Chapter

3 Motion in a Plane

TYPE A : MULTIPLE CHOICE QUESTIONS

1. Rain is falling vertically downwards with a velocity of 3 km/hr. A man walks in the rain with a velocity of 4 km/hr. The rain drop will fall on the man with a velocity of ***[1997]***
(a) 5 km/hr (b) 4 km/hr
(c) 1 km/hr (d) 3 km/hr

2. A body of mass 5 kg is moving in a circle of radius 1 m with an angular velocity of 2 rad/sec. Then the centripetal acceleration (in m/s^2) will be ***[1998]***
(a) 80 N (b) 30 N
(c) 10 N (d) 20 N

3. A body is projected at such angle that the horizontal range is three times the greatest height. The angle of projection is ***[1998]***
(a) 42° 8' (b) 53° 7'
(c) 33° 7' (d) 25° 8'

4. An aeroplane moves 400 m towards the north, 300 m towards west and then 1200 m vertically upwards, then its displacement from the initial position is ***[1998]***
(a) 1600 m (b) 1800 m
(c) 1500 m (d) 1300 m

5. The angle between $\left(\vec{P}+\vec{Q}\right)$ and $\left(\vec{P}-\vec{Q}\right)$ will be
(a) 90° only ***[1999]***
(b) between 0° and 180°
(c) 180° only
(d) none of these

6. Two equal vectors have a resultant equal to either of them, then the angle between them will be ***[2000]***
(a) 110° (b) 120°
(c) 60° (d) 150°

7. A stone tied to the end of a string of 80 cm long, is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 sec, then magnitude of acceleration of the same will be ***[2001]***
(a) 990 cm/sec^2 (b) 680 cm/sec^2
(c) 750 cm/sec^2 (d) 650 cm/sec^2

8. Two projectiles are projected with the same velocity. If one is projected at an angle of 30° and the other at 60° to the horizontal, the ratio of maximum heights reached, is ***[2001]***
(a) 1 : 3 (b) 2 : 1
(c) 3 : 1 (d) 1 : 4

9. A stone tied to a string is rotated with a uniform speed in a vertical plane . If mass of the stone is m, the length of the string is r and the linear speed of the stone is v, when the stone is at its lowest point, then the tension in the string will be (g = acceleration due to gravity) ***[2001]***
(a) $\frac{mv^2}{r}+mg$ (b) $\frac{mv^2}{r}-mg$
(c) $\frac{mv}{r}$ (d) mg

10. At the uppermost point of a projectile, its velocity and acceleration are at an angle of
(a) 180° (b) 90° ***[2002]***
(c) 60° (d) 45°

11. If vectors $\vec{P}=a\hat{i}+a\hat{j}+3\hat{k}$ and $Q=a\hat{i}-2\hat{j}-\hat{k}$ are perpendicular to each other, then the positive value of a is ***[2002]***
(a) zero (b) 1
(c) 2 (d) 3

12. The maximum range of a gun horizontal terrain is 10 km. If g = 10 m/s^2 what must be the muzzle velocity of the shell ***[2004]***
(a) 400 m/s (b) 200 m/s
(c) 100 m/s (d) 50 m/s

13. A projectile can have the same range R for two angles of projection. If t_1 and t_2 be the times of flights in the two cases, then the product of the two time of flights is proportional to ***[2006]***
(a) $\frac{1}{R^2}$ (b) R^2
(c) R (d) $\frac{1}{R}$

14. A car travels 6 km towards north at an angle of 45° to the east and then travels distance of 4 km towards north at an angle 135° to east. How far is the point from the starting point? What angle does the straight line joining its initial and final position makes with the east? ***[2008]***

(a) $\sqrt{50}$ km and $\tan^{-1}(5)$

(b) 10 km and $\tan^{-1}(\sqrt{5})$

(c) $\sqrt{52}$ km and $\tan^{-1}(5)$

(d) $\sqrt{52}$ km and $\tan^{-1}(\sqrt{5})$

15. If two forces of equal magnitudes act simultaneously on a body in the east and the north directions then ***[2009]***

(a) the body will displace in the north direction
(b) the body will displace in the east direction
(c) the body will displace in the north-east direction
(d) the body will remain at the rest.

16. Two vectors having equal magnitudes of x units acting at an angle of 45° have resultant $\sqrt{(2+\sqrt{2})}$ units. The value of x is ***[2009]***

(a) 0 (b) 1

(c) $\sqrt{2}$ (d) $2\sqrt{2}$

17. If R and H represent the horizontal range and the maximum height achieved by a projectile then which of the relation exists? ***[2009]***

(a) $\frac{H}{R} = 4\cot\theta$ (b) $\frac{R}{H} = 4\cot\theta$

(c) $\frac{H}{R} = 4\tan\theta$ (d) $\frac{R}{H} = 4\tan\theta$

18. The acceleration of a body in a non-uniform circular motion is 5 ms^{-2}. Which one of the following is correct? ***[2009]***

(a) The radial acceleration and the tangential accelerations are 3 ms^{-2} and 4 ms^{-2} respectively.
(b) The radial and the tangential accelerations are 2 ms^{-2} and 3 ms^{-2} respectively.
(c) The radial and the tangential accelerations are both 5 ms^{-2}.
(d) The radial and the tangential acceleration are 5 ms^{-2} and 3 ms^{-2} respectively.

19. An aircraft executes a horizontal loop with a speed of 150 m/s with its wings banked at an angle of 12°. The radius of the loop is ($g = 10$ m/s^2) ***[2010]***

(a) 10.6 km (b) 9.6 km
(c) 7.4 km (d) 5.8 km

20. For ordinary terrestrial experiments, the observer in an inertial frame in the following cases is ***[2010]***

(a) a child revolving in a giant wheel
(b) a driver in a sports car moving with a constant high speed of 200 kmh^{-1} on a straight road
(c) the pilot of an aeroplane which is taking off
(d) a cyclist negotiating a sharp curve

21. For a particle in a uniformly accelerated circular motion ***[2011]***

(a) velocity is radial and acceleration has both radial and transverse components
(b) velocity is transverse and acceleration has both radial and transverse components
(c) velocity is radial and acceleration is transverse only
(d) velocity is transverse and acceleration is radial only

22. For a given angle of the projectile if the initial velocity is doubled the range of the projectile becomes ***[2011]***

(a) Half (b) One -fourth
(c) Two times (d) Four times

23. If we can throw a ball upto a maximum height H, the maximum horizontal distance to which we can throw it is ***[2011]***

(a) 2H (b) $\sqrt{2}$H

(c) H (d) $\frac{H}{2}$

24. The vector sum of two forces is perpendicular to their vector differences. In that case, the forces ***[2012]***

(a) cannot be predicted
(b) are equal to each other
(c) are equal to each other in magnitude
(d) are not equal to each other in magnitude

25. A projectile can have the same range for two angles of projection. If h_1 and h_2 are maximum heights when the range in the two cases is R, then the relation between R, h_1 and h_2 is ***[2013]***

(a) $R = 4\sqrt{h_1 h_2}$ (b) $R = 2\sqrt{h_1 h_2}$

(c) $R = \sqrt{h_1 h_2}$ (d) None of these

26. A projectile thrown with velocity v making angle θ with vertical gains maximum height H in the time for which the projectile remains in air, the time period is ***[2013]***

(a) $\sqrt{H\cos\theta/g}$ (b) $\sqrt{2H\cos\theta/g}$

(c) $\sqrt{4H/g}$ (d) $\sqrt{8H/g}$

27. A bomb is released from a horizontal flying aeroplane. The trajectory of bomb is ***[2013]***

(a) a parabola (b) a straight line

(c) a circle (d) a hyperbola

28. A stone tied to the end of a string of 1 m long is whirled in a horizontal circle with a constant speed. If the stone makes 22 revolution in 44 seconds, what is the magnitude and direction of acceleration of the stone? ***[2014]***

(a) π^2 m s^{-2} and direction along the radius towards the centre.

(b) π^2 m s^{-2} and direction along the radius away from the centre.

(c) π^2 m s^{-2} and direction along the tangent to the circle.

(d) $\pi^2/4$ m s^{-2} and direction along the radius towards the centre.

29. Two projectiles are fired from the same point with the same speed at angles of projection 60º and 30º respectively. Which one of the following is true? ***[2014]***

(a) Their maximum height will be same

(b) Their range will be same

(c) Their landing velocity will be same

(d) Their time of flight will be same

30. A ball is thrown from a point with a speed 'v_0' at an elevation angle of θ. From the same point and at the same instant, a person starts running with a constant speed $\frac{'v_0'}{2}$ to catch the ball. Will the person be able to catch the ball? If yes, what should be the angle of projection θ ? ***[2016]***

(a) No (b) Yes, 30°

(c) Yes, 60° (d) Yes, 45°

31. A boy playing on the roof of a 10 m high building throws a ball with a speed of 10m/s at an angle of 30º with the horizontal. How far from the throwing point will the ball be at the height of 10 m from the ground ? ***[2017]***

$[g = 10 m/s^2, \sin 30^o = \frac{1}{2}, \cos 30^o = \frac{\sqrt{3}}{2}]$

(a) $5\sqrt{5}$ (b) 6

(c) 3 (d) $5\sqrt{3}$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Q. 32) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

32. **Assertion :** If a body is thrown upwards, the distance covered by it in the last second of upward motion is about 5 m irrespective of its initial speed

Reason : The distance covered in the last second of upward motion is equal to that covered in the first second of downward motion when the particle is dropped. ***[2000]***

Directions for (Qs.33-37) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

33. **Assertion :** The driver in a vehicle moving with a constant speed on a straight road is an inertial frame of reference.

    Reason : A reference frame in which Newton's laws of motion are applicable is non-inertial. ***[2009]***

34. **Assertion :** A tennis ball bounces higher on hills than in plains.

    Reason : Acceleration due to gravity on the hill is greater than that on the surface of earth. ***[2009]***

35. **Assertion :** When a particle moves in a circle with a uniform speed, its velocity and acceleration both changes.

    Reason : The centripetal acceleration in circular motion is dependent on angular velocity of the body. ***[2010]***

36. **Assertion :** Centripetal and centrifugal forces cancel each other.

    Reason : Centrifugal force is a reaction of centripetal force. ***[2011]***

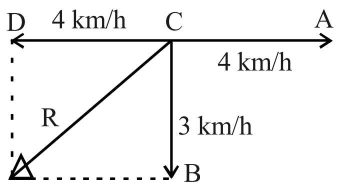
37. **Assertion :** The magnitude of velocity of two boats relative to river is same. Both boats start simultaneously from same point on one bank may reach opposite bank simultaneously moving along different paths.

    Reason : For boats to cross the river in same time. The component of their velocity relative to river in direction normal to flow should be same. ***[2015]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)**



In the figure, CB represents velocity of rain, CA represents velocity of the man. To find relative velocity of the rain with respect to man we add a velocity equal to that of man in opposite direction to the velocity of rain. It has been depicted by line CD. Now rain has two velocities simultaneously. Their resultatnt,

$R^2 = 4^2 + 3^2 \Rightarrow R = 5$

which gives us the value of relative velocity of rain.

2. **(d)** Centripetal acceleration $= \omega^2 r = 2 \times 2 \times 1$
$= 4\ m/s^2$

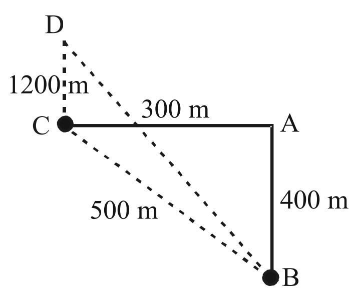
3. **(b)** $R = 3H;\ R = \dfrac{u^2 \sin 2\theta}{g}; H = \dfrac{u^2 \sin^2\theta}{2g}$

$$\frac{u^2 \sin 2\theta}{g} = \frac{3u^2 \sin^2\theta}{2g}$$

$$2\sin\theta\cos\theta = \frac{3\sin^2\theta}{2}$$

$$\tan\theta = \frac{4}{3} \Rightarrow \theta = 53°7'$$

4. **(d)**

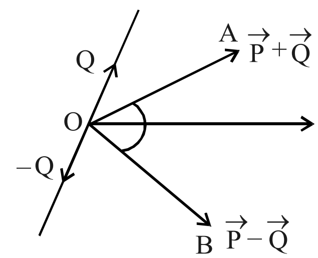


Here CD is perpendicular to the plane of paper. Required distance = BD

$BD^2 = CB^2 + CD^2 = 500^2 + 1200^2$

$BD = \sqrt{500^2 + 1200^2} = 1300m$

5. **(b)**



In the figure $\overrightarrow{OA}$ represents $(\vec{P} + \vec{Q})$, $\overrightarrow{OB}$ represents $(\vec{P} - \vec{Q})$. It is clear from the figure that angle between $\overrightarrow{OA}$ and $\overrightarrow{OB}$ may be between 0° and 180°.

6. **(b)** Applying the formula,

$$R^2 = P^2 + Q^2 + 2PQ\cos\alpha$$

$$P^2 = P^2 + P^2 + 2PP\cos\alpha$$

$$= 2P^2 + 2P^2\cos\alpha = 2P^2(1 + \cos\alpha)$$

$$1 + \cos\alpha = \frac{1}{2} \Rightarrow 2\cos^2\frac{\alpha}{2} = \frac{1}{2}$$

$$\cos^2\frac{\alpha}{2} = \frac{1}{4} \Rightarrow \cos\frac{\alpha}{2} = \frac{1}{2} = \cos 60°$$

$$\frac{\alpha}{2} = 60° \Rightarrow \alpha = 120°$$

7. **(a)** Centripetal $acc^n = \omega^2 r = (2\pi n)^2 \times r$

where frequency, $n = \dfrac{14}{25}$

$$\therefore acc^n = 4 \times \frac{22}{7} \times \frac{22}{7} \times \frac{14}{25} \times \frac{14}{25} \times 80$$

$$= 990\ cm/sec^2$$

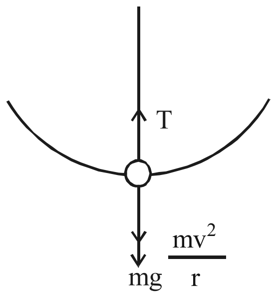
8. **(a)** For maximum height

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

$$H_1 = \frac{u^2 \sin^2 30°}{2g};\ H_2 = \frac{u^2 \sin^2 60°}{2g}$$

$$H_1 : H_2 = \sin^2 30° : \sin^2 60° = \frac{1/4}{3/4} = 1 : 3$$

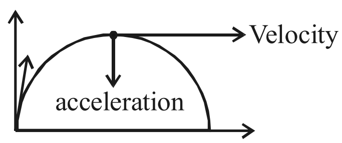
9. (a)



At the lowest point, as shown in the figure both mg and centrifugal force $\frac{mv^2}{r}$ will act in the same direction so,

$$T = mg + \frac{mv^2}{r}$$

10. (b)



As the figure implies, velocity acts in horizontal direction and acceleration due to gravity acts in vertical direction. So, angle between them is 90°.

11. (d) If $\vec{P}$ and $\vec{Q}$ are perpendicular to each other then $\vec{P}.\vec{Q} = 0$

(where vector $\vec{P} = a\hat{i} + a\hat{j} + 3\hat{k}$ and $\vec{Q} = a\hat{i} - 2\hat{j} - \hat{k}$)

$(a\hat{i} + a\hat{j} + 3\hat{k})(a\hat{i} - 2\hat{j} - \hat{k}) = 0$

$a^2 - 2a - 3 = 0 \Rightarrow (a-3)(a+1) = 0$

$a - 3 = 0 \Rightarrow a = 3$ and $a = -1$

12. (a) For maximum range

$$R = \frac{u^2}{g} \Rightarrow u^2 = gR$$

$u^2 = 16,000 \times 10 \Rightarrow u = 4 \times 100$

$u = 400 m/sec$

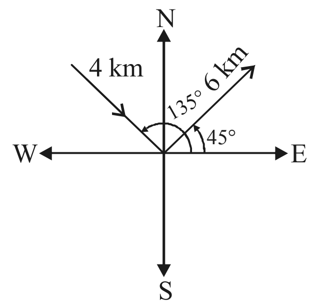
13. (c) $t_1 t_2 = \frac{2R}{g}$ (It is a formula)

$t_1 t_2 \propto R$

14. (c) Net distance travellel along x-direction,

$S_x = 6\cos 45°\hat{i} - 4\cos 45°\hat{i}$

$= 2 \times \frac{1}{\sqrt{2}} = \sqrt{2}$ km



Net distance travelled along y-direction

$S_y = 6\sin 45°\hat{j} + 4\sin 45°\hat{j}$

$= 10 \times \frac{1}{\sqrt{2}} = 5\sqrt{2}$ km

$\therefore$ Net distance travelled from the starting point,

$S = \sqrt{S_x{}^2 + S_y{}^2} = \sqrt{(\sqrt{2})^2 + (5\sqrt{2})^2}$

$= \sqrt{2 + 25 \times 2} = \sqrt{52}$ km

Angle which the resultant makes with the east direction

$\tan\theta = \frac{y}{x} = \frac{5\sqrt{2}}{\sqrt{2}}$ or $\theta = \tan^{-1}(5)$

15. (c) The resultant $\vec{F}$ of two forces $\vec{F}_1$ and $\vec{F}_2$ acting in the east and the north direction respectively will act in the north- east direction as per the parallelogram law of vector addition.

16. (b) Here, $P = x$ units, $Q = x$ units, $\theta = 45°$

$R = \sqrt{(2 + \sqrt{2})}$ units

We have, $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

or, $R = \sqrt{x^2 + x^2 + 2.x.x\cos 45°}$

or, $\sqrt{(2+\sqrt{2})} = \sqrt{2x^2 + 2x^2\frac{1}{\sqrt{2}}}$

$= \sqrt{2x^2 + \sqrt{2}x^2}$

or, $\sqrt{(2+\sqrt{2})} = \sqrt{x^2(2+\sqrt{2})}$

or, $\sqrt{(2+\sqrt{2})} = x\sqrt{(2+\sqrt{2})} \Rightarrow x = 1$

17. **(b)** $R = \frac{u^2 \sin 2\theta}{g} = \frac{2u^2 \sin\theta.\cos\theta}{g}$

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

$\therefore \frac{H}{R} = \frac{u^2 \sin^2\theta}{2g} \times \frac{g}{2u^2 \sin\theta.\cos\theta}$

$= \frac{\sin\theta}{4\cos\theta}$

$\Rightarrow \frac{R}{H} = \frac{4\cos\theta}{\sin\theta}$ or, $\frac{R}{H} = 4\cot\theta$

18. **(a)** The acceleration of a body in a non-uniform circular motion is the resultant of the radial and the tangential accelerations. If

$a_r = 3\ ms^{-2}$ and $a_t = 4\ ms^{-2}$

then, $a = \sqrt{a_r^2 + a_t^2} = \sqrt{(3)^2 + (4)^2}$

$= \sqrt{9+16} = \sqrt{25} = 5\ ms^{-2}$

19. **(a)** Using the relation for the radius (r) of loop

$\tan\theta = \frac{v^2}{rg}$

or $\tan 12^\circ = \frac{(150)^2}{r \times 10}$

or $r = \frac{2250}{0.2125} = 10.6 \times 10^3\ m = 10.6\ km.$

20. **(b)** The car moving with a constant velocity has no acceleration. Hence, it is an inertial frame.

21. **(b)** For a uniformly accelerated motion there are two acceleration, one along the radius called radial acceleration and another along tangent called tangential acceleration. Velocity is directed along the tangent.

22. **(d)** $R = \frac{u^2 \sin 2\theta}{g}$

$R' = \frac{(2u)^2 \sin 2\theta}{g} = 4R.$

23. **(a)** $H = \frac{u^2}{2g} \Rightarrow u^2 = 2gH$

For maximum horizontal distance

$x_{max} = \frac{u^2}{g} = \frac{2gH}{g} = 2H$

24. **(c)** $\vec{P}$ = vector sum $= \vec{A} + \vec{B}$

$\vec{Q}$ = vector differences $= \vec{A} - \vec{B}$

Since $\vec{P}$ and $\vec{Q}$ are perpendicular

$\therefore \vec{P}.\vec{Q} = 0$

$\Rightarrow (\vec{A}+\vec{B}).(\vec{A}-\vec{B}) = 0 \Rightarrow A^2 = B^2$

$\Rightarrow |A| = |B|$

25. **(a)** $h_1 = \frac{u^2 \sin^2\theta}{2g}$

$h_2 = \frac{u^2 \sin^2(90-\theta)}{2g}$, $R = \frac{u^2 \sin 2\theta}{g}$

Range R is same for angle θ and (90° – θ)

$\therefore h_1 h_2 = \frac{u^2 \sin^2\theta}{2g} \times \frac{u^2 \sin^2(90-\theta)}{2g}$

$= \frac{u^4 (\sin^2\theta) \times \sin^2(90-\theta)}{4g^2}$

[$\because \sin(90-\theta) = \cos\theta$]

$= \frac{u^4 (\sin^2\theta) \times \cos^2\theta}{4g^2}$

[$\because \sin 2\theta = 2\sin\theta\cos\theta$]

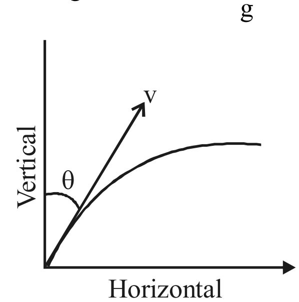
$= \frac{u^4 (\sin\theta\cos\theta)^2}{4g^2} = \frac{u^4 (\sin 2\theta)^2}{16g^2}$

$= \frac{(u^2 \sin 2\theta)^2}{16g^2} = \frac{R^2}{16}$

or, $R^2 = 16 h_1 h_2$ or $R = 4\sqrt{h_1 h_2}$

26. **(d)** Max. height $= H = \frac{v^2 \sin^2(90-\theta)}{2g}$ .....(i)

Time of flight, $T = \frac{2v\sin(90-\theta)}{g}$ ...(ii)

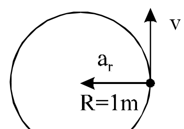


From (i), $\frac{v\cos\theta}{g}=\sqrt{\frac{2H}{g}}$,From (ii),

$T=2\sqrt{\frac{2H}{g}}=\sqrt{\frac{8H}{g}}$.

27. (a) A parabola

28. (a) $a_r = \omega^2 R$



$a_r = (2\pi 2)^2 R$

$= 4\pi^2 2^2 R = 4\pi^2\left(\frac{22}{44}\right)^2 (1) \quad \left[\because v = \frac{22}{44}\right]$

$a_t = \frac{dv}{dt} = 0$

$a_{net} = a_r = \pi^2\ ms^{-2}$ and direction along the radius towards the centre.

29. (b) Given, $u_1 = u_2 = u, \quad \theta_1 = 60°, \theta_2 = 30°$

In Ist case, we know that range

$R_1 = \frac{u^2 \sin 2(60°)}{g} = \frac{u^2 \sin 120°}{g} = \frac{u^2 \sin(90°+30°)}{g}$

$= \frac{u^2(\cos 30°)}{g} = \frac{\sqrt{3}u^2}{2g}$

In IInd case when $\theta_2 = 30°$, then

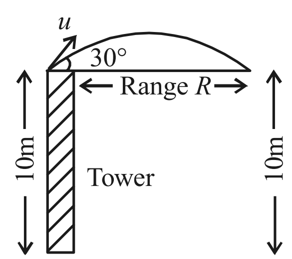
$R_2 = \frac{u^2 \sin 60°}{g} = \frac{u^2\sqrt{3}}{2g} \Rightarrow R_1 = R_2$

(we get same value of ranges).

30. (c) Yes, the person can catch the ball when horizontal velocity is equal to the horizontal component of ball's velocity, the motion of ball will be only in vertical direction w.r.t person for that $\frac{v_0}{2} = v_0 \cos\theta$ or $\theta = 60°$

31. (d) From the figure it is clear that range is required

$R = \frac{u^2 \sin 2\theta}{g} = \frac{(10)^2 \sin(2\times 30°)}{10} = 5\sqrt{3}$



Type B : Assertion Reason Questions

32. (a) For the distance covered in the last second, final velocity becomes zero. So if we drop an object with zero velocity it will cover the same distance in one second while going downwards.

Now distance travelled in the later case

$s = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2}\times 10 \times 1$

s = 5m

33. (c) A vehicle moving with constant speed on a straight road is an inertial frame. Newton's laws of motion is applicable only in inertial frame.

34. (c) Suppose that the tennis ball bounces with a velocity *u*. It will go up, till its velocity becomes zero. If *h* is the height up to which it rises on the hill, then

$(0)^2 - u^2 = 2(-g')h$

where g' is acceleration due to gravity on the hill.

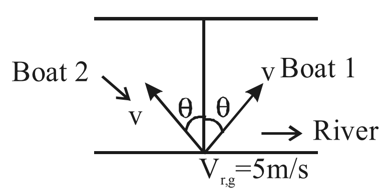
$\therefore\ h = \frac{u^2}{2g'}$

Since, the acceleration due to gravity on the hill (g') is less than that on earth (effect of height), it follows that tennis ball will bounce higher on hills than in plains.

35. (b) In uniform circular motion, the magnitude of velocity and acceleration remains same, but due to change in direction of motion, the direction of velocity and acceleration changes. Also the centripetal acceleration is given by $a = \omega^2 r$.

36. (d)

37. (a)



If component of velocities of boat relative to river is same normal to river flow (as shown in figure) both boats reach other bank simultaneously.