SHORT QUESTIONS AND ANSWERS

(A) (B)

Q No. 3.1: What is the difference between uniform and variable velocity? From the explanation of variable velocity, define acceleration. Give S.I units of velocity and acceleration.

Difference between Uniform and Variable Velocity

1. In case of uniform velocity, a body covers equal displacement in equal interval of time, whereas in case of variable velocity the body covers unequal displacement in equal interval of time.
2. In uniform velocity both direction and magnitude of the velocity remains unchanged with time whereas in variable velocity, either direction or magnitude of the velocity changes instantly.
3. In case of uniform velocity, time rate of change in velocity is zero while in case of variable velocity, time rate of change in velocity is non zero.

Acceleration

The time rate of change of velocity of the body is called acceleration. Consider a body is moving with initial velocity $\vec{v}_1$ and after some time Δt its velocity becomes $\vec{v}_2$, then the acceleration a of the object will be

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$$

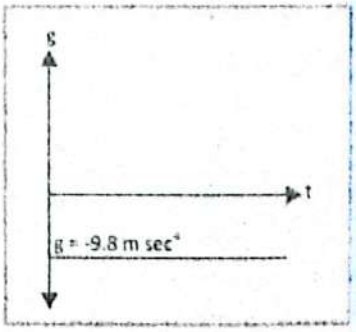
S.I unit of velocity: The S.I unit of velocity is meter per second or m sec^{-1}

S.I unit of acceleration: The S.I unit of velocity is meter per second per second or m sec^{-2}

Q No. 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. (FSB-2019) (GRW-2019) (GRW-2019) (FSB-2018) (DGK-2016) (BWP-2016)

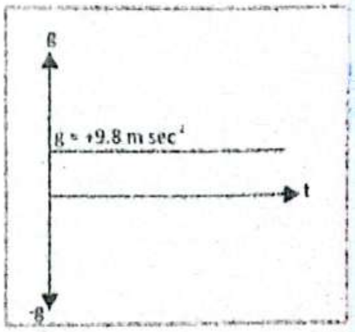
When Body is Projected Vertically Upward

When an object is thrown vertically upward, its velocity is vertically upward and acceleration due to gravity 'g' is vertically downward and sign of 'g' is negative because 'g' is opposite to velocity. But when the object returns to ground, now the direction of acceleration due to gravity 'g' is again negative because 'g' is always remain opposite to the initial velocity and its gravitational acceleration time graph is shown in Fig.



When Body is Dropped From Certain Height

When body is dropped from certain height then initial velocity and gravitational acceleration remain in same direction, so gravitational acceleration always remain positive as shown in gravitational acceleration time graph.



Q No. 3.3: Can the velocity of an object reverse its direction when acceleration is constant? If so, give an example. (BWP-2019) (LHR-2019) (SGD-2019) (MUL-2019) (LHR-2018) (LHR-2018) (RWP-2018) (SHW-2017) (SGD-2017) (FSB-2016) (FSB-2016) (LHR-2016) (LHR-2016) (RWP-2016)

Yes, the velocity of an object can reverse its direction when acceleration is constant.

For example, when an object is thrown vertically upward, velocity reverses its direction as it reaches the highest point and start moving vertically downward where as magnitude of acceleration due to gravity remains constant ($g = 9.8$ m sec^{-2}) during the whole journey.

Q No. 3.4: Specify the correct statements.

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

1. **The statement (b) is correct**

Reason

b. When an object moves along a circular path with constant speed, its velocity changes due to change in direction at every instant.

2. **The statement (c) is correct**

Reason

When the brake is applied on a moving car, it slows down and comes to rest due to negative acceleration in opposite direction. Thus, in the last moment, the v is zero but a is not zero.

3. **The statement (d) is correct**

Reason

When a body is thrown vertically upward, its velocity will be in upward direction which will decrease to zero because the object is moving in the opposite direction to the gravitational force. At the maximum height, its velocity becomes zero. After that the object will move vertically downward and the direction of velocity will be reversed. During the whole process, the magnitude of the acceleration due to gravity remains constant.

Q No. 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 second ball straight downward with the same speed. Which ball will have larger speed when it strikes the ground? Ignore air friction.

Both balls will hit the ground with same speed but at different times.
Case 1: When a ball is thrown upward with initial velocity v_i it will have same velocity v_i when it returns back to the same level. After that the ball will continue its motion in downward direction and hits the ground with velocity v_f.
Case 2: Thus, if the second ball is thrown vertically downward with initial velocity v_i from the same height, it will hit the ground with the same final velocity v_f.

Q No. 3.6: Explain the circumstances in which the velocity v and acceleration a of a 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) Velocity v and acceleration a of a car are parallel, when the car is accelerating as shown in Fig. (a).
ii) Velocity v and acceleration a of a car are antiparallel when the car is decelerating along straight path as shown in Fig. (b).
iii) The velocity 'v' and acceleration 'a' of a car are perpendicular to one another, when car takes a turn along circular road as shown in Fig. (c).
iv) v is zero and a is not zero, when the car is brought at rest from motion.
v) a is zero but v is not zero when the car is moving with uniform speed on straight path.

Q No. 3.7: Motion with constant velocity is a special case of motion with constant acceleration, is this statement true? Discuss.

The statement "motion with constant velocity is special case of motion with constant acceleration" is true.

Reason

Because in this case the velocity remain constant so acceleration of the body is equal to 0 ms^{-2} which is numerically a constant quantity.

Q No. 3.8: Find the change in momentum for an object subjected to a given force for a given time and state the law of motion in terms of momentum.

Consider an object of mass '*m*' moving initially with velocity v_i is acted upon by a constant force *F* for time Δt after which its final velocity becomes v_f then acceleration of the object is given by

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \quad \text{... (1)}$$

From Newton's second law of motion

$$\vec{a} = \frac{\vec{F}}{m} \quad \text{... (2)}$$

Comparing equation (1) and equation (2)

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

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

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

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

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

Which proves that time rate of change of momentum equals the applied force. This is another statement of 2nd law of motion.

Q No. 3.9: Define impulse and show that how it is related to linear momentum?

Impulse

A very large force acting upon a body for short interval of time, is known as impulsive force. The impulsive force varies from instant to instant in the short interval of time. So, it is more convenient to deal with product of force and time, instead of either quantity alone.

"The product of impulsive force and time interval, is called impulse of force".

It is a vector directed along the force and is denoted by $\vec{I}$.

Consider a bat hits a cricket ball with an average force F during time interval t then impulse of force, is given by

$$\vec{I} = \vec{F} \times t \quad \text{...(1)}$$

We know that

$$\vec{F} \times t = \Delta\vec{P} \quad \text{...(2)}$$

From equation (1) and equation (2)

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

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

This shows that impulse of force is equal to changing momentum

Q No. 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?

State law of Conservation of Linear Momentum

Law of conservation of linear momentum states that total linear momentum of an isolated system remains constant.

Importance of an Isolated System

Law of conservation of linear momentum holds for an isolated system of interacting bodies. If system is not completely isolated, the law of conservation of linear momentum is violated and micro level details cannot be explained.

Law is Useful Even Though the System is Not Completely Isolated

In ever day life, the effect of frictional forces and gravitational force is negligible. Thus, law of conservation of momentum can be applied to the systems which are not completely isolated.
For example, firing of gun, and motion of rocket etc.

Q No. 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?

In, elastic collision kinetic energy of the system of interacting bodies remains conserve, where as in, in-elastic collision the kinetic energy of the system of interacting bodies do not remain conserve. In both cases momentum is conserved.

Case of Bouncing Ball

In, elastic collision case of elastic collision, a bouncing ball would return to same height as it was dropped after bouncing from the ground because ball would not lose its kinetic energy during the impact with ground, where as in, inelastic collision bouncing ball would not return to same height as it was dropped after bouncing from the ground because some of kinetic energy of the ball is lost into sound, heat and deformation etc. during the impact with ground.

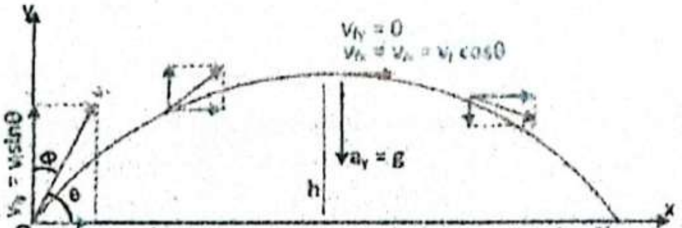
Effect of Kinetic Energy

In most cases, the kinetic energy is not conserved because it is fractionally transformed into heat, sound and work done in deforming system. In kinetic energy of the system of interacting bodies remain conserve, where as in, in-elastic collision the kinetic energy of the system of interacting bodies do not remain conserve.

Q No. 3.12: Explain what is meant by projectile motion. Derive the expression for
(a) Time of flight (b) Range of projectile
Show that the range of the projectile is maximum when the projectile is thrown at an angle of 45°with the horizontal.

Expression of Time of Flight

Consider an object projected with initial velocity v_i at an angle θ with x-axis as shown in Fig. 3.16 (b)



time taken by projectile from point of projection O(0,0) to point of strike S(x,0), is called time of flight. Considering vertical part of projectile motion from point O(0,0) to S(x,0)

$$y=0$$

$$v_{iy}=v_i\sin\theta$$

$$a_y=-g$$

$$t=?$$

Using equation of motion

$$y=v_{iy}t+\frac{1}{2}a_yt^2$$

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

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

$$0=v_i\sin\theta-\frac{1}{2}gt$$

$$\frac{1}{2}gt=v_i\sin\theta$$

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

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

Expression of Height

Maximum vertical distance of projectile is called its max height. Considering upward vertical motion of projectile

$$v_{iy}=v_i\sin\theta$$

$$v_{fy}=0$$

$$a_y=-g$$

$$y=h=?$$

Using equation of motion

$$2a_yy=v_{fy}^2-v_{iy}^2$$

$$2(-g)h=(0)^2-(v_i\sin\theta)^2$$

$$-2gh=0-v_i^2\sin^2\theta$$

$$-2gh=-v_i^2\sin^2\theta$$

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

Q No. 3.11: At what point or points in its path does a projectile have its minimum speed, its maximum speed?

At highest point the projectile has its minimum speed and at the point of projection and point of strike, the projectile has its maximum speed. At highest point vertical component of velocity of the projectile becomes zero but horizontal component has certain constant value. Therefore, speed of projectile at highest point is not zero but has certain minimum value. At the point of projection and point of land, vertical component of velocity has maximum value. Therefore, speed of projectile at point of projection and point of land is maximum as shown in Figure