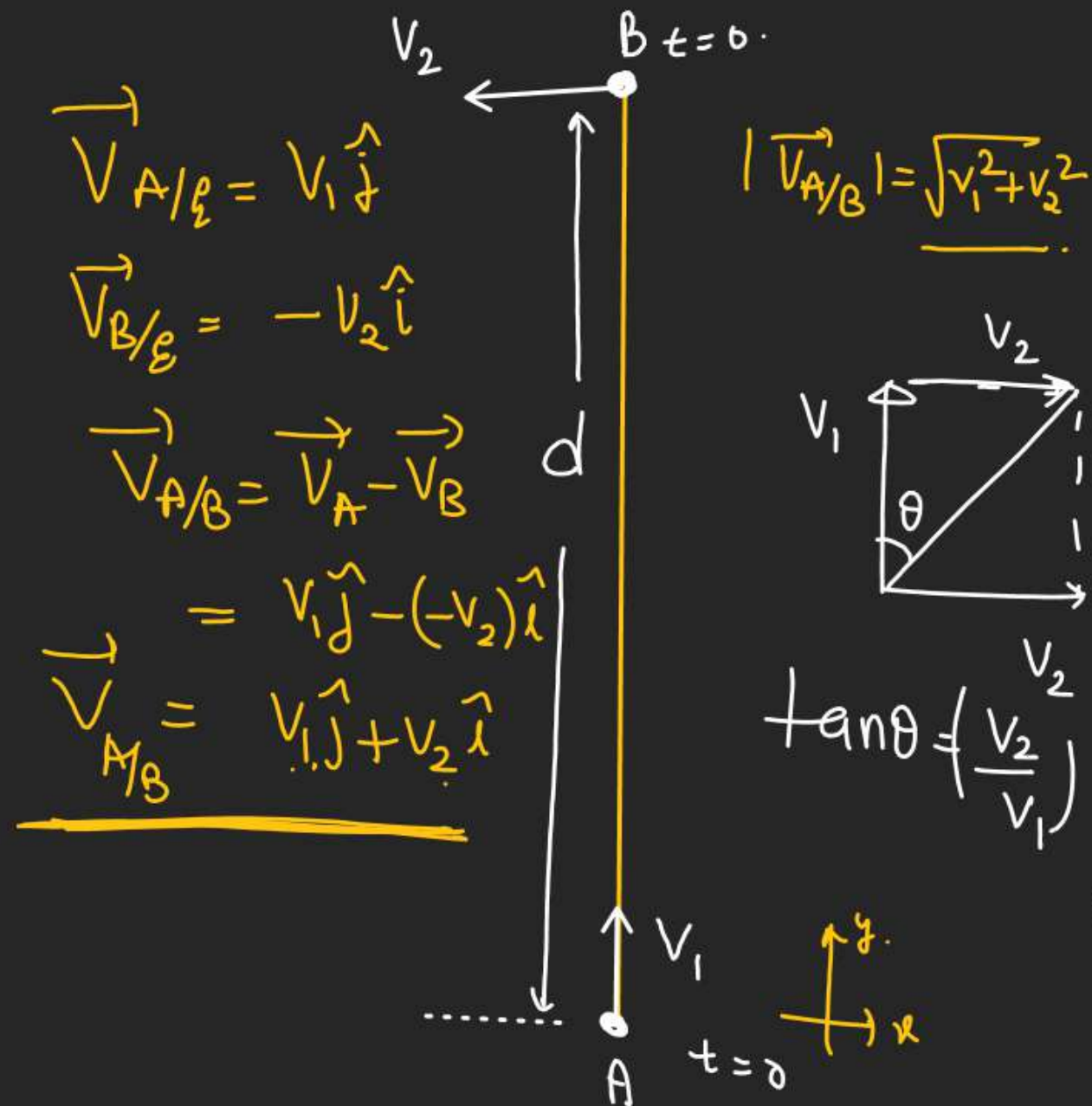


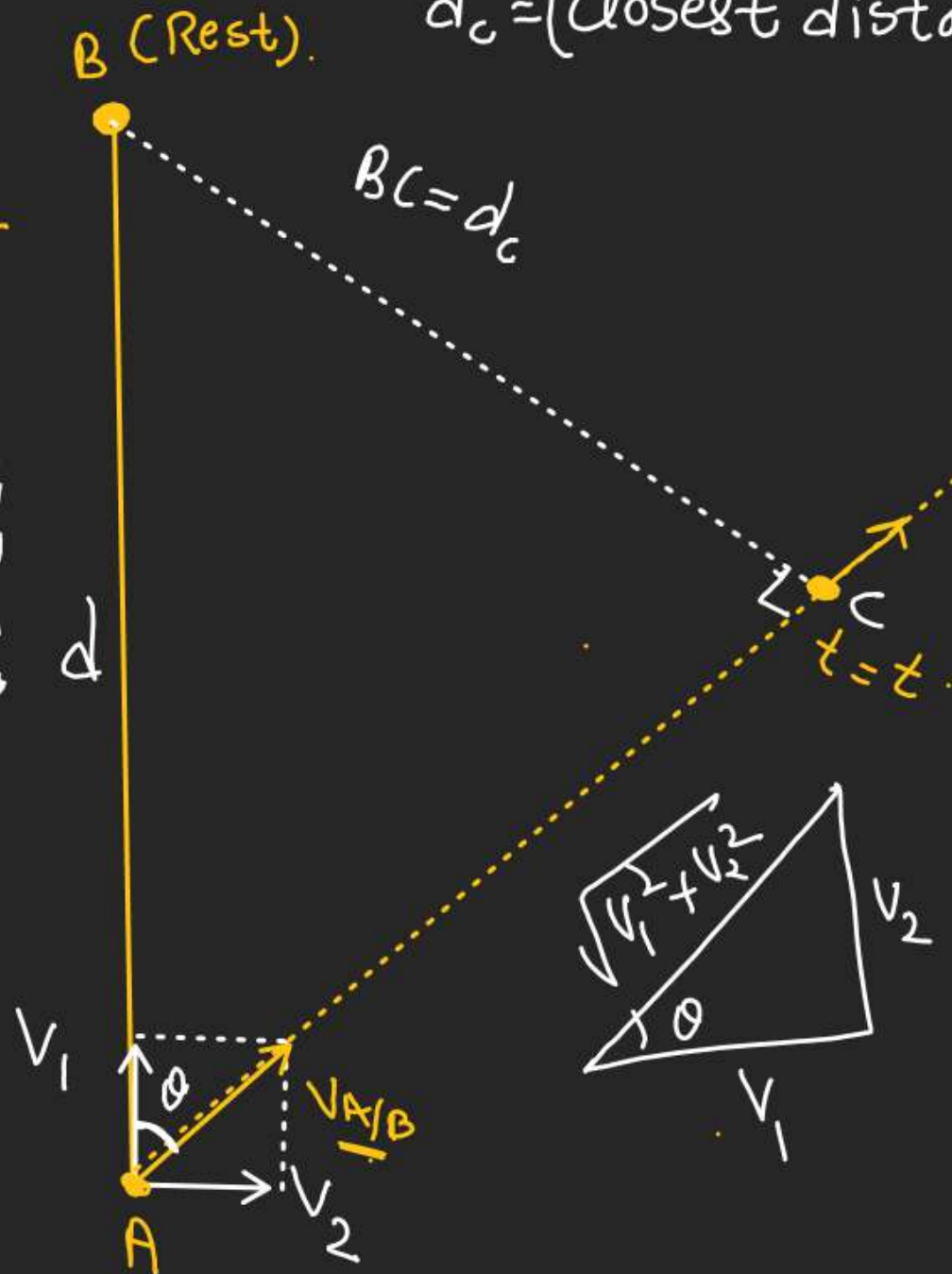
# Relative velocity

★★

Find the closest distance of approach b/w A & B.



$d_c = (\text{closest distance})$



In  $\triangle ABC$

$$\sin \theta = \frac{BC}{AB}$$

$$BC = AB \sin \theta$$

$$BC = d \sin \theta$$

$$d_c = \frac{d v_2}{\sqrt{v_1^2 + v_2^2}}$$

Time for closest distance

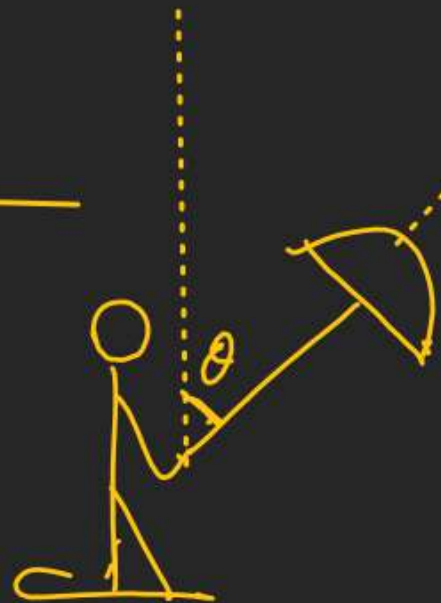
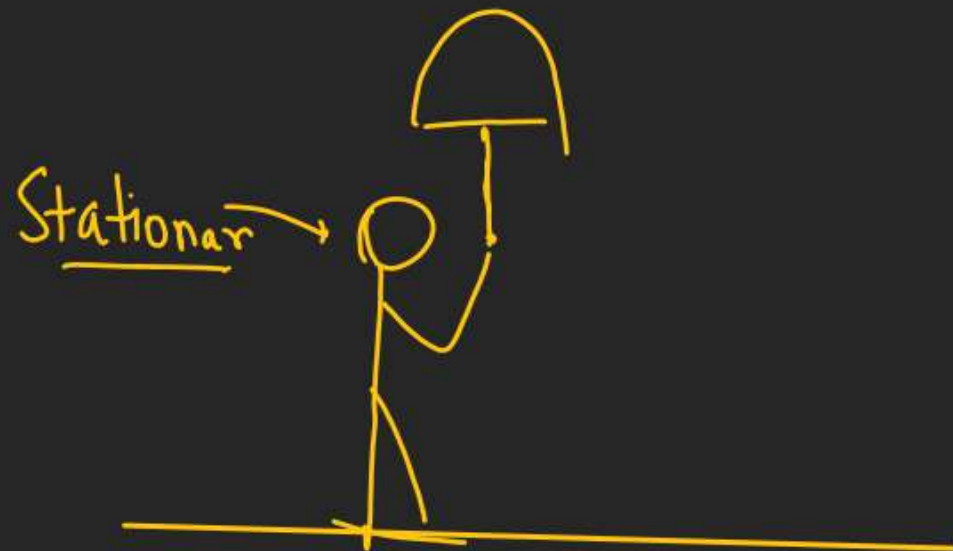
$$t = \frac{AC}{|\vec{V}_{A/B}|} = \frac{d \cos \theta}{\sqrt{v_1^2 + v_2^2}}$$

$$t = \frac{d v_1}{\sqrt{v_1^2 + v_2^2} \times \frac{1}{\sqrt{v_1^2 + v_2^2}}} = \left( \frac{d v_1}{v_1^2 + v_2^2} \right)$$

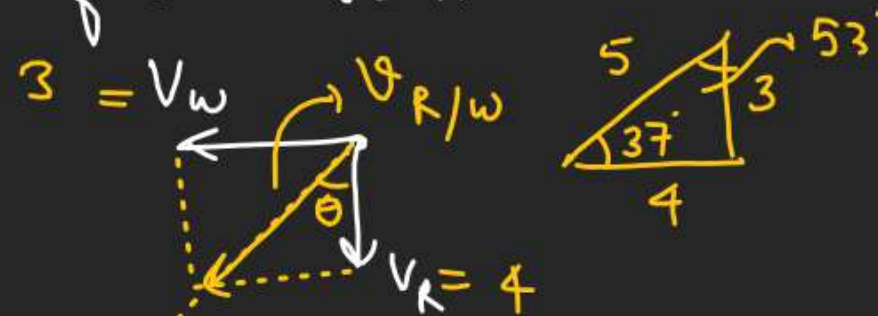
# Relative velocity

## Rain-man problem

↓  $V_R = 4 \text{ m/s}$



Wind starts blowing in west direction with velocity  $3 \text{ m/s}$ . Find the angle from vertical man rotates its hand to protect from rain

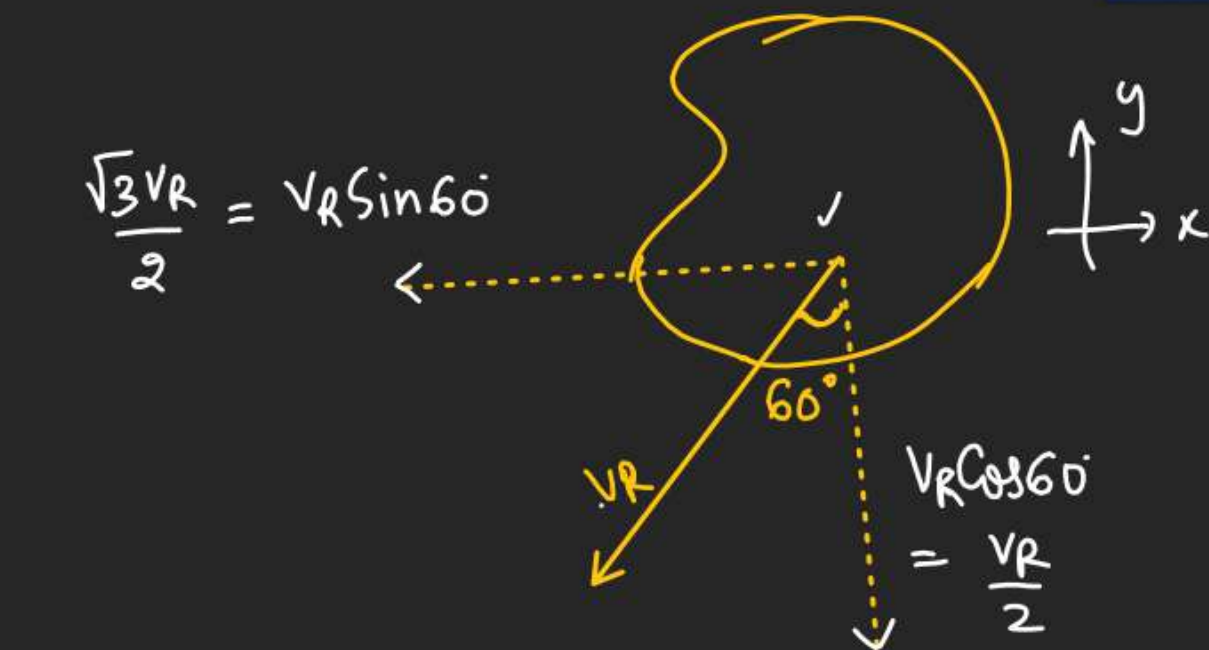


$$\tan \theta = \left( \frac{V_w}{V_R} \right)$$

$$\tan \theta = \frac{3}{4}$$

$$\underline{37^\circ}$$

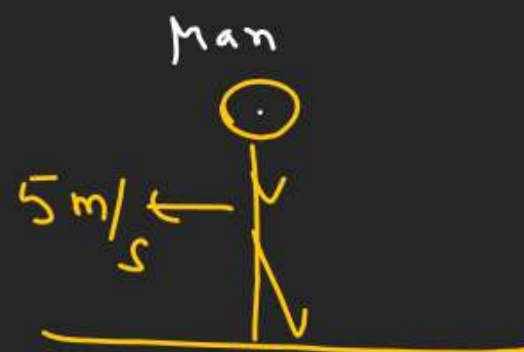
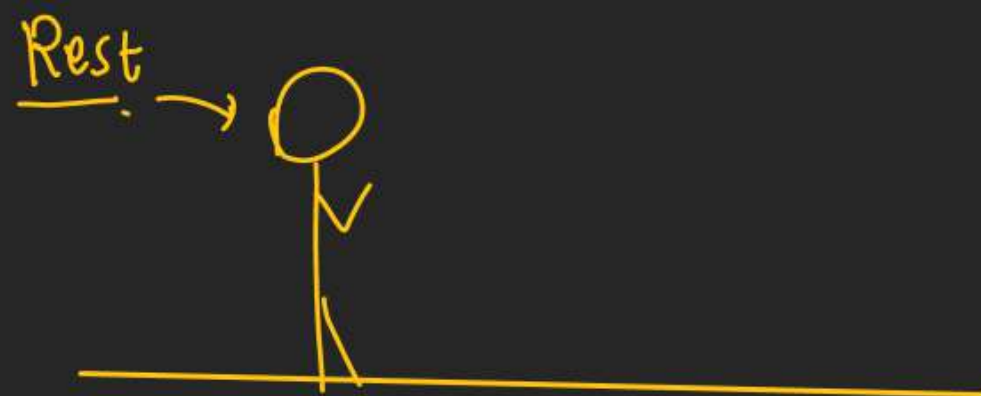
# Relative velocity



When man starts running with velocity  $5\text{ m/s}$ . Rain drops seem to fall vertically downward. Find the speed of the rain.



$\downarrow \downarrow \rightarrow V_{R/\text{man}}$



Sol<sup>n</sup>

$$\vec{V}_{R/E} = -\frac{\sqrt{3}V_R}{2}\hat{i} - \frac{V_R}{2}\hat{j}$$

$$\vec{V}_{\text{man}/E} = -5\hat{i}$$

$$\begin{aligned}\vec{V}_{R/\text{Man}} &= \vec{V}_{R/E} - \vec{V}_{\text{man}/E} \\ &= -\frac{\sqrt{3}V_R}{2}\hat{i} - \frac{V_R}{2}\hat{j} + 5\hat{i} \\ &= \left(5 - \frac{\sqrt{3}V_R}{2}\right)\hat{i} - \frac{V_R}{2}\hat{j}\end{aligned}$$

According to question

$$(V_{R/M})_x = 0$$

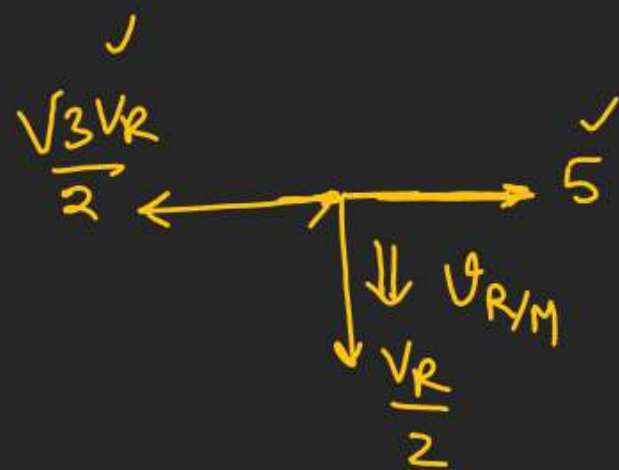
$$5 - \frac{\sqrt{3}V_R}{2} = 0 \Rightarrow V_R = \frac{10}{\sqrt{3}}\text{ m/s} \checkmark$$

# Relative velocity

(Trick)

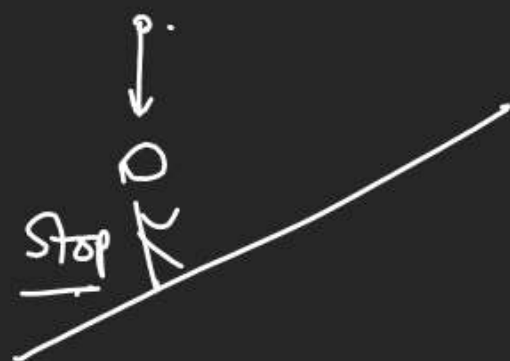
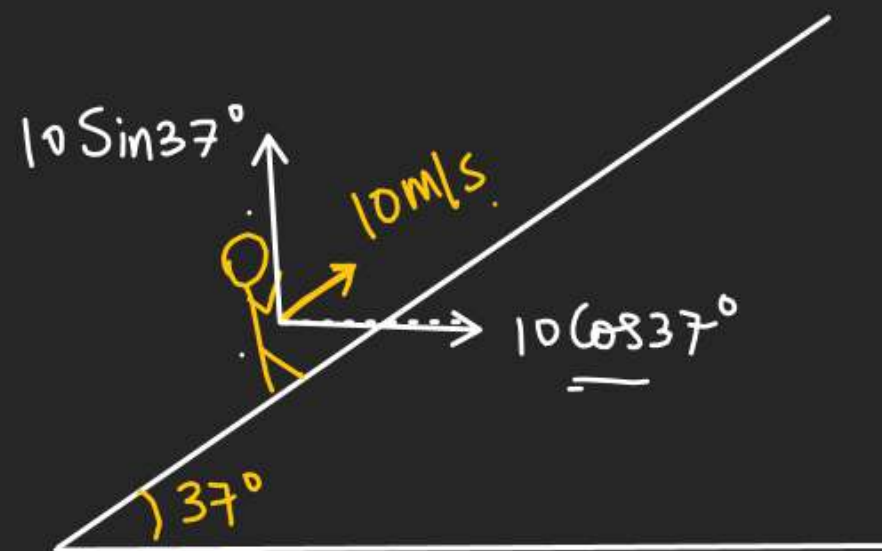
$$5 = \frac{\sqrt{3} V_R}{2}$$

$$V_R = \left( \frac{10}{\sqrt{3}} \text{ m/s} \right)$$



# Relative velocity

# W.r.t man rains drops falling vertically downward with speed 5 m/s.  
find. Speed of rain drop.



$$\begin{aligned}\vec{V}_{M/E} &= 10 \cos 37^\circ \hat{i} + 10 \sin 37^\circ \hat{j} \\ &= 10 \times \frac{4}{5} \hat{i} + 10 \times \frac{3}{5} \hat{j} \\ &= 8\hat{i} + 6\hat{j}\end{aligned}$$

$$\vec{V}_{R/E} = a\hat{i} - b\hat{j}$$

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

$$= a\hat{i} - b\hat{j} - 8\hat{i} + 6\hat{j} = (a-8)\hat{i} + (6-b)\hat{j}$$

According to question

$$(V_{R/M})_x = 0$$

$$a = 8$$

$$\vec{V}_{R/E} = 8\hat{i} - 11\hat{j}$$

$$(\vec{V}_{R/M})_y = -(b-6) \quad \text{Speed}$$

$$b-6 = 5$$

$$b = 11$$

$$|\vec{V}_{R/E}| = \sqrt{64 + 121} = \sqrt{185} \text{ m/s}$$

# Relative velocity

**Q.7** A girl standing on road holds her umbrella at  $45^\circ$  with the vertical to keep the rain away. If she starts running without umbrella with a speed of  $15\sqrt{2}\text{kmh}^{-1}$ , the rain drops hit her head vertically. The speed of rain drops with respect to the moving girl is:

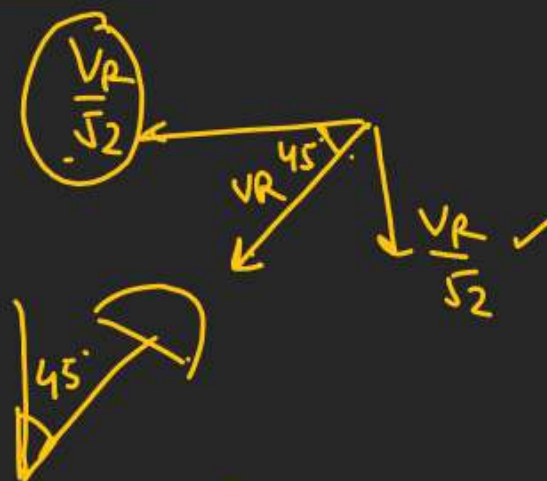
**[June 27, 2022 (I)]**

(A)  $30 \text{ kmh}^{-1}$

(B)  $\frac{25}{\sqrt{2}} \text{ kmh}^{-1}$

(C)  $\frac{30}{\sqrt{2}} \text{ kmh}^{-1}$

(D)  $25 \text{ kmh}^{-1}$



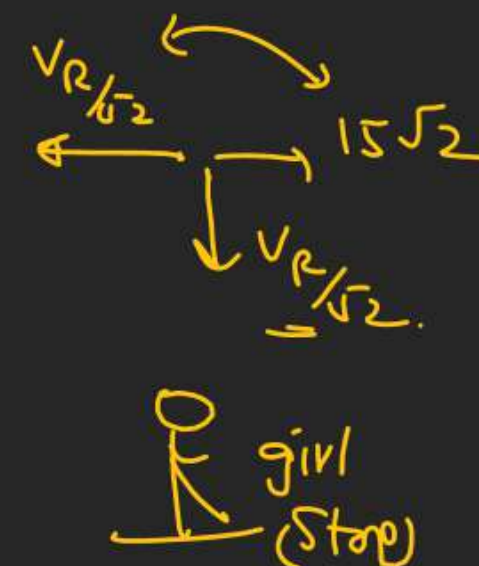
$$V_{R/girl} = \frac{V_R}{\sqrt{2}}$$

$$= \frac{30}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}} = 30 \text{ kmh}^{-1}$$

$$V_{R/\sqrt{2}} = V_{R/girl}$$

$$15\sqrt{2} = \frac{V_R}{\sqrt{2}}$$

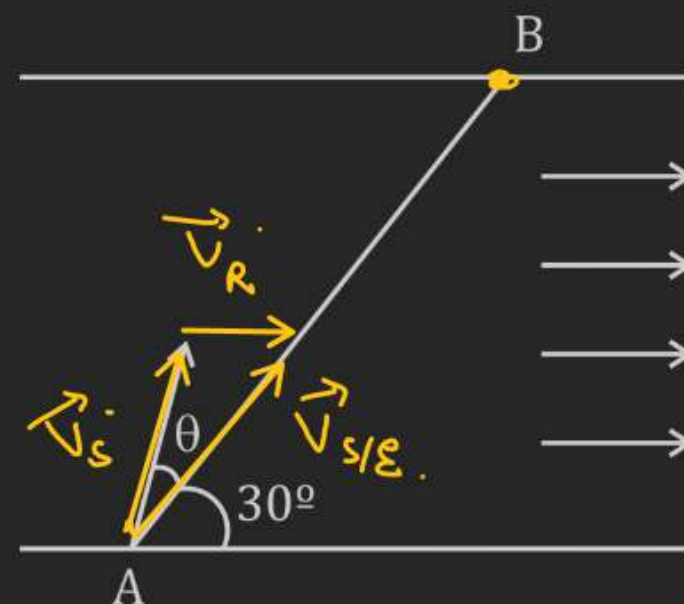
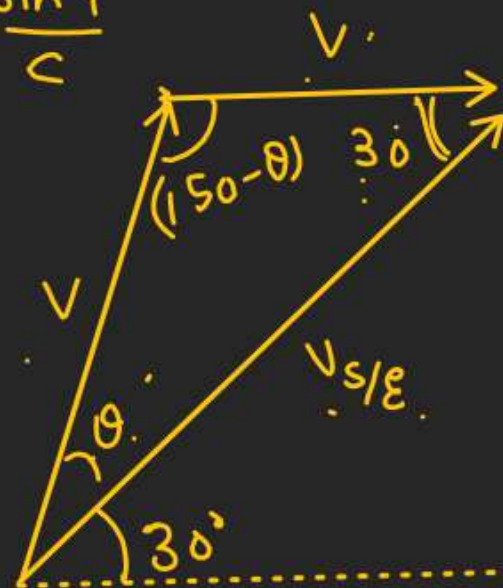
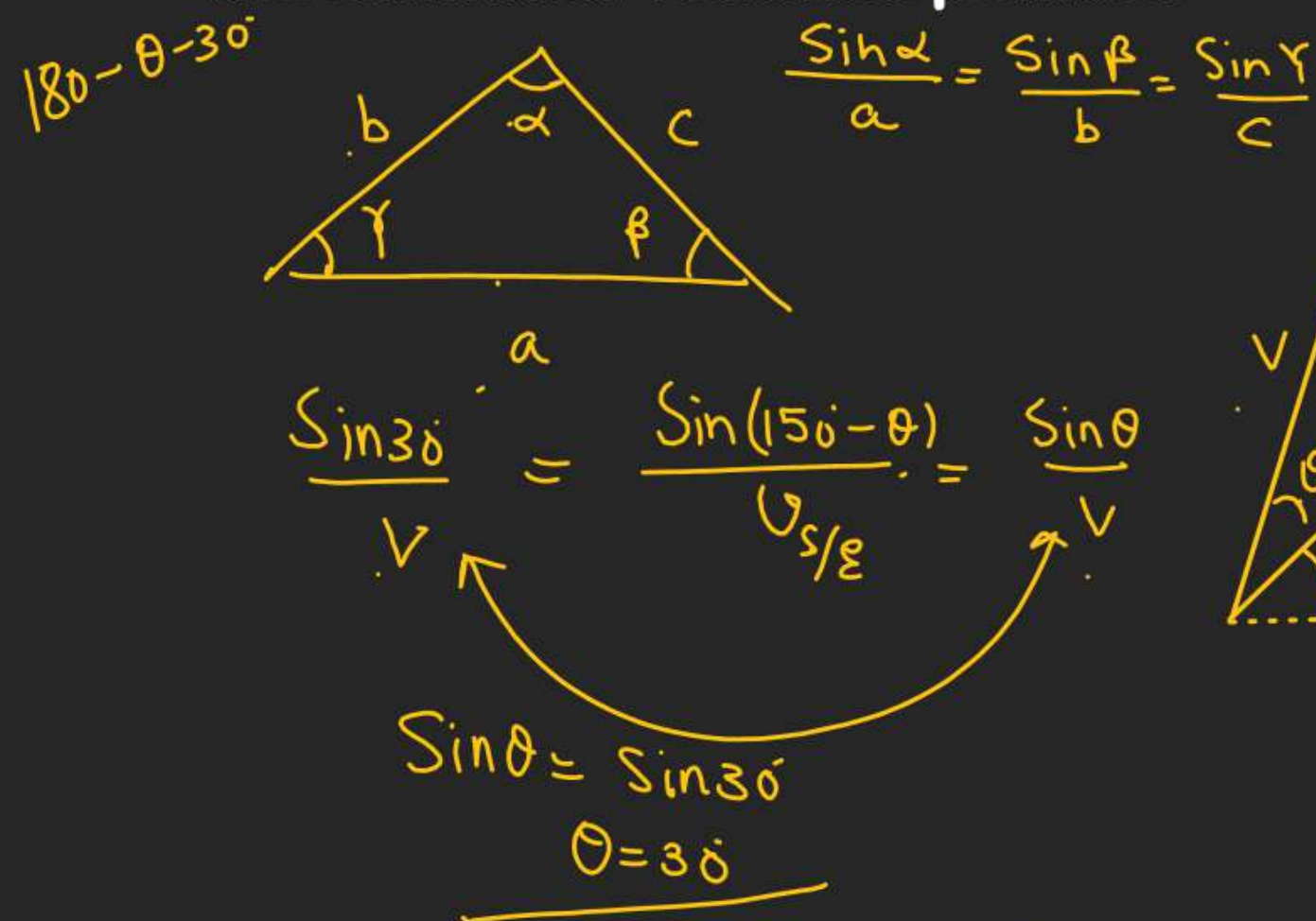
$$V_R = 30 \text{ km/h} \checkmark$$



# Relative velocity

**Q.8** A swimmer wants to cross a river from point A to point B. Line AB makes an angle of  $30^\circ$  with the flow of river. Magnitude of velocity of the swimmer is same as that of the river. The angle  $\theta$  with the line AB should be  $\_\_\circ$ , so that the swimmer reaches point B.

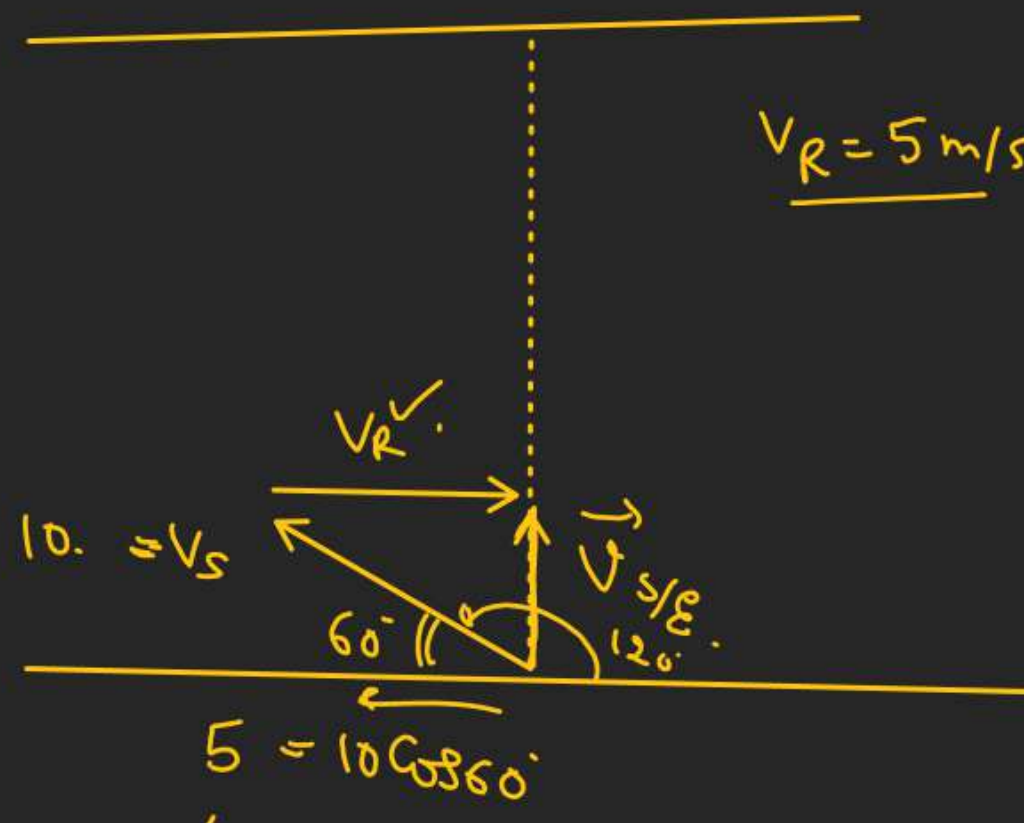
$V_R = V_S = V$  [NA, July 27, 2021 (II)]



## Relative velocity

**Q.9** A person is swimming with a speed of  $10 \text{ m/s}$  at an angle of  $120^\circ$  with the flow and reaches to a point directly opposite on the other side of the river. The speed of the flow is 'x' m / s. The value of 'x' to the nearest integer is

[March 18, 2021 (I)]



# Relative velocity

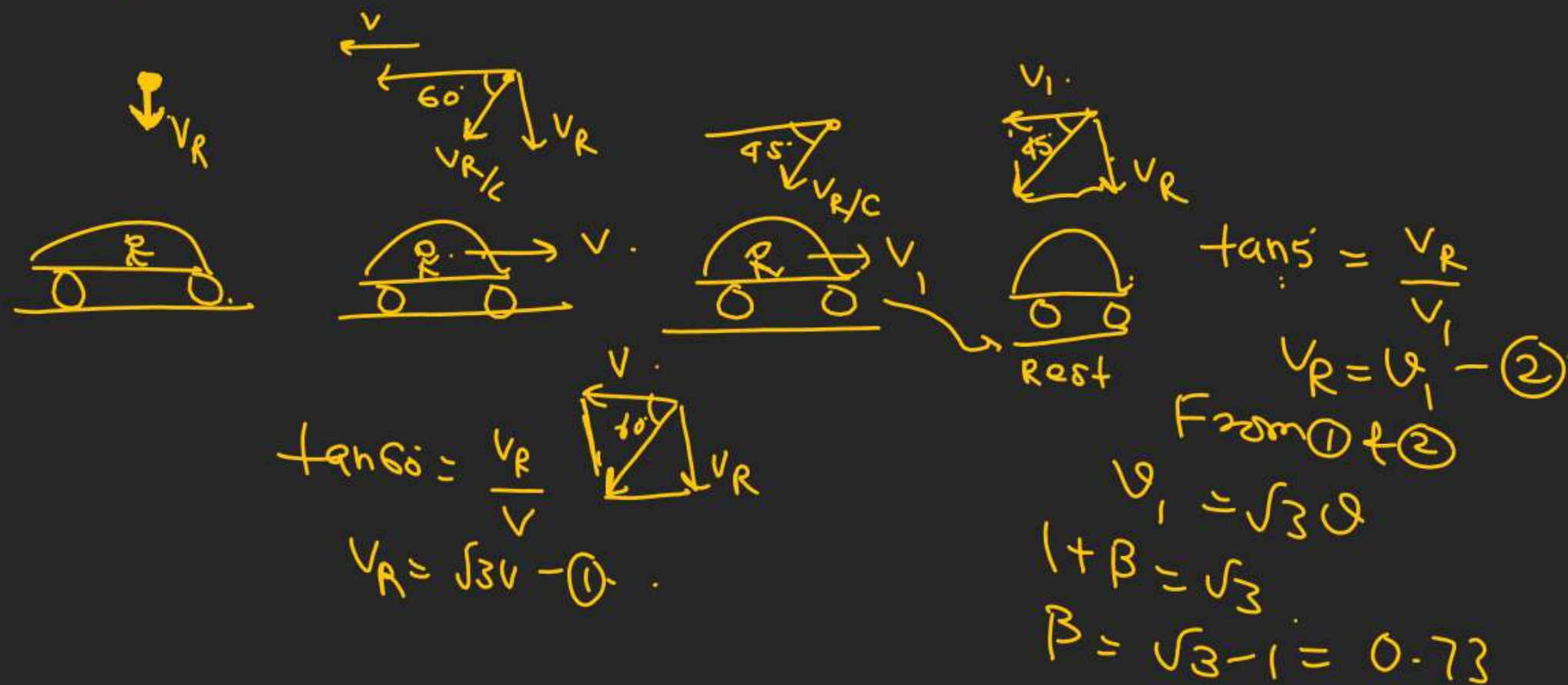
**Q.10** When a car is at rest, its driver sees raindrops falling on it vertically. When driving the car with speed  $v$ , he sees that raindrops are coming at an angle  $60^\circ$  from the horizontal. On further increasing the speed of the car to  $(1 + \beta)v$ , this angle changes to  $45^\circ$ . The value of  $\beta$  is close to: **[Sep. 06, 2020 (II)]**

(A) 0.73

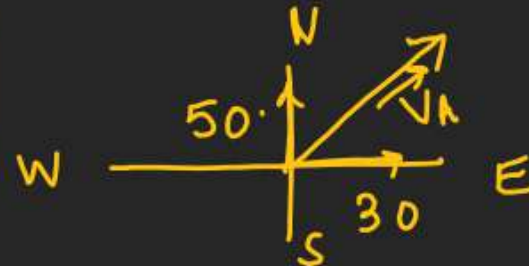
(B) 0.41

(C) 0.37

(D) 0.50



# Relative velocity



**Q.11** Ship A is sailing towards north-east with velocity  $\vec{v} = 30\hat{i} + 50\hat{j}$  km/hr where  $\hat{i}$  points east and  $\hat{j}$  north. Ship B is at a distance of 80 km east and 150 km north of Ship A and is sailing towards west at 10 km/hr. A will be at minimum distance from B in:

[8 April 2019 I]

- (A) 4.2hrs.
- (B) 2.6hrs.
- (C) 3.2hrs.
- (D) 2.2hrs.

