PHYSICS CLASS XI

CHAPTER – 4 MOTION IN A PLANE

Q.1. Can a body move on a curved path without having acceleration?

Ans. No, a body cannot move on a curved path without acceleration because while moving on a curved path, the velocity of the body changes with time.

Q.2. A particle cannot accelerate if its velocity is constant, why?

Ans. When the particle is moving with a contstant velocity, there is no change in velocity with time and hence, its acceleration is zero.

Q.3. The magnitude and direction of the acceleration of a body both are constant. Will the path of the body be necessarily be a straight line?

Ans. No, the acceleration of a body remains constant, the magnitude and direction of the velocity of the body may change.

Q.4. Give a few examples of motion in two dimensions.

Ans. A ball dropped from an aircraft flying horizontally, a gun shot fired at some angle with the horizontal, etc.

Q.5. A man moving in rain holds his umbrella inclined to the vertical even though the rain drops are falling vertically downwards. Why?

Ans. The man experiences the velocity of rain relative to himself. To protect himself from the rain, the man should hold umbrella in the direction of relative velocity of rain with respect to man.

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Q.6. A football is kicked into the air vertically upwards. What is its (i) acceleration and (iii) velocity at the highest point?

Ans. (i) Acceleration at the highest point = - g

(ii) Velocity at the highest point = 0.

Q.7. Can there be motion in two dimensions with an acceleration only in one dimension?

Ans. Yes, in a projectile motion the acceleration acts vertically downwards while the projectile follows a parabolic path.

Q.8. A stone is thrown vertically upwards and then it returns to the thrower. Is it a projectile ?

Ans. No, it is a projectile. Because a projectile should have two component velocities in two mutually perpendicular directions but in this case, the body has velocity only in one direction while going up or coming down.

Q.9. At what point in its trajectory does a projectile have its

(i) minimum speed and

(ii) maximum speed?

Ans. (i) Projectile has minimum speed at the highest point of its trajectory.

(ii) Projectile has maximum speed at the point of projection.

Q.10. A stone tied at the end of string is whirled in a circle. If the string breaks, the stone flies away tangentially. Why?

Ans. When a stone is going around a circular path, the instantaneous velocity of stone is acting as tangent to the circle. When the string breaks, the centripetal force stops to act. Due to inertia, the stone continues to move along the tangent circular path. So, the stone flies off tangentially to the circular path.

Q.11. The direction of the oblique projectile becomes horizontal at the maximum height. What is the cause of it?

Ans. At the maximum height of projectile, the vertical component velocity becomes zero and only horizontal component velocity of projectile is there.

Q.12. Two bodies are projected at an angle θ and $(\pi/2 - \theta)$ to the horizontal with the same speed. Find the ratio of their time of flight.

Ans. The times of flights are $T_1 = \frac{2u\,sin\theta}{g}$

and $T_2 = \frac{2usin\left(\frac{\pi}{2}-\theta\right)}{g} = \frac{2u\,cos\theta}{g}$

∴ $\frac{T_1}{T_2} = \frac{\sin\theta}{cos\theta} = \tan\theta$.

Q.13. A body is moving on a circular path with a constant speed. What is the nature of its acceleration?

Ans. The nature of its acceleration is centripetal, which is perpendicular to motion at every point and acts along the radius and directed towards the centre of the curved circular path.

Q.14. Is the rocket in flight is an illustration of projectile?

Ans. No, because it is propelled by combustion of fuel and does not move under the effect of gravity alone.

Q.15. Why does a tennis ball bounce higher on hills than in plains?

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Ans. Maximum height attained by a projectile ∝ 1/g. As the value of g is less on hills than on plains, so a tennis ball bounces higher on hills than on plains.

Q.16. The direction of the oblique projectile becomes horizontal at the maximum height. What is the cause of it?

Ans. When the height of projectile is maximum, the vertical component of velocity becomes zero and only horizontal component of velocity of projectile is there.

Q.17. What will be the net effect on maximum height of projectile when its angle of projection is changed from 30° to 60°, keeping the same initial velocity of projection?

Ans. As, $H \propto \sin^2\theta$

$$\Rightarrow \frac{H_1}{H_2} = \frac{(\sin 30°)^2}{(\sin 60°)^2} = \frac{1}{4} \times \frac{4}{3} = \frac{1}{3} \text{ or } H_2 = 3H_1$$

The maximum effect of a projectile is three times the initial vertical height.

Q.18. A person sitting in a running train throws a ball vertically upwards. What is the nature of the path described by the ball to a person?

(i) Sitting inside the train

(ii) Standing on the ground outside the train

Ans. (i) The nature of the path will be vertical straight line because the ball nhas only one velocity acting vertically.

(ii) The nature of the path will be a parabolic path because the ball has the vertical as well as horizontal component velocities.

Q.19. Prove that the horizontal range is same when angle of projection is

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(i) greater than 45° by certain value and

(ii) less than 45° by the same value.

Ans. The horizontal range of the projectile is given by

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

(i) If angle of projection

$\theta = 45° + \propto$ and $R = R_1$

then, $R_1 = \frac{u^2 \sin 2(45°+\propto)}{g} = \frac{u^2}{g} \cos 2\propto$ .... (i)

(ii) If angle of projection

$\theta = 45° - \propto$ and $R = R_2$

∴ $R_2 = \frac{u^2 \sin 2(45°-\propto)}{g} = \frac{u^2}{g} \cos 2\propto$ .... (ii)

Comparing Eqs. (i) and (ii), we have

$$R_1 = R_2$$

Q.20. A stone tied to the end of a string 80 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 s, what is the magnitude and direction of acceleration of the stone?

Ans. Here, r = 80 cm = 0.8 m, f = 14/25 s^{-1}

∴ $w = 2\pi f = 2 \times \frac{22}{7} \times \frac{14}{25} = \frac{88}{25} rad/s$

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The centripetal acceleration

$$a = w^2 r = \left(\frac{88}{25}\right)^2 \times 0.80 = 9.90 \text{ ms}^{-2}$$

The direction of centripetal acceleration is along the string directed towards the centre of circular path.

Q.21. An aircraft executes a horizontal loop of radius 1 km with a steady speed of 900 kmh^{-1}. Compare its centripetal acceleration with the acceleration due to gravity.

Ans. Here, r = 1km = 1000 m,

$v = 900 \text{ kmh}^{-1} = 900 \times (1000 \text{ m})/(60 \times 60 \text{ s})$

$= 250 \text{ ms}^{-1}$

Centripetal acceleration, $a = \frac{v^2}{r} = \frac{(250)^2}{1000}$

Now, $\frac{a}{g} = \frac{(250)^2}{1000} \times \frac{1}{9.8} = 6.38$

Q.22. A bullet fired at an angle of 30° with the horizontal hits the ground 3 km away. By adjusting its angle of projection, can one hope to hit a target 5 km away? Assume the muzzle speed to be fixed, and neglect air resistance.

Ans. Horizontal range

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

or $3 = \frac{u^2 sin 60°}{g} = \frac{u^2}{g}\sqrt{3}/2$ or $\frac{u^2}{g} = 2\sqrt{3}$

Since, the muzzle velocity is fixed

Therefore, maximum horizontal range,

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$R_{max} = \frac{u^2}{g} = 2\sqrt{3}$

$= 3.464$ km

Q.23. Find the angle of projection at which horizontal range and maximum height are equal.

Ans. Horizontal range = Maximum height (given)

$\therefore \quad \frac{u^2}{g} \sin 2\theta = \frac{u^2 sin^2\theta}{2g}$

$\Longrightarrow \quad 2 \sin\theta \cos\theta = \frac{sin^2\theta}{2}$ [$\therefore \sin 2\theta = 2 \cos\theta \sin\theta$]

$\tan\theta = 4 \Longrightarrow \theta = 75° \, 58'$

Q.24. A football is kicked 20m/s at a projection angle of 45°. A receiver on the goal line 25 m away in the direction of the kick runs the same instant to meet the ball. What must be his speed, if he has to catch the ball before it hits the ground.

Ans. Given, u = 20m/s, θ = 45°, d = 25 m

Horizontal range is given by

$R = \frac{u^2}{g} \sin 2\theta = \frac{(20)^2}{9.8} \sin 2(45°)$

$= \frac{400}{9.8} \times 1 = 40.82$ m

Time to flight, $T = \frac{2\,u\,sin\theta}{g} = \frac{2 \times 20}{9.8} \sin 45°$

$= 2.886$ s

The goal man is 25 m away in the direction of the ball, so to catch the ball, he is to cover a distance

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= 40.82 – 25 = 15.82 m in time 2.886 s.

∴ Velocity of the goal man to catch the ball

$$v = \frac{15.82}{2.886} = 5.48 \text{ m/s}$$

Q.25. How does the knowledge of projectile help, a player in the baseball game?

Ans. In the baseball game, a player has to throw a ball so that it goes a certain distance in the minimum time. The time would depend on velocity of ball and angle of throw with the horizontal. Thus, while playing a baseball game, the speed and angle of projection have to be adjusted suitably so that the ball covers the desired distance in minimum time. So, a player has to see the distance and air resistance while playing with a baseball game.

Q.26. A biker stands on the edge of a cliff 490 m above the ground and throws a stone horizontally with an initial speed of 15m/s. Neglecting air resistance, find the time taken by the stone to reach the ground and the speed with which it hits the ground. Consider g = 9.8 m/s^2.

Ans. Given. h = 490 m, u_x = 15 m/s,

a_y = 9.8 m/s, a_x = 0, u_y = 0

Time taken by the stone is

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times 490}{9.8}} = 10\text{s}$$

$v_x = u_x + a_x t = 15 + 0 \times 10 = 15$ m/s

$v_x = u_y + a_y t = 0 + 9.8 \times 10 = 98$ m/s

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{15^2 + 98^2} = 99.14 \text{ m/s}$$

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Q.27. The position of a particle is given by r = 3.0t $\hat{i}$ - 2.0 $t^2\hat{j}$ + 4.0 $\hat{k}$ where, t is in seconds and the coefficients have the proper units for r to be in meters.

(i) Find the v and a of the particle.

(ii) What is the magnitude and direction of velocity of the particle at t = 2s?

Ans. (i) Velocity v = $\frac{dr}{dt} = \frac{d}{dt}$ (3.0t $\hat{i}$ = 2.0$t^2\hat{j}$ + 4.0$\hat{k}$)

= [3.0$\hat{i}$ - 4.0t $\hat{j}$] ms^{-1}

Acceleration a = $\frac{dv}{dt} = \frac{d}{dt}$ (3.0$\hat{i}$ - 4.0t$\hat{j}$)

= 0 – 40 $\hat{j}$ = - 4.0$\hat{j}$ ms^{-2}

(ii) At time t = 2s, v = 3.0$\hat{i}$ - 4.0 × 2$\hat{j}$

= 3.0$\hat{i}$ - 8.0$\hat{j}$

v = $\sqrt{(3.0)^2 + (-8)^2}$

= $\sqrt{73}$ = 8.54 ms^{-1}

If θ is the angle which v makes with x – axis, then

tan $\theta = \frac{v_y}{v_x} = \frac{-8}{3}$ = - 2.667 = - tan 69.5°

∴ θ = 69.5° below the x – axis.

Q.28. A vector has magnitude and direction

(i) Does it have a location in the space ?

(ii) Can it vary with time?

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(iii) Will two equal vectors a and b at different locations in space necessarily have identical physical effects? Give example in support of your answer.

Ans. (i) A vector in general has no definite location in space because a vector remains unaffected whenever it is displaced anywhere in space provided its magnitude and direction do not change. However, a position vector has a definite location in space.

(ii) A vector can vary with time e.g., the velocity vector of an accelerate particle varies with time.

(iii) Two equal vectors at different locations in space do not necessarily have same physical effects. e.g., two equal forces acting at two different points on a body which can cause the rotation of a body about an axis will not produce equal turning effect.

Q.29. The maximum height attained by a projectile is increased by 10% by increasing its speed of projection without changing the angle of projection. What will the percentage increase in the horizontal range?

Ans. As, maximum height H = $\frac{u^2}{2g}\sin^2\theta$

Consider ΔH be the increase in H when u changes by Δ u, it can be obtained by differenting the above equation, we get

$$\Delta H = \frac{2u\,\Delta u\,sin^2\theta}{2g} = \frac{2\Delta u}{u}H \Longrightarrow \frac{\Delta H}{H} = \frac{2\Delta u}{u}$$

Given % increase in H is 10% so

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$$\frac{\Delta H}{H} = \frac{10}{100} = 0.1 \Rightarrow \frac{2\Delta u}{u} = 0.1$$

As, $R = \frac{u^2 sin2\theta}{g}$

∴ $\Delta R = \frac{2u\,\Delta u}{g} \sin 2\theta \Rightarrow \frac{\Delta R}{R} = \frac{2\Delta u}{u} = 0.1$

∴ % increase in horizontal range = $\frac{\Delta R}{R} \times 100$

= 0.1 × 100 = 10%

Q.30. In a flood hit areas of Uttarakhand, helicopter was dropping ration, medicines and other items for the victims. The helicopter was flying at a height of 49 m above the ground. Students of nearby school were helping the authorities to evacuate the victims. They saw a child was drowning. They rushed towards a child with life boat and saved the child.

(i) What is the time taken by the objects dropped from helicopter to reach the ground?

(ii) What values are shown by students ?

Ans. (i) Time taken by the object

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times 49}{9.8}} = 3.16s \qquad [\because h = 49m]$$

(ii) Students are helpful and concerned for others. They are brave and have the ability to act quickly.

Q.32. Hatrick and Peterson were good friends. They went to a international trade fair at Pragati Maidan. Peterson saw a shop, where people were firing at balloons. He also asked the shopkeeper for a gun. Peterson fired three shots but

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none of the shots hit the target and he was quite confused. Hatrick was watching Peterson. He told Peterson to fire at the balloon by taking aim just above the balloon. Peterson acted on his advice of Hatrick and then he successfully hited all the balloons.

(i) What values are shown by Hatrick?

(ii) Hatrick asked Peterson to take aim just above the balloon. Why?

Ans. (i) Hatrick is a good friend. He was concerned with his friend Peterson. He has high degree of general awareness.

(ii) Hatrick knew that the bullet falls under gravity, when fired. It follows a parabolic path. Peterson was firing the bullet by keeping the gun in the line of the sight and hence missing the target. Thus, the bullet has to be fired by keeping the gun tilted above the line of sight to hit the target.

Q.33. A foreigner arrived at Mumbai airport at around 1 AM in the morning. She found a taxi waiting outside. She asked the driver to drop her at the nearby hotel. The taxi driver obliged and drove the foreigner round and round in the city and dropped her at a hotel at around 1:30 AM in the morning.

The hotel was only few kilometre away but he charged her one thousand rupees. While driver was arguing with foreigner, a man from the hotel came out to help her. When he heard that driver was charging one thousand rupees, he scolded him and asked him to charge genuinely and not to spoil their country's name. Driver apologized to foreigner and refunded her eight hundred rupees.

(i) What does this show about the driver?

(ii) The hotel of the foreigner was at a distance of 10 km away from airport on a straight road and dishonest cabman took her along a circuitous path 23 km long and reached the hotel in 28 km. What was the average speed and magnitude of average velocity?

(iii) When is average speed and magnitude of average velocity?

Ans. (i) The honest cabman had put the reputation of the city at stake because of his greed for money. But he realized his mistake and apologized to foreigner.

(ii) Actual length of path travelled = 23 km

Displacement = 10 km

Time taken = 28 min = 28/60 h

Average speed of taxi = $\frac{actual\ path\ length}{time\ taken}$

$= \frac{23}{28/60} = 49.3\ km/h$

Magnitude of average velocity = $\frac{displacement}{time} = \frac{10}{28/60} = 21.4 km/h$

(iii) When an object is moving in a straight line.

Q.34. A particle starts from the origin at t = 0 with a velocity of 10.0 $\hat{j}$ m/s and moves in the x-y plane with a constant acceleration of (8.0 $\hat{i}$ + 2.0 $\hat{j}$) ms^{-2}.

(i) At what time is the x – coordinate of the particle 16 m? What is the y – coordinate of the particle at that time?

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(ii) What is the speed of the particle at that time?

Ans. Here, **u** = 10.0 $\hat{j}$ ms^{-1} at t = 0.

$$\mathbf{a} = \frac{dv}{dt} = (8.0\,\hat{\boldsymbol{i}} + 2.0\,\hat{\boldsymbol{j}})\ ms^{-2}$$

so, dv = (8.0 $\hat{\imath}$ + 2.0 $\hat{\jmath}$) dt

Integrating it within the limits of motion i.e., as time changes from 0 to t, velocity changes u to v, we have

$$\mathbf{v} - \mathbf{u} = (8.0\,\hat{\boldsymbol{i}} + 2.0\,\hat{\boldsymbol{j}})\,t$$

$$\Longrightarrow \quad \mathbf{v} = \mathbf{u} + 8.0t\,\hat{\boldsymbol{i}} + 2.0t\,\hat{\boldsymbol{j}}$$

As, $\mathbf{v} = \frac{d\mathbf{r}}{dt} \Rightarrow d\mathbf{r} = \mathbf{v}\,dt$

So, $d\mathbf{r} = (\mathbf{u} + 8.0t\,\hat{\imath} + 2.0t\,\hat{\boldsymbol{j}})\,dt$

Integrating it within the conditions of motions i.e., as time changes from 0 to t, displacement is from 0 to r, we have

$$\mathbf{r} = \mathbf{u}\,t + \frac{1}{2} \times 8.0t^2\,\hat{\boldsymbol{i}} + \frac{1}{2} \times 2.0t^2\hat{\boldsymbol{j}}$$

or $x\,\hat{\boldsymbol{i}} + y\,\hat{\boldsymbol{j}} = 10\,\hat{\boldsymbol{j}}\,t + 4.0t^2\hat{\boldsymbol{i}} + t^2\,\hat{\boldsymbol{j}}$

$$= 4.0t^2\,\hat{\boldsymbol{i}} + (10\,t + t^2)\,\hat{\boldsymbol{j}}$$

Here we have, x = 4.0 t^2 and y = 10 t + t^2

$\therefore$ $t = (x/4)^{\frac{1}{2}}$

(i) At x = 16 m, $t = (16/4)^{\frac{1}{2}}$ = 2s

$y = 10 \times 2 + 2^2 = 24$ m

(ii) Velocity of the particle at time t is

$\mathbf{v} = 10\,\hat{\boldsymbol{j}} + 80\,t\,\hat{\boldsymbol{i}} + 20t\,\hat{\boldsymbol{j}}$

When t = 2s, then,

$\mathbf{v} = 10\,\hat{\boldsymbol{j}} + 8.0 \times 2\hat{\boldsymbol{i}} + 2.0 \times 2\hat{\boldsymbol{j}} = 16\hat{\boldsymbol{i}} + 14\hat{\boldsymbol{j}}$

∴ Speed = $|\boldsymbol{v}| = \sqrt{16^2 + 14^2}$ = 21.26 ms^{-1}

Q.35. An airline passenger late for a flight walks on an airport moving sidewalk at a speed of 5.00 km/h relative to the sidewalk, in the direction of its motion. The sidewalk is moving at 3.00 km/h relative to the ground and has a total length of 135 m.

(i) What is the passenger's speed relative to the ground?

(ii) How long does it take him to reach the end of the sidewalk?

(iii How much of the sidewalk has he covered by the time he reaches the end?

Ans. The situation is sketched in figure. We assign a letter to each body in relative motion : P passenger, S sidewalk, G ground. The relative velocities $\mathbf{v}_{PS}$ and $\mathbf{v}_{SG}$ are given

$\mathbf{v}_{PS}$ = 5.00 km/h, to the right

$\mathbf{v}_{SG}$ = 3.00 km/h, to the right

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