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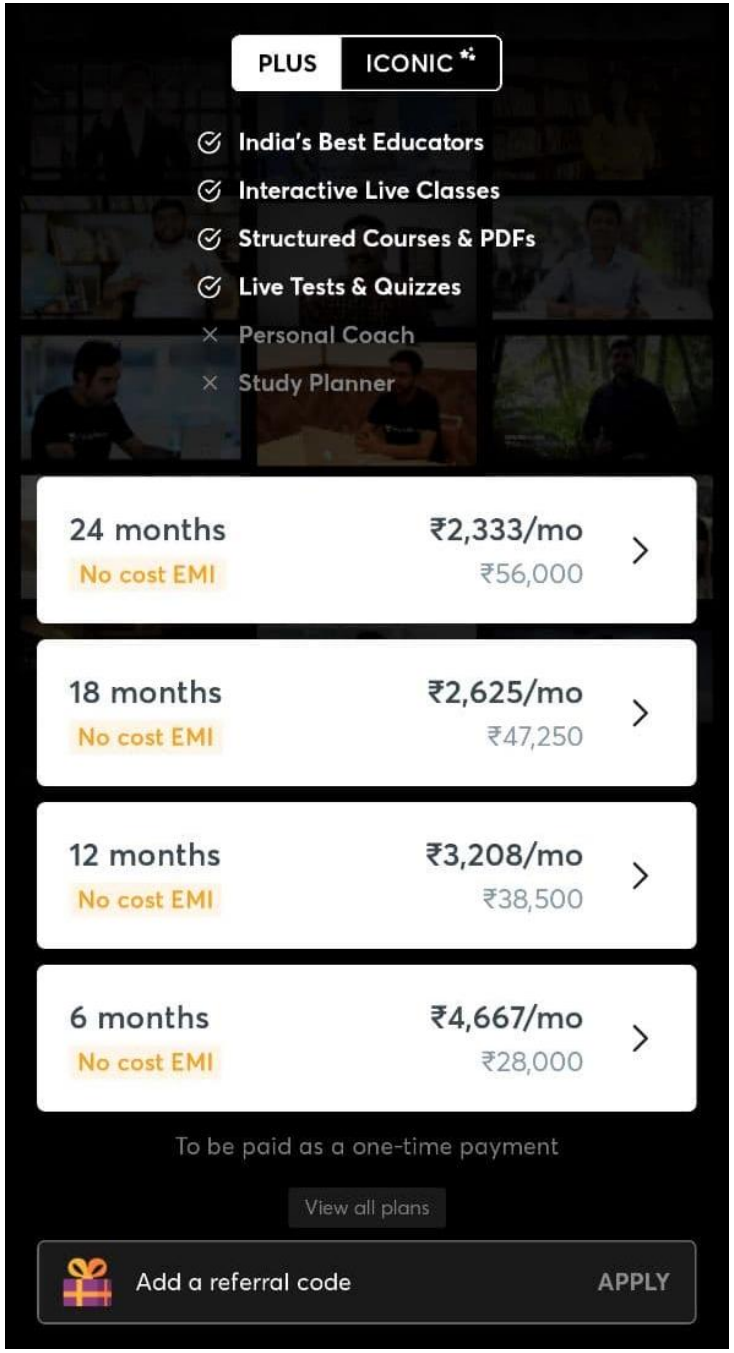

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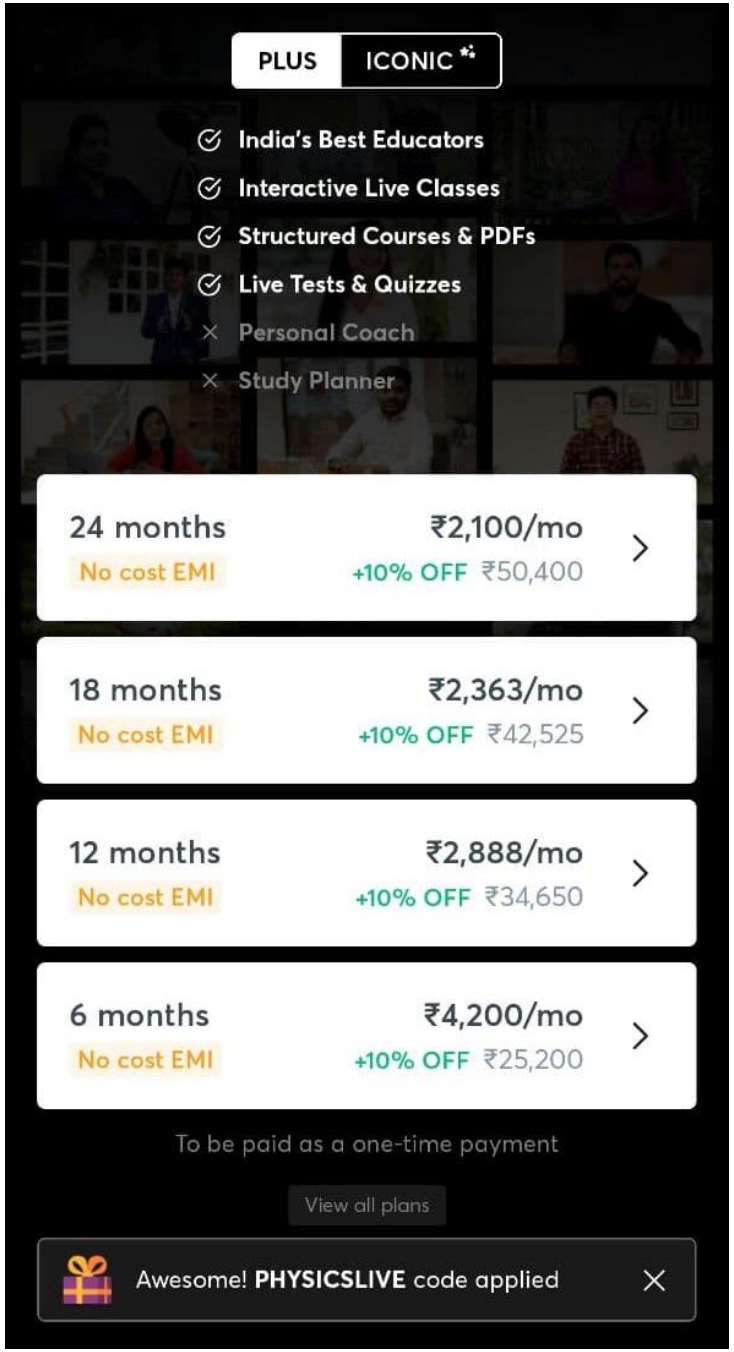

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JEE Main & Advanced, NSEP, INPhO, IPhO
Physics DPP

DPP-9 Relative motion (Rain-Man problems)

By Physicsaholics Team

Q) 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) $\sin^{-1}\left(\frac{1}{3}\right)$

Ans. b

Solution:

Velocity of rain w.r.t. car

$\tan\theta = 2/6 = 1/3 \Rightarrow \theta = \tan^{-1}(1/3)$

To hit windscreen normally angle of windscreen should be $90-\theta$ with vertical.

Ans $\rightarrow$ $90^\circ - \tan^{-1}(1/3) = \tan^{-1}(3)$

Q) 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

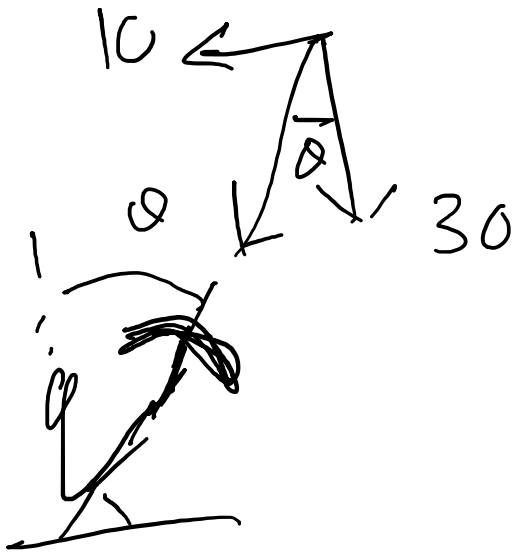
Ans. c

Solution:

$V_{r,g} = 30$ km/hr

$\rightarrow$ 10 km/hr

Velocity of rain w.r.t. cyclist =



Angle of umbrella with vertical

$= \theta = \tan^{-1}(10/30) = \tan^{-1}(1/3)$

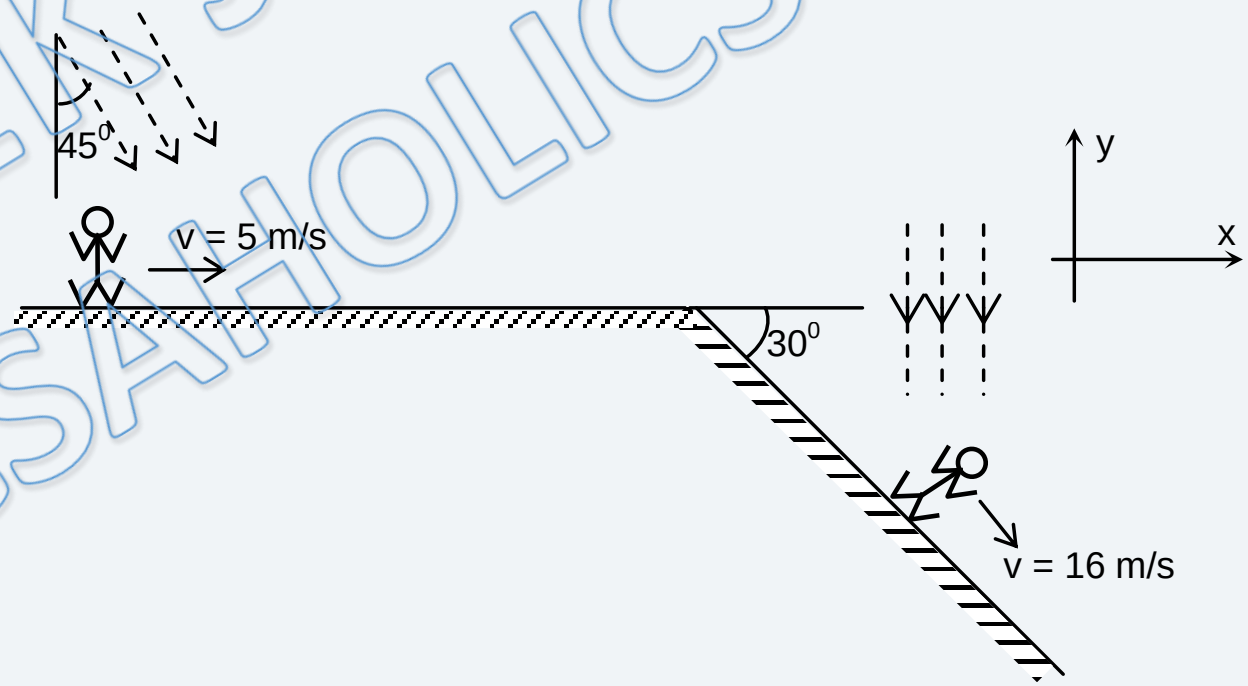
Q) A man moving with a velocity of 5 m/s on a horizontal road observes that raindrops fall at an angle of 45^0 with the vertical. When he moves with a velocity of 16 m/s along an inclined plane, which is inclined at 30^0 with the horizontal, he observes raindrops falling vertically downward as shown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

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

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

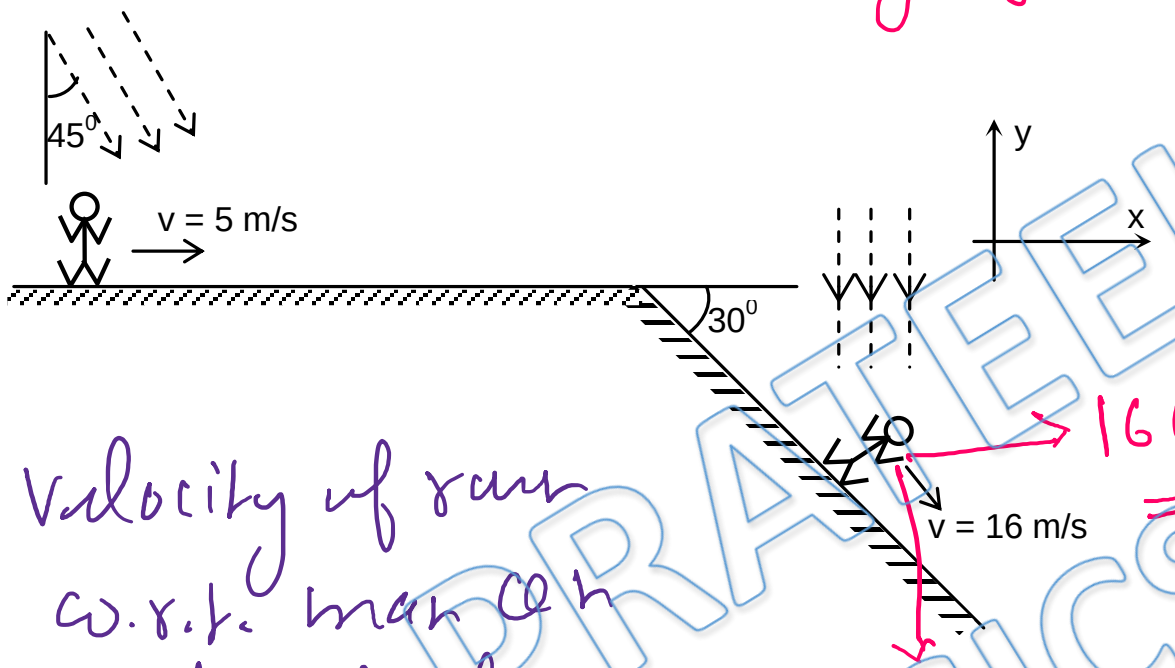
(c) $(8\sqrt{3} - 5)\hat{\imath} + 8\sqrt{3}\hat{\jmath}$

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



Ans. b

Solution:



Let actual velocity of rain drops is $\rightarrow u_1$, $\downarrow u_2$

Velocity of rain w.r.t. man on horizontal surface $= u_1 - 5^-$

Velocity of rain w.r.t. man on inclined plane $= (u_1 - 8\sqrt{3}) - (u_2 - 8)$

$16\cos 30^\circ = 8\sqrt{3}$

$16\sin 30^\circ = 8$

$\tan 45^\circ = \dfrac{u_1 - 5}{u_2}$

$\Rightarrow u_1 - 5 = u_2$ —(1)

$u_1 - 8\sqrt{3} = 0$

$\Rightarrow u_1 = 8\sqrt{3}$

$u_2 = 8\sqrt{3} - 5$

$\vec{V}_{r,y} = 8\sqrt{3}\,\hat{i} - (8\sqrt{3} - 5)\,\hat{j}$

Q) 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

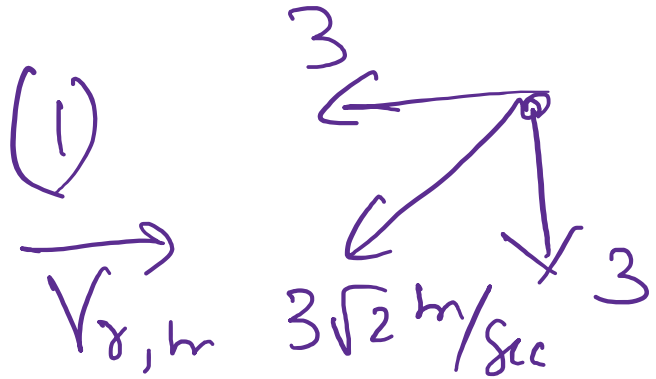
(c) 1.24 m/s, 60º in forward direction

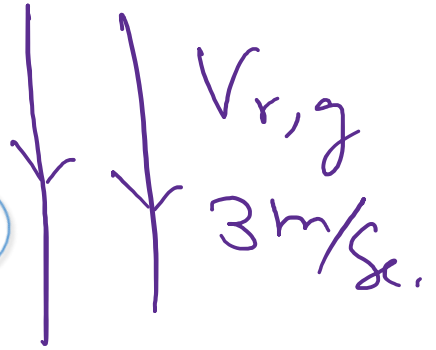
(d) None of these

Ans. b

Solution:

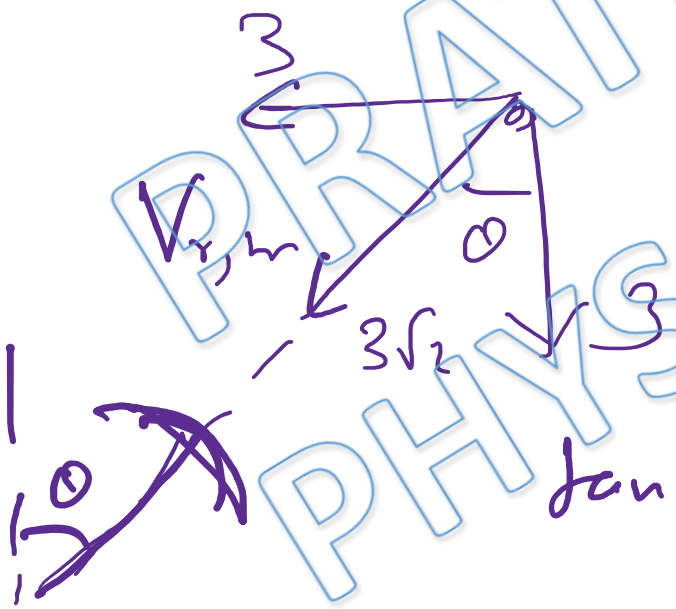
(I)





$\frac{g}{h} \rightarrow 3\,m/sec$

(II)



$\tan\theta = 3/3 = 1 \Rightarrow \theta = 45^\circ$

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Q) 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.

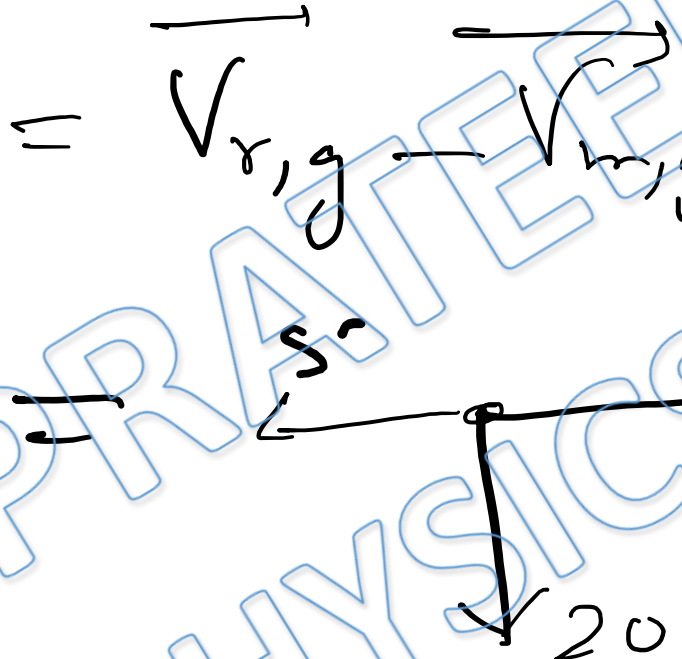
(a) $\tan^{-1} 2$ (b) $\tan^{-1} \frac{1}{\sqrt{2}}$ (c) $\tan^{-1} \frac{1}{2}$ (d) $\tan^{-1} 3$

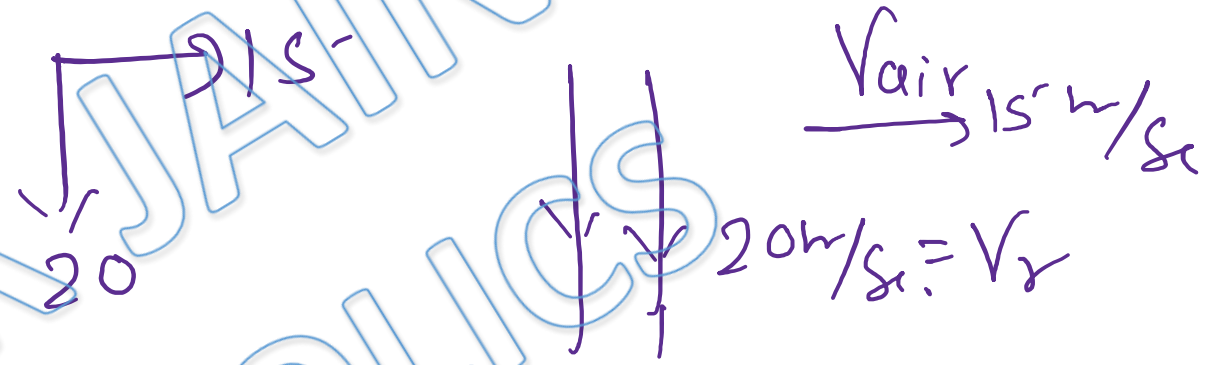
Ans. c

Solution:

$\vec{V}_{r,g} = \vec{V}_{r,air} + \vec{V}_{air,g}$

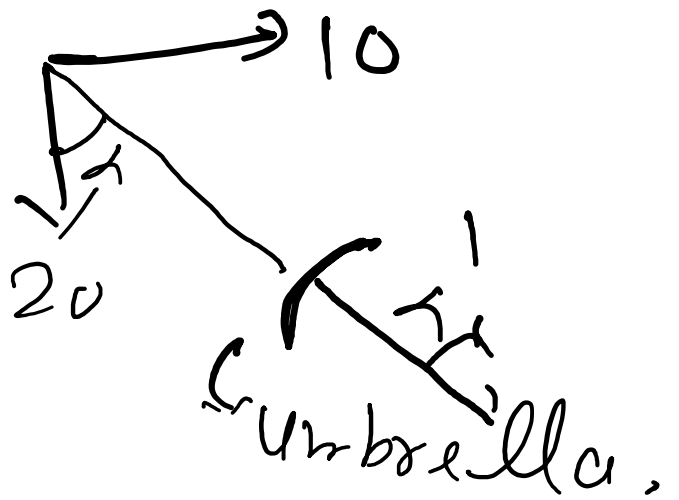
$\vec{V}_{r,m} = \vec{V}_{r,g} - \vec{V}_{m,g}$





$\frac{q}{2} \rightarrow 5\,m/s$

=



angle of umbrella with vertical $= \theta = \tan^{-1}\left(\frac{1}{2}\right)$

Q) 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

Ans. b

Solution:

horizontal velocity of rain w.r.t. ground
= " " " wind " " = 2m/sec

If man moves in same horizontal direction with 2m/sec, horizontal velocity of rain w.r.t. him will be zero.

⇒ rain will appear to fall vertically.

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Q) 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 :-

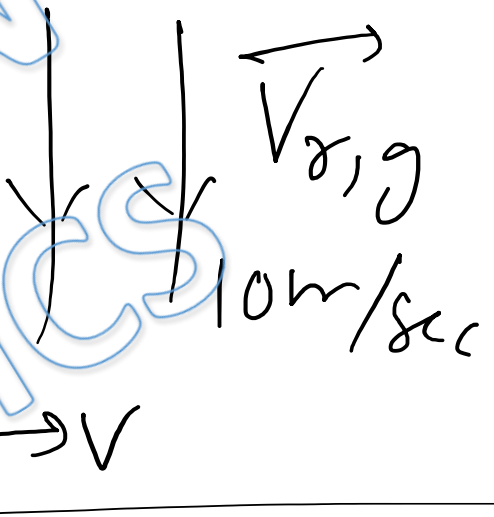
(a) 10m/s (b) $10\sqrt{3}$ m/s (c) 20 m/s (d) 20 3 m/s

Ans. b

Solution:

Velocity of rain w.r.t. cyclist

$= \sqrt{V^2+100}$ (V, 10)



$\Rightarrow \sqrt{V^2+100} = 20$

$\Rightarrow V^2 + 100 = 400$

$\Rightarrow V = 10\sqrt{3}$ m/sec

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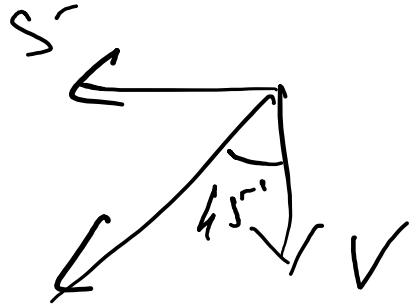
Q) To man running at a speed of 5 m/sec, the rain drops appear to be falling at an angle of 45° from the vertical. If the rain drops are actually falling vertically downwards , then velocity in m/sec is

(a) 5 (b) $5\sqrt{3}$ (c) $5\sqrt{2}$ (d) 4

Ans. a

Solution:

$\vec{V}_{r,m} =$ 

$\tan 45° = \frac{5}{V} = 1$

$V = 5 \text{ m/sec}$

$V_{r,g} = V$

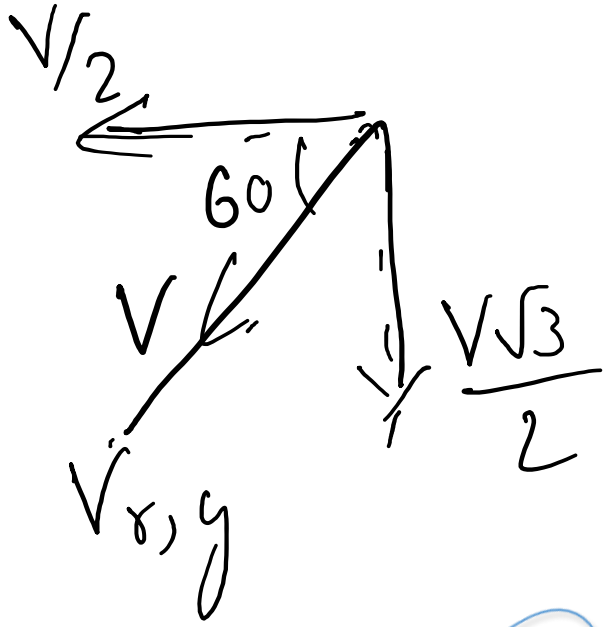
$\rightarrow 5 \text{ m/sec}$

Q) 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

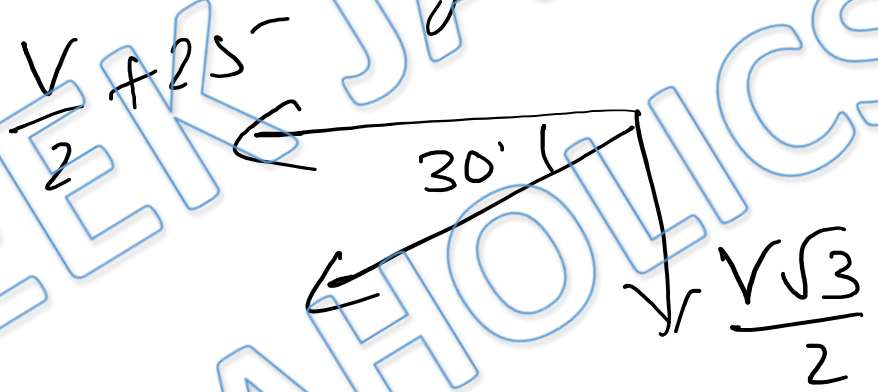
Ans. a

Solution:



$\frac{q}{2} \rightarrow 25\ m/sec$

Velocity of rain w.r.t man



$$\tan 30 = \frac{1}{\sqrt{3}} = \frac{V\sqrt{3}/2}{V/2 + 25}$$

$$\Rightarrow \frac{3}{2}V = V/2 + 25 \Rightarrow V = 25\ m/sec$$

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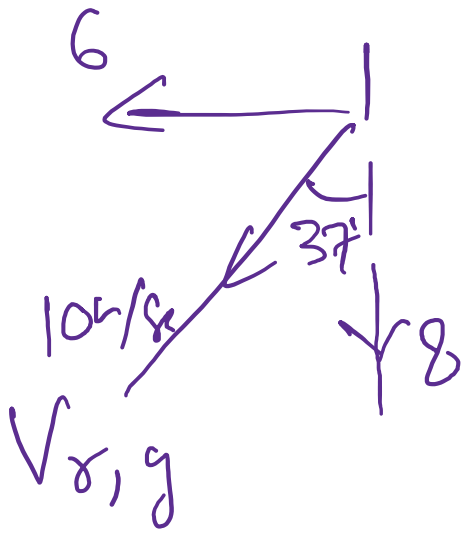
Q) Rain is falling with speed 10 m/s at angle 37° with vertical. To a moving man raindrops appear to fall with $8\sqrt{2}$ m/s. Possible speed(s) of man is(are)?

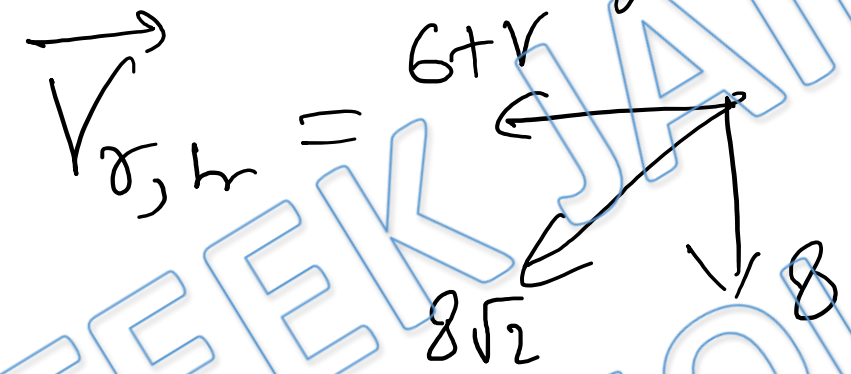
(a) 1 m/s (b) 6 m/s (c) 11 m/s (d) 15 m/s

Ans. b, c

Solution:



If man moves rightward with velocity V



$\Rightarrow 64 + (6+V)^2 = 128$

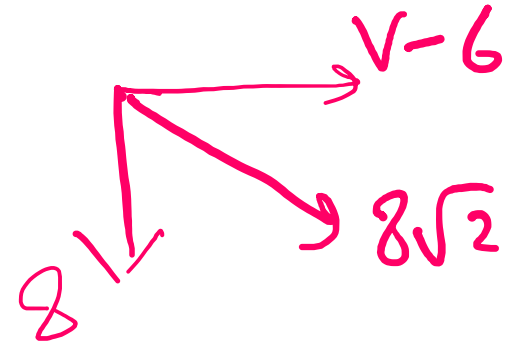
$(6+V)^2 = 64$

$6+V = 8$

$\Rightarrow V = 2.$

If man moves leftward with velocity V

$\Rightarrow$



$\Rightarrow (V-6)^2 + 8^2 = (8\sqrt{2})^2$

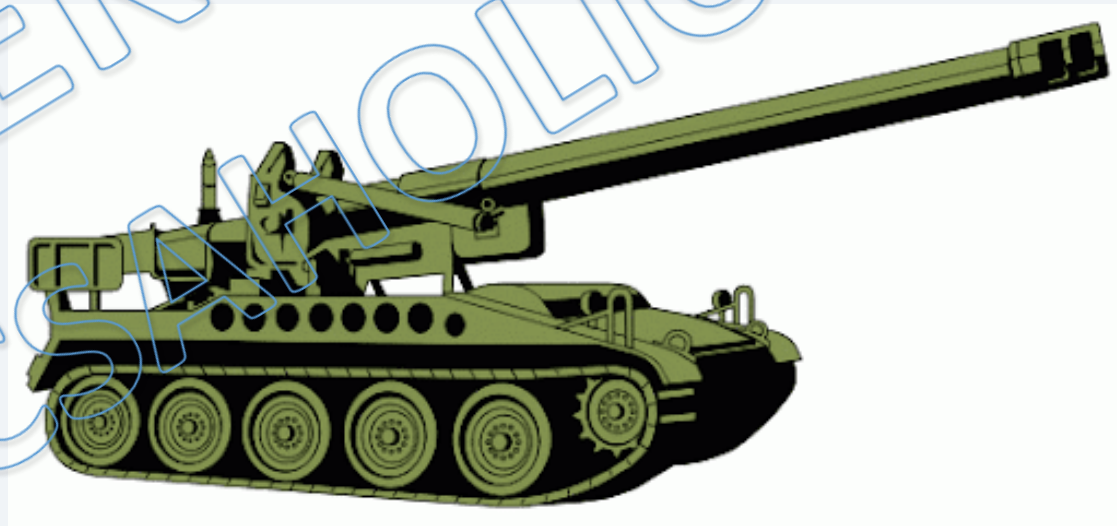
$\Rightarrow V = 14.$

If man moves in any other direction $2 < V < 14$

Q) 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?

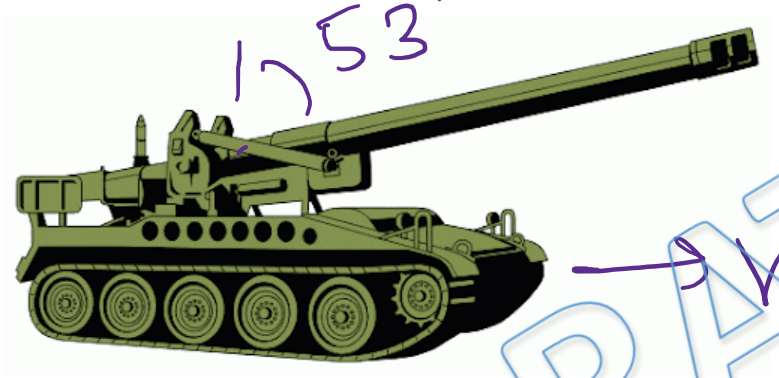
(a) 10 m/s (b) 6.66 m/s

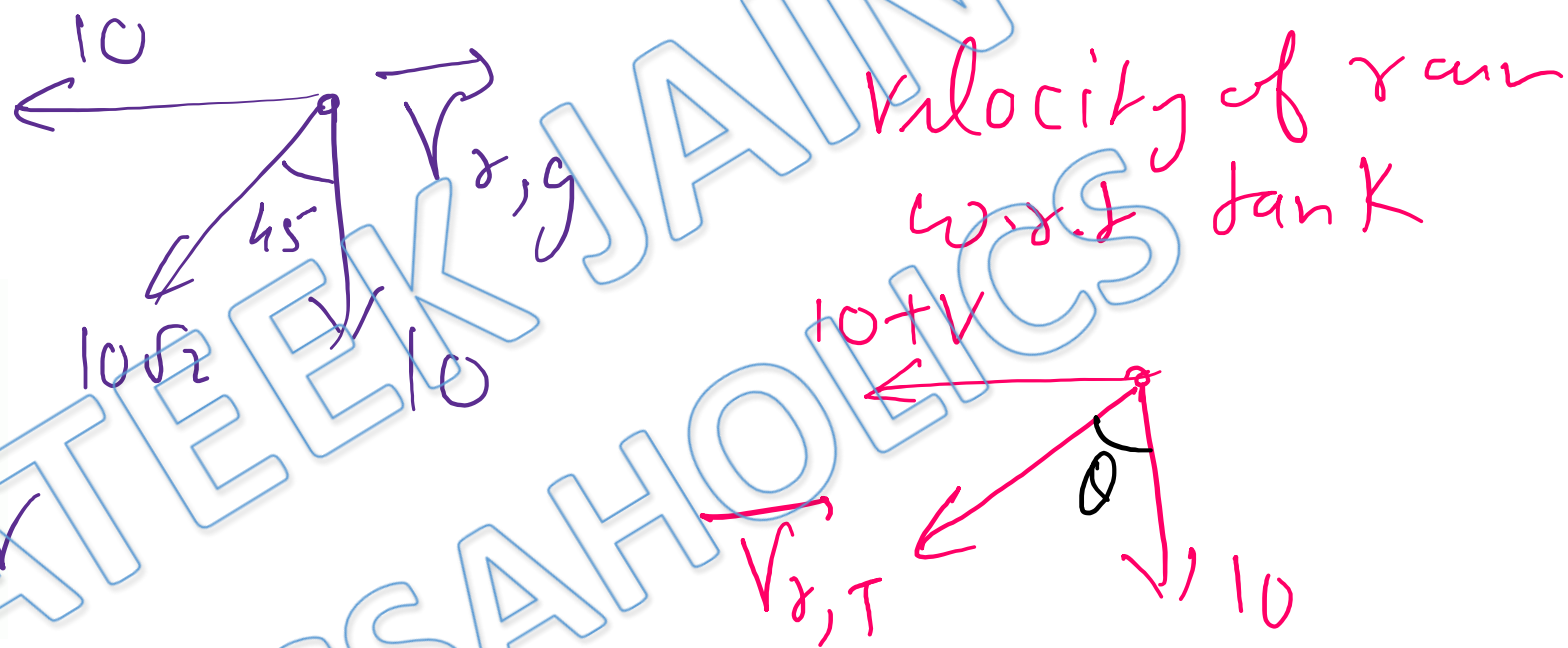
(c) 3.33 m/s (d) 0.33 m/s



Ans. c

Solution:





If $\vec{V}_{r,T}$ is ⊥r to length of barrel. Gts surface will not become wet. for this $\theta = 53°$

$$\tan 53° = \frac{10+V}{10} = \frac{4}{3} \Rightarrow 10+V = \frac{40}{3} \Rightarrow V = 10/3 \text{ m/sec}$$

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