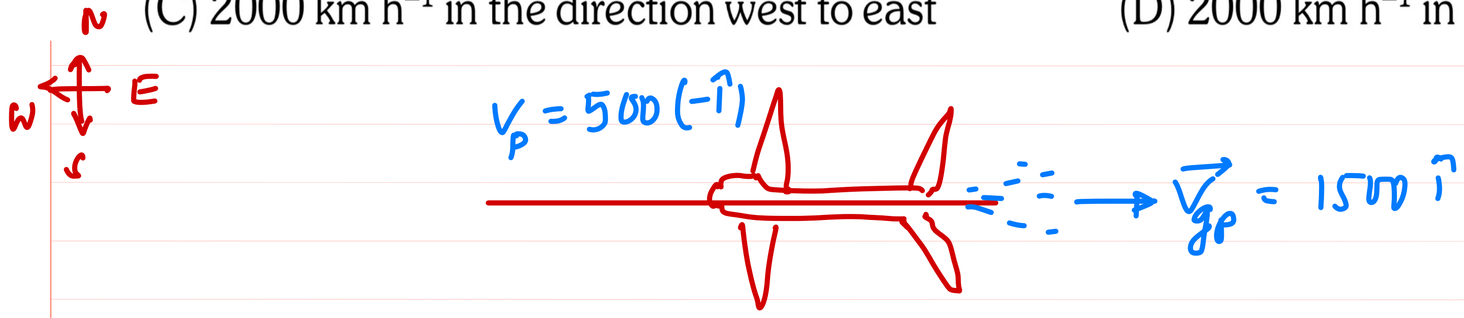
**21.** A jet airplane travelling from east to west at a speed of 500 km $h^{-1}$ ejected out gases of combustion at a speed of 1500 km $h^{-1}$ with respect to the jet plane. What is the velocity of the gases with respect to an observer on the ground?

(A) 1000 km $h^{-1}$ in the direction west to east

(B) 1000 km $h^{-1}$ in the direction east to west

(C) 2000 km $h^{-1}$ in the direction west to east

(D) 2000 km $h^{-1}$ in the direction east to west




$$\vec{V}_{gp} = \vec{V}_g - \vec{V}_p$$

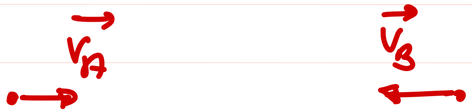
$$\vec{V}_g = \vec{V}_{gp} + \vec{V}_p$$

$$= 1500\hat{i} - 500\hat{i}$$

$$\boxed{\vec{V}_g = 1000\,\hat{i}}$$

**25.** The distance between two particles is decreasing at the rate of 6 m/sec. If these particles travel with same speeds and in the same direction, then the separation increases at the rate of 4 m/sec. The particles have speeds as

(A) 5 m/sec ; 1 m/sec (B) 4 m/sec ; 1 m/sec (C) 4 m/sec ; 2 m/sec (D) 5 m/sec ; 2 m/sec



$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$

$-6 = V_A + V_B$ — (1)

$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$

$+4 = V_A - V_B$ — (2)

(1) + (2)

$-2 = 2V_A \Rightarrow V_A = -1\ m/s$

$V_B = -5\ m/s$

**4.** A stationary person observes that rain is falling vertically down at 30 $kmh^{-1}$. A cyclist is moving up on an inclined plane making an angle 30° with horizontal at 10 $kmh^{-1}$. In which direction should the cyclist hold his umbrella to prevent himself from the rain ?

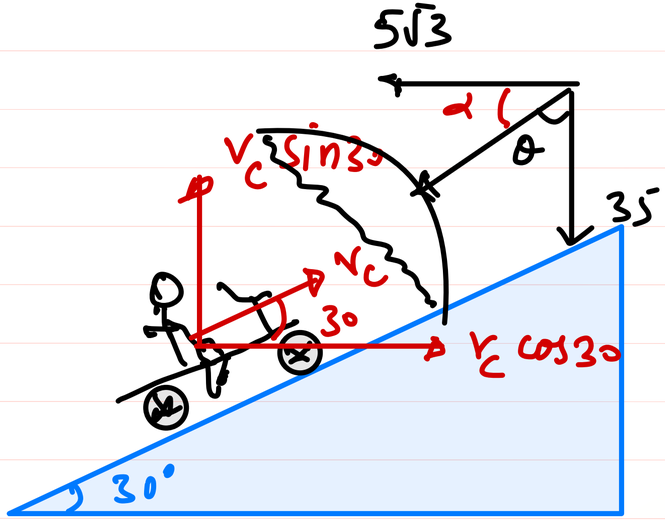
(A) At an angle $\tan^{-1}\left(\frac{3\sqrt{3}}{5}\right)$ with inclined plane

(B) At an angle $\tan^{-1}\left(\frac{3\sqrt{3}}{5}\right)$ with horizontal

(C) At angle $\tan^{-1}\left(\frac{\sqrt{3}}{7}\right)$ with inclined plane

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

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




$\vec{V}_C = 10\cos 30\,\hat{i} + 10\sin 30\,\hat{j}$

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

$\vec{V}_{RC} = -30\hat{j} - 5\sqrt{3}\,\hat{i} - 5\hat{j}$

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

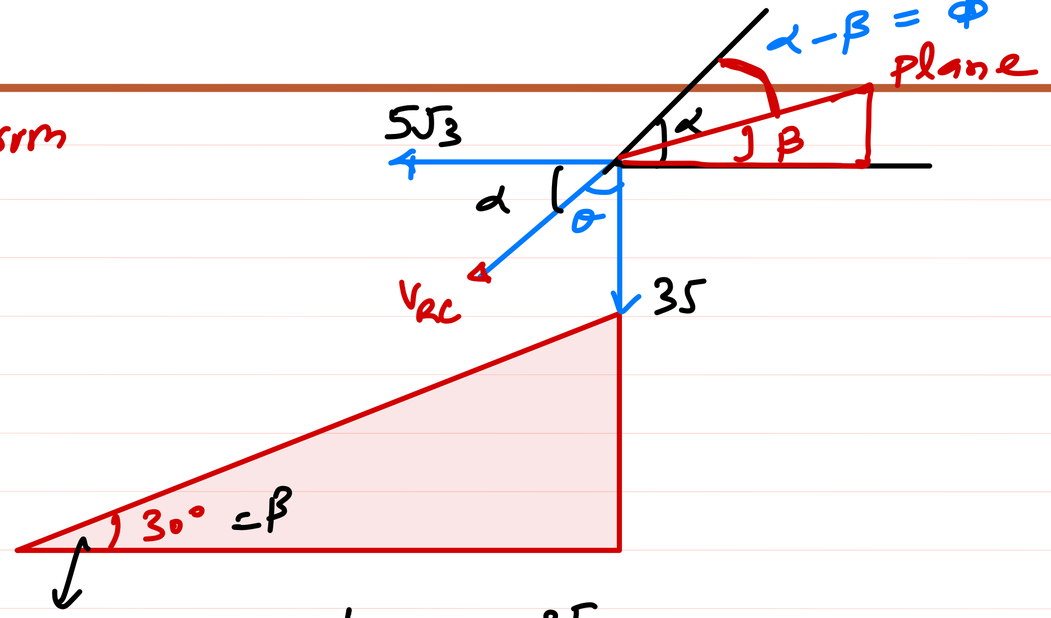
$\tan\theta = \frac{5\sqrt{3}}{35} = \frac{\sqrt{3}}{7}$

$\theta = \tan^{-1}\left(\frac{\sqrt{3}}{7}\right)$

with Horizontal

$\tan\alpha = \frac{35}{5\sqrt{3}} \Rightarrow$ **$\tan\alpha = \frac{7}{\sqrt{3}}$**

Angle form Inclined plane




$\tan\beta = \frac{1}{\sqrt{3}}$

$\tan\alpha = \frac{35}{5\sqrt{3}} = \frac{7}{\sqrt{3}}$

**Angle from inclined plane :-**

$\phi = \alpha - \beta$

$\tan\phi = \tan(\alpha-\beta)$

$= \frac{\tan\alpha - \tan\beta}{1+\tan\alpha\tan\beta}$

$= \frac{\frac{7}{\sqrt{3}} - \frac{1}{\sqrt{3}}}{1+\frac{7}{\sqrt{3}}\times\frac{1}{\sqrt{3}}}$

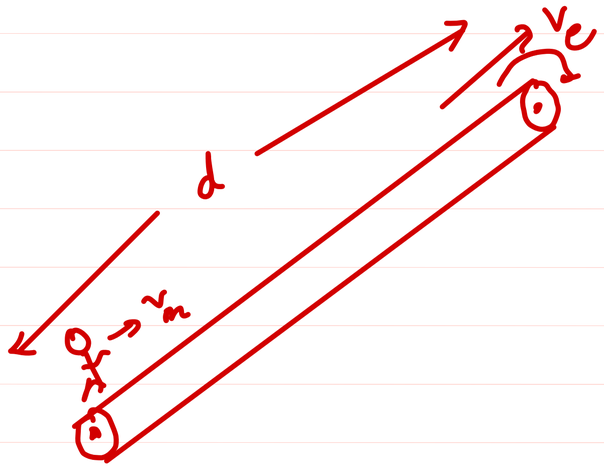
$= \frac{6}{\sqrt{3}} \times \frac{\sqrt{3}\times\sqrt{3}}{10}$

$\tan\phi = \frac{3\sqrt{3}}{5}$

$\boxed{\phi = \tan^{-1}\left(\frac{3\sqrt{3}}{5}\right)}$ from plane

**3*.** A person standing on the escalator takes time $t_1$ to reach the top of a tower when the escalator is moving. He takes time $t_2$ to reach the top of the tower when the escalator is standing. How long will he take if he walks up a moving escalator?

(A) $t_2 - t_1$ (B) $t_1 + t_2$ (C) $t_1 t_2/(t_1 - t_2)$ ~~(D)~~ $t_1 t_2/(t_1 + t_2)$



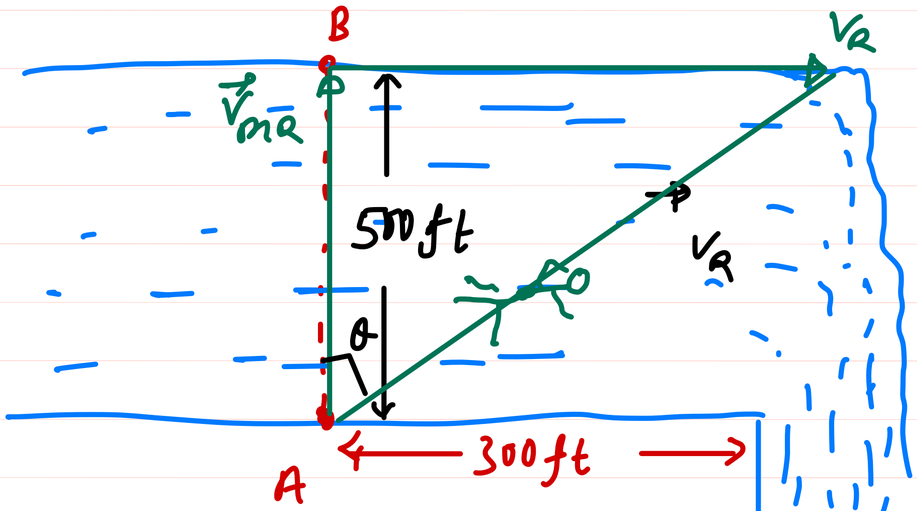

$$t_1 = \frac{d}{v_e} \Rightarrow v_e = \frac{d}{t_1}$$

$$t_2 = \frac{d}{v_m} \Rightarrow v_m = \frac{d}{t_2}$$

$$t = \frac{d}{v_m + v_e} = \frac{d}{\frac{d}{t_1} + \frac{d}{t_2}} = \frac{t_1 t_2}{t_1 + t_2}$$

**4*.** A battalion of soldiers is ordered to swim across a river 500 ft wide. At what minimum rate should they swim perpendicular to river flow in order to avoid being washed away by the waterfall 300 ft downstream. The speed of current being 3 m.p.h. :

(A) 6 m.p.h. (B) 5 m.p.h. (C) 4 m.p.h. (D) 2 m.p.h.



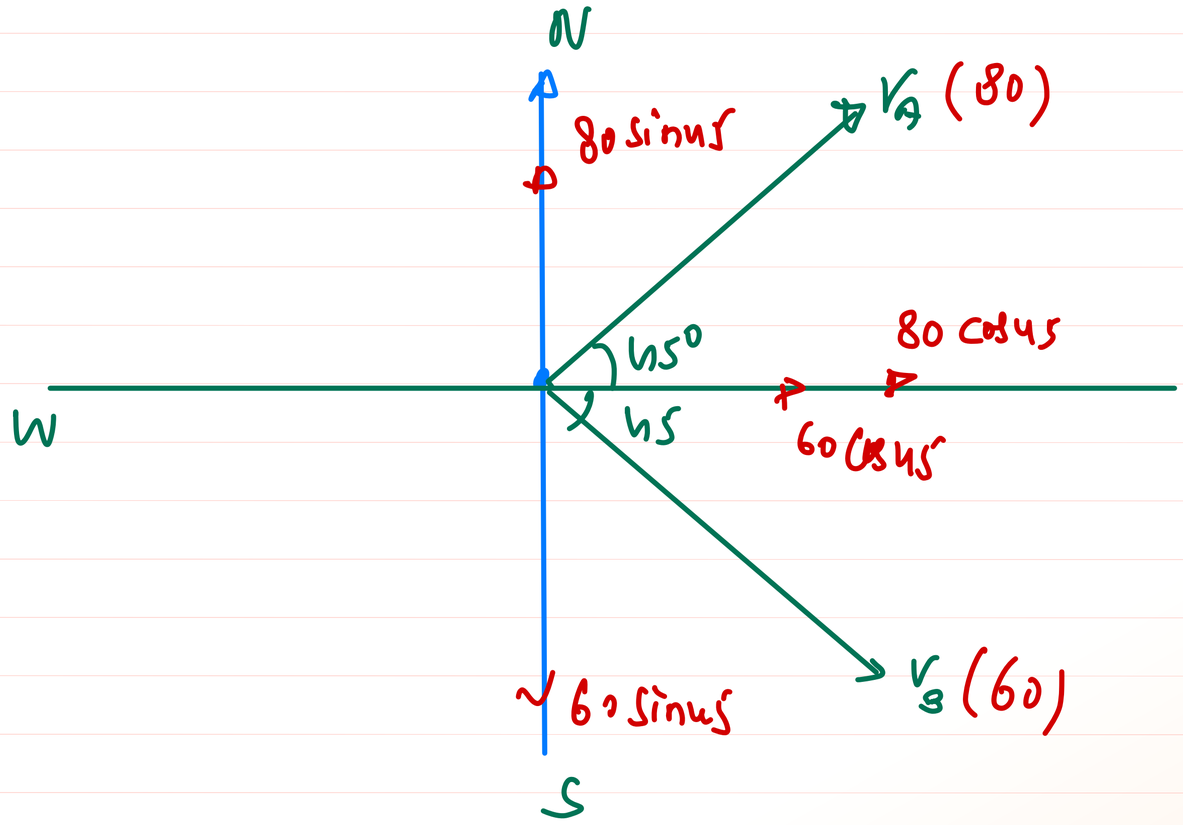

$V_R = 3$ mph

$$\tan\theta = \frac{V_R}{V_{mR}} = \frac{3\cancel{00}}{5\cancel{00}}$$

$V_{mR} = \frac{5}{3} V_R = \frac{5}{\cancel{3}} \times \cancel{3} = 5$ m.p.h

**2.** A car A is going north east at 80 $kmh^{-1}$ and another car B is going south east with a velocity of 60 $kmh^{-1}$. The velocity of A relative to B makes an angle with the north equal to

(A) $\tan^{-1}\left(\frac{2}{7}\right)$ (B) $\tan^{-1}\left(\frac{7}{2}\right)$ (C) $\tan^{-1}(7)$ ~~(D)~~ $\tan^{-1}\left(\frac{1}{7}\right)$




$\vec{V}_{AB} = \left(\frac{80}{\sqrt{2}}\hat{i} + \frac{80}{\sqrt{2}}\hat{j}\right) - \left(\frac{60}{\sqrt{2}}\hat{i} - \frac{60}{\sqrt{2}}\hat{j}\right)$

$\vec{V}_{AB} = \frac{20}{\sqrt{2}}\hat{i} + \frac{140}{\sqrt{2}}\hat{j}$

East

$\tan\theta = \frac{\frac{140}{\sqrt{2}}}{\frac{20}{\sqrt{2}}} = 7$

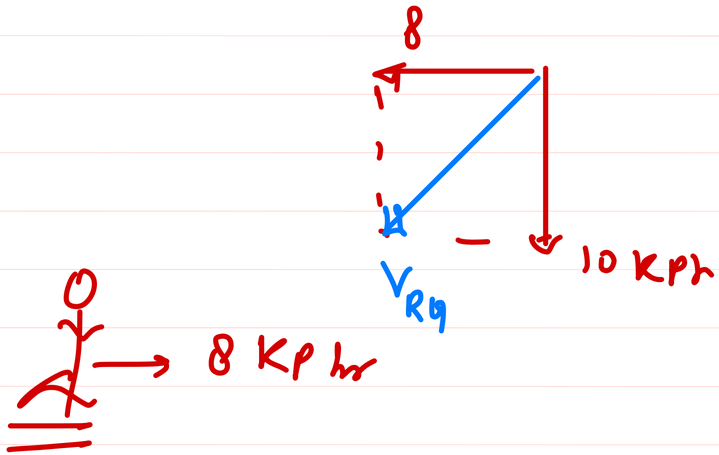
$\theta = \tan^{-1}(7)$

North

$\tan\alpha = \frac{\frac{20}{\sqrt{2}}}{\frac{140}{\sqrt{2}}} = \frac{1}{7}$

**9.** A girl is walking on a road with velocity of 8kph. Suddenly rain starts falling at 10kph in vertically downward direction. The velocity of rain w.r.t to girl is

(A) $\sqrt{7}$ kph (B) $\sqrt{13}$ kph (C) $\sqrt{6}$ kph (D) $\sqrt{164}$ kph

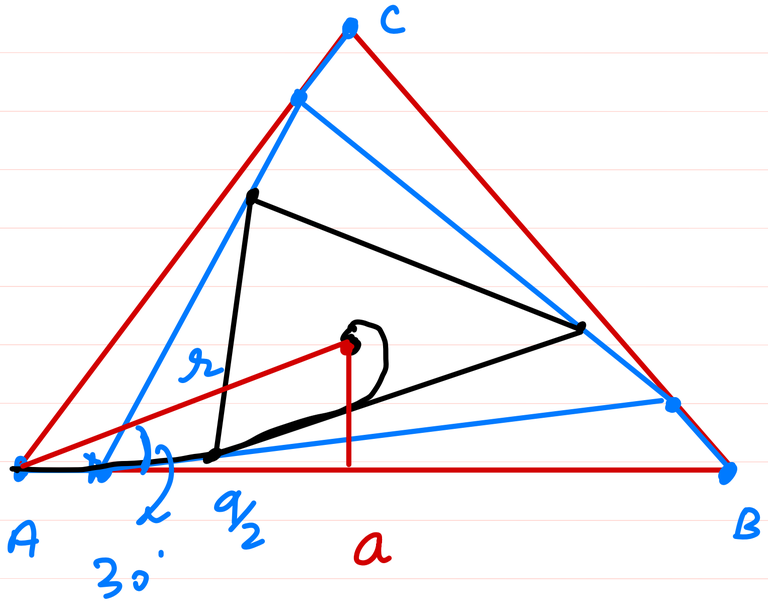



$V_{rg} = \sqrt{(10)^2 + 8^2}$

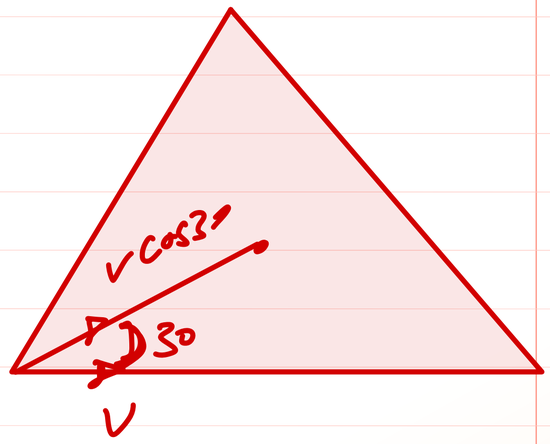
$= \sqrt{164}$

***Illustration 6*.***

Three particles A, B and C are situated at the vertices of an equilateral triangle ABC of side a at t = 0. Each of the particles moves with constant speed v. A always has its velocity along AB, B along BC and C along CA. At what time will the particle meet each other?




meet at centre




$$\cos 30 = \frac{a/2}{r}$$

$$\frac{\sqrt{3}}{2} = \frac{a}{2r} \Rightarrow \boxed{r = \frac{a}{\sqrt{3}}}$$

$$t = \frac{r}{v\cos 30} = \frac{a}{\sqrt{3} \times v \frac{\sqrt{3}}{2}}$$

$$\boxed{t = \frac{2a}{3v}}$$

Ans