4.MOTION IN A PLANE

Physics Smart Booklet

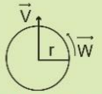
Theory + NCERT MCQs + Topic Wise Practice MCQs + NEET PYQs

MOTION IN A PLANE

Vector (magnitude + Direction)

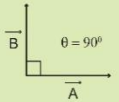
Basic Terminologies

- **Null vector:** $|\vec{A}| = 0$
- **Unit vector:** $\hat{A} = \frac{\vec{A}}{|\vec{A}|} = 1$
- **Equal vector:** $\left.\begin{matrix}\to A\\ \to B\end{matrix}\right\}|\vec{A}| = |\vec{B}|$
- **Axial vector:** used in rotation



$\vec{V} = \vec{r} \times \vec{w}$

- **Orthogonal vector Angle b/w** $\vec{A}$ & $\vec{B}$ $(\theta = 90^0)$



- **Parallel Vector :** $\vec{A}$, $\vec{B}$

Angel b/w $\vec{A}$ & $\vec{B}$ $(\theta = 0^0)$

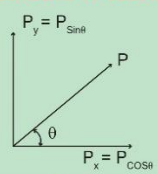
$\Rightarrow |\vec{A}| = n|\vec{B}|$

- **Anti-Parallel Vector :** $\vec{A}$, $\vec{B}$

Angel b/w $\vec{A}$ & $\vec{B}$ $(\theta = 180^0)$

$\Rightarrow |\vec{A}| = -n|\vec{B}|$

Resolution of vector



$P_y = P_{Sin\theta}$

$P_x = P_{COS\theta}$

Mathematical operations

$(9g\ \vec{A} = (a_1\hat{i} + b_1\hat{j} + c_1\hat{K})$ & $\vec{B} = (a_1\hat{i} + b_1\hat{j} + c_1\hat{K}))$

Arithmetic operations

Addition

$\vec{A} + \vec{B} = (a_1 + a_2)\hat{i} + (b_1 + b_2)\hat{j} + (c_1 + c_2)\hat{k}$

Subtraction

$\vec{A} + \vec{B} = (a_1 - a_2)\hat{i} + (b_1 - b_2)\hat{j} + (c_1 - c_2)\hat{k}$

Multiplication

Dot Product (Scalar Product)

1) $\vec{A} + \vec{B} = |\vec{A}||\vec{B}|\text{Cos}\theta$

2) $\vec{A}.\vec{B} = a_1a_2 + b_1b_2 + c_1c_2$

3) $\hat{i}.\hat{i} = 1$

$\hat{i}.\hat{j} = 0$

$\hat{i}.\hat{k} = 0$ etc

Cross Product (vector Product)

1) $\vec{A} + \vec{B} = |\vec{A}||\vec{B}|\sin\theta$

2) $\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \end{vmatrix}$

$\hat{i}(b_1c_2 - c_1b_2) + \hat{j}(a_1c_2 - c_1a_2) + \hat{k}(a_1b_2 - b_1a_2)$

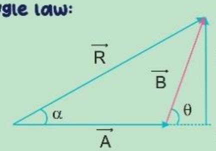
3) $\hat{i} \times \hat{i} = 0$

$\hat{i} \times \hat{j} = 1$

$\hat{i} \times \hat{k} = -1$

Vector law's

Triangle law:



$B_y = B\sin\theta$

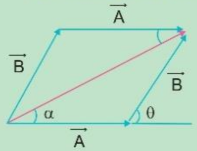
$B_x = B\cos\theta$

– $\vec{R} = (A + B\cos\theta)\hat{i} + B\sin\theta\hat{j}$

– $|\vec{R}| = \sqrt{|\vec{A}|^2 + |\vec{B}|^2 + 2|\vec{A}||\vec{B}|\cos\theta}$

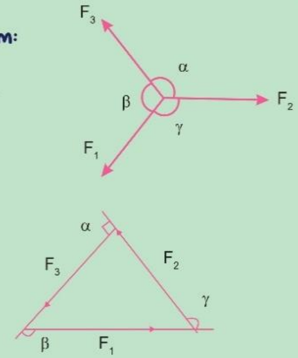
– $\tan\alpha = \frac{|\vec{B}|\sin\theta}{|\vec{A}| + |\vec{B}|\cos\theta}$

Parallelogram law:



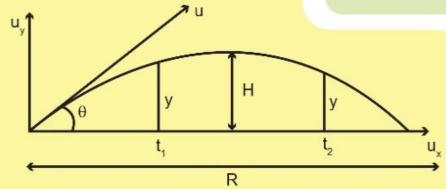
Lammis Theorem:

$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$



Projectile motion

oblique projectile



x – component

. $u_x = u_{Cos}\theta$

. $a_x = 0$

y – component

. $u_g = u_{sin}\theta$

. $a_g = -g$

Equation of Trajectory (parabolic track)

$y = x\tan\theta - \frac{1}{2}\frac{gx^2}{u^2\text{Cos}^2\theta} = x(1 - \frac{x}{R})\tan\theta$

Time of f hight (T). $T = 2u\sin\theta/g$

Range (R) $= u_xT, = \frac{\mu^2\sin^2\theta}{g}$

Height (H) $= \frac{\mu^2\sin^2\theta}{2g}$

Projectile passing same height at two different times t_1 and t_2 respectively

1) $y = \frac{1}{2}gt_1t_2$ 2) $t_1 = \frac{\mu\sin\theta}{g}\left[1 - \sqrt{1 - \left(\frac{2gy}{\mu\sin\theta}\right)^2}\right]$

3) $t_2 = \frac{\mu\sin\theta}{g}\left[1 + \sqrt{1 - \left(\frac{2gy}{\mu\sin\theta}\right)^2}\right]$

Projective with complimentary angles.
If $\theta 1 = \theta$ then $\theta_2 = 90 - \theta$

1) $R = H\cos\theta$ 2) $\frac{T0}{T_{90-0}} = \tan\theta$

RELATIVE MOTION ON 2 D – PLANE

Motion of one body w.r.t. other: $\dot{V}_{P/Q} = \dot{V}_P - \dot{V}_Q$

$V_{P/Q}$ = velocity of P w.e.t.Q

Umbrella problem: $V_{mG} = (V_m - V_G) = V_m$

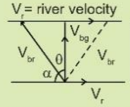
1) V_{rm} = velocity of rain w.r.t man 2) $V_{rm} = V_r - V_m$ 3) $\tan\theta = \frac{V_m}{V_r}$

River Boat Problem

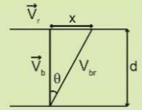
Shortest distance

$V_r = V_{br}\text{Cos}\alpha$ & $V_b = V_{br}\sin\alpha$

$V_{br}\sin\alpha = \frac{d}{t} = d_{min} = (V_{br}\sin\alpha)t$



Shortest time



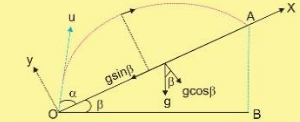
$V_{br} = \sqrt{V_b^2 + V_r^2}$

$t_{min} = \frac{d}{V_b} = \frac{\sqrt{X^2 + d^2}}{\sqrt{V_b^2 + V_r^2}}$

Drift (x) = $\vec{V}_r t_{min}$

$\tan\theta = \frac{V_r}{V_m} = \frac{x}{d}$

PROJECTILE ON INCLINED PLANE



X – Components

$u_x = u\cos\theta$

$a_x = g\sin\theta$

y – components

ug = usinθ

ay = g cosθ

Time of flight (T) $= \frac{2u\sin\theta}{g\cos\propto}$

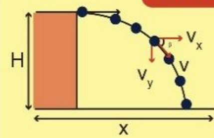
Height (H) $= \frac{u^2\sin^2\theta}{2g\cos\propto}$

Range (R) $= \frac{2u^2}{g}\frac{\sin\theta\cos(\propto + \theta)}{\cos^2\propto}$

for $R_{max} = \theta = \pi/4 + \propto/2$

for $H_{max} = \theta = 90^o$ or $\alpha = 0^o$

Horizontal projectile



$u_y = 0, u_x = u$

$x = u_xt = ut$, $t = x/u$

Equation of Trajectory

$Y = \frac{1}{2}gt^2 = \frac{1}{2}g\frac{X^2}{\mu^2}$

Range $(R) = u_xt = u\sqrt{\frac{2H}{g}}$

Time of flight $(T) = \sqrt{\frac{2H}{g}}$

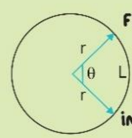
$V_{ins} = \sqrt{V_x^2 + V_y^2}$

$= \sqrt{u^2 + g^2t^2}$

$= \sqrt{u^2 + 2gy}$

$\tan\phi = \frac{V_y}{V_x} = \frac{gt}{u}$

Circular motion



Angular displacement (θ):

$\boxed{\ell = R\theta}$ ---- Angular displacement (rad.)

---- Radius (m)

---- Arc length (m)

Angular velocity (w):

$W = \frac{d0}{dt} = \frac{2\pi}{T} = 2\pi f(\text{rads}^{-1})$

T= Time period if = frequency

$\boxed{V = RW}$ ---- linear velocity (mS⁻¹)

Angular Acceleration (α):

$\propto = \frac{dw}{dt}(\text{rads}^{-2})$

$\boxed{a = R\propto}$

linear acceleration (mS⁻¹)

Equation of motion on Circular track:

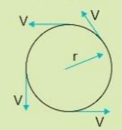
$w_f = w_i + \alpha t$

$\theta = w_{it} + \frac{1}{2}N\alpha t^2$

$w_f^2 - w_i^2 = 2\propto\theta$

Types of Circular motion:

Uniform circular motion

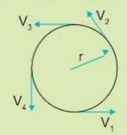


1) aτ (Tangential acceleration) = omS⁻²

2) a_r (Radial acceleration) = $\frac{V^2}{R}$

3) $a_{net} = \sqrt{a_T^2 + a_0^2} = a_r$

Non – uniform Circular motion



1) $V_1 \neq V_2 \neq V_3 \neq V_4$

2) $a_T \neq oms^{-2}$

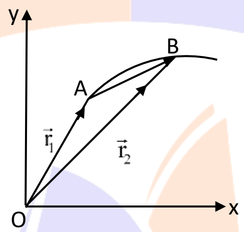
3) $a^r = \frac{V_{ins}^2}{R}$

4) $a_{net} = \sqrt{a_T^2 + a_r^2}$

MOTION IN A PLANE

Motion with uniform acceleration in a plane

Consider a point object moving in XY plane with an uniform acceleration $\vec{a}$. Let us suppose 'O' be the origin for measuring time and position of the object. Let the object be at positions A and B at times t_1 and t_2 respectively, where $\overline{OA} = \vec{r}_1$ and $\overline{OB} = \vec{r}_2$.



Let $\vec{v}_1$ and $\vec{v}_2$ be the velocities of object at instants t_1 and t_2 respectively,

then constant acceleration is given by

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

$$\vec{v}_2 - \vec{v}_1 = \vec{a}(t_2 - t_1)$$

$$\vec{v}_2 = \vec{v}_1 + \vec{a}(t_2 - t_1)$$

If $t_1 = 0$, $t_2 = t$, $\vec{v}_1 = \vec{u}$ and $\vec{v}_2 = v$ then

$$\boxed{\vec{v} = \vec{u} + \vec{a}t}$$

The above equation can be expressed in terms of rectangular components in XY plane as follows.

$\vec{u} = u_x\hat{i} + u_y\hat{j}$ where $u = \sqrt{u_x^2 + u_y^2}$

$\vec{v} = v_x\hat{i} + v_y\hat{j}$ where $v = \sqrt{v_x^2 + v_y^2}$

$\vec{a} = a_x\hat{i} + a_y\hat{j}$ where $a = \sqrt{a_x^2 + a_y^2}$

Also, $v_x = u_x + a_x t$ and $v_y = u_y + a_y t$

Displacement in x-direction is given by $x - x_0 = u_x t + \frac{1}{2}a_x t^2$

And displacement in y-direction is given by $y - y_0 = u_y t + \frac{1}{2}a_y t^2$

- ## Projectile

Projectile is the name given to a body thrown with some initial velocity making an angle θ [≠ 90°] with the horizontal direction, and then allowed to move in two dimensions under the action of gravity alone, without being propelled by any engine or fuel.

The path followed by a projectile is called its 'trajectory'. Examples of projectile are:

(i) A ball hit by a bat

(ii) A bullet fired from a gun or pistol

(iii) A javelin thrown by an athlete

(iv) A shot-put sphere thrown by an athlete

(v) A body dropped from an aeroplane in flight / bus / train

In the above examples, we find that a projectile moves under the combined effect of two velocities:

1. A uniform velocity in the horizontal direction, which would not change provided there is no air resistance.
2. A uniformly changing velocity in the vertical direction due to gravity.

To study the motion of a projectile, the following assumptions are made.

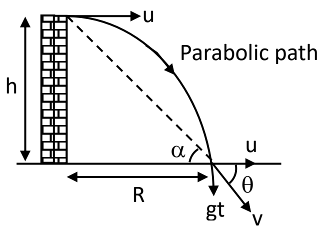
(i) There is no resistance of air.

(ii) The effect due to rotation of earth and curvature of the earth is neglected.

(iii) The acceleration due to gravity (g) is constant in magnitude and in direction at all points of the motion of projectile.

Horizontal Projectile

When a body is projected horizontally with a velocity from a point above the ground level, it is called a "horizontal projectile". When a stone is projected horizontally with a velocity 'u' from the top of a tower of height 'h' it describes a parabolic path as shown in figure.



(i) Time of descent, $t=\sqrt{\frac{2h}{g}}$ (independent of 'u')

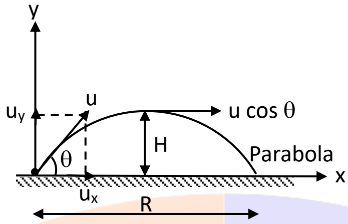
(ii) Horizontal displacement (or) range is $R=u\sqrt{\frac{2h}{g}}$

(iii) The speed with which it hits the ground is $v=\sqrt{u^2+2gh}=\sqrt{u^2+g^2t^2}$

(iv) The angle at which it strikes the ground is $\theta=\tan^{-1}\left(\frac{gt}{u}\right)=\tan^{-1}\left(\frac{\sqrt{2gh}}{u}\right)$

(v) If α is angle of elevation of point of projection from the point where the body hits the ground, then $\tan\alpha=\frac{h}{R}=\frac{\frac{gt^2}{2}}{ut}=\frac{gt}{2u} \Rightarrow \tan\alpha=\frac{\tan\theta}{2}$

Oblique Projectile



Any body projected into air with some velocity at an angle θ [≠ 90° and 0°] with the horizontal is called an "oblique projectile".

(i) Horizontal component of velocity is $u_x = u\cos\theta$, remains constant throughout the journey.

(ii) Vertical component of velocity $u_x = u\sin\theta$, varies at the rate of 'g'.

(iii) After a time 't':

(a) Horizontal component of velocity is $v_x = u\cos\theta\ (= u_x)$

(b) Vertical component of velocity is $v_y = u_y - gt = u\sin\theta - gt$

(c) Resultant velocity is $v = \sqrt{v_x^2 + v_y^2}$

(d) Direction of velocity is given by $\alpha = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

where α is the angle that $\vec{v}$ makes with horizontal.

(e) Horizontal displacement in a time 't' is $x = u_x t = (u\cos\theta)\,t$

(f) Vertical displacement in a time 't' is $y = u_y t - \frac{1}{2}gt^2 = (u\sin\theta)t - \frac{1}{2}gt^2$

(g) Net displacement of the body is $S = \sqrt{x^2 + y^2}$

(h) Equation of trajectory (which is a parabola) of an oblique projectile is

$$y = (\tan\theta)x - \left(\frac{g}{2u^2\cos^2\theta}\right)x^2 = Ax - Bx^2$$

From the above equation,

- $\theta = \tan^{-1}(A)$
- Range of projectile is $R = \frac{A}{B}$
- Maximum height is $H = \frac{A^2}{4B}$

(i) Time of ascent = Time of descent $= \frac{u\sin\theta}{g}$

Time of flight, $T = t_a + t_d = \frac{2u\sin\theta}{g}$

(j) Maximum height is $H = \frac{u^2 \sin^2 \theta}{2g}$

- At the maximum height, the vertical component of velocity becomes zero.
- The velocity of oblique projectile is minimum at the highest point and is equal to u cos θ.
- The angle between minimum velocity and acceleration is 90°.

(k) Horizontal range is $R = \frac{u^2 \sin 2\theta}{g} = \frac{2u_x u_y}{g}$

- Range is maximum when θ = 45°
- Maximum range is $R_{max} = \frac{u^2}{g}$
- When R is maximum, $H = \frac{R_{max}}{4} = \frac{u^2}{4g}$
- $R = \frac{gT^2}{2\tan\theta}$

If θ = 45°, then $R = \frac{gT^2}{2} \Rightarrow T = \sqrt{\frac{2R}{g}}$

(l) When two bodies are projected with same initial speed but at two different angles of projection, which are

(i) θ and (90° – θ) or

(ii) (45 + θ) and (45 – θ) or

(iii) θ with horizontal and θ with vertical

Then R_1 and R_2 the horizontal ranges, H_1 and H_2 the maximum heights and T_1 and T_2 the times of flight are given by

- $R_1 = R_2 = R$
- $\frac{T_1}{T_2} = \tan\theta$
- $T_1 T_2 = \frac{2R}{g}$
- $H_1 H_2 = \tan^2\theta$
- $H_1 + H_2 = \frac{u^2}{2g}$
- $R = 4\sqrt{H_1 H_2}$

(m) $H = \frac{u^2 \sin^2\theta}{2g}$ and $R = \frac{u^2 \sin 2\theta}{g} \Rightarrow 4H = R\tan\theta$

when R = H then θ = $\tan^{-1}(4) \simeq 76°$

(h) The angle between velocity and acceleration during the rise of projectile is 90° < θ < 180°.

The angle between velocity and acceleration during the fall of projectile is 0° < θ < 90°.

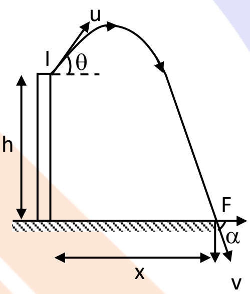
(o) At maximum height:

- Kinetic energy $= \frac{1}{2}mu_x^2 = \frac{1}{2}mu^2\cos^2\theta$
- Potential energy $= mgH = \frac{1}{2}mu^2\sin^2\theta$
- Total energy $= KE + PE = \frac{1}{2}mu^2$
- If KE = PE then $\theta = 45°$

(p) In terms of range, equation of trajectory is given by $y = x\tan\theta\left(1-\frac{x}{R}\right)$

(q) If the body is projected at an angle θ with horizontal in the upward direction from a height h, then

- $h = (-u\sin\theta)T + \frac{1}{2}gT^2$
- x = (u cos θ) T
- The velocity with which it strikes the ground is



$v = \sqrt{u^2 + 2gh}$

$[\ v_y^2 = (u\sin\theta)^2 + 2(-g)(-h) \Rightarrow v_y^2 = u^2\sin^2\theta + 2gh$

$v_x^2 = u^2\cos^2\theta$

$\therefore\ v = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 + 2gh}\ ]$

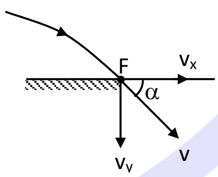
- The angle at which it strikes the ground is

$\alpha = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

$-\ v_y = (u\sin\theta) + (-g)\,T$

$v_y = gT - u\sin\theta$

$v_x = u\cos\theta$

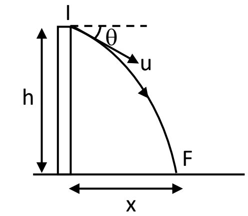


$\therefore\ \alpha = \tan^{-1}\left[\frac{gT - u\sin\theta}{u\cos\theta}\right]$ (OR)

$\alpha = \tan^{-1}\left[\frac{u^2\sin^2\theta + 2gh}{u\cos\theta}\right]$

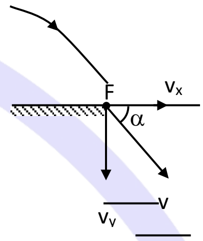
☞	In the above discussion, T is total time taken during the flight to reach point 'F' from point 'I'.

(r) If the body is projected at an angle θ from top of the tower in downward direction, then



- $h = (u\sin\theta)T + \frac{1}{2}gT^2$
- $x = (u\cos\theta)T$
- The velocity with which it strikes the ground is

  $v = \sqrt{u^2 + 2gh}$



- The angle at which it strikes the ground is $\alpha = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

  $v_y = u\sin\theta + gT$ and $v_x = u\cos\theta$

  Also $v_y = \sqrt{u^2\sin^2\theta + 2gh}$ and $v_x = u\cos\theta$

  $\therefore\ \alpha = \tan^{-1}\left[\frac{u\sin\theta + gT}{u\cos\theta}\right]$ (OR) $\alpha = \tan^{-1}\left[\frac{\sqrt{u^2\sin^2\theta + 2gh}}{u\cos\theta}\right]$

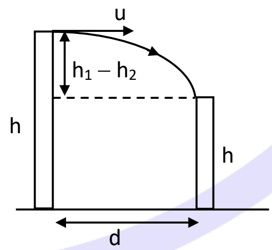
☞	In the above discussion, 'T' is the total time of flight i.e., time taken to reach point 'F' from point 'I'.

(s) Two bodies are projected horizontally from top of a tower of height 'h' in opposite directions with velocities u_1 and u_2.

- The time after which their velocity vectors are perpendicular is $= \frac{\sqrt{u_1u_2}}{g}$.
- The distance between them when their velocity vectors are perpendicular is

$x = (u_1 + u_2)\frac{\sqrt{u_1u_2}}{g}$.

(t) Two tall towers having heights h_1 and h_2 are separated by a distance 'd'. A person throws a ball horizontally with velocity 'u' from the top of the first tower to reach the top of the second tower, then:



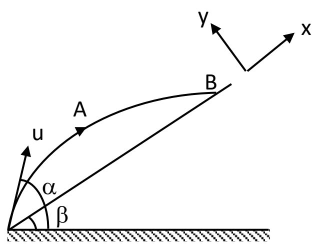
- Time taken, $t = \sqrt{\frac{2(h_1 - h_2)}{g}}$.
- Horizontal distance travelled, $d = ut$

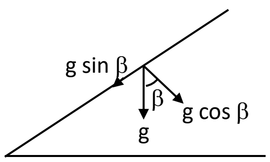
▪ Projectile motion on an inclined plane

(i) Up the plane

$u_x = u\cos(\alpha - \beta)$, $u_y = u\sin(\alpha - \beta)$

$a_x = -g\sin\beta$, $a_y = -g\cos\beta$





Time of flight is $T = \frac{2u\sin(\alpha - \beta)}{g\cos\beta}$

Range (= OB) is

$R = \frac{u^2}{g\cos^2\beta}[\sin(2\alpha - \beta) - \sin\beta]$

Range is max when $2\alpha - \beta = \frac{\pi}{2}$ (or) $\alpha = \frac{\pi}{4} + \frac{\beta}{2}$

And $R_{max} = \frac{u^2}{g\cos^2\beta}[1 - \sin\beta]$

$\Rightarrow$ when R is maximum, if corresponding time of flight is T′, then

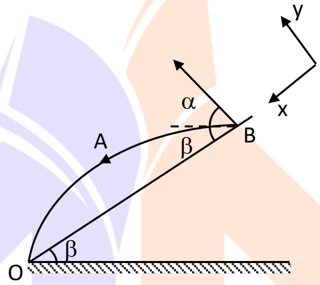
$T'^2 g = 2R_{max}$

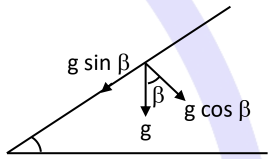
(ii) Down the plane

$u_x = u\cos(\alpha + \beta)$, $u_y = u\sin(\alpha + \beta)$,

$a_x = g\sin\beta$, $a_y = -g\cos\beta$

Time of flight is $T = \frac{2u\sin(\alpha+\beta)}{g\cos\beta}$





Range (= BO) is

$$R = \frac{u^2}{g\cos^2\beta}[\sin(2\alpha + \beta) + \sin\beta]$$

R is max when $2\alpha + \beta = \frac{\pi}{2}$ (or) $\alpha = \frac{\pi}{4} - \frac{\beta}{2}$

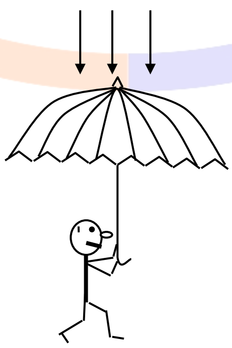
$$R_{max} = \frac{u^2}{g\cos^2\beta}[1 + \sin\beta]$$

$\Rightarrow$ when R is maximum, if corresponding time of flight is T′, then

$T'^2 g = 2R_{max}$

Relative velocity in 2 dimensions

Man walking in rain



Suppose a man is standing in a rain pouring vertically downwards. He has to hold the umbrella vertically not to get wet, as shown in the figure.

If he starts moving with a certain speed, the rain appears to him falling at a different speed, and at a different angle. So he has to alter the direction of umbrella not to get wet. The formula that we use in such types of problems, is $\vec{v}_{RM} = \vec{v}_R - \vec{v}_M$

where $\vec{v}_{RM}$ = velocity of rain with respect to man

$\vec{v}_R$ = velocity of rain with respect to ground, and

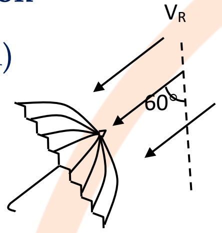
$\vec{v}_M$ = velocity of man with respect to ground

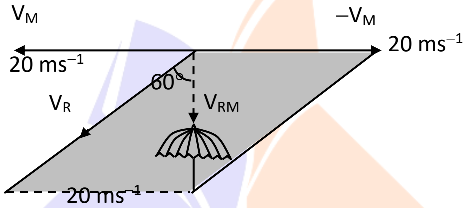
Illustrations

1. A person in a stationary vehicle on a road has to hold his umbrella at 60° with the vertical to keep the rain away. He throws the umbrella and drives the vehicle at 20 m s^{-1}. He finds that rain drops are falling vertically on him. Find the speed of the rain drops with respect to (i) the road, and (ii) the moving vehicle

Solution

(i)





When the man moves at 20 m s^{-1}, to find V_{RM}, $-V_M$ is drawn and diagonal of the parallelogram with sides V_R and $-V_M$, gives $-V_{RM}$ (see second figure).

In the second figure,

$$\sin 60° = \frac{20}{|V_R|} \Rightarrow |V_R| = \frac{20}{\sqrt{3}/2} = \frac{40}{\sqrt{3}} \text{ ms}^{-1}$$

(ii) From the second figure, $\tan 60° = \frac{20}{|V_{RM}|} \Rightarrow |V_{RM}| = \frac{20}{\sqrt{3}} \text{ ms}^{-1}$

∴ Speed of rain with respect to road $= \frac{40}{\sqrt{3}}$ ms^{-1}

and speed of rain with respect to moving vehicle = $\frac{20}{\sqrt{3}}$ ms^{-1}

▪ Motion of boat in a river

Consider a boat moving with a velocity v_B relative to the water in a river. If the water is still, v_B is also the velocity of the boat as measured by an observer on the shore (or we say w.r.t ground).

If the velocity of water current is v_W and the boat is moving downstream, then velocity of boat w.r.t ground (v_{BG}) is

$v_{BG} = v_B + v_W$

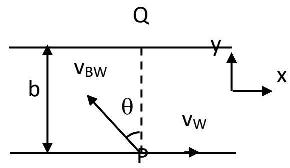
If the boat is moving upstream, velocity of boat w.r.t. ground is

$v_{BG} = v_B - v_W$

Suppose a boat starts at point P in the direction making an angle θ with the straight course as shown in the figure. Suppose Y-axis is taken along straight course i.e., along PQ and X-axis is along the velocity of river.

Now $\vec{v}_{BW}$ = velocity of boat with which boatman steers it (*sometimes this is also called velocity of boat w.r.t. water or velocity of boat in still water*)

$\vec{v}_W$ = velocity of water current of the river (*w.r.t. ground*)



v_{BG} = absolute velocity of boat i.e., velocity of boat w.r.t. ground

Velocity of boat w.r.t. water is $\vec{v}_{BW} = \vec{v}_{BG} - \vec{v}_W \Rightarrow \vec{v}_{BG} = \vec{v}_{BW} + \vec{v}_W$

So, $(v_{BG})_x = (v_{BW})_x + (v_W)_x = -v_{BW}\sin\theta + v_W$

$(v_{BG})_x = v_W - v_{BW}\sin\theta$ and

$(v_{BG})_y = (v_{BW})_y - (v_W)_y = v_{BW}\cos\theta + 0$

$(v_{BG})_y = v_{BW}\cos\theta$

Now, time taken by the boat to cross the river is

$$t = \frac{b}{(v_{BG})_y} = \frac{b}{v_{BW}\cos\theta}$$

$$\therefore\ t = \frac{b}{v_{BW}\cos\theta} \qquad \ldots (1)$$

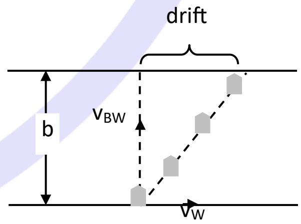
and the drift (i.e., displacement along x-axis when he reaches the other bank) is

$$d = (v_{BG})_x t = (v_W - v_{BW}\sin\theta)\frac{b}{v_{BW}\cos\theta}$$

$$\therefore\ \text{Drift } d = (v_W - v_{BW}\sin\theta)\frac{b}{v_{BW}\cos\theta} \qquad \ldots (2)$$

Special cases

Case (i) The boat crosses the river in the shortest time.



From Eq. (1) for t to be minimum,

$$\therefore\ t_{min} = \frac{b}{v_{BW}} \qquad \ldots (3)$$

In this case, drift, $d = v_W \cdot \frac{b}{v_{BW}}$ ... (4)

Case (ii) The boat crosses the river in the shortest path.

When the boat reaches the opposite shore, the path length is given by

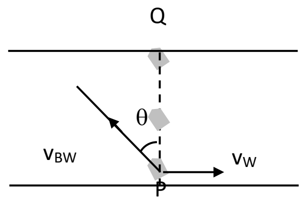
$$S = \sqrt{b^2 + d^2}$$

where b = width of the river and d = drift.

For S to be minimum $|d|$ should be minimum, as b is constant.

(a) **When $v_W < v_{BW}$ (which is usual)**

In this case, drift, d = 0 and S_{min} = b ; | X component of v_{BW} | = v_W and $\sin\theta = \frac{v_W}{v_{BW}}$, and the boat can reach the point Q which is exactly opposite P.



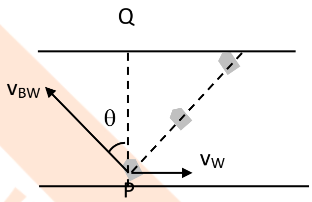
$$t = \frac{b}{v_{BW}\cos\theta} = \frac{b}{v_{BW}\sqrt{1-\sin^2\theta}}$$

$$= \frac{b}{v_{BW}\sqrt{1-\frac{v_W^2}{v_{BW}^2}}} = \frac{b}{\sqrt{v_{BW}^2 - v_W^2}}$$

$$\therefore \text{ time, } t = \frac{b}{\sqrt{v_{BW}^2 - v_W^2}}$$

(b) **When $v_W > v_{BW}$**

In this case, the boat cannot reach the point Q.



For d to be minimum, $\frac{d}{d\theta}(\text{drift}) = 0$

$$\frac{d}{d\theta}\left\{(v_W - v_{BW}\sin\theta)\frac{b}{v_{BW}\cos\theta}\right\} = 0 \quad \text{From eq. (2)}$$

or $$\frac{v_{BW}\cos\theta[-v_{BW}\cos\theta] - [v_W - v_{BW}\sin\theta](-v_{BW}\sin\theta)}{(v_{BW}\cos\theta)^2} b = 0$$

$$-v_{BW}^2\cos^2\theta + v_W v_{BW}\sin\theta - v_{BW}^2\sin^2\theta = 0$$

or, $$v_W v_{BW}\sin\theta = v_{BW}^2 \Rightarrow \sin\theta = \left(\frac{v_{BW}}{v_W}\right)$$

or, $$\theta = \sin^{-1}\left(\frac{v_{BW}}{v_W}\right) ; \cos\theta = \sqrt{1-\frac{v_{BW}^2}{v_W^2}} = \sqrt{\frac{v_W^2 - v_{BW}^2}{v_W^2}}$$

From eq. (2)

$$d_{min} = \left(v_W - v_{BW}\cdot\frac{v_{BW}}{v_W}\right)\frac{b\cdot v_W}{v_{BW}\sqrt{v_W^2 - v_{BW}^2}}$$

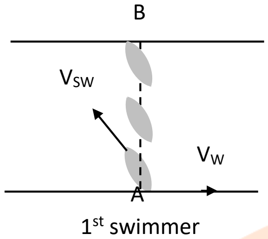
$$\therefore d_{min} = \frac{b\sqrt{v_W^2 - v_{BW}^2}}{v_{BW}} \qquad \therefore S_{min} = \sqrt{b^2 + d_{min}^2} = \sqrt{b^2 + \frac{b^2(v_W^2 - v_{BW}^2)}{v_{BW}^2}} = \sqrt{b^2\frac{v_W^2}{v_{BW}^2}}$$

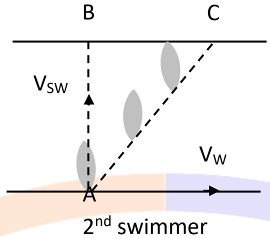
So, $S_{min} = b\frac{v_W}{v_{BW}}$

Illustrations

2. Two swimmers leave point A on one bank of the river to reach point B lying straight across on the other bank. The first swimmer reaches point B by swimming at an angle with the straight course. The second one swims at right angles to the steam and then walks the distance that he

has been carried away by the stream to get to point B. What was the velocity u of his walking if both the swimmers reached the destination simultaneously? The steam velocity, v_0 = 2 km h^{-1} and velocity v′ of each swimmer with respect to water equals 2.5 km h^{-1}?





Solution

In the following diagram, swimmer is substituted by boat.

In the case of 1st swimmer, $t_1 = \frac{b}{\sqrt{v_{SW}^2 - v_W^2}} = \frac{b}{\sqrt{(2.5)^2 - 2^2}} = \frac{b}{1.5}$

In the case of 2nd swimmer, $t_2'(= t_{min}) = \frac{b}{v_{SW}} = \frac{b}{2.5}$

BC = drift, $d = v_W \cdot \frac{b}{v_{SW}} = 2 \cdot \frac{b}{2.5} = \frac{4b}{5}$

$\therefore$ time taken for walking from C to B is $t_2'' = \frac{(4b/5)}{u} = \frac{4b}{5u}$

Total time taken by the 2nd swimmer to reach point B is

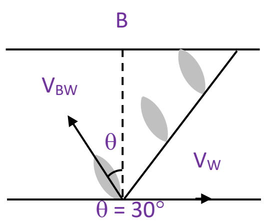
$$t_2 = t_2' + t_2'' = \frac{b}{2.5} + \frac{4b}{5u} = \frac{2b}{5} + \frac{4b}{5u}$$

From the problem, $t_1 = t_2$

$$\therefore \frac{b}{1.5} = \frac{2b}{5} + \frac{4b}{5u}; \frac{2b}{3} = \frac{2b}{5} + \frac{4b}{5u} \Rightarrow u = 3 \text{km h}^{-1}$$

3. A boat moves relative to water with a velocity which is 2 times less than the river flow velocity. At what angle to the stream direction must the boat move to minimize drifting?

Solution



Here $v_W > v_{BW}$. So, $\sin\theta = \frac{v_{BW}}{v_W}$

Given, $v_{BW} = \frac{v_W}{2}$

$$\therefore \sin\theta = \frac{v_{BW}}{v_W} = \frac{1}{2} \Rightarrow \theta = 30°$$

This is the angle that v_{BW} makes with the straight course.

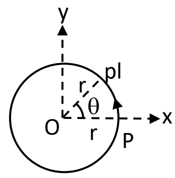
The desired angle is 90° + 30° = 120°

The boat must be steered at an angle 120° with the direction of river flow to minimize drifting. The situation is shown in the figure.

- ## Circular motion

- ### Angular displacement (θ)

It is the angle through which the radius vector representing the position of a particle that moves along a circle, has rotated.



$$\theta = \frac{\text{arclength } (l)}{\text{radius (r)}}$$

☞ Small angular displacements ($d\theta$) are vectors because they obey laws of vector addition. Large angular displacement are not vectors because they do not obey the laws of vector addition S.I. unit of angular displacement is radian (= rad).

Angular velocity (ω): It is the rate of change of angular displacement of a particle that moves on a circle.

$$\omega = \frac{d\theta}{dt}$$

S.I. Unit: radian second^{-1} (= rad s^{-1}).

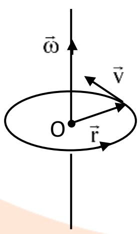
Angular acceleration (α): It is the rate of change of angular velocity of a particle that moves along a circle.

$$\alpha = \frac{d\omega}{dt}. \quad \text{Also } \alpha = \frac{d^2\theta}{dt^2}$$

S.I. Unit: radian second^{-2} (= rad s^{-2})

- When a particle moves along a circle of radius r, then it possesses both linear velocity $\vec{v}$ and angular velocity $\vec{\omega}$. The relation between them is

$$\boxed{\vec{v} = \vec{\omega} \times \vec{r}}$$



The direction $\vec{v}$ is along the tangent in the plane of circle. The direction of $\vec{\omega}$ is along the axis of rotation and the direction of $\vec{r}$ is along the radius away from the centre (or) radially outwards. The directions of $\vec{v}$, $\vec{\omega}$ and $\vec{r}$ are mutually perpendicular.

$$\boxed{v = \omega r}$$

- If a particle is moving along a circle with uniform speed and completes 'n' revolutions in 't' second, its angular velocity is

$$\boxed{\omega = \frac{2\pi n}{t}}$$

- If T is time period of revolution and f is frequency then $\boxed{\omega = \frac{2\pi}{T} = 2\pi f}$

☞ Other units of ω are revolutions per minute (rpm), revolutions per second (rps).

1 rps = 60 rpm

$1\ \text{rpm} = \frac{\pi}{30}\ \text{rad s}^{-1}$

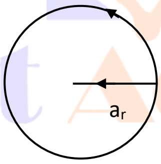
1 rps = 2π rad s^{-1}

But the standard unit (i.e., S.I. unit) of ω is rad s^{-1} only.

Uniform circular motion

If a particle moves on a circle with constant speed, its motion is called "uniform circular motion" (UCM). In UCM, speed, KE, time period, frequency, angular velocity, magnitude of centripetal acceleration, magnitude of centripetal force, magnitude of linear momentum are constants. But, velocity, centripetal acceleration, centripetal force, linear momentum in UCM are changing (due to change in their direction).

Centripetal acceleration (a_r)



A particle executing uniform circular motion, due to change in direction of velocity, possesses an acceleration called centripetal acceleration (a_r). a_r is in a direction towards the centre of circle (or) radially inwards.

$$\vec{a}_r = \vec{\omega} \times \vec{v} = \vec{\omega} \times (\vec{\omega} \times \vec{r})$$

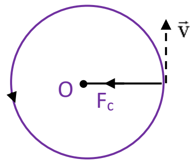
$$a_r = \omega v = r\omega^2 = \frac{v^2}{r}$$

☞ The directions of $\vec{a}_r$, $\vec{\omega}$ and $\vec{v}$ are mutually perpendicular.

Centripetal force ($\vec{F}_c$)**:** To revolve a particle of mass 'm' at a speed 'v' along a circle of radius 'r', a force must act on the particle in a direction perpendicular to the direction of velocity and towards the centre of the circle. This force is called centripetal force.

$$\boxed{F_c = m\omega v = mr\omega^2 = \frac{mv^2}{r}}$$

The workdone by centripetal force is zero because displacement of revolving particle is zero in the direction of centripetal force (OR) the instantaneous direction of centripetal force is perpendicular to instantaneous direction of velocity of particle.

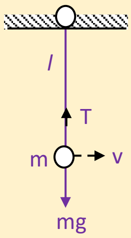


When a particle is moving along a circle, if the centripetal force ceases to act then the particle tends to move along the direction of tangent.

If a body of mass 'm' is rotated along a circle of radius 'r' in horizontal plane at a uniform speed 'v' by means of light horizontal string then tension in the string is

$$\boxed{T = \frac{mv^2}{r} = mr\omega^2 = m\omega v}$$

☞ Students are often confused over the centripetal force. They think that this force acts on a particle moving in a circle. This force does not act but required for moving in a circle which is being provided by the other forces acting on the particle. Let us take an example. Suppose a particle of mass 'm' is moving in a vertical circle with the help of a string of length 'l' fixed at point 'O'. Let 'v' be the speed of the particle at the lowest position. When the students are asked, what forces are acting on the particle in this position? They immediately would say, three forces are acting on the particle (i) tension (ii) weight, mg and (iii) centripetal force, $\frac{mv^2}{l}(r = l)$.



However, they are wrong. Only first two forces T and mg are acting on the particle. Third force $\frac{mv^2}{l}$ is required for circular motion and is provided by T and mg. Thus the resultant of these two forces is $\frac{mv^2}{l}$ towards 'O' or, we can write $T - mg = \frac{mv^2}{l}$.

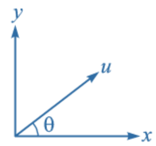
▪ Centrifugal force

Centrifugal force has a tendency to pull the body along radially outward direction. Centrifugal force is a "pseudo force" with respect to "inertial frame of reference". But with respect to rotating frame of reference (or non-inertial frame of reference) it is a real force. Centrifugal force and centripetal force are NOT the action reaction pair according to Newton's third law.

Magnitude of centrifugal force $= mr\omega^2 = \frac{mv^2}{r} = m\omega v$

Illustrations

4. A particle is projected with initial velocity $u = 20\sqrt{2}\ ms^{-1}$ at θ = 45°. The range (R), maximum height (H) and Time of flight (T), respectively are (g = 10 ms⁻²)



(A) 80 m, 20 m, 4 s
(B) 100 m, 40 m, 6 s
(C) 80 m, 40 m, 3 s
(D) 90 m, 50 m, 4 s

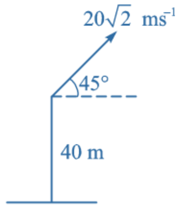
Ans (A)

$$R = \frac{u^2 \sin 2\theta}{g} = \frac{(20\sqrt{2})^2 \sin 90°}{10} = 80\ m$$

$$H = \frac{u^2 \sin^2\theta}{2g} = \frac{(20\sqrt{2})^2\left(\frac{1}{\sqrt{2}}\right)^2}{2(10)} = 20 \text{ m}$$

$$T = \frac{2u\sin\theta}{g} = \frac{2(20\sqrt{2})\left(\frac{1}{\sqrt{2}}\right)}{10} = 4 \text{ s}$$

5. A particle is thrown from a tower of height 40 m as shown in the figure. The time when the particle strikes the ground and the distance of this point from foot of tower, respectively, are (g = 10 ms^{-2})



(A) 6.235 s, 123.5 m (B) 5.46 s, 109.2 m
(C) 4.45 s, 98.8 m (D) 7.015 s, 143.7 m

Ans (B)

Let us take upward direction as + ve and downward direction as − ve

$s_y = -40$ m, $a_y = -g = -10$ ms^{-2},

$u_y = +20\sqrt{2}\sin 45° = 20 \text{ ms}^{-1},\ t = T$

$s_y = u_y t + \frac{1}{2}a_y t^2 \Rightarrow -40 = 20T + \frac{1}{2}(-10)T^2$

$5T^2 - 20T - 40 = 0 \Rightarrow T^2 - 4T - 8 = 0 \Rightarrow T = 5.46$ s

$R = u_x.T = 20\sqrt{2}\cos 45° \times 5.46 = 20 \times 5.46 = 109.2$ m

6. A boy whirls a stone of small mass in a horizontal circle of radius 1.5 m and at height 2.9 m above level ground. The string breaks and the stone flies off horizontally and strikes the ground after travelling a horizontal distance of 10 m. The magnitude of the centripetal acceleration of the stone while in circular motion is [g = 9.8 ms^{-2}]

(A) 33 ms^{-2} (B) 43 ms^{-2} (C) 23 ms^{-2} (D) 52 ms^{-2}

Ans (B)

Let the speed of stone in circular motion is u.

When the string is cut, stone becomes a horizontal projectile.

h = 2.9 m, R = 10 m, $R = u\sqrt{\frac{2h}{g}}$

$\therefore\ 10 = u\sqrt{\frac{2\times 2.9}{9.8}} \Rightarrow u = 13 \text{ ms}^{-1}$

Centripetal acceleration $= \frac{u^2}{r} = \frac{13^2}{1.5} = 43 \text{ ms}^{-2}$

7. Two particles revolve concentrically in a horizontal plane in the same direction. The time required to complete one revolution for particle A is 3 min, while for particle B is 1 min. The time required for A to complete one revolution relative to B is

(A) 2 min (B) 1 min (C) 1.5 min (D) 1.25 min

Ans (C)

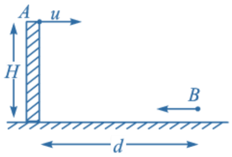
$\omega_A = \frac{2\pi}{3}, \qquad \omega_B = \frac{2\pi}{1}$

$\omega_{AB} = \omega_A - \omega_B$

$\omega_{AB} = \frac{2\pi}{3} - \frac{2\pi}{1} = \frac{-4\pi}{3};\ |\omega_{AB}| = \frac{4\pi}{3}$

$\frac{4\pi}{3} = \frac{2\pi}{T_{AB}} \Rightarrow T_{AB} = 1.5 \text{ min}$

8. Two particles A and B are placed as shown in the figure. The particle A, on the top of tower, is projected horizontally with a velocity u and the B is projected along the surface towards the tower simultaneously. If particles meet each other, then the speed of projection of particle B is [Ignore friction]



(A) $d\sqrt{\frac{g}{2H}}-u$ (B) $d\sqrt{\frac{g}{2H}}$ (C) $d\sqrt{\frac{g}{2H}}+u$ (D) u

Ans (A)

Let the speed of B is v, which is constant

In the horizontal direction $u_r = u + v$

Let the time at which they meet is t

$$(u+v)t = d \Rightarrow t = \frac{d}{u+v}$$

In the same time, in the vertical direction

$$H = \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2H}{g}}$$

$$\therefore \quad \frac{d}{u+v} = \sqrt{\frac{2H}{g}} \Rightarrow u + v = d\sqrt{\frac{g}{2H}}$$

$$v = d\sqrt{\frac{g}{2H}} - u$$

Aliter:

Let the time taken is t. Then $t = \sqrt{\frac{2H}{g}}$

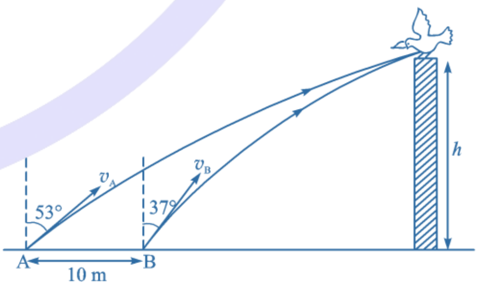
Range of A is $R = u\sqrt{\frac{2H}{g}}$

Distance moved by B is $vt = v\sqrt{\frac{2H}{g}}$

Total distance d = Range + Distance moved by $B = R + vt$

$$\therefore \; u\sqrt{\frac{2H}{g}} + v\sqrt{\frac{2H}{g}} = d \;\Rightarrow\; v = d\sqrt{\frac{g}{2H}} - u$$

9. Two boys stationed at A and B fire bullets simultaneously at a bird stationed at C. The bullets are fired from A and B at angles of 53° and 37° with the vertical. Both the bullets fire the bird simultaneously. If v_A = 60 units the value of v_A is



(A) 80 units (B) 70 units

(C) 100 units (D) 110 units

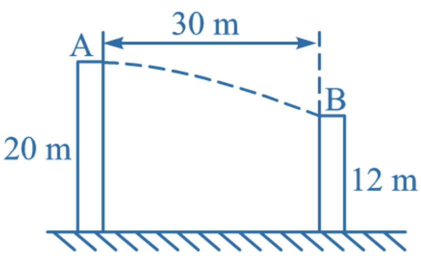
Ans (A)

The vertical components must be equal.

$$\therefore v_A \cos 53° = v_B \cos 37°$$

$$v_A . \frac{3}{5} = 60 . \frac{4}{5} \Rightarrow v_A = 80 \text{ units}$$

10. A boy wants to throw a ball from a point A so as to just reach point B as shown. The minimum velocity with which the boy should throw the ball is [$g = 10\ ms^{-2}$]



(A) 2.4 ms^{-1} (B) 23.8 ms^{-1}
(C) 238 ms^{-1} (D) 47.4 ms^{-1}

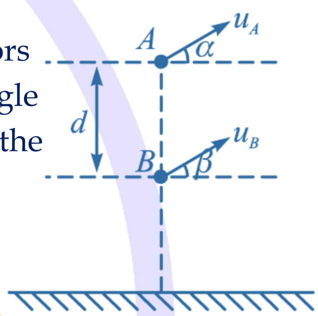
Ans (B)

$h = 20 - 12 = 8$ m

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times 8}{10}} = \sqrt{1.6} = 1.26\ s$$

$$x = u_x t \Rightarrow u_x = \frac{x}{t} = \frac{30}{1.26} = 23.8\ ms^{-1}$$

11. Two bodies A and B are thrown simultaneously from the different floors of a tower having distance d between them. Velocity of A is u_A at an angle a with horizontal and velocity of B is u_B at an angle b with horizontal. If the two particles collide in mid air $\frac{u_A}{u_B} =$



(A) $\frac{\cos\beta}{\cos\alpha}$ (B) $\frac{\sin\alpha}{\sin\beta}$ (C) $\frac{\tan\alpha}{\tan\beta}$ (D) $\frac{\cot\alpha}{\cot\beta}$

Ans (A)

For collision to occur $(u_{AB})_x = 0$ or $(u_A)_x = (u_B)_x$

$$\therefore\ u_A \cos\alpha = u_B \cos\beta \Rightarrow \frac{u_A}{u_B} = \frac{\cos\beta}{\cos\alpha}$$

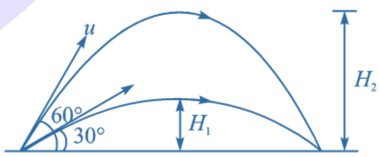
12. A particle is moving along a circular path with uniform speed. The angle by which its angular velocity changes when it completes half of the circular path is

(A) 0° (B) 45° (C) 180° (D) 360°

Ans (A)

Angular velocity is perpendicular to plane of rotation.

13. A body is projected at angles of 30° and 60° with the same speed. The horizontal ranges are R_1 and R_2 and maximum heights are H_1 and H_2 respectively. Then



(A) $\frac{R_1}{R_2} > 1$ (B) $\frac{H_1}{H_2} > 1$

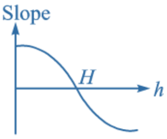
(C) $\frac{R_1}{R_2} < 1$ (D) $\frac{H_1}{H_2} < 1$

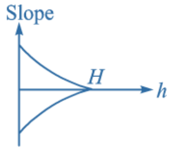
Ans (D)

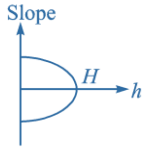
$R_1 = R_2$

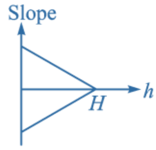
$\frac{H_1}{H_2} < 1$

14. For a projectile projected at an acute angle to the horizontal, among the graphs shown, the graph that depicts the variation of slope of the trajectory traced out by the projectile with height h risen (Max. height = H) is

(A) 

(B) 

(C) 

(D) 

Ans (C)

Let the angle of projection be α

Then slope $\tan\theta = \frac{v_y}{v_x} = \frac{\sqrt{u_y^2 - 2gh}}{u_x} = \sqrt{\left(\frac{u_y}{u_x}\right)^2 - \frac{2gh}{u_x^2}}$

Let slope = y and $h = x$. Then $y^2 = a - bx$

Aliter

$$y = (\tan\alpha)x - \frac{g}{2u^2\cos^2\alpha}x^2$$

$$\Rightarrow \frac{dy}{dx} = \tan\alpha - \frac{g}{u^2\cos^2\alpha}x$$

$x = u\cos\alpha.t$, substituting this,

$$\frac{dy}{dx} = \tan\alpha - \frac{g}{u\cos\alpha}t \qquad \dots (1)$$

$$h = u_y t - \frac{1}{2}gt^2 \Rightarrow \frac{1}{2}gt^2 - u_y t + h = 0$$

$$\Rightarrow t = \frac{u_y \pm \sqrt{u_y^2 - 2gh}}{g}$$

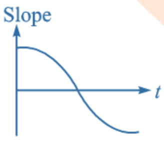
Substituting this in equation (i), we get

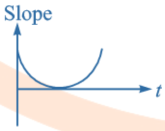
Slope = $\tan\alpha - \frac{g}{u\cos\alpha}\left[\frac{u_y}{g} \pm \frac{\sqrt{u_y^2 - 2gh}}{g}\right]$

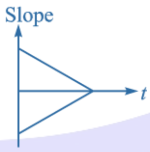
or slope = $\tan\alpha \mp \sqrt{\frac{u_y^2}{u_x^2} - \frac{2gh}{u_x^2}}$

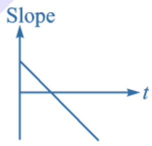
Let slope = y and $h = x$ then $y^2 = a - bx$

15. A projectile is projected at an angle of 45° to the horizontal. The slope of trajectory of the body varies with time t as

(A) 

(B) 

(C) 

(D) 

Ans (D)

Slope is $\tan\theta = \frac{v_y}{v_x} = \frac{u_y - gt}{u_x} = \frac{u_y}{u_x} - \left(\frac{g}{u_x}\right)t$

$\tan\theta = \frac{u_y}{u_x} - \left(\frac{g}{u_x}\right)t$ [similar to $y = c - mx$]

Aliter

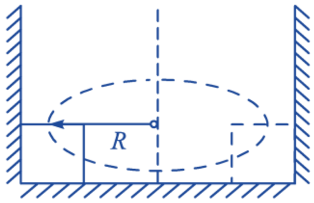
$$y = (\tan\alpha)x - \frac{g}{2u^2\cos^2 x}x^2$$

Slope = $\frac{dy}{dx} = \tan\alpha - \frac{g}{u^2\cos^2\alpha}x$;

But $x = u\cos\alpha.t$

So slope = $\tan\alpha - \left(\frac{g}{u\cos\alpha}\right)t$ [Similar to $y = c - mx$]

16. A block of mass m is revolving in a smooth horizontal plane with a constant speed v. If the radius of the circular path is R, the total contact force received by the block is

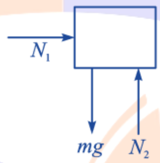


(A) $m\sqrt{\frac{v^4}{R^2}+g^2}$ (B) $\frac{mv^2}{R}$

(C) $\frac{1}{2}m\sqrt{\frac{v^4}{R^2}+g^2}$ (D) $\frac{1}{3}\frac{mv^2}{R}$

Ans (A)

FBD of block:



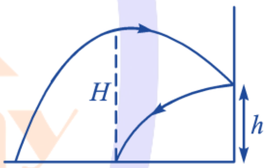
$N_2 = mg$

N_1 supplies centripetal force

$\therefore N_1 = \frac{mv^2}{R}$

Net contact force, $N=\sqrt{N_1^2+N_2^2}=\sqrt{\left(\frac{m^2v^4}{R^2}\right)+m^2g^2}$ or, $N=m\sqrt{\frac{v^4}{R^2}+g^2}$

17. A stone is projected from a horizontal plane. It attains maximum height H and strikes a stationary smooth wall and falls on the ground vertically below the maximum height. Assume the collision to be elastic. The height of the point on the wall where ball strikes is



(A) $\frac{H}{2}$ (B) $\frac{H}{4}$

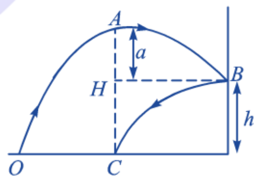
(C) $\frac{3H}{4}$ (D) none of these

Ans (C)

Due to collision, vertical component of velocity of stone does not change. So, time to reach the ground here is equal to time of flight of oblique projectile i.e. $T=\frac{2u\sin\theta}{g}=\frac{2u_y}{g}$. Because collision is elastic, even horizontal component remains same except for getting reversed.

If the time taken from B to C is t, then time taken from O to A is $2t$ and from A to B is t.

From A to B and to C:- $H=\frac{1}{2}g(2t)^2=2gt^2$



In the figure, $a=\frac{1}{2}gt^2=\frac{H}{4}$

$\therefore h=H-a=H-\frac{H}{4}=\frac{3H}{4}$

NCERT LINE BY LINE QUESTIONS

1. Two vectors are said to be equal, if **[NCERT Pg. 66)**
(a) They have equal magnitude only
(b) Same direction only
(c) They have equal magnitude and same direction
(d) They have unequal magnitude and same direction

2. A null vector has **[NCERT Pg. 68)**
(a) Zero magnitude, specified direction
(b) Zero magnitude, arbitrary direction

(c) Non-zero magnitude, no direction
(d) Non-zero magnitude, arbitrary direction

3. To a person moving with a speed of 5 m/s towards east, rain appears to be falling vertically downward with speed m/s. The actual velocity of rain is **[NCERT Pg. 69)**
(a)10 m/s at 30° with vertical
(b) 20 m/s at 30° with vertical
(c) 10 m/s at 60° with vertical
(d) 20 m/s at 60° with vertical

4. A vector can be resolved **[NCERT Pg. 70)**
(a) Only in two components
(b) Only in three components
(c) In any number of components
(d) Either two or three components

5. The magnitude of component of a vector **[NCERT Pg. 70)**
(a) Is always less than magnitude of vector
(b) Is always equal to magnitude of vector
(c) May be greater than magnitude of vector
(d) Is always greater than magnitude of vector

6 A motor boat is racing towards north at 25 km/h and the water current in that region is 10 km/h in the direction of 60° east of south. The resultant velocity of the boat is nearly **[NCERT Pg. 72]**
(a) 22 km/h (b) 12 km/h (c) 35 km/h (d) 26 km/h

7 In uniform circular motion, the centripetal acceleration is **[NCERT Pg. 79]**
(a) Due to change in magnitude of velocity only
(b) Due to change in direction of velocity only
(c) Due to change in both magnitude and direction of velocity
(d) Neither due to change in magnitude of velocity nor due to change in direction

8. In circular motion, the direction of angular velocity is **[NCERT Pg. 80]**
(a) In the plane of circle (b) Perpendicular to plane of circle
(c) In the direction of velocity (d) In the direction of acceleration

9. The shape of the trajectory of an object is determined by **[NCERT Pg. 85]**
(a) Acceleration only (b) Velocity of projection only
(c) Initial position and initial velocity only
(d) Initial position, initial velocity and acceleration

10. Which of the following vector operation is meaningful? **[NCERT Pg. 85)**
(a) Multiplication of any two vectors (b) Adding any two vectors
(c) Adding a component of vector to the same vector
(d) Both (b) and (c)

11. Which of the following quantities is/are vector? **[NCERT Pg. 85]**
(a) Angular frequency (b) Angular velocity
(c) Number of moles (d) Both (a) and (b)

12. Which of the following option is correct? **[NCERT Pg. 86]**
(a) Each component of a vector is always scalar
(b) Three vectors not lying in a plane can never add up to give null vector
(c) Two vectors of different magnitude can be add up to give null vector

(d) Minimum number of vectors to give null vector is five

13. A particle A is moving with velocity $(3\hat{i}+4\hat{j})$ m/s and particle 6 is moving with velocity $(-3\hat{i}-4\hat{j})$ m/s. The magnitude of velocity of B w.r.t A is **[NCERT Pg. 76]**
(a) 6 m/s (b) 8 m/s (c) 10 m/s (d) 5 m/s

14. If two vectors $\vec{A}=a\hat{i}+6\hat{j}$ $\vec{B}=b\hat{i}+c\hat{j}$ and are equal then correct options for value of a, 6 and c is **[NCERT Pg. 66]**
(a)a = 4 (b)a = c (c)c = 6 (d) Both (a) and (c)

15. Equation of trajectory of projectile is $y=\sqrt{3}x-5x^2$, Then angle of projection with vertical is (Assume x-axis as horizontal and y-axis as vertical) **[NCERT Pg. 78]**
(a) 45° (b) 30° (c) 60° (d) 53°

16. A projectile is projected with initial velocity $(10\hat{i}+20\hat{j})$ m/s from the ground. The velocity of the body just before hitting the ground is **[NCERT Pg. 79]**
(a) $10\hat{i}+20\hat{j}$ (b) $-10\hat{i}+20\hat{j}$ (c) $10\hat{i}-20\hat{j}$ (d) $-10\hat{i}-20\hat{j}$

17. The component of $(3\hat{i}+4\hat{j})$ in the direction of $(\hat{i}-\hat{j})$ is **[NCERT Pg. 87]**
(a) $\frac{\hat{j}-\hat{i}}{2}$ (b) $\frac{\hat{i}-\hat{j}}{2}$ (c) $\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$ (d) $\frac{1}{\sqrt{2}}(\hat{j}-\hat{i})$

18. The correct statement for a scalar quantity is **[NCERT Pg. 87]**
(a) It is conserved in a process
(b) It can never take negative values
(c) It does not vary from one point to another in space
(d) It has the same value for the observers with different orientations of axis

19. A man can swim with a speed of 5 km/h in still water. How long does he take to cross a river 1.0 km wide, if the river is flowing steadily at 3 km/h and he makes his strokes normal to the river current? **[NCERT Pg. 86]**
(a) 20 min (b) 30 min (c) 12 min (d) 15 min

20. A particle starts from origin at t=0 s with a velocity 4.0 $\hat{j}$ m/s and moves in *x-y* plane with a constant acceleration of $(6\hat{i}+4\hat{j})$ m/s² - The time after which y-coordinate of particle will be 48 m, will be **[NCERT Pg. 87]**
(a) 6s (b) 4s (c) 8s (d) 5s

NCERT BASED PRACTICE QUESTIONS

21 Two vectors of same magnitude inclined at an angle θ the resultant will make angle from on vector is
(a) $\frac{\theta}{2}$ (b) $\frac{\theta}{4}$ (c) θ (d) $\frac{\theta}{6}$

22 A particle is projected at an angle θ with the horizontal then at the top point of trajectory the angle between acceleration and velocity is
(a) 900 (b) 450
(c) 1800 (d) 00

23 A ball is dropped from the top of a tower in a high speed wind. The wind exerts a steady force on the ball. The path followed by the ball will be

(a) Parabola (b) circular are

(c) elliptical (d) straight line

24 A boy throws a ball with a velocity v0 at an angle α to the horizontal. At the same instant he starts running with uniform velocity to catch the ball before it hits the ground. To achieve this he should run the velocity of

(a) $v_0 \cos\alpha$ (b) $v_0 \sin\alpha$

(c) $v_0 \tan\alpha$ (d) $\sqrt{v_0^2 \tan\alpha}$

25 When a particle is thrown horizontally, the resultant velocity of the particle at any time t is given by

(a) g t (b) $\frac{1}{2}gt^2$ (c) $\sqrt{u^2+g^2t^2}$ (d) $\sqrt{u^2-g^2t^2}$

26 When a particle is projected at an angle 30^0 the horizontal range is 120m if particle is projected at an angle 120^0 the horizontal range will be

(a) 60 m (b) 120 m (c) 180 m (d) 90 m

27 A particle is thrown upward with a speed u at an angle θ with horizontal. When the particle makes an angle ϕ with the horizontal its speed changes to υ then

(a) $\upsilon = u\cos\theta\cos\phi$ (b) $\upsilon = u\cos\theta\sec\phi$

(c) $\upsilon = u\cos\theta$ (d) $\upsilon = u\sec\theta\cos\phi$

28 The particle attain maximum horizontal range when thrown at an angle θ with horizontal value of θ must be

(a) 45^0 (b) 60^0 (c) 30^0 (d) 90^0

29 If a particle is thrown with initial velocity u then the maximum height attained by the particle if horizontal range is maximum

(a) $\frac{u^2}{2g}$ (b) $\frac{u^2}{4g}$ (c) $\frac{u^2}{g}$ (d) $\frac{u^2}{8g}$

30 Maximum height attained by the particle if thrown with initial velocity u and at an angle θ with horizontal

(a) $\frac{u^2\sin^2\theta}{2g}$ (b) $\frac{u^2\sin^2\theta}{g}$ (c) $\frac{u^2\sin 2\theta}{g}$ (d) $\frac{u^2\sin 2\theta}{2g}$

31 When a particle is thrown θ with inital velocity u and angle θ with horizontal then time of flight of the particle is

(a) $\frac{2u\sin\theta}{g}$ (b) $\frac{u\sin\theta}{g}$ (c) $\frac{u\cos\theta}{g}$ (d) $\frac{2u\cos\theta}{g}$

32 If a particle is moving with constant speed then which of the following can be correct

(a) acceleration must be zero (b) velocity is constant

(c) acceleration is constant (d) none of these

33. If a body is moving in a curved path then

(a) acceleration may be zero (b) velocity may be constant

(c) acceleration must not be zero (d) None of these

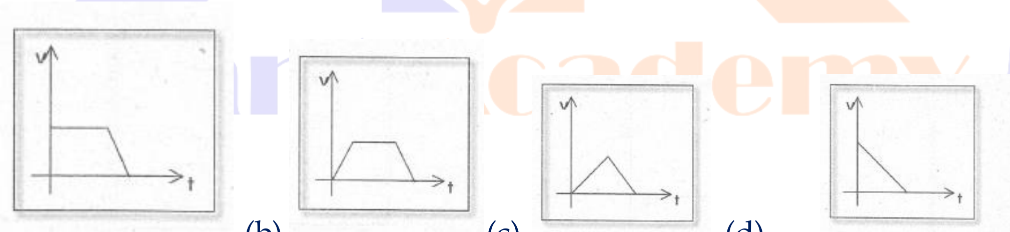
34. If a body is moving with uniform acceleration with inital velocity u and final velocity υ then average velocity of the particle is

(a) $\frac{u+\upsilon}{2}$ (b) $\frac{u-\upsilon}{2}$ (c) u (d) υ

35. If a body travels with a uniform acceleration a_1 for time t_1 and uniform acceleration a_2 for time t_2 then average acceleration is

(a) $\frac{a_1t_1+a_2t_2}{t_1+t_2}$ (b) $\frac{a_1t_1+a_2t_2}{t_1}$ (c) $\frac{a_1t_1+a_2t_2}{t_2}$ (d) $\frac{a_1t_1-a_2t_2}{t_1-t_2}$

36. In the following V-t graphs, identify the graph that represents a body moving with uniform velocity and then with uniform retardation until it stops.



(a) (b) (c) (d)

37. The distance travelled by a body is directly proportional to the square of the time taken. Its acceleration

(a) increases (b) decreases (c) become zero (d) remains constant

38. If $\left|\vec{A}.\vec{B}\right| = \left|\vec{A}\times\vec{B}\right|$,then resultant of $\bar{A}$ and $\bar{B}$ is

(a) A + B (b) A – B

(c) $(A^2 + B^2 + 2AB)^{1/2}$ (d) $\left(A^2+B^2+\sqrt{2}AB\right)^{1/2}$

39. What can be the angle between $(\bar{A}+\bar{B})and\left(\bar{A}-\bar{B}\right)$?

(a) 0^0 only (b) 90^0 only (c) 180^0 only (d) between 0^0 to 180^0

40 A particle is projected at angle θ from the horizontal with kinetic energy T. The kinetic energy of the particle at the highest point of the path is

(a) 0 (b) T sin θ (c) T $\cos^2\theta$ (d) T $\sin^2\theta$

41 A cricket ball is hit at 45^0 to the horizontal with a kinetic energy E_k the kinetic energy at the highest point is

(a) E_k (b) $E_k/2$ (c) $E_k / \sqrt{2}$ (d) zero

42 The vector ($\hat{i} + \hat{j}$) has magnitude

(a) 1 (b) $\frac{1}{\sqrt{2}}$ (c) $\sqrt{2}$ (d) 2

43. The ceiling of a long hall is 25m high what is the maximum horizontal distance that a ball thrown with a speed of 40m/s can go without hitting the ceiling of the ball?

(a) 150. 5m (b) 200.5m (c) 160.5m (d) 140.5m

44. A cricketer can throw a ball to a maximum horizontal distance of 100m. Then the night above the ground the cricketer can throw the ball is

(a) 50 m (b) 60 m (c) 80 m (d) 40 m

45. An aircraft executes a horizontal loop of radius 1.00 km with a constant speed of 900 km/h ratio of its centripetal acceleration to the acceleration due to gravity is

(a) 6.4 (b) 3.2 (c) 4.8 (d) 5.4

46. An aircraft is flying at a height of 3400m above the ground. If the angle subs tended at a ground observation point by the aircraft positions 10s apart is 30^0. Then speed of aircraft is

(a) 182 m/s (b) 152 m/s (c) 178 m/s (d) 148 m/s

47. An object while moving may not have

(a) variable speed but constant velocity

(b) variable velocity but constant speed

(c) Non- zero acceleration but constant speed

(d) Non-zero acceleration but constant velocity

48. A stone is dropped from a height of 45m what will be the distance travelled by it during last one second of its motion?

(a) 35 m (b) 25 m (c) 12.5 m (d) 10 m

49. The angle of projection at which the horizontal range and maximum height of projectile are equal is

(a) 45^0 (b) 60^0 (c) $\theta = \tan^{-1} 4$ (d) $\theta = \tan^{-1} (0.25)$

50. Which one is a vector quantity?

(a) energy (b) torque (c) both of these (d) none of these

51. The angular speed of a flywheel making 120 revolution per minute is

(a) 2π rad/s (b) $4\pi^2$ rad/s

(c) π rad/s (d) 4π rad/s

52. Two bodies A and B of masses 2M and M are dropped from heights 2H and H respectively. The ratio of times t_A / t_B taken by them to reach the ground is

(a) $\frac{1}{4}$ (b) 1 (c) $\sqrt{2}$ (d) 2

53. A man wants to hit a target he should point his riffle

(a) higher than target (b) lower than target

(c) in the same direction as target (d) nothing can be said

54. When a body is thrown horizontally from the top of a tower in air, it follows

(a) horizontal path (b) vertical path

(c) parabolic path (d) nothing can be said

55. If $\overline{A}\times\overline{B}=\overline{C}$ which of the following statement is not correct?

(a) $\overline{C}\perp\overline{A}$ (b) $\overline{C}\perp\overline{B}$ (c) $\overline{C}\perp(\overline{A}\times\overline{B})$ (d) $\overline{C}\perp(\overline{A}+\overline{B})$

56. The resultant of two forces 10N and 5N can never be

(a) 4N (b) 5N (c) 8 N (d) 12N

57. If $\overline{A}.\overline{B}=AB$,then angle between $\overline{A}and\ \overline{B}$ is

(a) zero (b) 90^0 (c) 180^0 (d) none of the above

58. Which of the following operations with two vectors can not be defined in vector algebra?

(a) addition (b) subtraction (c) multiplication (d) division

59. Cross product of two similar vector is

(a) zero (b) 1 (c) infinity (d) scalar

60. Two vectors $\overline{A}$ and $\overline{B}$ are such that $|\overline{A}+\overline{B}|=|\overline{A}-\overline{B}|$ then angle between the vectors $\overline{A}$ and $\overline{B}$ is

(a) 0^0 (b) 60^0 (c) 90^0 (d) 180^0

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Relative Velocity

1. A person standing on a moving truck throws a stone vertically up relative to himself. To a person, standing on the ground, the stone appears to: (immediately after being thrown).

1) Rise vertically up and come down 2) Rise towards the rear of the truck

3) Move along a parabolic path

4) Rise straight and forward but inclined to the direction of motion of truck.

2. Two particles are projected, between a certain time gaps. While both are in air, the velocity of one particle relative to the other:

1) Varies linearly with time
2) Is always constant in magnitude and direction
3) Is always constant in magnitude only
4) is always constant in direction only

3. A man runs along a horizontal road holding his umbrella vertical in order to afford maximum protection from rain. The rain is actually:

1) Falling vertical
2) Coming from front of the man
3) Coming from the back of the man
4) Either of 1), 2) or 3).

4. Two persons P and Q are flying in a helicopter horizontally at a constant speed. All of a sudden, P falls down. During the fall of P, at any instant, Q locates P:

1) Vertically down
2) Down, at an angle (acute) to the front of vertical
3) Down at an angle (acute) to the rear of vertical
4) Whose position depends upon the speed of the helicopter

5. To the captain of a ship A travelling with velocity $\vec{v}_A = \left(3\hat{i} - 4\hat{j}\right)$ km/h, a second ship B appears to have a velocity $\left(5\hat{i} + 12\hat{j}\right)$ km/h. What is the true velocity of the ship B?

1) $2\hat{i} + 16\hat{j}$ km/h
2) $13\hat{i} + 8\hat{j}$ km/h
3) $-2\hat{i} - 16\hat{j}$ km/h
4) $8\left(\hat{i} + \hat{j}\right)$ km/h

6. A boat is moving with a velocity $3\hat{i} + 4\hat{j}$ with respect to the ground. The water in the river is flowing with a velocity $-3\hat{i} - 4\hat{j}$ with respect to the ground. The velocity of the boat relative to the water is

1) $6\hat{i} + 8\hat{j}$
2) $8\hat{i} + 6\hat{j}$
3) $6\hat{i} + 6\hat{j}$
4) none of these

7. A car 'A' moves due north at a speed of 40 km/hr, while another car '13' moves due east at a speed of 30 km/ hr. Find the velocity of car B relative to car A (both in magnitude and direction).

1) 40 km/hr, at an angle $\tan^{-1}\left(\frac{3}{5}\right)$ east of south
2) 50 km/hr, at an angle $\tan^{-1}\left(\frac{3}{5}\right)$ east of south
3) 40 km/hr, at an angle $\tan^{-1}\left(\frac{3}{4}\right)$ east of south
4) 50 km/hr. at an angle $\tan^{-1}\left(\frac{3}{4}\right)$ east of south

8. A moves with 65 km/h while B is coming back of A with 80 km/h. The relative velocity of B with respect to A is
(1) 80 km/h
(2) 60 km/h
(3) 15 km/h
(4) 145 km/h

9. A river flow with a speed more than the maximum speed with which a person can swim in the still water. He intends to cross the river by shortest possible path (i.e., he wants to reach the point on the opposite bank which directly opposite to the starting point). Which of the following correct?
(1) He should start normal to the river bank
(2) He should start in such a way that, he moves normal to the bank, relative to the bank.
(3) He should start in a particular (calculated) direction making an obtuse angle with the direction of water current
(4) The man cannot cross the river, in that way

10. A ship A is moving Westwards with a speed of 10 km h^{-1} and a ship B 100 km south of A, is moving Northwards with a speed of 10km h^{-1}. The time after which the distance between them becomes shortest, is"

1) 5h 2) $5\sqrt{2}$h 3) $10\sqrt{2}$h 4) 0 h

11. A boat is moving with a velocity 2i + 3j with respect to ground. The water in the river is moving with a velocity –2i – 3j with respect to ground. The relative velocity of the boat with respect to water is

(1) 4 j (2) –4i + 6j (3) 4i + 6j (4) 6j

12. A boat which has a speed of 6 km/hr in still water crosses a river of width 1 km along the shortest possible path in 20 minutes. The velocity of the river water in km/hr is

(1) 5 (2) 4 (3) 3 (4) 1

13. A boat *B* is moving upstream with velocity 3 m/s with respect to ground. An observer standing on boat observes that a swimmer *S* is crossing the river perpendicular to the direction of motion of boat. If river flow velocity is 4 m/s and swimmer crosses the river of width 100 m in 50 sec, then

(1) velocity of swimmer w.r.t ground is $\sqrt{13}\text{m/s}$

(2) drift of swimmer along river is zero

(3) drift of swimmer along river will be 50 m

(4) velocity of swimmer w.r.t ground is 2 m/s

14. Two boys are standing at the ends A and B of a ground where AB = a. The boy at B starts running in a direction perpendicular to AB with velocity v1. The boy at A starts running simultaneously with velocity v and catches the other boy in a time t, where t is

1) $\frac{a^2}{\sqrt{v^2+v_1^2}}$ 2) $\frac{a^2}{v^2-v_1^2}$ 3) $\frac{a^2}{v^2+v_1^2}$ 4) $\sqrt{\frac{a^2}{v^2-v_1^2}}$

15. A bus is moving on a straight road towards north with a uniform speed of 50 km/hour turns through 90°. If the speed remains unchanged after turning, the increase in the velocity of bus in the turning process is

(1) 70.7 km/hour along south-west direction (2) zero

(3) 50 km/hour along west (4) 70.7 km/hour along north-west direction.

16. Two cars are moving in the same direction with the same speed 30 km/hr. They are separated by a distance of 5 km, the speed of a car moving in the opposite direction if it meets these two cars at an interval of 4 minutes, will be

(1) 40 km/hr (2) 45 km/hr (3) 30 km/hr (4) 15 km/hr

17. A car is going in south with a speed of 5 m/s. To a man sitting in car a bus appears to move towards west with a speed of $2\sqrt{6}\ \text{m/s}$. What is the actual speed of the bus?

1) 4 ms^{-1} 2) 3 ms^{-1} 3) 7 ms^{-1} 4) none of these

18. A flag is mounted on a car moving due North with velocity of 20 km/hr. Strong winds are blowing due East with velocity of 20 km/hr. The flag will point in direction

1) East 2) North-East 3) South-East 4) South-West

19. Wind is blowing in the north direction at speed of 2 m/s which causes the rain to fall at some angle with the vertical. With what velocity should a cyclist drive so that the rain appears vertical to him?

1) 2 m/s south 2) 2 rn/s north 3) 4 rn/s west 4) 4 m/s south

20. A car is moving along a road with a speed of 45 km/hr. In what direction must a body be projected from it with a velocity of 25 m/s, so that its resultant motion is at right angles to the direction of car?

1) At an angle of 120° with the direction of motion of car.

2) At an angle of 60° with the direction of motion of car.

3) At an angle of 90° with the direction of motion of car.

4) At an angle of 135° with the direction of motion of car.

21. Three ships A, B & C are in motion. The motion of A as seen by B is with speed v towards north-east. The motion of B as seen by C is with speed v towards the north west. Then as seen by A, C will be moving towards

1) north 2) south 3) east 4) west

22. A boat travels from south bank to north bank of a river with a maximum speed of 8 km/h. To arrive at a point opposite to the point of start, the boat should start at an angle:

1) $\tan^{-1}(1/2)$ W of N 2) $\tan^{-1}(1/2)$ N of W

3) 30^0 W of N 4) 30^0 N of W

23. A swimmer crosses a flowing stream of width ω to and fro in time t_1. The time taken to cover the same distance up and down the stream is t_2. I f t_3 is the time the swimmer would take to swim a distance 2ω in still water, then

1) $t_1^2 = t_2 t_3$ 2) $t_2^2 = t_1 t_3$ 3) $t_3^2 = t_1 t_2$ 4) $t_3 = t_1 + t_2$

24. A boat having a speed of 5 km/hr. in still water, crosses a river of width I km long the shortest possible path in 15 minutes. The speed of the river in Km/hr.

1) 1 2) 3 3) 4 4) $\sqrt{41}$

25. A man is crossing a river flowing with velocity of 5 m/s. He reaches a point directly across at a distance of 60 m in 5 sec. His velocity in still water should be

(1) 12 m/s (2) 13 m/s 3) 5 m/s 4) 10 m/s

26. A river is flowing due east with a speed 3 ms^{-1}. A swimmer can swim in still water at a speed of 4 ms^{-1}. If swimmer starts swimming due north, then the resultant velocity of the swimmer is

1) 3 ms^{-1} 2) 5 ms^{-1} 3) 7 ms^{-1} 4) 2 ms^{-1}

27. A boy can swim in still water at 1 m/s. He swims across a river flowing at 0.6 m/s which is 336 in wide. If he travels in shortest possible time, then what time he takes to cross the river?

1) 250 s 2) 420 s 3) 340 s 4) 336 s

28. A man can swim in still water with a speed of 2m/s. If he wants to cross a river of water current speed $\sqrt{3}$ m/s along shortest possible path, then in which direction should he swim?

1)at an angle 120° to the water current

2)at an angle 150° to the water current

3)at an angle 90° to the water current

4)none of these

29. A river flows with a speed more than the maximum speed with which a person can swim in still water. He intends to cross the river by shortest possible path. Which of the following, is correct?

1) He should start normal to the river hank.

(2) He should start in such a way that, he moves normal to the hank, relative to the bank

(3) He should start in a particular (calculated) direction making an obtuse angle with the direction of water current.

4) The man cannot cross the river, in that way.

30. A man wishes to cross a river in a boat. If he crosses the river in minimum time he takes 10 minutes with a drift of 120 m. If he crosses the river taking shortest route, he takes 12.5 minutes. Find velocity of the boat with respect to water.

1) 20 m/min 2) 12 m/min 3) 10 in/min 4) 8 m/min

31. A person walks at the rate of 3 km/hr. Rain appears to him in vertical direction at the rate of $3\sqrt{3}$ km/hr. Find magnitude and direction of true velocity of rain.

1) 6 km/hr, inclined at an angle of 45° to the vertical towards the person's motion.

2) 3 km/hr, inclined at an angle of 30° to the vertical towards the person's motion.

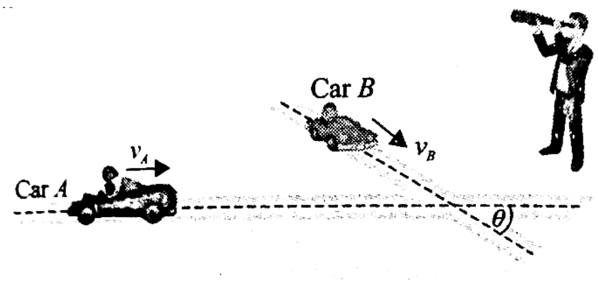
3) 6 km/hr, inclined at an angle of 30° to the vertical towards the person's motion.

4) 6 km/hr, inclined at an angle of 60° to the vertical towards the person's motion.

32. Rain is falling vertically with a speed of 35 m/s. Wind starts blowing after sometime with a speed of 12 m/s in east to west direction. At what angle with the vertical should a boy waiting at a bus stop hold his umbrella to protect himself from rain?

1) $\sin^{-1}\left(\frac{12}{35}\right)$ 2) $\cos^{-1}\left(\frac{12}{35}\right)$ 3) $\tan^{-1}\left(\frac{12}{35}\right)$ 4) $\cot^{-1}\left(\frac{12}{35}\right)$

33. Two cars A and B are moving as shown in figure. Calculate the relative velocity of A with respect to B. Also draw the direction of motion of car A as seen from car B.

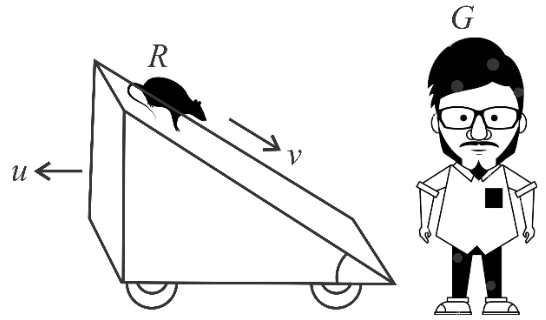


1) $\sqrt{v_A^2+v_B^2+2v_A.v_B\cos\left(180^0-\theta\right)}$, $\tan^{-1}\left(\frac{v_B\sin\theta}{v_A-v_B\cos\theta}\right)$

2) $\sqrt{v_A^2+v_B^2+2v_A.v_B\cos(180^0+\theta)}$, $\tan^{-1}\left(\dfrac{v_B\sin\theta}{v_A+v_B\cos\theta}\right)$

3) $\sqrt{v_A^2+v_B^2}$, $\tan^{-1}\left(\dfrac{v_B\sin\theta}{v_A+v_B\cos\theta}\right)$ 4) $\sqrt{v_A^2-v_B^2+2v_A.v_B\cos(180^0+\theta)}$, $\tan^{-1}\left(\dfrac{v_B\sin\theta}{v_A+v_B\cos\theta}\right)$

34. A rat is moving down the slant of a wedge of angle of inclination θ, with a velocity $\vec{v}$, as shown in the figure. If the wedge moves towards left with a velocity $\vec{u}$, find



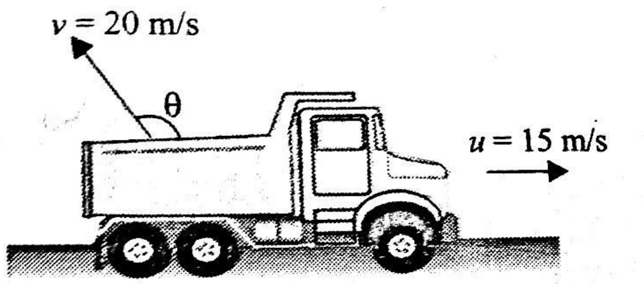
1) velocity of the rat relative to ground,

2) Value of θ, if the rate moves vertically downward relative to an observer G fixed with the ground

1) $\sqrt{u^2+v^2}$, $\theta=\cos^{-1}\dfrac{u}{v}$ 2) $\sqrt{u^2+v^2}$, $\theta=\cos^{-1}\dfrac{v}{u}$

3) $\sqrt{u^2-v^2}$, $\theta=\cos^{-1}\dfrac{v}{u}$ 4) $\sqrt{u^2+v^2-2uv\cos\theta}$, $\theta=\cos^{-1}\dfrac{u}{v}$

35. A truck is moving a constant velocity of u =54 km/hr. In what direction should a stone be projected up with a velocity of v = 30 m/s, from the floor of the truck, so as to appear at right angles to the truck, for a person standing on earth?



1) $\theta=120^0$ 2) $\theta=60^0$ 3) $\theta=45^0$ 4) $\theta=53^0$

36. A block slips along an incline of a wedge. Due to the reaction of the block on the wedge, it slips backwards. An observer on the wedge will see the block moving straight down the incline. To find the absolute velocity of the block

1) $\dfrac{v\sin\theta}{v\cos\theta-V}$ 2) $\dfrac{v\cos\theta}{v\cos\theta-V}$ 3) $\dfrac{v\cos\theta}{v\cos\theta+V}$ 4) $\dfrac{v\cot\theta}{v\cos\theta+V}$

37. A political party has to start its procession in an area where wind is blowing at a speed of $30\sqrt{2}$ km h^{-1} and party flags on the cars are fluttering along north-east direction. If the procession starts with a speed of 40

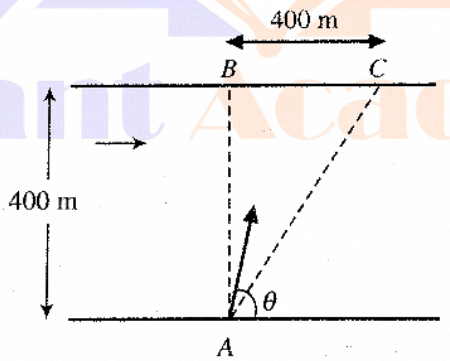
kmph^{-1} towards north, find the direction of flags on the cars.

1) $\theta = \tan^{-1}(2/3)$ N – W
2) $\theta = \tan^{-1}(1/3)$ S of E
3) $\theta = \tan^{-1}(2/3)$ S of E
4) $\theta = \tan^{-1}(2/3)$ N of W

38. A bird is flying due east with a velocity of 4 ms^{-1}. The wind starts to blow with a velocity of 3 ms^{-1} due north. What is the magnitude of relative velocity of bird w.r.t wind? Find out its direction also

1) $5ms^{-1}; \beta = \tan^{-1}\left(\frac{3}{4}\right)$ from east toward south
2) $4ms^{-1}; \beta = \tan^{-1}\left(\frac{3}{4}\right)$ from east toward south
3) $3ms^{-1}; \beta = \tan^{-1}\left(\frac{3}{4}\right)$ N – W
4) $5ms^{-1}; \beta = \sin^{-1}\left(\frac{3}{4}\right)$ from east toward south

39. A river is flowing with a speed of 1 kmh^{-1}. A swimmer wants to go to point C starting from A. He swims with a speed of 5 kmh^{-1} at an angle θ w.r.t the river flow. If AB = BC = 400m, at what angle with the river bank should the swimmer swim?



1) $\theta = 53^0$
2) $\theta = 35^0$
3) $\theta = 40^0$
4) $\theta = 45^0$

40. A person standing on a road has to hold his umbrella at 60^0 with the vertical to keep the rain away. He throws the umbrella and starts running at 20 ms^{-1}. He find that rain drops are hitting his head vertically. Find the speed of the rain drops with respect to (a) the road and (b) the moving person.

1) $\frac{40}{\sqrt{3}}$ m/sec, $\frac{20}{\sqrt{3}}$ m/sec
2) $\frac{30}{\sqrt{3}}$ m/sec, $\frac{10}{\sqrt{3}}$ m/sec
3) $\frac{30}{\sqrt{3}}$ m/sec, $\frac{20}{\sqrt{3}}$ m/sec
4) 30m/sec, 20m/sec

41. An aeroplane pilot wishes to fly due west. A wind of 100 kmh^{-1} is blowing towards south.

a) If the speed of the plane (its speed in still air) is 300 kmh^{-1}, in which direction should the pilot head?

b) What is the speed of the plane with respect to ground? Illustrate with a vector diagram

1) $\theta = \cos^{-1}\left(\frac{1}{3}\right), 100\sqrt{2}kmh^{-1}$
2) $\theta = \sin^{-1}\left(\frac{2}{3}\right), 200\sqrt{2}kmh^{-1}$

3) $\theta = \sin^{-1}\left(\frac{1}{3}\right), 200\sqrt{2}\text{kmh}^{-1}$ 4) $\theta = \sin^{-1}\left(\frac{1}{3}\right), 100\sqrt{2}\text{kmh}^{-1}$

42. Ship A is travelling with a velocity of 5 km h^{-1} due east. A second ship is heading 30^0 east of north. What should be the speed of second ship if it is to remain always due north with respect to the first ship?

1)10 km h^{-1} 2) 9 km h^{-1} 3) 8 km h^{-1} 4) 7 km h^{-1}

43. Rain, driven by the wind, falls on a railway compartment with a velocity of 20 ms^{-1} at an angle of 30^0 to the vertical. The train moves, along the direction of wind flow, at a speed of 108 kmh^{-1}. Determine the apparent velocity of rain for a person sitting in the train?

1) $20\sqrt{7}\text{ms}^{-1}$ 2) $10\sqrt{7}\text{ms}^{-1}$ 3) $15\sqrt{7}\text{ms}^{-1}$ 4) $10\sqrt{7}\text{km h}^{-1}$

44. The ratio of the distance carried away by the water current, downstream, in crossing a river, by a persons, making same angle with downstream and upstream is2:1. The ratio of the speed of person to the water current cannot be less than

1) 1/3 2) 4/5 3) 2/5 4) 4/3

45. Rain appears to fall vertically to a man walking at 3 km h^{-1} but when he changes his speed to double, the rain appears to fall at 45^0 with vertical. Study the following statements and find which of them are correct.

i. Velocity of rain is $2\sqrt{3}$ km h^{-1}

ii. The angle of fall of rain (with vertical) is $\theta = \tan^{-1}\left(\frac{1}{\sqrt{2}}\right)$

iii. The angle of fall of rain (with vertical) is $\theta = \sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$

iv. Velocity of rain is $3\sqrt{2}$ kmh^{-1}

1) statements (i) and (ii) are correct 2) statements (i) and (iii)are correct

3) Statements (iii) and (iv)are correct 4) statements (ii) and (iv)are correct

46. Raindrops are hitting the back of a man walking at a speed of 5 km h^{-1} if he now starts running in the same direction with a constant acceleration, the magnitude of the velocity of the rain with respect to him will

1) Gradually increase 2) gradually decrease

3) first decrease then increase 4) first increase then decrease

Topic 2: Projectile Motion

47. Which one is the largest when the height attained by the projectile is the greatest?
(1) Range (2) Time of flight (3) Angle of projectile with the vertical (4) None of these

48. Two projectiles A and B are thrown with the same speed but angles are 40º and 50º with the horizontal. Then
(1) A will fall earlier (2) B will fall earlier
(3) both will fall at the same time (4) None of these

49. A body is projected, making an acute angle with the horizontal. If angle between velocity $\vec{v}$ and acceleration $\vec{g}$ is θ, then

1) $\theta = 90^0$ 2) $\theta = 0^0$ 3) $90^0 < \theta < 0^0$ 4) $0^0 < \theta < 180^0$

50. A stone is thrown with a velocity u making an angle θ with the horizontal. The horizontal distance covered by its fall to ground is maximum when the angle θ is equal to

1) 0^0 2) 30^0 3) 45^0 4) 90^0

51. If range is double the maximum height of a projectile, then θ is

1) $\tan^{-1}$ 2) $\tan^{-1}1/4$ 3) $\tan^{-1}1$ 4) $\tan^{-1}2$

52. For angles of projection of a projectile $(45^0 - \theta)$ and $(45^0 + \theta)$, the horizontal ranges described by the projectile are in the ratio of

1) 1:3 2) 1:2 3) 2:1 4) 1:1

53. A person can throw a stone to a maximum distance of h metre. The maximum distance to which he can throw the stone is

1) h 2) h/2 3) 2h 4) 3h

54. Two balls are projected at an angle θ and $(90^0 - \theta)$ to the horizontal with the same speed. The ratio of their maximum vertical heights is

1) 1:1 2) $\tan\theta : 1$ 3) $1 : \tan\theta$ 4) $\tan^2\theta : 1$

55. A body is thrown with a velocity of 9.8 ms^{-1} making an angle of 30^0 with the horizontal. It will hit the ground after a time

1) 3.0s 2) 2.0s 3) 1.5s 4) 1s

56. The velocity of projection of a body is increased by 2%.Other factors remaining unchanged, what will be the percentage change in the maximum height attained?

(1) 1% (2) 2 % (3) 4 % (4) 8 %

57. A particle moves in a plane with a constant acceleration in a direction different from the initial velocity. The path of the particle is a/an

(1) straight line (2) arc of a circle (3) parabola (4) ellipse

58. A particle reaches its highest point when it has covered exactly one half of its horizontal range. The corresponding point on the displacement-time graph is characterized by

(1) negative slope and zero curvature (2) zero slope and negative curvature
(3) zero slope and positive curvature (4) positive slope and zero curvature

59. The range of a particle when launched at an angle of 15° with the horizontal is 1.5 km. What is the range of the projectile when launched at an angle of 45° to the horizontal?

(1) 1.5 km (2) 3.0 km (3) 6.3 km (4) 0.75 km

60. A body is thrown horizontally with a velocity $\sqrt{2gh}$ from the top of a tower of height h. It strikes the level ground through the foot of the tower at a distance x from the tower. The value of x is

1) gh 2) gh/2 3) 2h 4) 2gh/3

61. A projectile is thrown at an angle of 40^0 with the horizontal and its range is R_1. Another projectile is thrown at an angle 40^0 with the vertical and its range is R_2 What is the relation between R_1 and R_2

1) $R_1 = R_2$ 2) $R_1 = 2R_2$ 3) $2R_1 = R_2$ 4) $RR_1 = 4R_2/$

62. The equation of a projectile is $y = \sqrt{3}x - \frac{gx^2}{2}$ the angle of projection is given by

1) $\tan\theta = \frac{1}{\sqrt{3}}$ 2) $\tan\theta = \sqrt{3}$ 3) $\frac{\pi}{2}$ 4) zero

63. A gun fires two bullets at 60^0 and 30^0 with horizontal. The bullets strike at some horizontal distance. The ratio of maximum height for the two bullets is in the ratio
(1) 2 : 1 (2) 3 : 1 (3) 4 : 1 (4) 1 : 1

64. A projectile thrown with a speed v at an angle θ has a range R on the surface of earth. For same v and θ, its range on the surface of moon will be $\left[g_{moon} = \frac{g_{Earth}}{6}\right]$
1) R/6 2) R 3) 6R 4) 36R

65. An object is projected with a velocity of 20m/s making an angle of 45^0 with horizontal. The equation for the trajectory is $h = Ax - Bx^2$ wher h is height, x is horizontal distance. A and B are constant. There ration A:B is ($g = 10ms^{-2}$)
1) 1:5 2) 5:1 3) 1:40 4) 40:1

66. A particle is projected with a velocity *v* such that its range on the horizontal plane is twice the greatest height attained by it. The range of the projectile is (where g is acceleration due to gravity)
1) $\frac{4v^2}{5g}$ 2) $\frac{4g}{5v^2}$ 3) $\frac{v^2}{g}$ 4) $\frac{4v^2}{\sqrt{5}g}$

67. A ball is thrown from the ground with a velocity of $20\sqrt{3}$ m/s making an angle of 60° with the horizontal. The ball will be at a height of 40 m from the ground after a time t equal to($g = 10ms^{-2}$)
1) $\sqrt{2}$ sec 2) $\sqrt{3}$ sec 3) 2 sec 4) 3 sec

68. A bomb is dropped on an enemy post by an aeroplane flying horizontally with a velocity of 60 km h^{-1} and at a height of 490 m. At the time of dropping the bomb, how far the aeroplane should be from the enemy post so that the bomb may directly hit the target ?
1) $\frac{400}{3}$ m 2) $\frac{500}{3}$ m 3) $\frac{1700}{3}$ m 4) 498m

69. A body is projected horizontally from a point above the ground and motion of the body is described by the equation $x = 2t, y = 5t^2$ where x, and y are horizontal and vertical coordinates in metre after time t. The initial velocity of the body will be
1) $\sqrt{29}$ m/s horizontal (2) 5 m/s horizontal (3) 2 m/s vertical (4) 2 m/s horizontal

70. 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
1) $\sqrt{H\cos\theta/g}$ 2) $\sqrt{2H\cos\theta/g}$ 3) $\sqrt{4H/g}$ 4) $\sqrt{8H/g}$

71. A person aims a gun at a bird from a point at a horizontal distance of 100 m. If the gun can impact a speed of 500 ms^{-1} to the bullet. At what height above the bird must he aim his gun in order to hit it? ($g = 10ms^{-2}$)
1) 10.4 cm 2) 20.35 cm 3) 50 cm 4) 100 cms

72. A man standing on the roof of a house of height h throws one particle vertically downwards and another particle horizontally with the same velocity u. The ratio of their velocities when they reach the earth's surface will be
1) $\sqrt{2gh+u^2} : u$ 2) 1:2 3) 1:1 4) $\sqrt{2gh+u^2} : \sqrt{2gh}$

73. If V1 is velocity of a body projected from the point A and V2 is the velocity of a body projected from point B which is vertically below the highest point C. if both the bodies collide, then
1) $V_1 = \frac{1}{2}V_2$ 2) $V_2 = \frac{1}{2}V_1$ 3) $V_1 = V_2$ 4) Two bodies can't collide

74. A projectile can have the same range R for two angles of projection. It t1 and t2 be the times of flight in the two cases, then what is the product of two times of flight?

1) $t_1t_2 \propto R^2$ 2) $t_1t_2 \propto R$ 3) $t_1t_2 \propto \frac{1}{R}$ 4) $t_1t_2 \propto \frac{1}{R^2}$

75. A ball rolls off to the top of a staircase with a horizontal velocity u m/s. If the steps are h metre high and b metre wide, the ball will hit the edge of the nth step, if

1) $n = \frac{2hu}{gb^2}$ 2) $n = \frac{2hu^2}{gb}$ 3) $n = \frac{2hu^2}{gb^2}$ 4) $n = \frac{hu^2}{gb^2}$

76. A water fountain on the ground sprinkles water all around it. If the speed of water coming out of the fountain is *v*, the total area around the fountain that gets wet is

1) $\pi\frac{v^4}{g^2}$ 2) $\pi\frac{v^4}{2g^2}$ 3) $\pi\frac{v^2}{g^2}$ 4) $\pi\frac{v^2}{g}$

77. A ball projected from ground at an angle of 45° just clears a wall in front. If point of projection is 4 m from the foot of wall and ball strikes the ground at a distance of 6 m on the other side of the wall, the height of the wall is :

1) 4.4 m 2) 2.4 m 3) 3.6 m 4) 1.6 m

78. A boy can throw a stone up to a maximum height of 10 m. The maximum horizontal distance that the boy can throw the same stone up to will be

1) $20\sqrt{2}$m 2) 10m 3) $10\sqrt{2}$m 4) 20m

79. The velocity of a projectile at the initial point A is $(2\hat{i}+3\hat{j})$ m/s its velocity (in m/s) at point B is

1) $-2\hat{i}+3\hat{j}$ 2) $2\hat{i}-3\hat{j}$ 3) $2\hat{i}+3\hat{j}$ 4) $-2\hat{i}-3\hat{j}$

80. If t_m is the time taken by a projectile to achieve the maximum height, then the total time of flight t_f related to t_m as

1) $t_m = 2T_f$ 2) $t_f = t_m$ 3) $T_f = 2t_m$ 4) none of these

Topic 3: Circular Motion

81. In uniform circular motion

(1) both velocity and acceleration are constant

(2) acceleration and speed are constant but velocity changes

(3) both acceleration and velocity change

(4) both acceleration and speed are constant

82. The length of second's hand in a watch is 1 cm. The change in velocity of its tip in 15 seconds is:

1) zero 2) $\frac{\pi}{30\sqrt{2}}$ cm/s 3) $\frac{\pi}{30}$ cm/s 4) $\frac{\pi\sqrt{2}}{30}$ cm/s

83. An aircraft executes a horizontal loop of radius 1.00 km with a stedy speed of 900 km/h. The ratio of centripetal acceleration to acceleration due to gravity is $[g = 9.8 m/s^2]$

1) 6.38 2) 9.98 3) 11.33 4) 12.13

84. A particle moves in a circle of radius 30 cm. Its linear speed is given by : V = 2t, where t in second and v in m/s. Find out its radial and tangential acceleration at t = 3 sec respectively.

1) $220 m/sec^2, 50 m/sec^2$ 2) $110 m/sec^2, 5 m/sec^2$

3) $120 m/sec^2, 2 m/sec^2$ 4) $110 m/sec^2, 10 m/sec^2$

85. A particle *P* is moving in a circle of radius '*a*' with a uniform speed *v*. *C* is the centre of the circle and *AB* is a diameter. When passing through *B* the angular velocity of *P* about *A* and *C* are in the ratio:

(1) 1 : 1 (2) 1 : 2 (3) 2 : 1 (4) 4 : 1

86. A particle moves in a circle of radius 25 cm at two revolutions per second. The acceleration of the particle in meter per second^2 is
(1) π^2 (2) 8 π^2 (3) 4 π^2 (4) 2 π^2

87. A wheel rotates with constant acceleration of 2.0 rod/s^2, if the wheel starts from rest the number of revolutions it makes in the first ten seconds will be approximately
(1) 32 (2) 24 (3) 16 (4) 8

88. A car is moving along a circular path of radius 500 m with a speed of 30 m/s. If at some instant, its speed increases at the rate of 2 m/s2, then at that instant the magnitude of resultant acceleration will be:
(1) 4.7 m/s^2 (2) 3.8 m/s^2 (3) 3 m/s2 4) 2.7 m/s2

89. A car runs at a constant speed on a circular track of radius 100 m, taking 62.8 seconds in every circular loop. The average velocity and average speed for each circular loop respectively, is
(1) 0, 10 m/s (2) 10 m/s, 10 m/s (3) 10 m/s, 0 (4) 0, 0

90. A particle describes uniform circular motion in a circle of radius 2 m, with the angular speed of 2 rad s^{-1}. The magnitude of the change in its velocity in $\frac{\pi}{2}$ s is
(1) 0 ms^{-1} (2) 2 2 ms^{-1} (3) 8 ms^{-1} (4) 4 ms^{-1}

NEET PREVIOUS YEARS QUESTIONS

1. The position vector of a particle $\vec{R}$ as a function of time is given by $\vec{R} = 4\sin(2\pi t)\hat{i} + 4\cos(2\pi t)\hat{j}$
Where R is in meter, t in seconds and $\hat{i}$ and $\hat{j}$ denote unit vectors along x-and y-directions, respectively. Which one of the following statements is wrong for the motion of particle? **(2015)**
(1) Magnitude of acceleration vector is $\frac{v^2}{R}$, where v is the velocity of particle
(2) Magnitude of the velocity of particle is 8 meter/second
(3) Path of the particle is a circle of radius 4 meter. (4) Acceleration vector is along $-\vec{R}$

2. A particle is moving such that its position coordinate (x, y) are (2m, 3m) at time t = 0 (6m, 7m) at time t = 2 s and (13m, 14m) at time t = 5s.
Average velocity vector $\left(\vec{V}_{av}\right)$ from t = 0 to t = 5s is **(2014)**
1) $\frac{1}{5}\left(13\hat{i}+14\hat{j}\right)$ 2) $\frac{7}{3}\left(\hat{i}+\hat{j}\right)$ 3) $2\left(\hat{i}+\hat{j}\right)$ 4) $\frac{11}{5}\left(\hat{i}+\hat{j}\right)$

3. The speed of a swimmer in still water is 20 m/s. The speed of river water is 10 m/s and is flowing due east. If he is standing on the south bank and wishes to cross the river along the shortest path, the angle at which he should make his strokes w.r.t. north is given by : **[NEET-2019]**
(1) 30° west (2) 0° (3) 60° west (4) 45° west

4. A particle starting from rest, moves in a circle of radius 'r'. It attains a velocity of V_0 m/s in the nth round. Its angular acceleration will be :- **[NEET – 2019 (ODISSA)]**
1) $\frac{V_0}{n} rad/s^2$ 2) $\frac{V_0^2}{2\pi nr^2} rad/s^2$ 3) $\frac{V_0^2}{4\pi nr^2} rad/s^2$ 4) $\frac{V_0^2}{4\pi nr} rad/s^2$

5. Two bullets are fired horizontally and simultaneously towards each other from roof tops of two buildings 100 m apart and of same height of 200m with the same velocity of 25 m/s. When and where will the two bullets collide. (g =10 m/s^2) **[NEET – 2019 (ODISSA)]**
(1) after 2s at a height 180 m (2) after 2s at a height of 20 m
(3) after 4s at a height of 120 m (4) they will not collide

6. A particle moving in a circle of radius R with a uniform speed takes a time T to complete one revolution. If this particle were projected with the same speed at an angle 'θ' to the horizontal, the maximum height attained by it equals 4R . The angle of projection θ, is then given by : **[NEET-2021]**

1. $\theta = \cos^{-1}\left(\frac{\pi^2 R}{gT^2}\right)^{1/2}$ 2. $\theta = \sin^{-1}\left(\frac{\pi^2 R}{gT^2}\right)^{1/2}$ 3. $\theta = \sin^{-1}\left(\frac{2gT^2}{\pi^2 R}\right)^{1/2}$ 4. $\theta = \cos^{-1}\left(\frac{gT^2}{\pi^2 R}\right)^{1/2}$

7. A car starts from rest and accelerates at 5 m/s^2. At t = 4 s, a ball is dropped out of a window by a person sitting in the car. What is the velocity and acceleration of the ball at t = 6s? **[NEET-2021]**

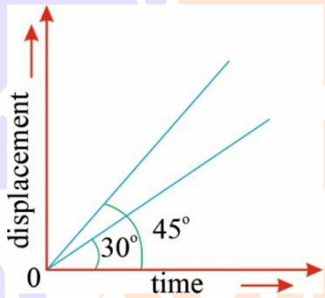
(Take g = 10 m/s^2)

1) 20 m/s, 0 2) $20\sqrt{2}$ m/s, 0 3) $20\sqrt{2}$ m/s, 10 m/s^2 4) 20 m/s, 5 m/s^2

8. The angular speed of a fly wheel moving with uniform angular acceleration changes from 1200 rpm to 3120 rpm in 16 seconds. The angular acceleration in rad/s^2 is **[NEET-2022]**

1) 2π 2) 4π 3) 12π 4) 104π

9. The displacement – time graphs of two moving particles make angles of 30^0 and 45^0 with the x – Axis as shown in the figure. The ratio of their respective velocity is **[NEET-2022]**



1) $\sqrt{3}:1$ 2) 1:1 3) 1:2 4) $1:\sqrt{3}$

10. A ball is projected with a velocity, 10 ms^{-1}, at an angle of 60° with the vertical direction. Its speed at the highest point of its trajectory will be : **[NEET-2022]**

1) Zero 2) $5\sqrt{3}\,ms^{-1}$ 3) $5\,ms^{-1}$ 4) $10\,ms^{-1}$

NCERT LINE BY LINE QUESTIONS – ANSWERS

1. 3	2. 2	3. 1	4. 3	5. 3	6. 1	7. 2	8. 2	9. 4	10. 1
11. 2	12. 2	13. 3	14. 4	15. 2	16. 3	17. 1	18. 4	19. 3	20. 2
21. a	22. a	23. d	24. a	25. c	26. b	27. b	28. a	29. b	30. A
31. a	32. c	33. c	34. a	35. a	36. a	37. d	38. d	39. b	40. c
41. b	42. c	43. a	44. a	45. a	46. a	47.a,d	48. b	49. c	50. B
51. d	52. c	53. a	54. c	55. c	56. a	57. a	58. d	59. a	60. c

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1) 3	2) 2	3) 2	4) 1	5) 4	6) 1	7) 4	8) 3	9) 4	10) 1
11) 3	12) 1	13) 1	14) 4	15) 1	16) 2	17) 3	18) 3	19) 2	20) 1
21) 2	22) 3	23) 1	24) 2	25) 2	26) 2	27) 4	28) 2	29) 4	30) 1
31) 3	32) 3	33) 1	34) 4	35) 1	36) 1	37) 2	38) 1	39) 1	40) 1
41) 3	42) 1	43) 2	44) 1	45) 3	46) 3	47) 2	48) 1	49) 4	50) 3
51) 4	52) 4	53) 2	54) 4	55) 4	56) 3	57) 3	58) 3	59) 2	60) 3
61) 1	62) 2	63) 2	64) 3	65) 4	66) 1	67) 3	68) 2	69) 4	70) 4
71) 2	72) 3	73) 2	74) 2	75) 3	76) 1	77) 2	78) 4	79) 2	80) 3
81) 3	82) 4	83) 1	84) 3	85) 2	86) 3	87) 3	88) 4	89) 1	90) 3

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1) 2	2) 4	3) 1	4) 3	5) 1	6) 3	7) 3	8) 2	9) 4	10) 2

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. 3) With respect to the an on ground, the stone has horizontal velocity (equal to that of the truck) as well as vertical velocity. So, it would appear to move along a parabolic path.

2. 2) The relative acceleration of one particle w.r.t to the other is zero, so relative velocity is constant in magnitude and direction.

3. (2) The horizontal component of rain should have same direction and magnitude as the velocity of man.
4. (1) Horizontal components of their velocities are equal so Q views P to be flitting vertically downwards.

5. 4) $\vec{v}_B = \vec{v}_{BA} + \vec{v}_A = \left(5\hat{i} + 12\hat{j}\right) + \left(3\hat{i} - 4\hat{j}\right)$

$\vec{v}_B = 8\hat{i} + 8\hat{j}$

6. 1) $\overrightarrow{V_b} = 3\hat{i} + 4\hat{j}, \overrightarrow{V_w} = -3\hat{i} - 4\hat{j}$

$\overrightarrow{V_{b/w}} = \overrightarrow{V_b} - \overrightarrow{V_w} = 6\hat{i} + 8\hat{j}$

7. 4) $\vec{v}_A = 40\hat{j}, \vec{v}_B = 30\hat{i}$

$\vec{v}_{B/A} = \vec{v}_B - \vec{v}_A = 30\hat{i} - 40\hat{j}$

$\left|\vec{v}_{B/A}\right| = \sqrt{30^2 + 40^2} = 50km/h$

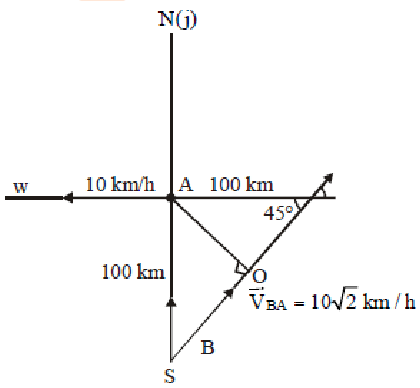
8. 3) $\vec{v}_{BA} = \vec{v}_B - \vec{v}_A = 80 - 65 = 15km/hr$
[$\because$ both are moving in the same direction]

9. 4)

10. 1) $\vec{V}_A = 10\left(-\hat{i}\right)$ and $\vec{V}_B = 10\left(\hat{j}\right)$

$\vec{V}_B = 10\left(\hat{j}\right) + 10\hat{i} = 10\sqrt{2}km/h$

Distance $OB = 100\cos 45^0 = 50\sqrt{2}km$



Time taken to reach the shortest distance between A and B = $\frac{OB}{V_{BA}} = \frac{50\sqrt{2}}{10\sqrt{2}} = 5h$

11. 3) Relative velocity = (2i + 3j) - (-2i - 3j) = 4i + 6j .

12. 1) Speed along the shortest path = $\frac{1}{20/60} = 3km/hr$

Speed of water $v = \sqrt{6^2 - 3^2} = 5km/hr$

13. 1) $\vec{v}_{SB} = v\hat{j} = \vec{v}_s + 3\hat{i}$

$\vec{v}_s = v\hat{j} - 3\hat{i}$ and $v = \frac{100}{50} = 2m/s$

$\therefore \left|\vec{v}_s\right| = \sqrt{v^2 + (3)^2} = \sqrt{2^2 + 9} = \sqrt{13}m/s$

Drift = 50 $\times$ 3 = 150m

14. 4)

15. 1) $\vec{v}_1 = 50km\ h^{-1}$ due North ;

$\vec{v}_2 = 50km\ h^{-1}$ due West

Angle between $\vec{v}_1$ and $\vec{v}_2 = 90^0$

$-\vec{v}_1 = 50kmh^{-1}$ due south

$\therefore$ change in velocity = $\left|\vec{v}_2 - \vec{v}_1\right| = \left|\vec{v}_2 + \left(-\vec{v}_1\right)\right| = \sqrt{v_2^2 + v_1^2} = \sqrt{50^2 + 50^2} = 70.7km/h$

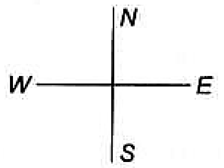
16. 2) The two cars (say A and B) are moving with same velocity, the relative velocity of one (say B) with respect to the other A, $\vec{v}_{BA} = \vec{v}_B - \vec{v}_A = v - v = 0$ So the relative separation between them (= 5 km) always remains the same. Now if the velocity of car (say C) moving in opposite direction to A and B, is $\vec{v}_c$ r relative to ground then the velocity of car C relative to A and B will be $\vec{v}_{rel} = \vec{v}_c - \vec{v}$ But as $\vec{v}$ is opposite to v_c

So, $\vec{v}_{rel} = \vec{v}_c - (-30) = (v_c + 30)\,km/hr$

So, the time taken by it to cross the cars A and B $t = \frac{d}{v_{rel}} \Rightarrow \frac{4}{60} = \frac{5}{v_c + 30} \Rightarrow v_c = 45 km/hr$

17. 3)

$\vec{v}_c = -5\hat{j}$



$v_{a,b,c} = -2\sqrt{6}\,\hat{i}$

$\vec{v}_b = \vec{v}_{bc} + \vec{v}_c = -2\sqrt{6}\hat{i} - 5\hat{j}$

$|\vec{v}_b| = \sqrt{4\times 6 + 25} = 7$ m/s

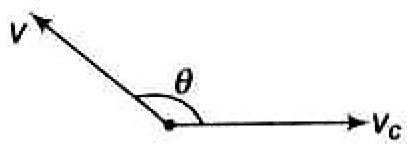
18. 3) $\vec{v}_w = 20\hat{i}, \vec{v}_c = 20\hat{i}$ here we have to look for velocity of wind w.r.t car. So

$\vec{v}_{w/C} = \vec{v}_w - \vec{v}_c = 20\hat{i} - 20\hat{j}$

This is in south-east direction

19. 2) Horizontal component of rain's velocity will be equal to velocity of wind which is 2 m/s in north direction. If cyclist goes towards north with velocity 2 m/s, then w.r.t him rain's horizontal component of velocity will be zero, and he will see only vertical component.

20. 1) $v_c = 45 km/h = \frac{25}{2} m/s$



For the resultant motion to be upwards.

$v\cos\theta + v_c = 0$

$\cos\theta = -\frac{v_c}{v} = -\frac{25/2}{25} = -\frac{1}{2} \Rightarrow \theta = 120^0$

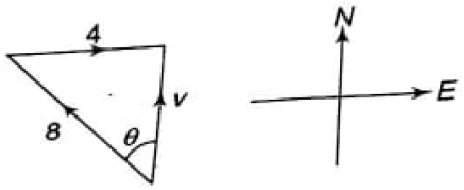
21. 2) $\vec{v}_A = \vec{v}_B = v\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right); \vec{v}_B - \vec{v}_C = v\left(\frac{-\hat{i}+\hat{j}}{\sqrt{2}}\right)$

Adding: $\Rightarrow \vec{v}_A - \vec{v}_C = \frac{2v}{\sqrt{2}}\hat{j} \Rightarrow \vec{v}_C - \vec{v}_A = -\sqrt{2}v\hat{j} = \sqrt{2}v(-\hat{j})$

So C will be moving towards south as seen by A. or $\alpha_P > 10 m/s^2$

22. 3) In order to arrive at the opposite bank, the boast should start at an angle θ with north such that sin $\theta = \frac{4}{8}$ or $\theta = 30^0$. The real velocity of boat will be

$v = \sqrt{8^2 - 4^2} = \sqrt{48}, \theta = 30^0$ W of N



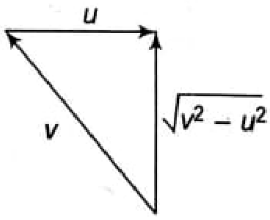
23. 1) Let v be the river velocity and u the velocity of swimmer in still water. Then

$$t_1 = 2\left(\frac{W}{\sqrt{u^2 - v^2}}\right)$$

$$t_2 = \frac{W}{u+v} + \frac{W}{u-v} = \frac{2uW}{u^2 - v^2} \text{ and } t_3 = \frac{2W}{u}$$

Now we can see that $t_1^2 = t_2 t_3$

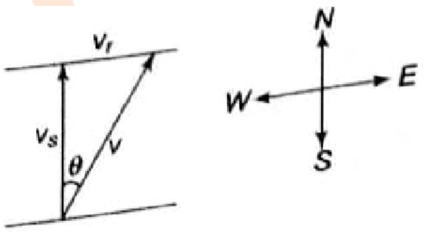
24. 2) $t = \frac{d}{\sqrt{v^2 - u^2}}$



$$\Rightarrow \frac{15}{60} = \frac{1}{\sqrt{5^2 - u^2}} \Rightarrow u = 3 km/h$$

25. 2) $t = \frac{d}{\sqrt{v^2 - u^2}} \Rightarrow 5 = \frac{60}{\sqrt{v^2 - 5^2}} \Rightarrow v = 13 m/s$

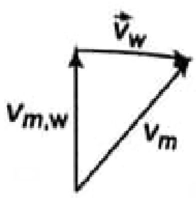
26. 2)



Here, velocity of water flowing in river, n_r=3ms^{-1} velocity of swimmer in still water, n_s= 4ms^{-1} from figure, The resultant velocity of the swimmer is

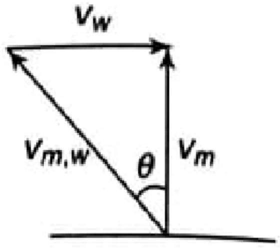
$$v = \sqrt{v_s^2 + v_r^2} = \sqrt{(4)^2 + (3)^2} = \sqrt{25} = 5 ms^{-1}$$

27. 4) Time to cross river $T = \frac{336}{1} = 336 \sec$

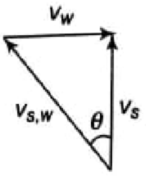


28. 2) $\sin\theta = \frac{\sqrt{3}}{2} \Rightarrow \theta = 60^0$

Hence 150^0 with water current



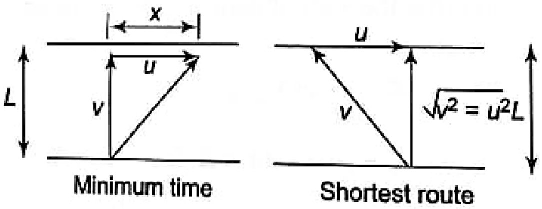
29. 4)



In this case As $v_w > v_{sw}$

As $\sin\theta$ cannot be greater than 1, he cannot reach directly opposite bank in this way.

30. 1)



$10 = \frac{L}{v}$ ....(i)

$12.5 = \frac{L}{\sqrt{v^2 - u^2}} = \frac{L}{v\sqrt{1-u^2/v^2}}$ ....(ii)

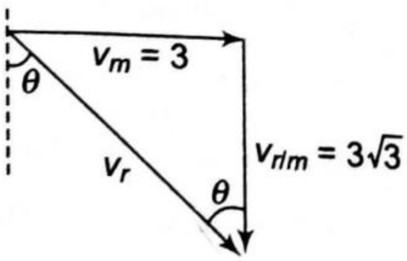
From (i) and (ii) $\frac{1}{12.5} = \frac{L}{v} \times \frac{v\sqrt{1-u^2/v^2}}{L}$

$\frac{4}{5} = \sqrt{1 - \frac{12^2}{v^2}}$

$\frac{16}{25} = 1 - \frac{12^2}{v^2} \Rightarrow \frac{12^2}{v^2} = 1 - \frac{16}{25} = \frac{9}{25}$

$\frac{12}{v} = \frac{3}{5} \Rightarrow v = \frac{12 \times 5}{3} = 20 = m/s$

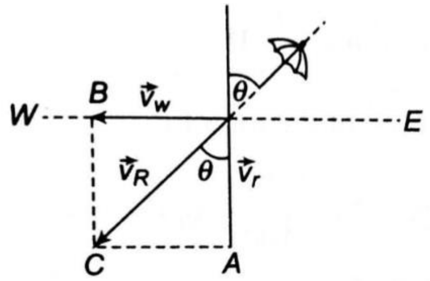
31. 3) $\vec{v}_{r/m} = \vec{v}_r - \vec{v}_m$



$\vec{v}_r = \vec{v}_{r/m} + \vec{v}_m$

$\tan\theta = \frac{3}{3\sqrt{3}} = \frac{1}{\sqrt{3}} \Rightarrow \theta = 30^0$

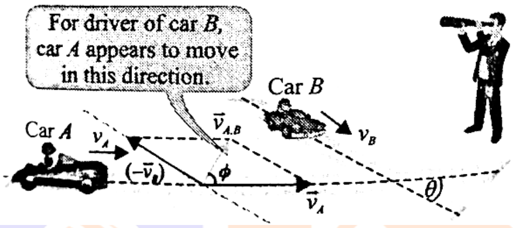
32. 3)



The velocity of the rain and the wind are represented by the vectors $\vec{v}_r$ and $\vec{v}_w$ as shown in the figure. To protect himself from the rain the boy should hold his umbrella in the direction of resultant velocity $\vec{v}_R$. If θ is the angle which resultant velocity $\vec{v}_R$ makes with the vertical, then

$$\tan\theta = \frac{v_w}{v_r} = \frac{12}{35} \text{ or } t\theta = \tan^{-1}\left(\frac{12}{35}\right)$$

33. 1) Direction of motion of car A as seen from car B



Velocity of car A as seen from car B

$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B = \vec{v}_A + \left(-\vec{v}_B\right)$

Magnitude : $\left|\vec{v}_{A,B}\right| = \sqrt{v_A^2 + v_B^2 + 2v_A.v_B.\cos\left(180^0 - \theta\right)}$

Direction: $\tan\phi = \dfrac{v_B\sin\left(180^0-\theta\right)}{v_A + v_B\cos\left(180^0-\theta\right)} \Rightarrow \phi = \tan^{-1}\left(\dfrac{v_B\sin\theta}{v_A - v_B\cos\theta}\right)$

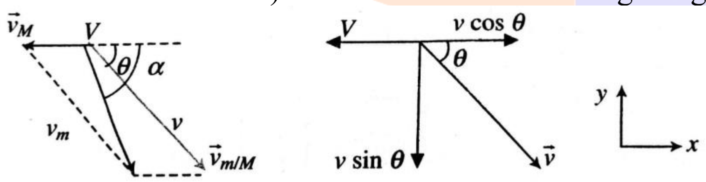
34. 4)

35. 1)

36. 1) We know that

$$\vec{v}_{m/M} = \vec{v}_m - \vec{v}_M \Rightarrow \vec{v}_m = \vec{v}_{m/M} + \vec{v}_M$$

Not that a single subscript implies absolute velocity .The absolute velocity of block is the vector sum of its velocity relative to the wedge and velocity of wedge relative to ground. The absolute velocity of block (ground reference frame) is shown in the vector diagram given in figure.



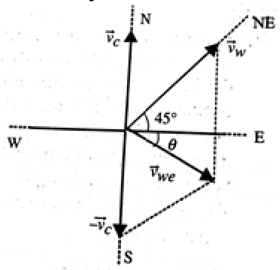
$\left|\vec{v}_m\right| = \sqrt{v^2 + V^2 + 2vV\cos\left(\pi-\theta\right)} = \sqrt{v^2 + V^2 - 2vV\cos\theta}$ we can derive this result by resolving v into its components .Sum of x-components $V_x = v\cos\theta - V$

Sum of y-components $V_y = v\sin\theta$

Resultant velocity $\sqrt{V_x^2 + V_y^2} = \sqrt{\left(v\cos\theta - V\right)^2 + \left(v\sin\theta\right)^2} = \sqrt{v^2 + V^2 - 2vV\cos\theta}$

$$\tan\alpha = \frac{V_y}{V_x} = \frac{v\sin\theta}{v\cos\theta - V}$$

37. 2)When the procession is stationary, the flags flutter along the north-east direction. It means wind is flowing along the north-east direction. The flags will start fluttering along the direction of the relative velocity of wind w.r.t procession.

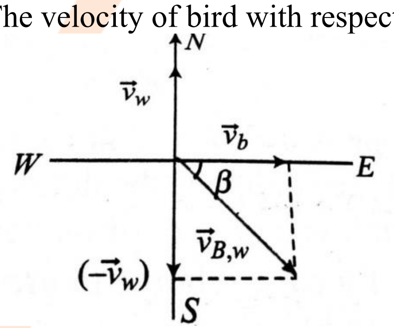


$\vec{v}_{wc} = \vec{v}_w - \vec{v}_c = \left(30\sqrt{2}\cos 45^0\hat{i} + 30\sqrt{2}\sin 45^0\hat{j}\right) - 40\hat{j} = 30\hat{i} - 10\hat{j}\left(ms^{-1}\right)$

$\tan\theta = \frac{10}{30} = \frac{1}{3}$

So the flag will flutter in a direction at $\theta = \tan^{-1}(1/3)$ S of E

38. 1)The velocity of bird with respect to wind can be given as



$\vec{v}_{b,w} = \vec{v}_b - \vec{v}_w = \vec{v}_b + \left(-\vec{v}_w\right) = 4\hat{i} + \left(-3\hat{j}\right)\left(ms^{-1}\right) = 4\hat{i} - 3\hat{j}\left(ms^{-1}\right)$

$\left|\vec{v}_b, w\right| = \sqrt{(4)^2 + (3)^2} = 5ms^{-1}$

Here the direction of the relative velocity of the bird is

$\left|\tan\beta\right| = \frac{3}{4} \Rightarrow \beta = \tan^{-1}\left(\frac{3}{4}\right)$

Hence, the relative velocity of the bird with respect to wind is $5ms^{-1}$ and in the direction $\tan^{-1}\left(\frac{3}{4}\right)$ from east toward south

39. 1)

40. 1)Given $\theta = 60^0$ and velocity of person $\vec{v}_P = \overrightarrow{OA} = 20ms^{-1}$

This velocity is same as the velocity of person w.r.t ground. First of all let us see how the diagram works out.

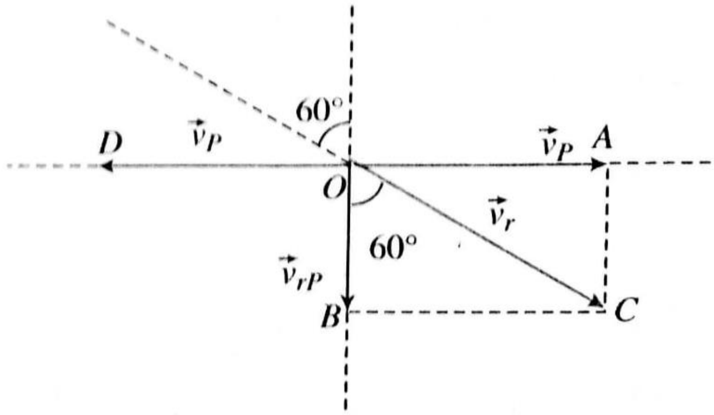
$\vec{v}_{rP} = \overrightarrow{OB} =$ Velocity of rain w.r.t person

$\vec{v}_r = \overrightarrow{OC} =$ velocity of rain w.r.t person

Values of $\vec{v}_r$ and $\vec{v}_{rP}$ can be obtained by using simple trigonometric relations

a) Speed of rain drops w.r.t Earth = $\vec{v}_r = \overrightarrow{OC}$

From $\Delta OAB, \frac{CB}{OC} = \sin 60^0 \Rightarrow OC = \frac{CB}{\sin 60^0} = \frac{20}{\sqrt{3}/2} = \frac{40}{\sqrt{3}} m/sec$



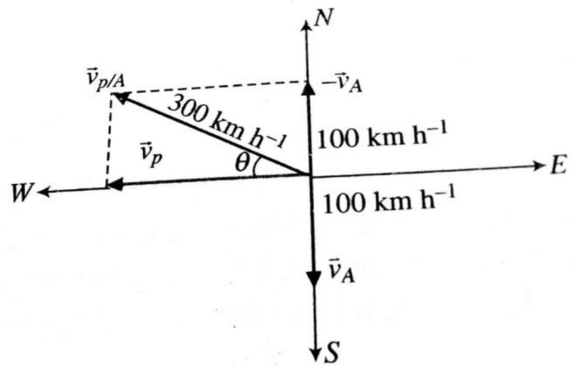
b) Speed of rain w.r.t the person, $\vec{v}_{rP} = \overrightarrow{OB}$

from $\frac{OB}{CB} = \cot 60^0 \Rightarrow OB = CB\cot 60^0 = \frac{20}{\sqrt{3}}$ m/sec

41. 3)Velocity of air (wind) = $\vec{v}_A = 100 kmh^{-1}$

Velocity of plane w.r.t air = $\vec{v}_{P/A} = 300 kmh^{-1}$

$\vec{v}_P = \vec{v}_{P/A} + \vec{v}_A$



The velocity of the plane will be the vector sum of two velocities. Velocity of air and velocity of plane w.r.t air: if the plane is to move towards west finally, then the N-S component of velocity should be zero. For this

$\vec{v}_{P/A} \sin\theta = \vec{v}_A$

$\Rightarrow 300\sin\theta = 100 \Rightarrow \sin\theta = \frac{1}{3} \Rightarrow \theta = \sin^{-1}\left(\frac{1}{3}\right)$

So the pilot should head in direction $\theta = \sin^{-1}\left(\frac{1}{3}\right)$ N of W

Speed of plane w.r.t ground, $\vec{v}_P = \vec{v}_{P/A}\cos\theta = 300\sqrt{1-\sin^2\theta} = 300\sqrt{1-\left(\frac{1}{3}\right)^2} = 200\sqrt{2} kmh^{-1}$

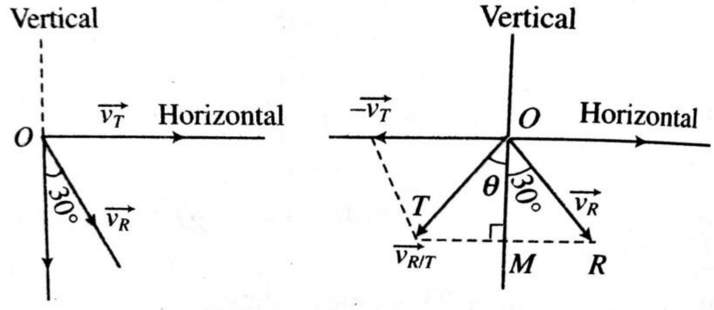
42. 1) for B always to be north of A, the velocity components of both along east should be same

$v_2\cos 60^0 = v_1 \Rightarrow v_2 = 10 kmh^{-1}$

43. 2) Speed of train = $108 \times \frac{5}{18} = 30 ms^{-1}$

Let $\vec{v}_R$ and $\vec{v}_T$ represent the respective velocities of rain and train. Now, the relative velocity of rain w.r.t person (train) is given by $v_{R.T} = \vec{v}_R - \vec{v}_T \Rightarrow \vec{v}_R + \left(-\vec{v}_T\right)$

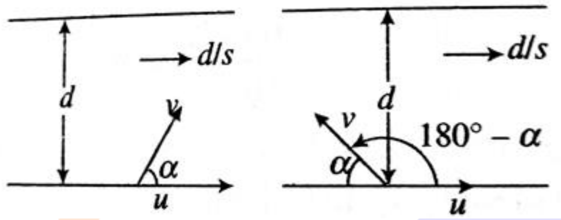
Let $\overrightarrow{OR}$ and $\overrightarrow{RT}$ represent the vectors, respectively, in magnitude and direction



$$OT^2 = OR^2 + RT^2 + 2OR.RT\cos120^0 = 20^2 + 30^2 - 2\times20\times30\times\frac{1}{2}$$

$$= 400 + 900 - 600 = 700 = \sqrt{700}ms^{-1} = 10\sqrt{7}ms^{-1}$$

44. 1) Motion of the person making an angel (say α) with the downstream



The time taken to cross the river = $\dfrac{d}{v\sin\alpha}$

The distance carried away downstream in the same time = speed $\times$time

$$x_1 = (u + v\cos\alpha)\frac{d}{v\sin\alpha}$$

Motion of the person making α angle with upstream

The time taken to cross the river is equal to $\dfrac{d}{v\sin\alpha}$

Distance carried away downstream in the same time

$$x_2 = \left[u + v\cos\left(180^0 - \alpha\right)\right]\frac{d}{v\sin\alpha}$$

$$\Rightarrow x_2 = (u - v\cos\alpha)\frac{d}{v\sin\alpha} \text{ given } \frac{(u + v\cos\alpha)\frac{d}{v\sin\alpha}}{(u - v\cos\alpha)\frac{d}{v\sin\alpha}} = \frac{2}{1}$$

$$\frac{(u + v\cos\alpha)}{(u - v\cos\alpha)} = \frac{2}{1} \Rightarrow 3v\cos\alpha = u \quad \Rightarrow \frac{v}{u} = \frac{\sec\alpha}{3}$$

$$\sec\alpha \geq 1 \Rightarrow \frac{\sec\alpha}{3} \geq \frac{1}{3}$$

From Eq. (iii), $\dfrac{v}{u} \geq \dfrac{1}{3}$ so v/u cannot be less than 1/3.

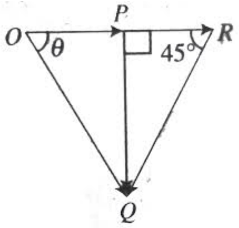
45. 3) case I : Let OP = $3\hat{i}$ be the velocity of man. $\overrightarrow{OQ}$ be the velocity of rain. PQ is the velocity of rain relative to man.

Case II: $\overrightarrow{OR} = 6\hat{i}$ is the new velocity of man

$\overrightarrow{RQ}$ = new velocity of rain relative to an

OP = PR = PQ = 3 Now $OQ^2 = OP^2 + PQ^2$, i.e., $OQ^2 = 3^2 + 3^2$ i.e., $OQ == 3\sqrt{2}kmh^{-1}$ and

$$\tan\theta = \frac{PQ}{OP} = \frac{3}{3} = 1, \text{ i.e.}, \theta = 45^0$$



46. 3) The magnitude will decrease till the direction of the velocity with respect to man becomes vertical . It will increase thereafter.

47. 2) y_m is largest when $\theta = 90^0$ from the horizontal. So, time of flight is largest.

48. 1) $T = \frac{2u\sin\theta}{g}$, lesser is the value of θ, lesser is $\sin\theta$ and hence lesser will be the time taken. Hence A will fall earlier.

49. (4) Here velocity is acting upwards when projectile is going upwards and acceleration is downwards. The angle θ between $\vec{v}$ and $\vec{a}$ is more than 0º and less than 180º.

50. (c) Since range on horizontal plane is $R = \frac{u^2\sin 2\theta}{g}$ so it is max. when $\sin 2\theta = 1 \Rightarrow \theta = \frac{\pi}{4}$

51. 4) $\frac{u^2 2\sin\theta\cos\theta}{g} = 2\times\frac{u^2\sin^2\theta}{2g}$ or $\tan\theta = 2$

52. 4) $(45^0-\theta)\&(45^0+\theta)$ are complementary angles as $45^0-\theta+45^0+\theta = 90^0$ We know that if angle of projection of two projectiles make complementary angles, their ranges are equal. In this case also, the range will be same. So the ratio is 1 : 1.

53. 2) $R = h = \frac{u^2\sin 2\theta}{g}$ when $2\theta = 90^0 \Rightarrow \frac{u^2}{g} = h$

Height H is given by: $H = \frac{u^2\sin^2\theta}{2g}$ when $\theta = 90^0, H = H_{max} = \frac{u^2}{2g} = \frac{h}{2}$

54. 4) $\frac{H_1}{H_2} = \frac{u^2\sin^2\theta/2g}{u^2\sin^2(90^0-\theta)} = \tan^2\theta$

55. 4) Time of flight $= \frac{2u\sin\theta}{g} = \frac{2\times9.8\times\sin30^0}{9.8} = 2\times\frac{1}{2} = 1\text{sec}$

56. 3) We know that, $y_m = H = \frac{(u\sin\theta)^2}{2g} = \frac{u^2\sin^2\theta}{2g}$

$\therefore \frac{\Delta H}{H} = \frac{2\Delta u}{u}$ given $\frac{\Delta u}{u} = 2\%$

$\therefore \frac{\Delta H}{H} = 2\times2 = 4\%$

57. 3) Only in case of parabolic motion, the direction and magnitude of the velocity changes, acceleration remains same. Morever, in case of uniform circular motion, the direction changes.

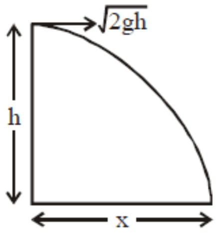
58. 3) At the highest point, the slope is zero and curvature is positive.

59. 2) $R_{15^0} = \frac{u^2\sin(2\times15^0)}{g} = \frac{u^2}{2g} = 1.5\text{km}$

$R_{45^0} = \frac{u^2\sin(2\times45^0)}{g} = \frac{u^2}{g} = 1.5\times2 = 3\text{km}$

60. 3) $u_y = 0, s_y = -h, a_y = -g, t_y = ?$

$s = ut + \frac{1}{2}at^2$



$\therefore -h = -\frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2h}{g}}$

Velocity = x/t

$\therefore x = \sqrt{2gh} \times \sqrt{\frac{2h}{g}} = 2h$

61. 1) R is same for both θ and $(90 - \theta)$. If angle w.r.t. vertical is 40º then w.r.t. horizontal direction it will be 90º – 40º = 50º.

62. 2) Comparing the given equation with $y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$, we get $\tan\theta = \sqrt{3}$

63. 2) The bullets are fired at the same initial speed

$$\frac{H}{H'} = \frac{u^2\sin^2 60^0}{2g} \times \frac{2g}{u^2\sin^2 30^0} = \frac{\sin^2 60^0}{\sin^2 30^0} = \frac{\left(\sqrt{3}/2\right)^2}{(1/2)^2} = 3/1$$

64. 3) On earth, $R = u^2\sin 2\theta/g$ on moon, $g' = g/6$ $R' = u^2\sin 20/g' = 6u^2\sin 2\theta/g = 6R$

65. 4) Standard equation of projectile motion

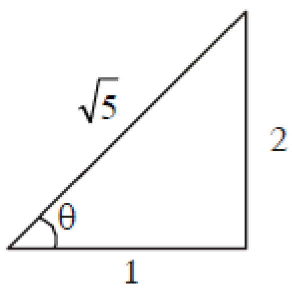
$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

Comparing with given equation

$$A = \tan\theta \text{ and } B = \frac{g}{2u^2\cos^2\theta}$$

So $\frac{A}{B} = \frac{\tan\theta \times 2u^2\cos^2\theta}{g} = 40$

66. 1) We know, $R = 4H\cot\theta \Rightarrow \cot\theta = \frac{1}{2}$ From triangle we can say that $\sin\theta = \frac{2}{\sqrt{5}}, \cos\theta = \frac{1}{\sqrt{5}}$



$$\therefore \text{Range of projectile } R = \frac{2v^2\sin\theta\cos\theta}{g} = \frac{2v^2}{g} \times \frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{5}} = \frac{4v^2}{5g}$$

67. 3) As, $s = u\sin\theta t - \frac{1}{2}gt^2$ so $40 = 20\sqrt{3} \times \left(\sqrt{3}/2\right)t - \frac{1}{2} \times 10 \times t^2$ or $5t^2 - 30t + 40 = 0$ or $t^2 - 6t + 8 = 0$

Or t = 2 or 4.

The minimum time t = 2s.

68. 2) Time taken for vertical direction motion

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 490}{9.8}} = \sqrt{100} = 10s$$

The same time is for horizontal direction.

$\therefore x = vt = \left(60 \times \frac{5}{18}\right) \times 10 = \frac{500}{3} m$

69. 4) The horizontal velocity of the projectile remains constant throughout the journey. Since the body is projected horizontally, the initial velocity will be same as the horizontal velocity at any point. Since,

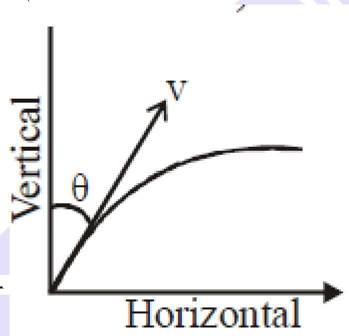
$x = 2t, \frac{dx}{dt} = 2$

$\therefore$ Horizontal velocity = 2 m/s
$\therefore$ Initial velocity = 2 m/s

70. 4) 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)



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

71. 2)
72. 3)
73. 2) Two bodies will collide at the highest point if both cover the same vertical height in the same time.

So $\frac{V_1^2 \sin^2 30^0}{2g} = \frac{V_2^2}{2g} \Rightarrow \frac{V_2}{V_1} = \sin 30^0 = \frac{1}{2} \therefore V_2 = \frac{1}{2}V_1$

74. 2) The horizontal range is the same for the angles of projection θ and $(90-\theta)$

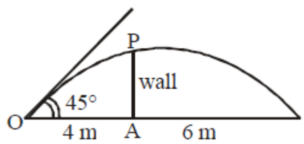
$t_1 = \frac{2u\sin\theta}{g}, t_2 = \frac{2u\sin(90^0-\theta)}{g} = \frac{2u\cos\theta}{g}$

$t_1 t_2 = \frac{2u\sin\theta}{g} \times \frac{2u\cos\theta}{g} = \frac{2}{g}\left[\frac{u^2\sin 2\theta}{g}\right] = \frac{2}{g}R$

where $R = \frac{u^2 \sin 2\theta}{g}$ Hence $t_1 t_2 \propto R$ (as R is constant)

75. 3)
76. 1)
77. 2) As ball is projected at an angle 45° to the horizontal therefore Range = 4H or

$10 = 4H \Rightarrow H = \frac{10}{4} = 2.5m$



$(\because \text{Range} = 4m + 6m = 10m)$

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

$\therefore\ u^2 = \frac{H \times 2g}{\sin^2\theta} = \frac{2.5 \times 2 \times 10}{\left(\frac{1}{\sqrt{2}}\right)^2} = 100$ or, $u = \sqrt{100} = 10\ ms^{-1}$

Height of wall PA $= OA \tan\theta - \frac{1}{2}\frac{g(OA)^2}{u^2\cos^2\theta}$

$= 4 - \frac{1}{2} \times \frac{10 \times 16}{10 \times 10 \times \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{2}}} = 2.4\,m$

78. 4) $R = \frac{u^2\sin^2\theta}{g}, H = \frac{u^2\sin^2\theta}{2g}$

H_{max} at $2\theta = 90^0$

$H_{max} = \frac{u^2}{2g}$

$\frac{u^2}{2g} = 10 \Rightarrow u^2 = 10g \times 2$

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

$R_{max} = \frac{10 \times g \times 2}{g} = 20$metre

79. 2) At point B the direction of velocity component of the projectile along Y - axis reverses.
Hence, $\vec{V}_B = 2\hat{i} - 3\hat{j}$

80. 3) $V_y = u\sin\theta = gt_m = 0$

$\therefore t_m = \frac{u_y \sin\theta}{g}$ (time to reach the maximum height)

Total time of flight $T_f = \frac{2(u\sin\theta)}{g}$

$\therefore T_f = 2t_m$

81. 3) In circular motion with constant speed, acceleration is always inward, its magnitude is constant but direction changes, hence acceleration changes, so does velocity

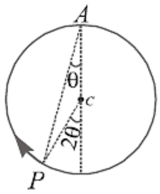
82. 4) $\Delta v = \sqrt{2v} = \sqrt{2}\omega r = \sqrt{2}\left(\frac{2\pi}{60}\right) \times 1 = \frac{\pi\sqrt{2}}{30}\,cm/s$

83. 1) $a_c = \frac{v^2}{r} = \frac{(250)^2}{10^3} = 62.5 m/s^2 \Rightarrow a_c/g = \frac{62.5}{9.8} = 6.38$

84. 3) Given : r = 30 cm = 0.3 cm = 0.3 m and V = 2t Radial acceleration at t = 3 sec

$a_r = \frac{v^2}{r} = \frac{4t^2}{0.3} = \frac{4 \times (3)^2}{0.3} = 120 m/s^2$ and tangential acceleration $a_t = \frac{dv}{dt} = 2 m/s^2$

85. 2) From the geometry of the figure, the angle traverses about A and C are θ and 2θ respectively. So



$\omega_A = \frac{\theta}{t}$ and $\omega_C = \frac{2\theta}{t} = 2\omega_A$

86. 3) Here $T = \frac{1}{2}$ sec the required centripetal acceleration for moving in a circle is

$a_C = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = r\omega^2 = r \times (2\pi / T)^2$ so $a_c = 0.25 \times (2\pi / 0.5)^2 = 16\pi^2 \times .25 = 4.0\pi^2$

87. 3)

88. 4)

89. 1) Distance covered in one circular loop = $2\pi r = 2 \times 3.14 \times 100 = 628m$

Speed = $\frac{628}{62.8} = 10m / sec$

Displacement in one circular loop = 0

Velocity = $\frac{0}{time} = 0$

90. 3) Given $\omega = 2 rad\, s^{-1}, r = 2m, t = \frac{\pi}{2} s$

Angular displacement, $\theta = \omega t = 2 \times \frac{\pi}{2} = \pi$ rad

Linear velocity, $v = r \times \omega = 2 \times 2 = 4ms^{-1}$

$\therefore$ change in velocity, $\Delta v = 2v \sin\frac{\theta}{2} = 2 \times 4 \times \sin\left(\frac{\pi}{2}\right) = 8m/s$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. 2) Here, $x = 4\sin(2\pi t)......(i)$

$y = 4\cos(2\pi t)....(ii)$

Squaring and adding equation (*i*) and (*ii*)

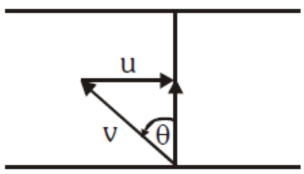
x2 + y2 = 42 □□R = 4 Motion of the particle is circular motion, acceleration vector is along – $\vec{R}$ and its magnitude= $\frac{V^2}{R}$

Velocity of particle, V = $\omega R = (2\pi)(4) = 8\pi$

2. 4) $\vec{v}_{av} = \frac{\Delta\vec{r}(\text{displacement})}{\Delta t(\text{time taken})} = \frac{(13-2)\hat{i} + (14-3)\hat{j}}{5-0} = \frac{11}{5}(\hat{i} + \hat{j})$

3. 1)

v = 20 m/s ; u = 10 m/s



$\sin\theta = \frac{u}{v} = \frac{10}{20} = \frac{1}{2}$

$\Rightarrow \theta = 30°$ west

4. 3)

5. 1)

6. 3).

$$4R = \frac{u^2 \sin^2 \theta}{2g}, T = \frac{2\pi R}{u}$$

$$u = \frac{2\pi R}{T}$$

$$4R = \frac{4\pi^2 R^2}{T^2} \times \frac{\sin^2 \theta}{2g}$$

$$\sin^2 \theta = \frac{2gT^2}{\pi^2 R}; \sin \theta = \sqrt{\frac{2gT^2}{\pi^2 R}}; \theta = \sin^{-1}\left(\frac{2gT^2}{\pi^2 R}\right)^{1/2}$$

7. 3)

Initial velocity of car = 0

Acceleration of car = 5 m/s^2

Velocity of car at t = 4 s; $v = u + at$

$\Rightarrow v = 0 + 5 \times 4 = 20$ ms^{-1}

At t = 4 s, A ball is dropped out of a window so velocity of ball at this instant is 20 ms^{-1} along horizontal.

After 2 seconds of motion :

Horizontal velocity of ball = 20 ms^{-1} ($\because a_x = 0$)

Vertical velocity of ball (v_y) = $u_y + a_y t$

$v_y = 0 + 10 \times 2 = 20$ ms^{-1} ($\because a_y = g = 10$ m/s^2)

So magnitude of velocity of ball

$(v) = \sqrt{v_x^2 + v_y^2} = 20\sqrt{2}$ m/s

Acceleration of ball at t = 6 s is g = 10 m/s^2

As ball is under free fall.

8. $$a = \frac{\omega_2 - \omega_1}{t} = \frac{2\pi(52-20)}{16} = 4\pi$$

9. $\tan\theta = V$

$$\frac{V_1}{V_2} = \frac{\tan\theta_1}{\tan\theta_2} = \frac{\tan 30^0}{\tan 45^0} = \frac{1/\sqrt{3}}{1} = 1:\sqrt{3}$$

10. Velocity at highest point $= u\sin\theta$

$= 10\sin 60^0 = 5\sqrt{3}\, ms^{-1}$