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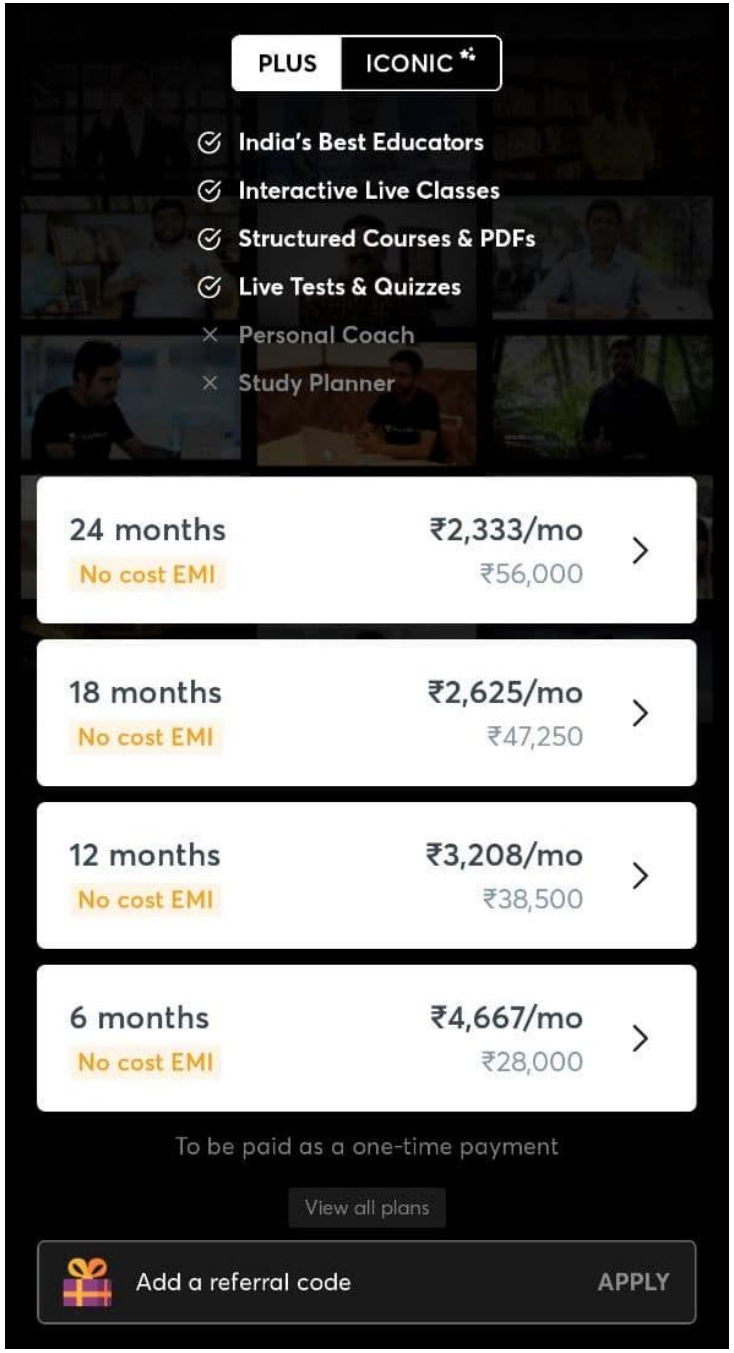

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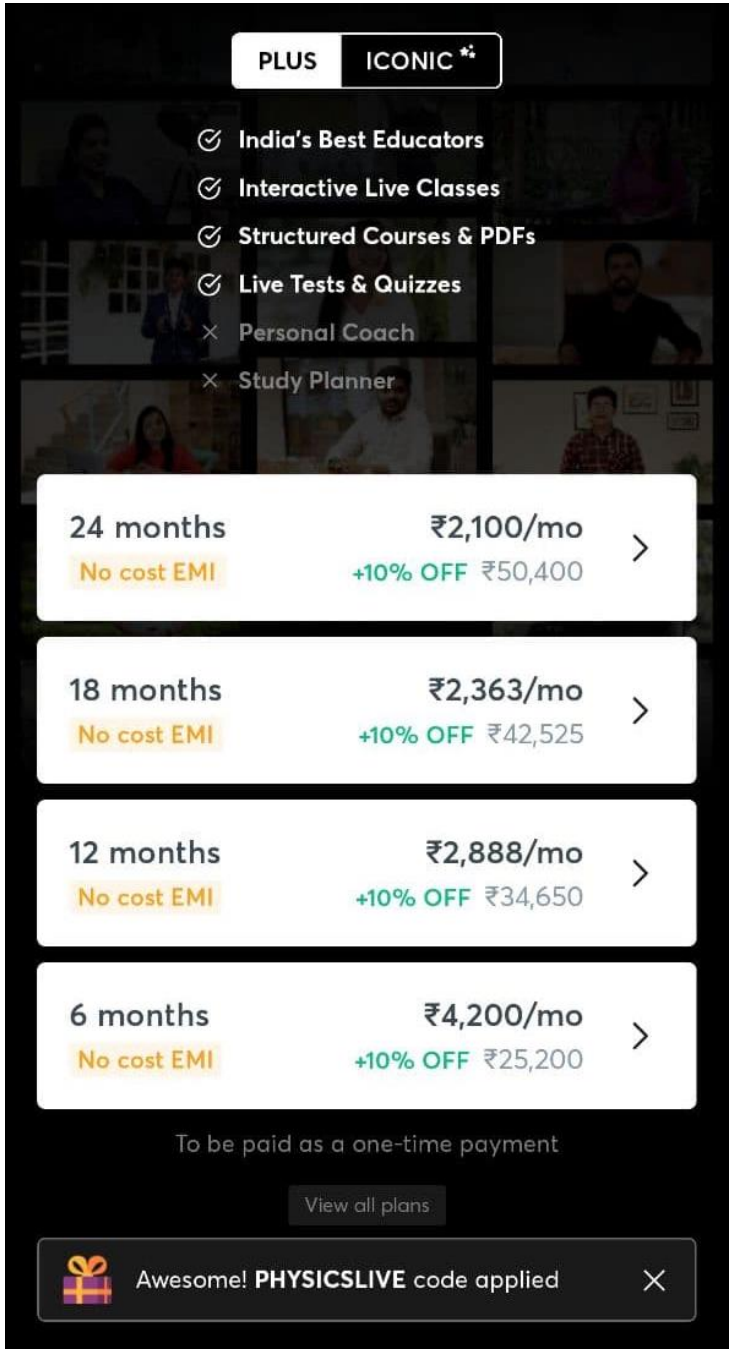

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Physics DPP

DPP-9 Relative motion (Rain-Man problems)

By Physicsaholics Team

Q) A man standing on a road hold his umbrella at 30° with the vertical to keep the rain away. He throws the umbrella and starts running at 10 km/hr. He finds that raindrops are hitting his head vertically, the speed of raindrops with respect to the road will be:

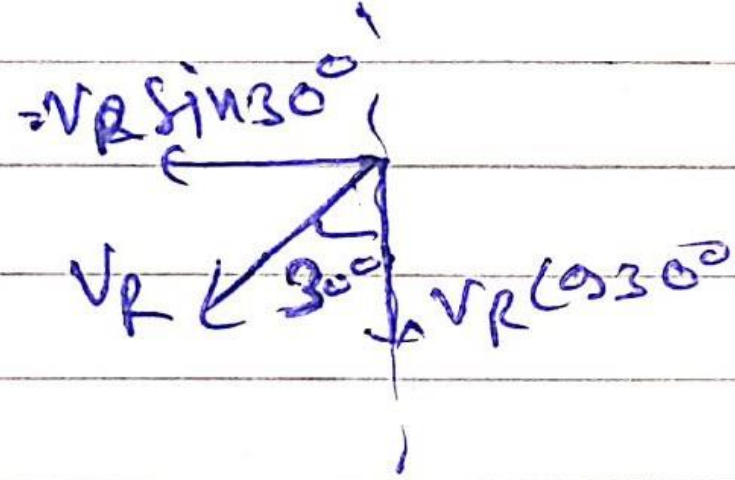
(a) 10 km/hr

(b) 20 km/hr

(c) 30 km/hr

(d) 40 km/hr

Ans. b



if rain drops are falling vertically w.r.t. man

then; relative velocity in horizontal dirⁿ = 0

$\therefore V_{man} = V_R \sin 30^\circ$

$10 = V_R \left(\frac{1}{2}\right)$

$$\boxed{V_R = 20 \text{ km/hr}}$$

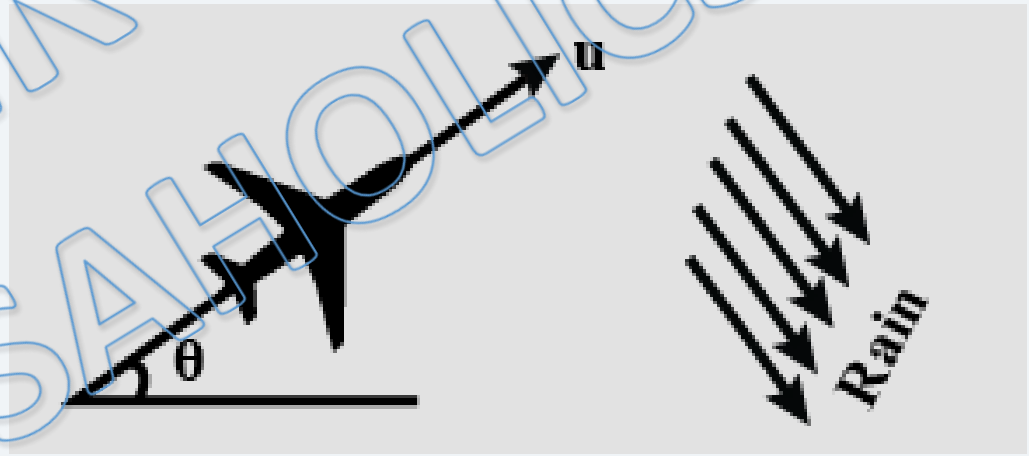
Q) Rain is falling with a speed of $12\sqrt{2}$m/s at angle of 45^0 with the vertical line. A man in glider going at a speed of u at an angle of 37^0 with respect to the ground. Find the speed of the glider so that rain appears to him falling vertically. Consider the motion of the glider and rain drops in the same vertical plane:

(a) $15\ m/s$

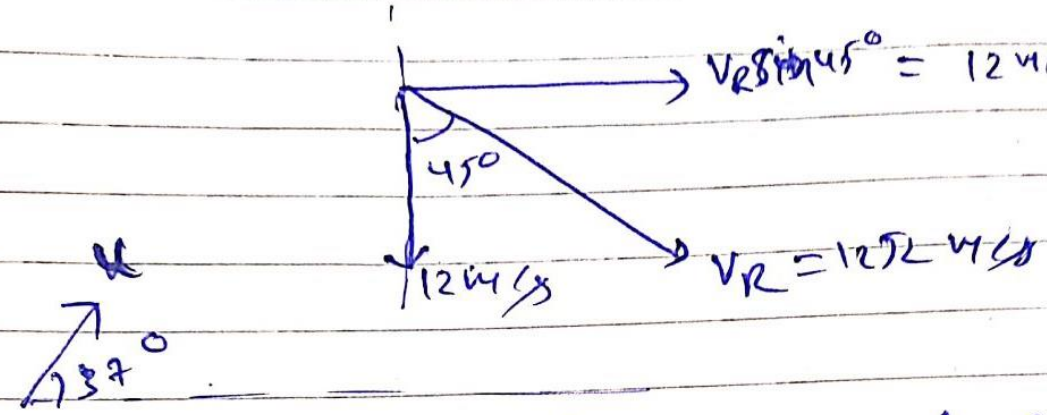
(b) $30\ m/s$

(c) $10\ m/s$

(d) $20\ m/s$



Ans. a



$$\vec{u_g} = u_x \hat{i} + u_y \hat{j} = (u\cos 37^\circ)\hat{i} + (u \sin 37^\circ)\hat{j}$$

$$\vec{u_g} = \frac{4u}{5}\hat{i} + \frac{3u}{5}\hat{j}$$

$$\vec{V_R} = 12\hat{i} + 12\hat{j} = V_x \hat{i} + V_y \hat{j}$$

velocity of Rain w.r.t. glider.

$$\vec{V_{R/g}} = \vec{V_R} - \vec{u_g} = \left(12 - \frac{4u}{5}\right)\hat{i} + \left(12 - \frac{3u}{5}\right)\hat{j}$$

if $\vec{V}_{R/g}$ is vertical

$\therefore$ Component of u or $\hat{i} = 0$

$$12 - \frac{4u}{5} = 0 \Rightarrow \boxed{u = 15 \text{ m/s}}$$

Q) A man is walking due east at the rate of 2 km/h. The rain appears to him to come down vertically at the rate of 2 km/h. The actual velocity and angle through which rain is falling with the vertical respectively are

(a) $2\sqrt{2}\ km/h, 45^0$

(b) $\frac{1}{\sqrt{2}}\ km/h, 30^0$

(c) $2\ km/h, 0^0$

(d) $2\ km/h, 90^0$

Ans. a

$\vec{V}_{R/M} = u\hat{i}$

Velocity of man w.r.t. ground

$$\vec{V}_M = V\hat{i} = 2\ km/h\ (\hat{i})$$

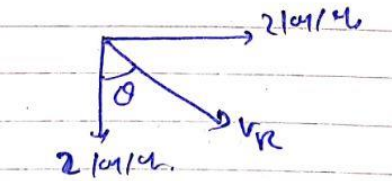
Velocity of Rain w.r.t. man.

$$\vec{V}_{R/M} = u(-\hat{j}) = 2\ km/h\ (-\hat{j})$$

$$\vec{V}_{R/M} = \vec{V}_R - \vec{V}_M$$

$$\vec{V}_R = \vec{V}_{R/M} + \vec{V}_M$$

$$\vec{V}_R = -2\hat{j} + 2\hat{i}$$



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

$$\boxed{\theta = 45^\circ}$$

$$V_R = \sqrt{2^2 + 2^2} = 2\sqrt{2}\ km/h.$$

$$\boxed{V_R = 2\sqrt{2}\ km/h}$$

Q) When a man moves down the inclined plane with a constant speed 5m/s which makes an angle of 37^0 with the horizontal, he finds that the rain is falling vertically downward. When he moves up the same inclined plane with the same speed, he finds that the rain makes an angle $\theta = \tan^{-1}\left(\frac{7}{8}\right)$ with the horizontal. The speed of the rain is:

(a) $\sqrt{116}\ m/s$

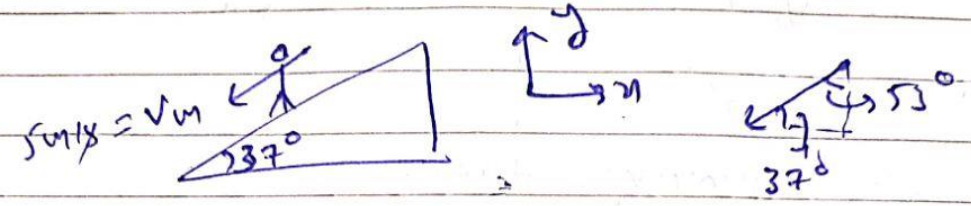
(b) $\sqrt{32}\ m/s$

(c) $5\ m/s$

(d) $\sqrt{73}\ m/s$

Ans. b

when moving down to incline:



$$\vec{v_m} = v_m \sin 53^\circ (-\hat{i}) + v_m \cos 53^\circ (-\hat{j})$$

$$\vec{v_m} = 5 \sin 53^\circ (-\hat{i}) + 5 \cos 53^\circ (-\hat{j})$$

$$\boxed{\vec{v_m} = -4\hat{i} - 3\hat{j}}$$

Let velocity of Rain w.r.t. ground

$$\vec{v_R} = v_x \hat{i} + v_y \hat{j}$$

it man observes rain falling vertical

∴ relative velocity of rain w.r.t. man is in $\hat{j}$

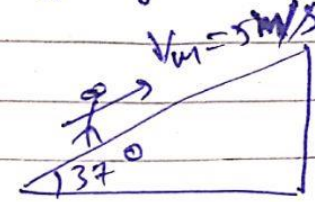
$$\vec{v_{R/m}} = (v_x - (-4))\hat{i} + (v_y - (-3))\hat{j}$$

in x-dir ⇒ $v_{rel} = 0$

$$v_x - (-4) = 0$$

$$\boxed{v_x = -4\hat{i}}$$

when going up to incline



$$\vec{v_m} = 5\cos 37^\circ \hat{i} + 5 \sin 37^\circ \hat{j}$$

$$\boxed{\vec{v_m} = 4\hat{i} + 3\hat{j}}$$

$$\vec{v_R} = v_x \hat{i} + v_y \hat{j}$$

$$\vec{v_R} = -4\hat{i} + v_y \hat{j}$$

$$\vec{v_{R/m}} = (-4-4)\hat{i} + (v_y - 3)\hat{j}$$

$$\tan\theta = \frac{v_y - 3}{-8} = \frac{7}{8}$$

$$v_y - 3 = -7 \Rightarrow v_y = -4 \text{ m/s}$$

$$\boxed{\vec{v_y} = -4\hat{j}}$$

$$\vec{v_R} = v_x \hat{i} + v_y \hat{j}$$

$$\boxed{\vec{v} = -4\hat{i} - 4\hat{j}}$$

$$v = \sqrt{4^2 + 4^2} = \sqrt{32}$$

$$\boxed{v = \sqrt{32} \text{ m/s}}$$

Q) A stationary person observes that rain is falling vertically down at 30km/hr. A cyclist is moving up on an inclined plane making an angle 30^0 with horizontal at 10km/hr. In what direction should the cyclist hold his umbrella to prevent himself from rain?

(a) At an angle $\tan^{-1}\left(\frac{\sqrt{2}}{7}\right)$ with the vertical.

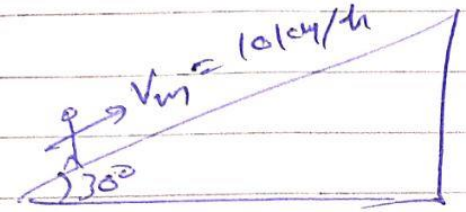
(b) At an angle $\tan^{-1}\left(\frac{\sqrt{3}}{7}\right)$ with the horizontal

(c) At an angle $\tan^{-1}\left(\frac{\sqrt{3}}{7}\right)$ with the vertical

(d) At an angle $\tan^{-1}\left(\frac{\sqrt{2}}{7}\right)$ with the horizontal

Ans. c

$\vec{V}_R = -30\hat{j}$ (km/h)



$\vec{V_m} = (10\cos 30°)\hat{i} + (10\sin 30°)(\hat{j})$

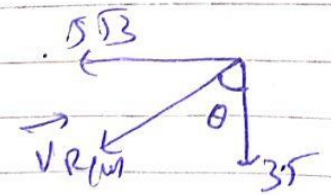
$\vec{V_m} = 5\sqrt{3}\,\hat{i} + 5\hat{j}$

$\vec{V}_{R/m} = \vec{V_R} - \vec{V_m}$

$= -30\hat{j} - 5\sqrt{3}\,\hat{i} + 5\hat{j}$

$\vec{V}_{R/m} = -5\sqrt{3}\,\hat{i} - (30+5)\hat{j}$

$\vec{V}_{R/m} = -5\sqrt{3}\,\hat{i} - 35\hat{j}$



Angle from vertical $\Rightarrow \theta = \tan^{-1}\left(\frac{5\sqrt{3}}{35}\right)$

$$\theta = \tan^{-1}\frac{\sqrt{3}}{7}$$

Q) Rain is falling vertically downwards with a speed of 4 km/h. A girl moves on a straight road with a velocity of 3 km/h. The apparent velocity of rain with respect to the girl is:

(a) 3 km/h

(b) 4 km/h

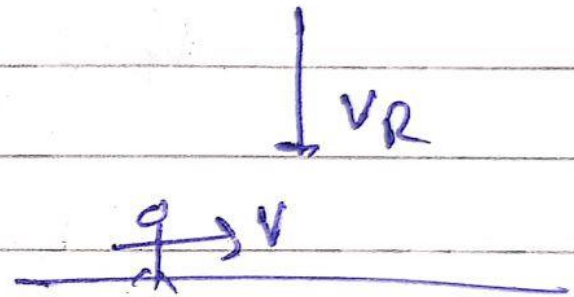
(c) 5 km/h

(d) 7 km/h

Ans. c

$\vec{V_R} = -4\hat{j}$ (km/h)

$\vec{V_G} = 3\hat{i}$ (km/h)



$\vec{V_{R/G}} = \vec{V_R} - \vec{V_G}$

$\vec{V_{R/G}} = -4\hat{j} - 3\hat{i} = -3\hat{i} - 4\hat{j}$

$V_{R/G} = 5$ km/h

Q) A man is cycling at 4 m/s On a horizontal rod. To him, rain appears to fall at 30^0 from vertical. If he doubles his velocity, rain appears to fall at 60^0 to vertical. Find the velocity of the rain:

(a) 4 m/s

(b) 5 m/s

(c) 6 m/s

(d) $4\sqrt{3}$ m/s

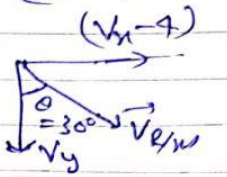
Ans. a

Velocity of man $\Rightarrow \vec{V_m} = V\hat{j} = 4\hat{j}$ (m/s) is $\vec{V_m}$

& let Velocity of rain: $\vec{V_R} = V_x\hat{i} + V_y\hat{j}$

w.r.t. man.

$\vec{V_{R/M}} = \vec{V_R} - \vec{V_m} = (V_x - 4)\hat{i} + V_y\hat{j}$



$\tan\theta = \tan 30° = \frac{V_x - 4}{V_y}$ — (1)

when; $\vec{V_m} = (2\times 4)\hat{j} = 8\hat{j}$ (m/s)

$\vec{V_{R/M}} = (V_x - 8)\hat{i} + V_y\hat{j}$

Now; $\theta = 60°$

$\therefore \tan 60° = \frac{V_x - 8}{V_y}$ — (2)

$\frac{(1)}{(2)} = \frac{\tan 30°}{\tan 60°} = \frac{V_x - 4}{V_x - 8} \Rightarrow \frac{1}{\sqrt{3}} = \frac{V_x - 4}{V_x - 8}$

$\frac{1}{3} = \frac{V_x - 4}{V_x - 8} \Rightarrow V_x - 8 = 3V_x - 12$

$2V_x = 4 \Rightarrow \boxed{V_x = 2 m/s}$

Now put V_x in eq (1)

$\sqrt{3} = \frac{2-8}{V_y} \Rightarrow V_y = \frac{-6}{\sqrt{3}} = -2\sqrt{3}$ m/s

$\therefore \vec{V_R} = 2\hat{i} + (-2\sqrt{3})\hat{j}$

$\boxed{\vec{V_R} = 2\hat{i} - 2\sqrt{3}\hat{j}}$ $V_R = 4\ m/s$

Q) A man running on a horizontal road at 8 km/h finds the rain falling vertically. He increases his speed to 12 km/h and finds that the drops make angle 30^0 with the vertical. Find the speed and direction of the rain with respect to the road:

(a) $\tan^{-1}\left(\frac{2}{\sqrt{3}}\right)$

(b) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

(c) $\tan^{-1}\left(\frac{\sqrt{5}}{3}\right)$

(d) $\cos^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Ans. a

$\vec{V}_{M_1} = 8\hat{i}$ (km/h)

$\vec{V}_R = V_x\hat{i} + V_y\hat{j}$

$\vec{V}_{R/M} = (V_x - 8)\hat{i} + V_y\hat{j}$

$\vec{V}_{R/M}$ is vertical

then $V_x - 8 = 0 \Rightarrow \boxed{V_x = 8 \text{ km/h}}$

Now when $\vec{V}_{M_2} = 12\hat{i}$

$\vec{V}_{R/M} = (V_x - 12)\hat{i} + V_y\hat{j}$

$\theta = 30^\circ$ with vertical

$$\tan 30^\circ = \frac{V_x - 12}{V_y} = \frac{1}{\sqrt{3}}$$

$\boxed{V_y = -4\sqrt{3} \text{ km/h}}$

$\boxed{\vec{V}_R = 8\hat{i} - 4\sqrt{3}\hat{j}}$

$$\tan\alpha = \frac{8}{4\sqrt{3}} = \frac{2}{\sqrt{3}} \Rightarrow \boxed{\alpha = \tan^{-1}\left(\frac{2}{\sqrt{3}}\right)}$$

with vertical.

Q) A man holds an umbrella at 30^0 with the vertical to keep himself dry. Then he runs at a speed of 10 m/s, and find the raindrops to be hitting vertically. Study the following statements and find the correct options:

(1) Velocity of rain w.r.t. Earth is 20 m/s

(2) Velocity of rain w.r.t. man is $10\sqrt{3}$ m/s

(3) Velocity of rain w.r.t. Earth is 30 m/s

(4) Velocity of rain w.r.t. man is $10\sqrt{2}$ m/s

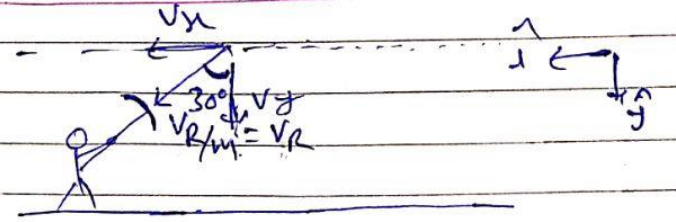
(a) Statement (2) and (3) are correct.

(b) Statement (1) and (2) are correct.

(c) Statement (3) and (4) are correct.

(d) Statement (2) and (4) are correct.

Ans. b



initially $v_m = 0$

$\therefore v_{R/m} = v_R$; $\vec{v_R} = v_x\hat{i} + v_y\hat{j}$

$v_x = v_R \sin 30°$; $v_y = v_R \cos 30°$

Now

$\vec{v_m} = 10 \text{ m/s}\,\hat{i}$

$\vec{v_{R/m}} = (v_x - 10)\hat{i} + v_y\hat{j}$

if $\vec{v_{R/m}}$ is vertical

then $v_x - 10 = 0$

$v_x = 10$

$v_R \sin 30° = 10$

$\boxed{v_R = 20 \text{ m/s}}$

↳ velocity of rain w.r.t. Earth.

w.r.t. man.

$\vec{v_{R/m}} = v_y\hat{j}$

$v_y = v_R \cos 30° = 20 \times \frac{\sqrt{3}}{2} = 10\sqrt{3} \text{ m/s}$

$\vec{v_{R/m}} = (10\hat{i} + 10\sqrt{3}\hat{j}) - (10\hat{i})$

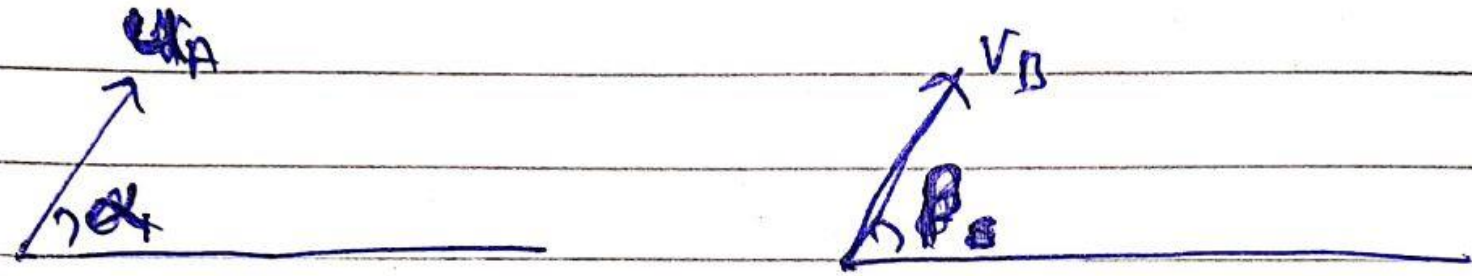
$\vec{v_{R/m}} = 10\sqrt{3}\hat{j}$

$\boxed{v_{R/m} = 10\sqrt{3} \text{ m/s}}$

Q) The path of one projectile as seen from another projectile is a:

(a) Straight line
(b) Parabola
(c) Hyperbola
(d) Circle

Ans. a



$$\vec{v_A} = (u_A \cos\alpha)\hat{i} + (u_A \sin\alpha - gt)\hat{j}$$

$$\vec{v_B} = (u_B \cos\beta)\hat{i} + (u_B \sin\beta - gt)\hat{j}$$

$$\boxed{\vec{v_{A/B}} = (u_A \cos\alpha - u_B \cos\beta)\hat{i} + (u_A \sin\alpha - u_B \sin\beta)\hat{j}}$$

$\vec{v_{A/B}}$ = constant

$\therefore \vec{a}_{A/B} = (-g\hat{j}) - (g\hat{j}) = 0$

$\therefore$ Path - Straight line

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Chalo Niklo