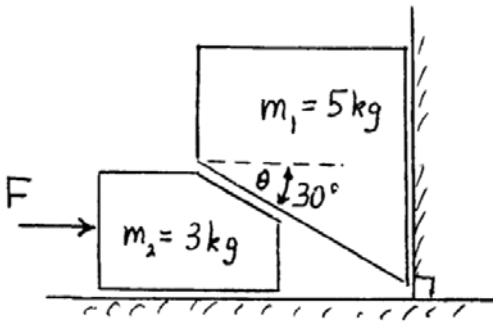
ECE 105 Quiz 2B

Individual (10 marks): A constant horizontal force F is applied to a block of mass m_2 = 3kg, which is in contact with another block of mass m_1 = 5 kg. As block m_2 moves horizontally to the right with a_2 = 0.5 m/s^2. Block m_1 moves vertically up. If all contact surfaces are frictionless, find the magnitude of the force F.



Solution approach:

1. Prepare Free Body Diagrams (FBD) for the 2 objects individually, labeling all forces and accelerations and chose an XY coordinate system for each object.
2. Apply Newton's second law to the forces in X and Y direction separately.
3. Consider the geometric relationship between the acceleration of object m_1, object m_2 and the angle θ shown in the figure.

$\Sigma F_x = m_2 a_2$

$F - N_1 \sin\theta = m_2 a_2$ (1)

$\Sigma F_y = m_1 a_1$

$N_1 \cos\theta - m_1 g = m_1 a_1$ (2)

From geometry; time taken m_2 travels Δx = time taken m_1 travels Δy => $\tan\theta = \frac{\Delta y}{\Delta x} = \frac{a_1}{a_2}$ (3)

Divide (1) by (2)

$$\Rightarrow \frac{N_1 \sin\theta}{N_2 \cos\theta} = \tan\theta = \frac{F - m_2 a_2}{m_1 a_1 + m_1 g} \quad (4)$$

From (3) $\rightarrow a_1 = a_2 \tan(\theta)$ (5) $\rightarrow$ sub (5) in (4)

$$\Rightarrow F = m_2 a_2 + m_1 \tan\theta \left[g + a_2 \tan\theta \right]$$

$F = 3kg \times 0.5 m/s^2 + 5kg \times \tan(30°) \left[9.8 m/s^2 + 0.5 m/s^2 \times \tan \right]$

$F = 1.5 + 2.9 \times [9.8 + 0.29] = 30.8 N$

$\boxed{F = 30.8 N}$

Group work:

6. As the 2 objects are moving, how many normal forces are acting on object m_1?
    a. None – Normal forces do not act on frictionless surfaces.
    b. 3 - one from the floor, one from the wall and one from the contact surface with m_2;
    c. 1 – from the wall;
    d. 2 – one from the wall and one from the contact surface with m_2; **X**

7. What is the direction of the normal force exerted by object m_1 on object m_2?
    a. Parallel to the ground;
    b. Perpendicular to the ground;
    c. Pointing downward and Inclined at angle θ with respect to the vertical axis (perpendicular to ground); **X**
    d. Pointing upward and Inclined at angle θ with respect to the vertical axis (perpendicular to ground);

8. What is the magnitude of the normal force exerted by m_1 on m_2?
    a. $(F - m_2a_2) / \cos(\theta)$
    b. $(F - m_2a_2) / \sin(\theta)$ **X**
    c. $\frac{1}{2} m_1g$
    d. m_1g

9. Is the displacement Δy of m_1 related to the displacement Δx of m_2 and how?
    a. $\Delta y = \Delta x \tan(\theta)$ **X**
    b. $\Delta x = \Delta y \tan(\theta)$
    c. $\Delta x = \Delta y$
    d. They are not related – the objects move independently of each other.

10. Is the acceleration a_1 related to the acceleration a_2 and how?
    a. $a_1 = a_2$
    b. $a_1 = 2a_2$
    c. $a_1 = a_2 \tan(\theta)$ **X**
    d. $a_2 = a_1 \tan(\theta)$