Physicsaholics

DPP – 9 (Kinematics)

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Q 1. A glass wind screen whose inclination with the vertical can be changed is mourned on a car. The car moves horizontally with a speed of 2 m/s. At what angle a with the vertical should the wind screen be placed so that the rain drops falling vertically downwards with velocity 6 m/s strike the wind screen perpendicularly?

(a) $\tan^{-1}\left(\frac{1}{3}\right)$ (b) $\tan^{-1}(3)$ (c) $\cos^{-1}(3)$ (d) $\sin^{-1}\left(\frac{1}{3}\right)$

Q 2. A stationary person observes that rain is falling vertically down at 30 km/hr. A cyclist is moving on the level road, at 10 km/hr. In which direction the cyclist should hold his umbrella to prevent himself from rain.

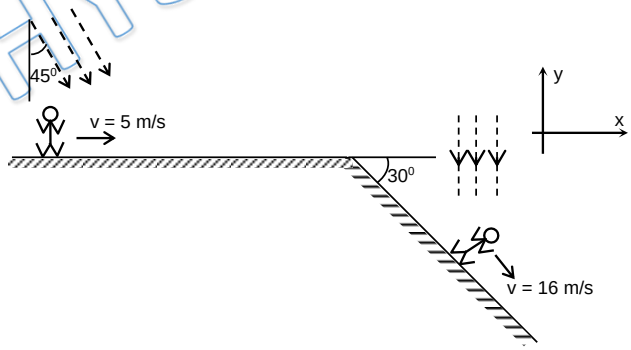
(a) $\tan^{-1}\frac{1}{3}$ from horizontal

(b) $\tan^{-1}3$ from vertical

(c) $\tan^{-1}\frac{1}{3}$ from vertical

(d) $\tan^{-1}3$ from horizontal

Q 3. A man moving with a velocity of 5 m/s on a horizontal road observes that raindrops fall at an angle of 45^0 with the vertical. When he moves with a velocity of 16 m/s along an inclined plane, which is inclined at 30^0 with the horizontal, he observes raindrops falling vertically downward as shown in the figure. Find the actual velocity of the raindrops.



(a) $8\sqrt{3}\hat{\imath} + (8\sqrt{3} - 5)\hat{\jmath}$

(b) $8\sqrt{3}\hat{\imath} - (8\sqrt{3} - 5)\hat{\jmath}$

(c) $(8\sqrt{3} - 5)\hat{\imath} + 8\sqrt{3}\hat{\jmath}$

(d) $(8\sqrt{3} + 5)\hat{\imath} - 8\sqrt{3}\hat{\jmath}$

Q 4. A man is walking at a speed 3 m/s rain drops are falling vertically with a speed 3 m/s –
(i) What is the velocity of rain drop with respect to the man ?
(ii) At what angle from vertical, the man should hold his umbrella ?
(a) 2.42 m/s, 30º in forward direction
(b) 4.24 m/s, 45º in forward direction
(c) 1.24 m/s, 60º in forward direction
(d) None of these

Q 5. Rain is falling vertically with a speed of 20 m/s relative to air. A person is running in the rain with a velocity of 5 m/s and a wind is also blowing with a speed of 15 m/s (both towards east). Find the angle with the vertical at which the person should hold his umbrella so that he may not get drenched.
(a) $\tan^{-1} 2$ (b) $\tan^{-1} \frac{1}{\sqrt{2}}$ (c) $\tan^{-1} \frac{1}{2}$ (d) $\tan^{-1} 3$

Q 6. 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 :
(a) 2 m/s south (b) 2 m/s north
(c) 4 m/s west (d) 4 m/s south

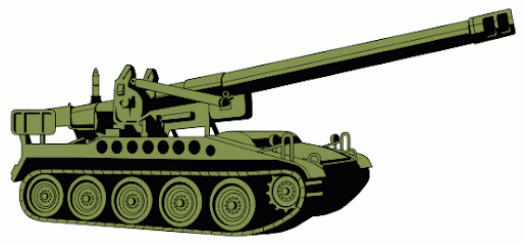
Q 7. Raindrops are falling vertically with a velocity 10m/s. To a cyclist moving on a straight road the rain drops appear to be coming with a velocity of 20m/s. The velocity of cyclist is :-
(a) 10m/s (b) $10\sqrt{3}$ m/s (c) 20 m/s (d) 20 3 m/s

Q 8. To man running at a speed of 5 m/sec, the rain drops appear to be falling at an angle of 45° from the vertical. If the rain drops are actually falling vertically downwards , then velocity in m/sec is
(a) 5 (b) $5\sqrt{3}$ (c) $5\sqrt{2}$ (d) 4

Q 9. A stationary man observes that the rain strikes him at an angle 60° to the horizontal. When he begins to move with a velocity of 25 m/s then the drops appear to strike him at an angle of 30° from horizontal. The velocity of the rain drops is :
(a) 25 m/s (b) 50 m/s (c) 12.5 m/s (d) $24\sqrt{2}$ m/s

Q 10. Rain is falling with speed 10 m/s at angle 37° with vertical. To a moving man raindrops appear to fall with $8\sqrt{2}$ m/s. Possible speed(s) of man is(are)?
(a) 1 m/s (b) 6 m/s (c) 11 m/s (d) 15 m/s

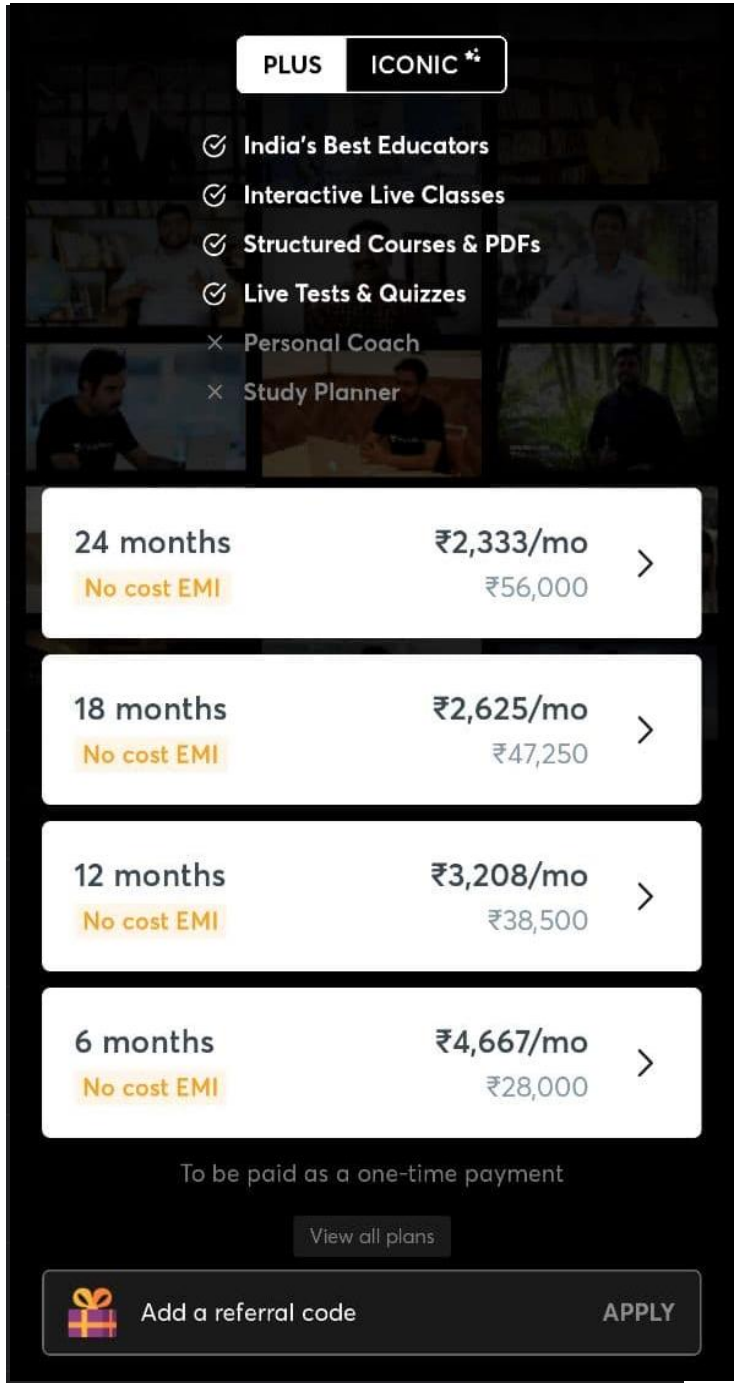
Q 11. Barrel of an Indian Army tank is at angle 53^o with vertical as shown in figure. Rain is falling at angle 45° with vertical with speed $10\sqrt{2}$ m/s. What can be the speed of tank in order to prevent the surface of barrel from being wet?



(a) 10 m/s (b) 6.66 m/s
(c) 3.33 m/s (d) 0.33 m/s

Answer Key

Q.1 b	**Q.2 c**	**Q.3 b**	**Q.4 b**	**Q.5 c**
Q.6 b	**Q.7 b**	**Q.8 a**	**Q.9 a**	**Q.10 b,c**
Q.11 c				



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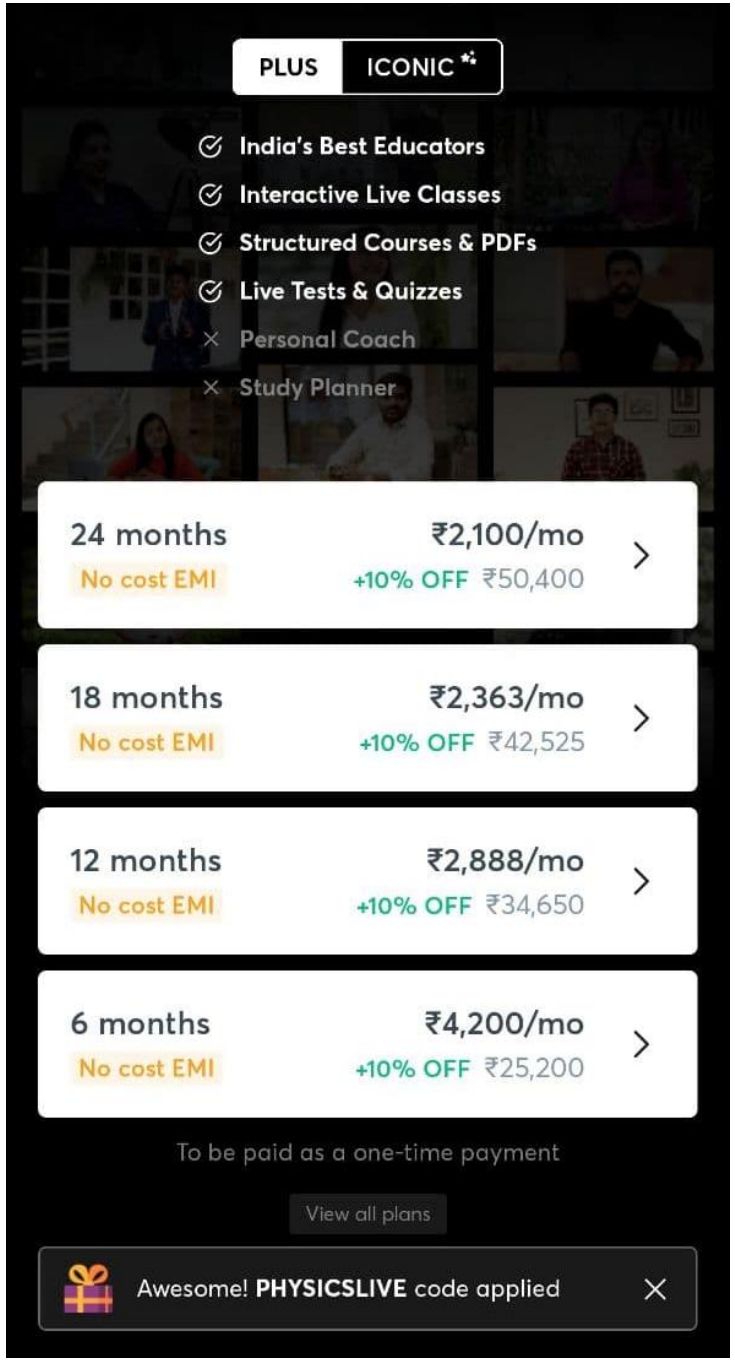
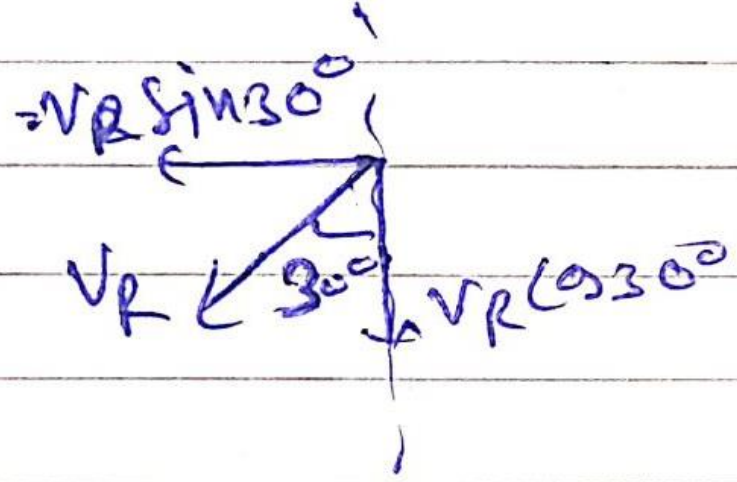


Written Solution

DPP-9 Relative motion (Rain-Man problems)

By Physicsaholics Team

Solution.1



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

then; $\text{disp}^n = 0$

relative velocity in horizontal

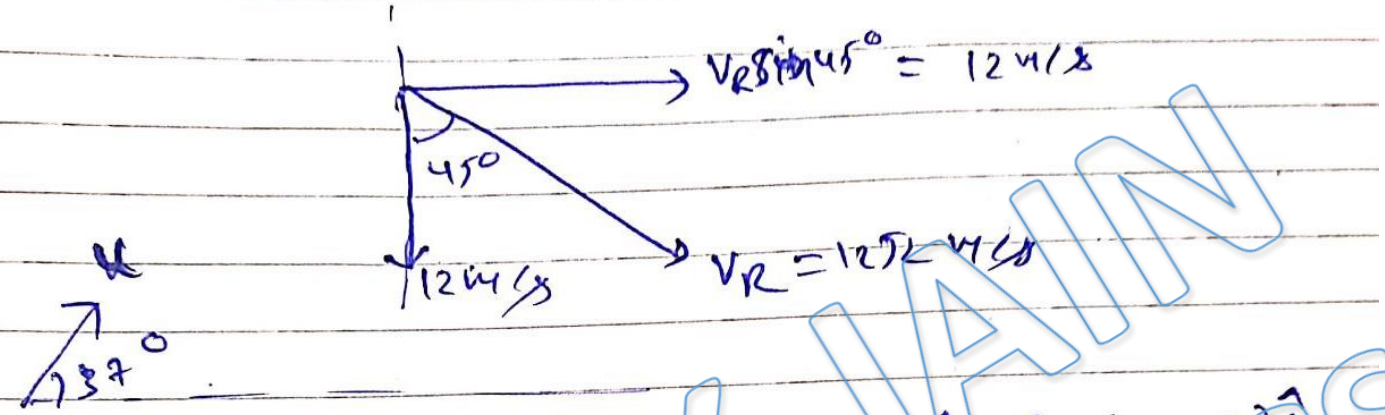
$\therefore V_{man} = V_R \sin 30^\circ$

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

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

Ans.b

Solution.2



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

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

$\vec{v_R} = 12\hat{i} + 12\hat{j} = v_x\hat{i} + v_y\hat{j}$

Velocity of Rain w.r.t. glider.

$\vec{v}_{R/g} = \vec{v_R} - \vec{u_g} = (12 - \frac{4}{5}u)\hat{i} + (12 - \frac{3}{5}u)\hat{j}$

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

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

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

Ans.a

Solution.3

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

Velocity of man w.r.t. ground

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

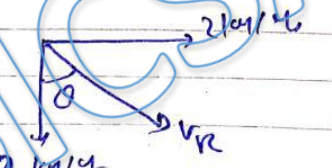
Velocity of Rain w.r.t. man.

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

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

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

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



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

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

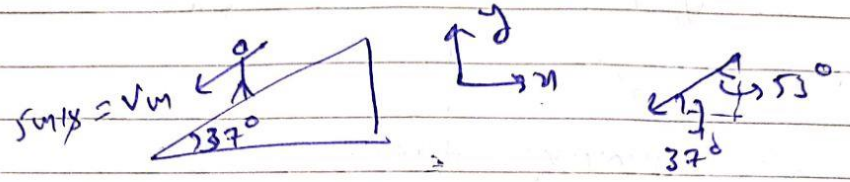
$V_R = \sqrt{2^2 + 2^2} = 2\sqrt{2}\ km/h.$

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

Ans.a

Solution.4

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 $\hat{j}$

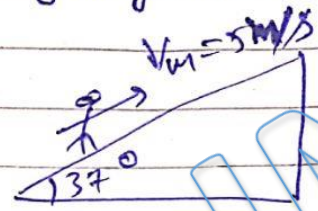
$$\vec{v_{R/m}} = (v_x - (-4))\hat{i} + (v_y - (-3))\hat{j}$$

in x-dir ⇒ $v_{rel} = 0$

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

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

when going up to incline



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

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

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

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

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

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

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

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

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

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

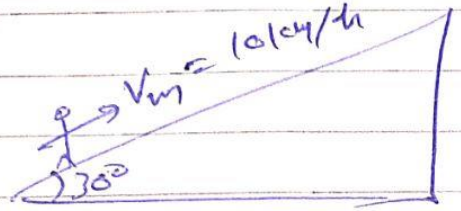
$$v = \sqrt{4^2 + 4^2} = \sqrt{32}$$

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

Ans.b

Solution.5

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



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

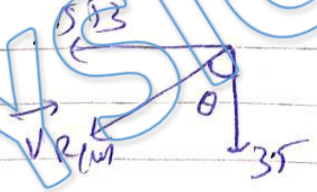
$\vec{V}_m = 5\sqrt{3}\hat{i} + 5\hat{j}$

$\vec{V}_{R/m} = \vec{V}_R - \vec{V}_m$

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

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

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



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

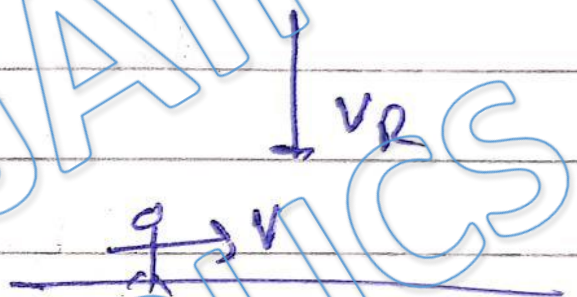
$\boxed{\theta = \tan^{-1}\frac{\sqrt{3}}{7}}$

Ans.c

Solution.6

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

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

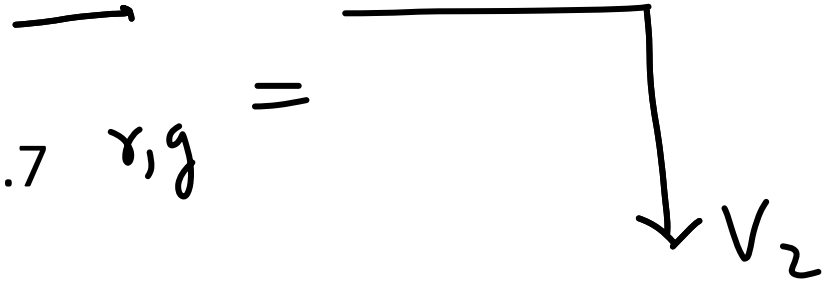


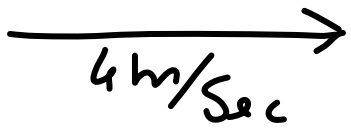
$\vec{V_{R/G}} = \vec{V_R} - \vec{V_G}$

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

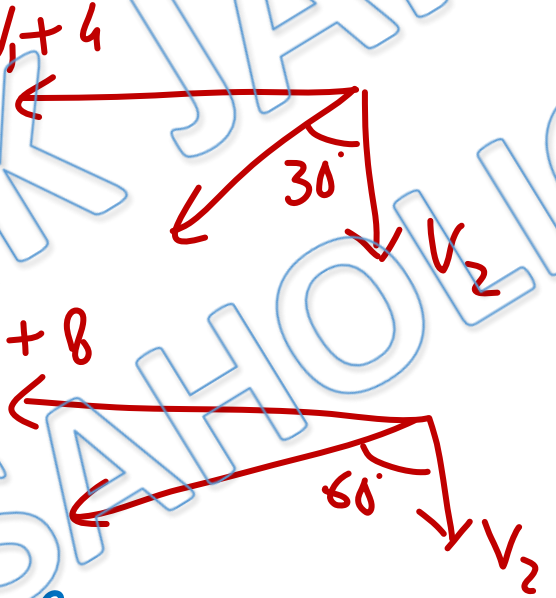
$V_{R/G} = 5$ km/h

Ans.c

Solution.7 $\vec{v}_{r,g}$ = 

, $\vec{V}_{m,g}$ (initial) = 

Initial velocity of rain w.r.t. man



$\tan 30 = \frac{V_1+4}{V_2} = \frac{1}{\sqrt{3}}$

final ,, ,, ,, ,, ,,

$\tan 60 = \frac{V_1+8}{V_2} = \sqrt{3}$

$\Rightarrow \frac{V_1+4}{V_1+8} = \frac{1}{3} \Rightarrow 3V_1+12 = V_1+8 \Rightarrow 2V_1 = -4 \Rightarrow V_1 = -2$

$V_2 = \sqrt{3}(V_1+4) = 2\sqrt{3} \Rightarrow |\vec{V}_{r,g}| = \sqrt{V_1^2+V_2^2} = 4\ m/Sec$ Ans.a

$V_R = 4\ m/s$

Solution.8

$\vec{v}_{M_j} = 8\hat{i}$ (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 $\vec{v}_{M_j} = 12\hat{i}$

$\vec{v}_{R/M} = (v_x - 12)\hat{i} + v_y\hat{j}$

$\theta = 30°$ with vertical

$\tan 30° = \dfrac{v_x - 12}{v_y} = \dfrac{1}{\sqrt{3}}$

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

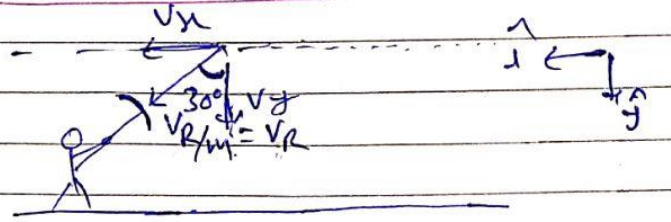
$\boxed{\vec{v}_R = 8\hat{i} - 4\sqrt{3}\hat{j}}$

$v_R = \sqrt{8^2 + (4\sqrt{3})^2}$

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

Ans.a

Solution.9



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,

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

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

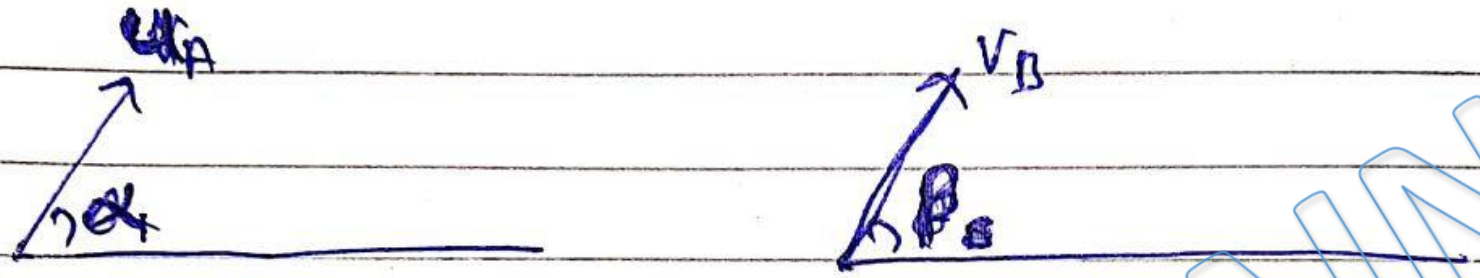
$\vec{v_{R/m}} = (10\hat{i} + 10\sqrt{3}\hat{j}) - (10\hat{i})$

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

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

Ans.b

Solution.10



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

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

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

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

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

$\therefore$ Path - straight line

Ans.a

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