reason for loss of kinetic energy:

In case of inelastic collision, the loss of kinetic energy is due to

- Friction of ball with floor
- Friction of ball and air
- Sound

12. Explain what is meant by projectile motion? Derive the expression 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 horizontal.

Ans: The two-dimensional motion under the constant acceleration due to gravity and inertia is called projectile motion.

Example:

1) A football kicked by a player.
2) A ball thrown by a cricketer.
3) A missile fired from launching pad.

Time of flight:

The time taken by body to cover the distance from the place of projection to the place where it just hit the ground is called time of flight.

Since the projectile covers no vertical distance after its total time of flight. So, S = h = 0. If $\mathbf{V_i sin\theta}$ is the vertical component of initial velocity. Then,

$$S = V_i t + \frac{1}{2}gt^2$$

$$0 = (v_i sin\theta)t - \frac{1}{2}gt^2$$

$$\frac{1}{2}gt^2 = (v_i sin\theta)t$$

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

Range of projectile:

Maximum distance which a projectile cover in the horizontal distance is called range of the projectile. If $v_i cos\theta$ is horizontal of initial velocity then range of projectile R for the total time of flight t can be expressed as,

$$R = V_{ix} \times t$$

$$R = V_i cos\theta \times \frac{2v_i sin\theta}{g}$$

$$R = \frac{V_i^2(2Sin\theta cos\theta)}{g}$$

$$R = \frac{V_i^2 Sin2\theta}{g}$$

Maximum Range:

The range of the projectile is maximum when the value of Sinθ has maximum value. The maximum value of sine function is one. Thus

$$Sin2\theta = 1$$

$$2\theta = Sin^{-1}(1)$$

$$2\theta = 90^o$$

$$\theta = 45^o$$

$$R = \frac{v_i^2 sin2\theta}{g}$$

$$R_{max} = \frac{v_i^2 sin2(45^o)}{g}$$

$$R_{max} = \frac{v_i^2 sin90^o}{g}$$

$$R_{max} = \frac{v_i^2}{g}$$

13. At what point or points in its path does a projectile have its minimum speed, its maximum speed?

Ans: Minimum Speed:

The speed of the ball is minimum at its **maximum height** because at this point the vertical component of velocity becomes zero.

Maximum Speed: -

The speed of ball is maximum at

- Its point of projection.
- The point just to hit the ground (Point of landing)

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