Constraint Motion

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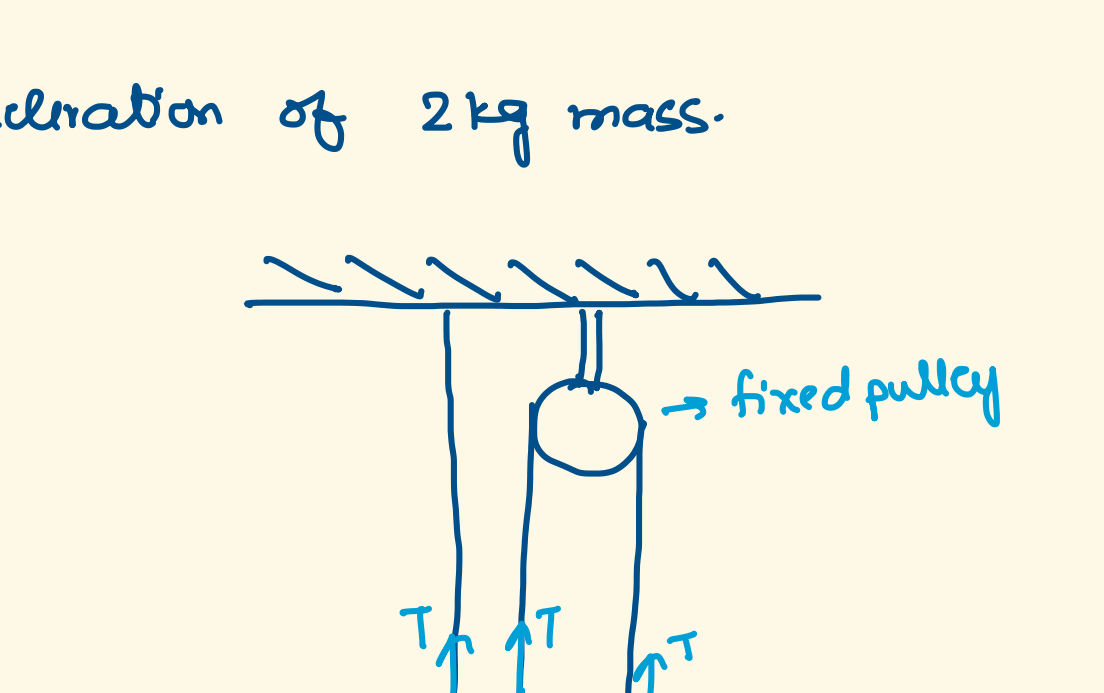
1. Problem 01:

Find acceleration of 2 kg mass.



Solution: We know that,

∴ Work done by Tension force (T) = 0 because Tension force is internal force.

Which means,

$$T_1 \cdot x_1 + T_2 \cdot x_2 = 0 \Rightarrow \Sigma T \cdot x = 0$$

differentiating w.r.t time both sides, we get

$$T_1 \cdot v_1 + T_2 v_2 = 0 \Rightarrow \Sigma T \cdot v = 0$$

differentiating w.r.t time both sides, we get

$$T_1 a_1 + T_2 \cdot a_2 = 0 \Rightarrow \boxed{\Sigma T \cdot a = 0}$$

Coming back to our problem:

$$\Sigma T \cdot a = 0$$
$$-Ta_2 + (2T)a_1 = 0$$
$$2Ta_1 = Ta_2$$
$$\boxed{2a_1 = a_2}$$

Equation of motion on 2kg object:

$$-2g + T = 2(-a_2) = 2(-2a_1)$$

$$-2g + T = -4a_1 \quad \text{--- (1)}$$

Equation of motion on 1 kg object:

$$+2T - 1 \cdot g = 1\, a_1 \quad \text{--- (2)}$$

∴ 2 · Eq (1) − Eq (2) :-

$$-4g + 2T = -8a_1$$
$$\ominus \quad 2T - 1g = 1a_1$$
$$-3g = -9a_1$$

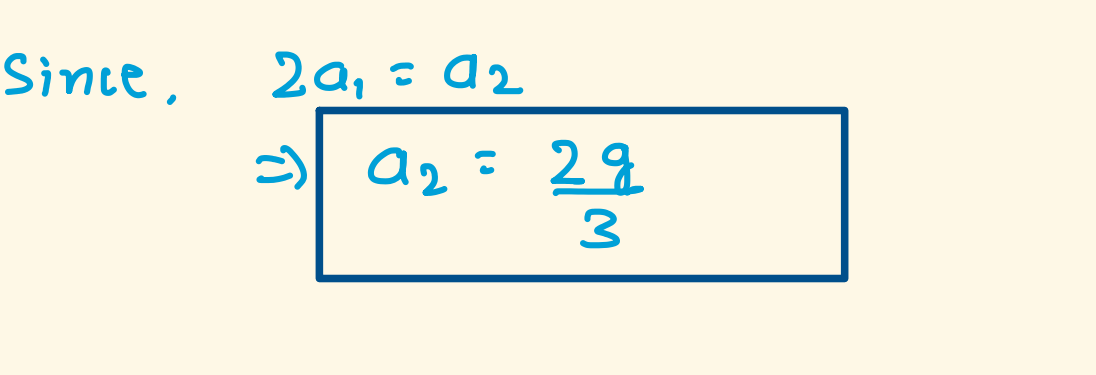
$$\boxed{a_1 = g/3}$$

Since, $2a_1 = a_2$

$$\Rightarrow \boxed{a_2 = \frac{2g}{3}}$$

So, the acceleration on 2kg mass is $-\frac{2g}{3}$ m/s² (going downwards)

2. Problem 02:



Find acceleration of 1 kg mass.

$$\therefore \quad \Sigma Ta = 0$$
$$-Ta_1 + (2T)a_2 = 0$$
$$Ta_1 = 2Ta_2$$
$$\boxed{a_1 = 2a_2}$$

Equation of motion on 2kg block:

$$-2g + T = 2(-a_1)$$
$$-2g + T = 2(-2a_2)$$

$$-2g + T = -4a_2 \quad \text{--- (1)}$$

Equation of motion on 1kg mass:

$$+2T = 1(a_2)$$
$$2T = a_2 \quad \text{--- (2)}$$

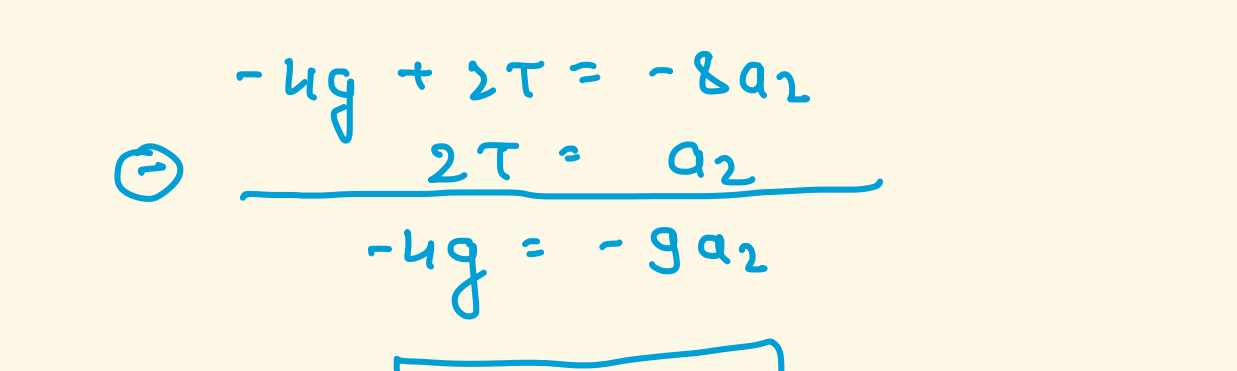
∴ 2 · Eq (1) − Eq (2) :

$$-4g + 2T = -8a_2$$
$$\ominus \quad 2T = a_2$$
$$-4g = -9a_2$$

$$\boxed{a_2 = \frac{4g}{9}}$$

3. Problem 03:

Find acceleration of block ① :-



Solution:

$$\Sigma T \cdot a = 0$$

↳ this is a dot product

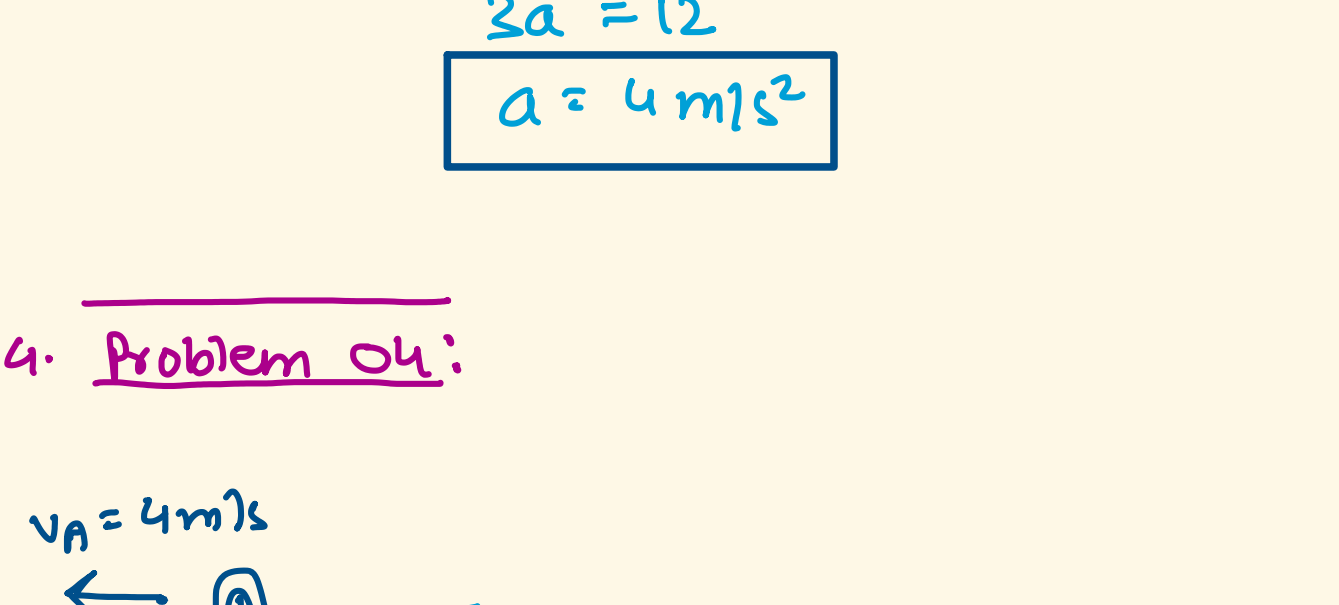
$\vec{a} \cdot \vec{b} = ab\cos\theta$ ↳ angle b/w $\vec{a}$ and $\vec{b}$

$$\therefore \quad \Sigma T \cdot a = 0$$
$$\underbrace{(2T) \cdot (6)\cos(180^\circ)}_{\text{Block ②}} + \underbrace{(3T)\, a \cos(0^\circ)}_{\text{Block ①}} = 0$$

$$(2T)(6)(-1) + (3T)(a)(1) = 0$$

$$-12T + 3Ta = 0$$
$$3a = 12$$
$$\boxed{a = 4 \text{ m/s}^2}$$

4. Problem 04:



Solution:

$$\therefore \quad \Sigma T \cdot v = 0$$

$$T \cdot v_A \cos(180^\circ) + T \cdot v_B \cos(37^\circ) = 0$$
$$v_A(-1) + v_B \cos 37^\circ = 0$$

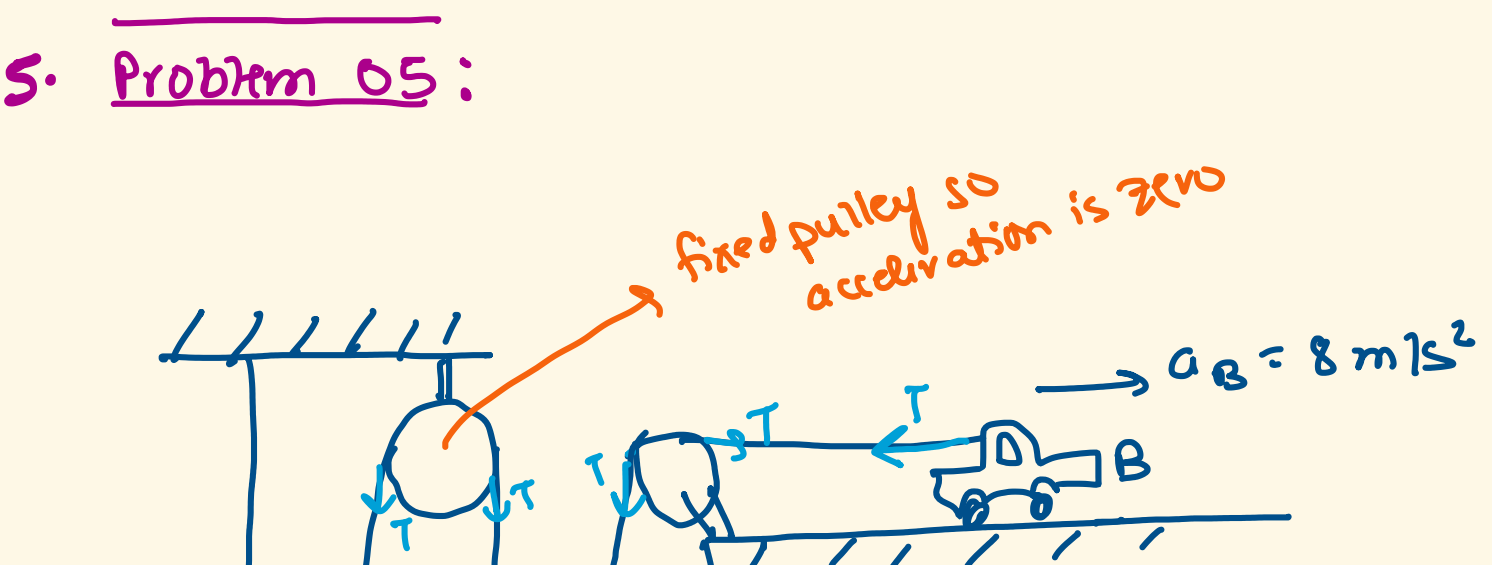
$$-v_A = -v_B \cos 37^\circ$$
$$v_A = v_B\left(\frac{4}{5}\right)$$

$$v_B = \frac{5}{4} v_A$$

$$= \frac{5}{4} \times 4$$

$$\boxed{v_B = 5 \text{ m/s}}$$

5. Problem 05:

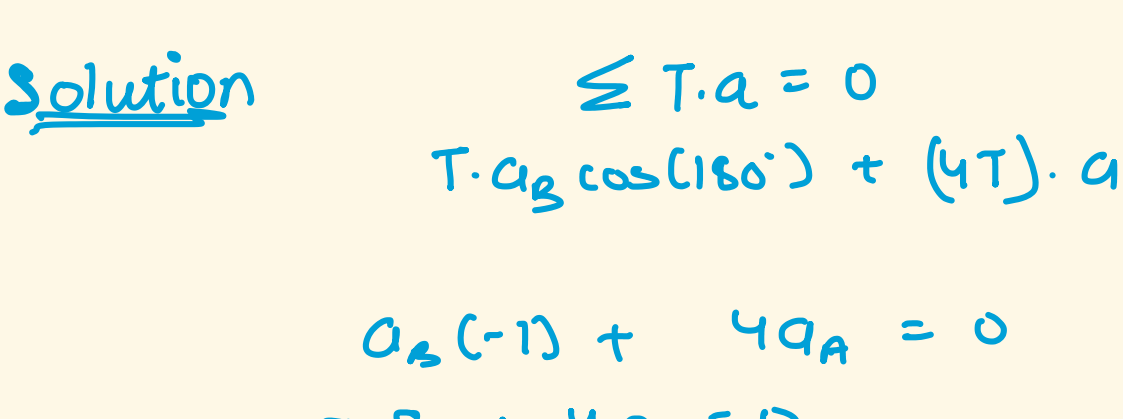


Solution

$$\Sigma T \cdot a = 0$$
$$T \cdot a_B \cos(180^\circ) + (4T) \cdot a_A \cos 0^\circ = 0$$

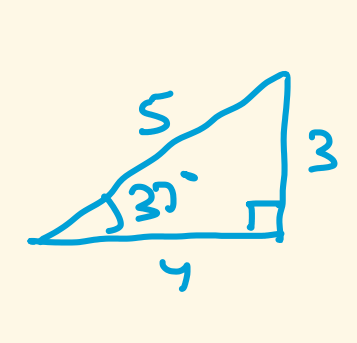
$$a_B(-1) + 4a_A = 0$$
$$-8 + 4a_A = 0$$
$$\boxed{a_A = 2 \text{ m/s}^2}$$

6. Problem 06:



Solution:

$$\Sigma T \cdot v = 0$$
$$T \cdot v_A \cos 180^\circ + Tv \cos 37^\circ = 0$$
$$T(4)(-1) + T \cdot (v)\left(\frac{4}{5}\right) = 0$$



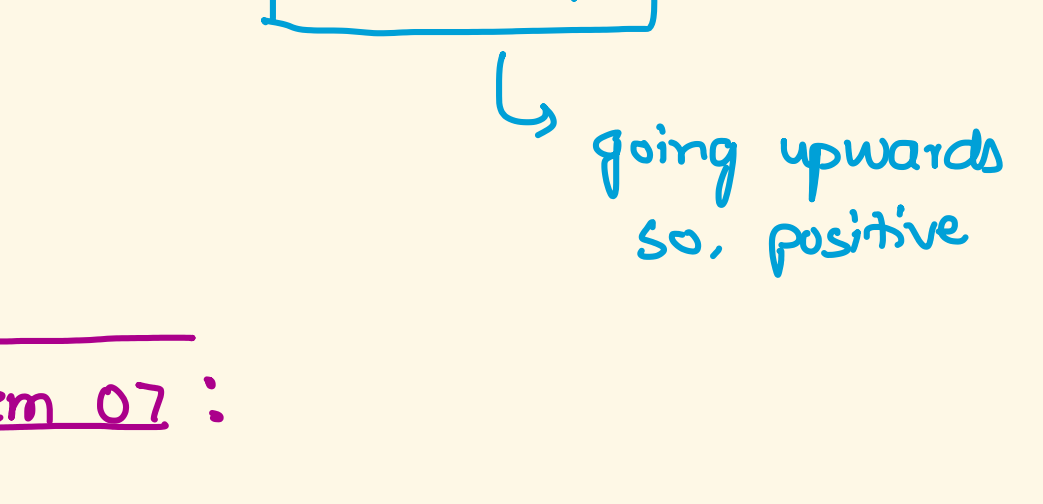
$$-4 + \frac{4v}{5} = 0$$

$$4\frac{v}{5} = 4$$

$$\boxed{v = +5 \text{ m/s}}$$

↳ going upwards so, positive

7. Problem 07:



Options:

(a) $2u\cos\theta$ (b) $u\cos\theta$

(c) $\frac{u}{\cos\theta}$ (d) $\frac{u}{2\cos\theta}$

Solution:

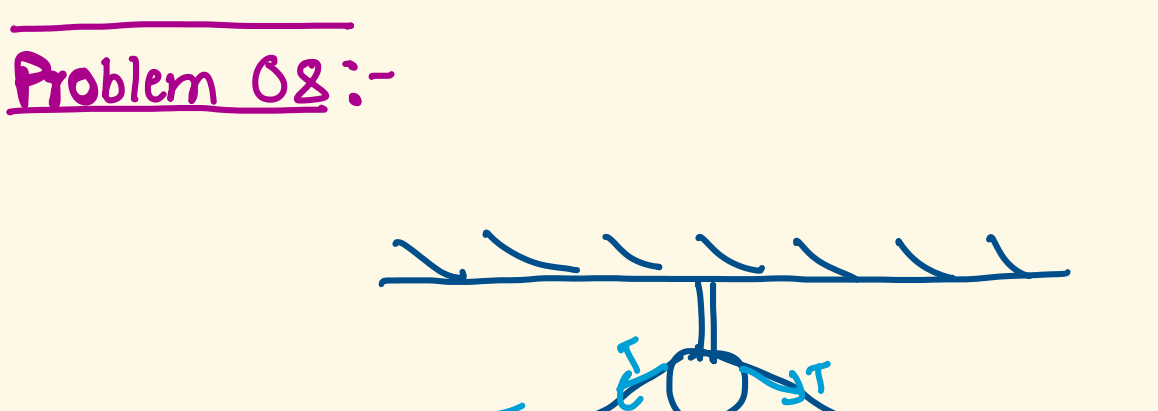
$$\Sigma T \cdot v = 0$$

$$\underbrace{Tu\cos(180^\circ)}_{\text{Block A}} + \underbrace{2T\cos\theta \cdot v}_{\text{Block m}} + \underbrace{Tu\cos 180^\circ}_{\text{Block A}} = 0$$

$$-u + 2\cos\theta(v) - u = 0$$
$$2v\cos\theta = 2u$$

$$\boxed{v = \frac{u}{\cos\theta}}$$ option (c) ✓

8. Problem 08:-



Solution:

$$\Sigma T \cdot v = 0$$
$$Tv_B \cos(53^\circ) + Tv_A \cos(180^\circ - 37^\circ) = 0$$

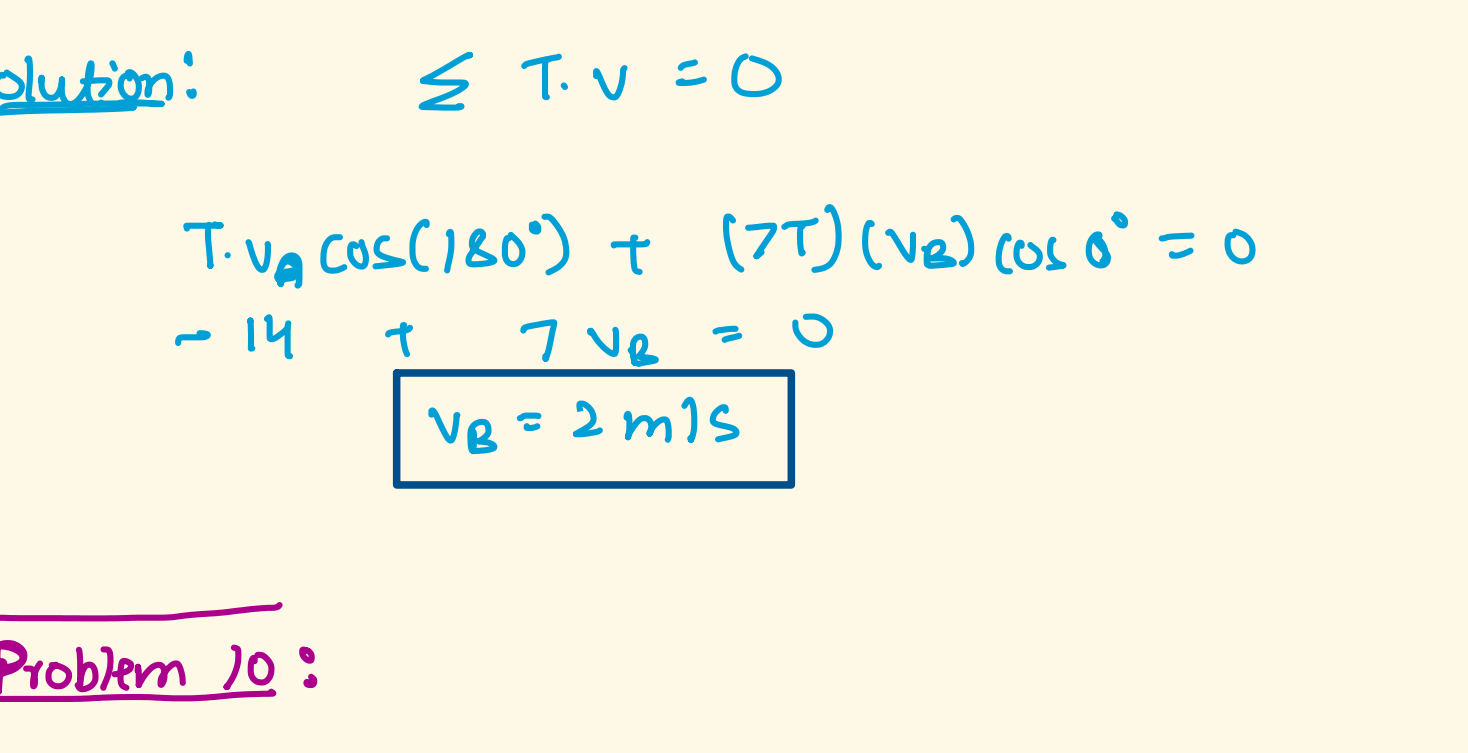
$$v_B\left(\frac{3}{5}\right) + (9)(-\cos 37^\circ) = 0$$

$$\frac{3v_B}{5} - 9\left(\frac{4}{5}\right) = 0$$

$$3v_B - 36 = 0$$

$$\boxed{v_B = 12 \text{ m/s}}$$

9. Problem 09:

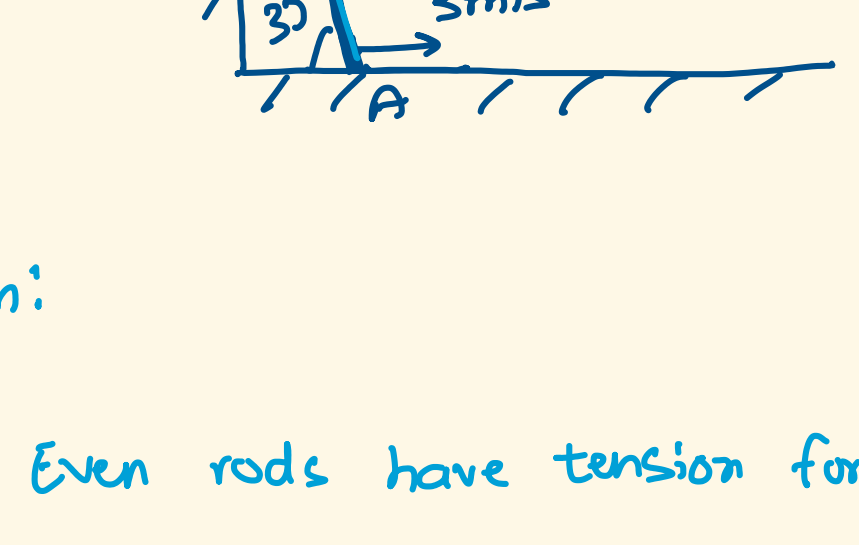


Solution:

$$\Sigma T \cdot v = 0$$

$$T \cdot v_A \cos(180^\circ) + (7T)(v_B)\cos 0^\circ = 0$$
$$-14 + 7v_B = 0$$
$$\boxed{v_B = 2 \text{ m/s}}$$

10. Problem 10:

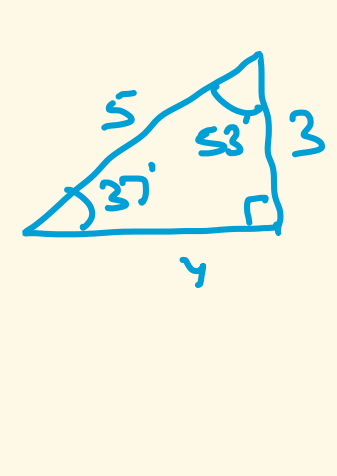


Solution:

Note: Even rods have tension force.

$$\Sigma T \cdot v = 0$$
$$Tv_A\cos(180^\circ - 37^\circ) + Tv_B \cos 53^\circ = 0$$

$$3(-\cos 37^\circ) + v_B\cos 53^\circ = 0$$
$$-3\left(\frac{4}{5}\right) + v_B\left(\frac{3}{5}\right) = 0$$



$$\boxed{v_B = 4 \text{ m/s}}$$

11. References:

1. Physics Wallah - Alakh Pandey

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