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Class: XI
Subject: Physics
Topic: Motion in a plane
No. of Questions: 30

Q1. Two stones are projected with the same speed, but are making different angles with the horizontal. Their horizontal ranges are equal. The angle of projection of one is $\pi/3$ and the maximum height reached by it is 102 m. The maximum height reached by the other in metre is

A. 336
B. 224
C. 56
D. 34

Sol: D

Q2. Two railway tracks are parallel to the West-East direction. Along one track, train A moves with a speed of 50 km/h from West to East while along the second track train B moves with a speed of 90 km/h from East to West. The relative velocity of B with respect to A is

A. 110 km/h
B. 120 km/s
C. 130 km/h
D. 140 km/h

Sol: D

Q3. From the top of a tower, a stone is thrown up and reaches the ground in time $t_1 = 9$ s. A second stone is thrown down with the same speed and reaches the ground in time $t_2 = 4$ s. A third stone is released from rest and reaches the ground in time $t_3$, which is equal to

A. 6.5 s
B. 6 s
C. $\frac{5}{36}$ s
D. 65 s

Sol: B

Taking downward motion of the first stone from $A$ to ground, we have

$$h = -ut_1 + \frac{1}{2}gt_1^2 \quad \text{....(1)}$$

Taking downward motion of second stone from $A$ to ground, we have

$$h = ut_2 + \frac{1}{2}gt_2^2 \quad \text{....(2)}$$

Third stone

$$h = \frac{1}{2}gt_3^2 \quad \text{....(3)}$$

Multiplying Eq. (1) by $t_2$ and Eq. (2) by $t_1$ and adding, we get

$$h(t_1 + t_2) = \frac{1}{2}g\,t_1\,t_2(t_1 + t_2)$$

$$\Rightarrow \quad h = \frac{1}{2}gt_1\,t_2$$

From Eqs. (3) and (4), $t_3^2 = t_1 t_2$

or $t_3 = \sqrt{t_1\,t_2} = \sqrt{9 \times 4} = 6\text{ s}$

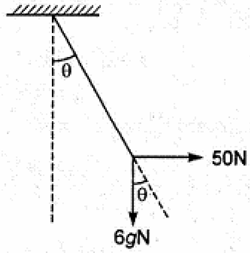
Q4. An object is thrown up against gravity with a velocity of 30 m/s. If the acceleration due to gravity is 10 m/s$^2$, then, the velocity of the body after 2 s is
A. 5 m/s
B. 10 m/s
C. 20 m/s
D. 30 m/s

Sol: B
v = u+at. Here, a is the acceleration due to gravity which acts in the direction opposite to the motion of the body; hence, a= -10m/s$^2$.
So, v = 30 - 10 * 2 = 10 m/s

Q5. A mass of 6 kg is suspended by a rope of length 2 m from a ceiling. A force of 50 N in the horizontal direction is applied at the mid-point of the rope. The angle made by the rope with the vertical, in equilibrium is
A. 50$^o$
B. 60$^o$
C. 30$^o$
D. 40$^o$

Sol: D

$\tan\theta = \frac{50}{6g} = 0.83$




or $\tan\theta = \tan 40^\circ$

or $\theta = 40^\circ$

Q6. A body is projected vertically up with a velocity 'v' and after some time it returns to the point from which it was projected. The average velocity and average speed of the body for the total flight are

A. v and v/2
B. 0 and v/2
C. 0 and 0
D. v and 0

Sol: B

Net displacement is zero. So, average velocity is zero.Average speed = (0 + v)/2 = v/2

Q7. A car is moving on a circular path of radius 500 m with an instantaneous speed of 30 m/s. If its speed is increasing at the rate of 2 $m/s^2$, what will be the resultant acceleration at that instant?

A. 3.0 $m/s^2$
B. 4.5 $m/s^2$
C. 2.7 $m/s^2$
D. 6.0 $m/s^2$

Sol: C

Q8. A projectile can have the same range 'R' for two angles of projection. If $T_1$ and $T_2$ be the time of flights in the two cases, the product of the two times of flights will be directly proportional to

A. $1/R^2$
B. $1/R$
C. $R$
D. $R^2$

Sol: C

Let the angle of projection are
$\theta$ and $(\pi/2-\theta)$

$$T_1 = \frac{2u\sin\theta}{g}$$

$$T_2 = \frac{2u\sin(\pi/2-\theta)}{g}$$

$$T_1 \times T_2 = \frac{4u^2\sin\theta\cos\theta}{g^2}$$

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

Q9. A car runs at a constant speed on a circular track of radius 100 m, taking 62.8 sec for every circular lap. What will be the respective average velocity and average speed for each circular lap?

A. 0, 0
B. 0, 10 m/s
C. 10 m/s, 10 m/s
D. 10 m/s, 0

Sol: B

Q10. A ball is released from the top of a tower of height 'h' metres. It takes 'T' seconds to reach the ground. What is the position of the ball from earth in T/3 seconds?

A. h/9 metre from the ground
B. 7h/9 metre from the ground
C. 8h/9 metre from the ground
D. 17h/18 metre from the ground

Sol: C

$$h = \frac{1}{2}gT^2$$

$$h' = \frac{1}{2}g\left(\frac{T}{3}\right)^2$$

$$h' = \frac{h}{9}$$

$$h - h' = \frac{8}{9}h$$

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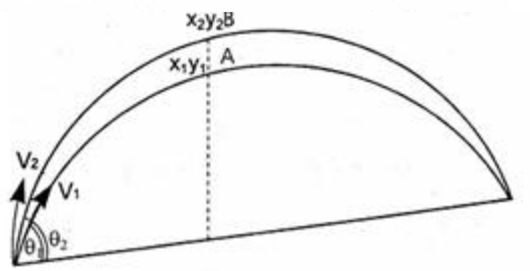
Q11. Two balls are projected simultaneously in the same vertical plane from the same point with velocities $V_1$ and $V_2$ with angles $\theta_1$ and $\theta_2$ respectively with the horizontal. If $V_1 \cos \theta_1 = V_2 \cos \theta_2$, the path of one ball as seen from the position of other ball is

A. parabola
B. horizontal straight line
C. vertical straight line
D. straight line making $45^o$ with the vertical

Sol: C

For the ball projected with velocity $V_1$ at an angle $\theta_1$ with horizontal line, the horizontal distance covered after $t$ time.




$$x_1 = V_1 \cos\theta_1 t$$

Similarly, for second ball throw with velocity $V_2$ at an angle $\theta_2$ with horizontal, horizontal distance covered after time $t$.

$$x_2 = V_2 \cos\theta_2 t$$

The vertical distances covered are

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$$y_1 = V_1 \sin\theta_1 \, t - \frac{1}{2}gt^2$$

and $$y_2 = V_2 \sin\theta_2 t - \frac{1}{2}gt^2$$

$\therefore \quad x_2 - x_1 = (V_2\cos\theta_2 - V_1\cos\theta_1)t$

and $y_2 - y_1 = (V_2\sin\theta_2 - V_1\sin\theta_1)t$

$$\therefore \frac{y_2 - y_1}{x_2 - x_1} = \frac{V_2\sin\theta_2 - V_1\sin\theta_1}{V_2\cos\theta_2 - V_1\cos\theta_1}$$

but $V_1\cos\theta_1 = V_2\cos\theta_2$

$$\therefore \frac{y_2 - y_1}{x_2 - x_1} = \frac{V_2\sin\theta_2 - V_1\sin\theta_1}{0} = \infty$$

$\Rightarrow \quad x_2 - x_1 = 0$

and $\quad y_2 - y_1 = \infty$

This means line joining the position of particles after time $t$ will be a straight line and parallel to the $y$-axis.

Q12. A particle is displaced from a position $(2\vec{i} - \vec{j} + \vec{k})$ to another position $(3\vec{i} + 2\vec{j} - 2\vec{k})$ under the action of the force of $(2\vec{i} + \vec{j} - \vec{k})$. The work done by the force in an arbitrary unit is

A. 8
B. 10
C. 12
D. 16

Sol: A

Work done

$$W = \vec{\mathbf{F}} \cdot \vec{\mathbf{r}}$$

$$= (2\hat{\mathbf{i}} + \hat{\mathbf{j}} - \hat{\mathbf{k}}) \cdot [(3\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - 2\hat{\mathbf{k}}) - (2\hat{\mathbf{i}} - \hat{\mathbf{j}} + \hat{\mathbf{k}})]$$

$$= (2\hat{\mathbf{i}} + \hat{\mathbf{j}} - \hat{\mathbf{k}}) \cdot (\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 3\hat{\mathbf{k}})$$

$$= 2 + 3 + 3$$

$$= 8 \text{ unit}$$

Directions: The following question has four choices out of which ONLY ONE is correct.

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Q13. A bomber plane is moving horizontally with a speed of 500 m/s and a bomb released from it strikes the ground in 10 sec. The angle with the horizontal at which the bomb strikes the ground is ($g = 10\ m/s^2$)

A. $\tan^{-1}(1)$
B. $\tan^{-1}(5)$
C. $\tan^{-1}\left(\frac{1}{5}\right)$
D. $\sin^{-1}\left(\frac{1}{5}\right)$

Sol: C

Let the vertical component of velocity when the bomb strikes the ground = $V_v$
Let the horizontal component of velocity when the bomb strikes the ground = $V_H V_v = 0 + gt$
where t = 10 sec$V_v = 10 * 10 = 100$ m/s
$V_H = 500$ m/s

Tan $\theta$ = $\frac{V_V}{V_H} = \frac{100}{500} = \frac{1}{5}$

Hence, $\theta = tan^{-1}\left(\frac{1}{5}\right)$.

Q14. What should be the speeds of two persons such that when they move uniformly towards each other, they get 3.0 m closer each second and when they move uniformly in the same direction with the original speeds, they get 3.0 m closer each 10 sec?

A. 1.35 m/s
B. 13.5 m/s
C. 135 m/s
D. 0.135 m/s

Sol: A

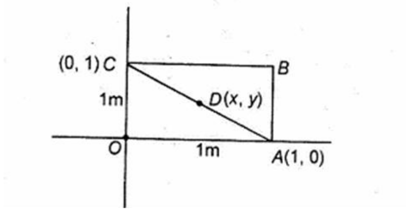
Q15. Four particles, each of mass 1 kg are placed at the corners of a square OABC of side 1 m. 'O' is at the origin of the co-ordinate system. OA and OC are aligned along positive X-axis and positive Y-axis respectively. The position vector of the centre of mass is (in 'm')

A. i+j
B. 0.5(i+j)
C. (i-j)
D. 0.5(i-j)

Sol: B

We can show the situation as :
The centre of mass of square is at point $D(x, y)$.
The position co-ordinate of point $D$

$$(x, y) \equiv \left(\frac{0+1}{2}, \frac{1+0}{2}\right)$$




$$\equiv \left(\frac{1}{2}, \frac{1}{2}\right)$$

Hence, position vector or centre of mass $D$ is

$$= x\hat{\mathbf{i}} + y\hat{\mathbf{j}}$$
$$= \frac{1}{2}\hat{\mathbf{i}} + \frac{1}{2}\hat{\mathbf{j}}$$
$$= \frac{1}{2}(\hat{\mathbf{i}} + \hat{\mathbf{j}})$$

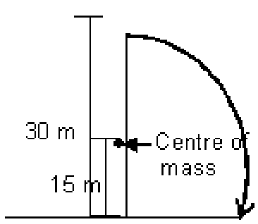
Q16. A pole is held vertically with one end on ground. The length of the pole is 30 m. The pole is allowed to fall. Assuming that lower end of the pole does not slip, the upper end will strike the ground with a velocity of ($g = 10$ m $s^{-2}$)

A. 5 $ms^{-1}$
B. 10 $ms^{-1}$
C. 20 $ms^{-1}$
D. 30 $ms^{-1}$

Sol: D

Change in potential energy = mg x 15 = 15 mg
Change in kinetic energy = 15 mg

$$\frac{I}{2}\omega^2 - 0 = 15 \text{ mg}$$ (about point in contact with ground)




$$\frac{ml^2\omega^2}{2 \times 3} = 15 \text{ mg}$$

$$\frac{30 \times 30 \times \omega^2}{6} = 15$$

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$10\omega^2 = 10$
$\omega^2 = 1$
$\omega = 1$
$V = r\omega$
$= 30$ m x 1 rad/s
$= 30$ m/s

Q17. A body of mass 'm' has a kinetic energy equal to one-fourth kinetic energy of another body of mass $\frac{m}{4}$. If the speed of the heavier body is increased by 4 m/s, its new kinetic energy equals to the original kinetic energy of the lighter body. The original speed of the heavier body in m/s is

A. 8
B. 6
C. 4
D. 2

Sol: C

$$\frac{1}{2}mv_1^2 = \frac{1}{4} * \frac{1}{2} * \frac{m}{4}v_2^2$$

$$v_1^2 = \frac{v_2^2}{16} \qquad 4v_1 = v_2$$

Speed of body of mass m = $v_1 + 4$

$$\frac{1}{2}m(v_1+4)^2 = \frac{1}{2}\frac{m}{4}v_2^2$$

$$v_1 + 4 = \frac{v_2}{2}$$

$$v_1 = 4m/s$$

Q18. A car is moving in a circular track of radius 10 m with a constant speed of 10 m/s. A plumb bob is suspended from the roof of the car by a light rigid rod of length 1m . The angle made by the rod with the vertical is

A. $0^o$
B. $30^0$
C. $45^0$
D. $60^0$

Sol: C

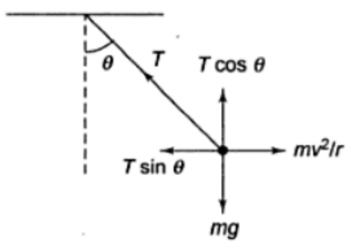
The forces acting on the bob are: (i) its weight mg and (ii) Tension from the rod = T. Resolving T into components along horizontal and vertical directions as shown in the figure. mg = T cos $\theta$ …….(1)

and T sin $\theta$ = $F_c$ …….(2) where $F_c$ = centripetal force

From (2), T sin $\theta$ = $\frac{mv^2}{r}$ Dividing eq (1) and (2)We get,

$\Rightarrow$ tan $\theta$ = $\frac{v^2}{rg}$ = $\frac{(10)^2}{10\times10}$ = 1

Thus, $\theta$ = $45^0$




Q19. Two bodies are thrown up at angles of $45^o$ and $60^o$, respectively with the horizontal. If both the bodies attain the same vertical height, the ratio of velocities with which these are thrown is

A. $\sqrt{1/3}$

B. $2/\sqrt{3}$

C. $\sqrt{3/2}$

D. $\sqrt{2/3}$

Sol: C

Let body be projected at an angle θ with the horizontal with a velocity $u$. The height attained is given by

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

Given, $H_1 = H_2$

$$\therefore \quad \frac{u_1^2 \sin^2\theta_1}{2g} = \frac{u_2^2 \sin^2\theta_2}{2g}$$

$$\Rightarrow \quad \frac{u_1}{u_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

$$\Rightarrow \quad \frac{u_1}{u_2} = \frac{\sin 60^\circ}{\sin 45^\circ}$$

$$\Rightarrow \quad \frac{u_1}{u_2} = \frac{\sqrt{3}/2}{1/\sqrt{2}}$$

$$\Rightarrow \quad \frac{u_1}{u_2} = \sqrt{\frac{3}{2}}.$$

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Q20. A motorcycle moving with a velocity of 72 km/hour on a flat road takes a turn on the road at a point where the radius of curvature of the road is 20 m. The acceleration due to gravity is 10 m / $s^2$. In order to avoid skidding, he must not bent with respect to the vertical plane by an angle greater than

A. $\Theta = \tan^{-1}(2)$
B. $\Theta = \tan^{-1}(6)$
C. $\Theta = \tan^{-1}(4)$
D. $\Theta = \tan^{-1}(25.92)$

Sol: A

Using the formula for motor cycle not ot to skid

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

where $r = 20$ m

$$v = 72 \text{ km/hour}$$
$$= 72 \times \frac{5}{18} = 20 \text{ m/s}$$

$$\therefore \quad \theta = \tan^{-1}\left(\frac{20 \times 20}{20 \times 10}\right)$$

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

Q21. What will be the effect on horizontal range of a projectile when its initial velocity is doubled, keeping the angle of projection same?

Sol. Four times the initial horizontal range.

Q22. What will be the effect on maximum height of a projectile when its angle of projection is changed from $30^o$ to $60^o$, keeping the same initial velocity of projection?

Sol. Three times the initial vertical height.

Q23. What is the angular velocity of the hour hand of a clock?

Sol. □□□6 radian per hour.

Q24. A body is moving on a curved path with a constant speed. What is the nature of its acceleration?

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Sol. Acceleration must be perpendicular to the direction of motion and is called centripetal acceleration.

Q25. A stone tied at the end of string is whirled in a circle. If the string breaks, the stone flies away tangentially. Why?

Sol. When a stone is moving around a circular path, its velocity acts tangent to the circle. When the string breaks, the centripetal force will not act. Due to inertia, the stone continues to move along the tangent to circular path, and flies off tangentially to the circular path.

Q26. What are the two angles of projection of a projectile projected with velocity 30m/s, so that the horizontal range is 45m. Take, g = 10m/s$^2$.

Sol. $R = \frac{u^2 \sin 2\theta}{g} = \frac{(30)^2 \sin 2\theta}{10} = 45$

$\Rightarrow \sin 2\,\theta = \frac{450}{(30)^2}$

$\sin 2\theta = 1/2$

$2\theta = 30^o\ or\ 150^o \Rightarrow \theta\ 15^o\ or\ 75^o$

Q27. The blades of an aeroplane propeller are rotating at the rate of 600 revolutions per minute. Calculate its angular velocity.

Sol. $v = 600$ revolutions/min

$v = \frac{600}{60}$ revolutions/sec.

$w = 2\pi v = 2 \times \pi \times \frac{600}{60}$

$w = 20\pi\ rdd\ /\ s$

Q28. What is a uniform circular motion? Explain the terms time period, frequency and angular velocity. Establish relation between them.

Sol. When an object moves in a circular path with constant speed then the motion is called uniform circular motion

Time period – The time taken by the object to complete one revolution

Frequency – The total number of revolutions in one second is called the frequency.

Angular velocity – It is defined as the time rate of change of angular displacement.

$W = \frac{2\pi}{T} = 2\pi v \qquad \left(\because \frac{1}{T} = v\right)$

Q29. A body of mass m is thrown with velocity '��' at angle of 30$^o$ to the horizontal and another body B of the same mass is thrown with velocity ��at an angle of 60$^o$ to the horizontal. Find the ratio of the horizontal range and maximum height of A and B?

Sol. (1) When $\theta = 30^o$ $R_A = \frac{\mu^2}{g} \sin 2\,(30^o)$

$R_A = \frac{\mu^2}{g} \times \frac{\sqrt{3}}{2}$

When $\theta = 60^o$ $R_B = \frac{\mu^2}{g} sin2\ (60^o)$

$R_B = \frac{\mu^2}{g} \times \frac{\sqrt{3}}{2}$

$R_A : R_B = 1 : 1$

(2) When $\theta = 30^o H_A = \frac{\mu^2}{g} \sin^2 30^o$

$H_A = \frac{\mu^2}{2g}\left(\frac{1}{4}\right)$

When $\theta = 60^o H_B = \frac{\mu^2}{2g} sing^2 60^o$

$H_B = \frac{\mu^2}{g}\left(\frac{3}{4}\right)$

$H_A : H_B = 1 : 3$

Q30. At what point of projectile motion (i) potential energy maximum (ii) Kinetic energy maximum (iii) total mechanical energy is maximum

Sol. (1) P.E. Will be maximum at the highest point

(P.E.) highest point = mgH

$(P.E.)_H = mg\left(\frac{\mu^2 \sin^2 \theta}{2g}\right)$

$(P.E.)_H = \frac{1}{2} m\mu^2 \sin^2 \theta$

(2) K.E. will be minimum at the highest point

$(K. E.)_H = \frac{1}{2} m\ (v_H)^2$

(Vertical component of velocity is zero)

$(K.E.)_H = \frac{1}{2} \vartheta \cos^2 \theta$

(3) Total mechanical energy

$(K.E.)_H + (P.E.)_H$

$\frac{1}{2} mu^2 \cos^2 \theta + \frac{1}{2} mu^2 \sin^2 \theta$

$\frac{1}{2} mu^2 (\cos^2 \theta + \sin^2 \theta)$

$\frac{1}{2} m\, u^2$