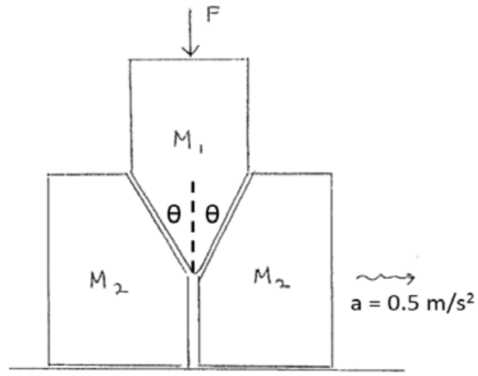
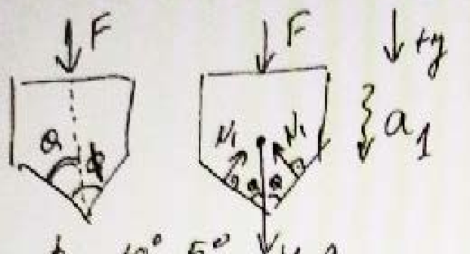
ECE 105 Quiz 2A

Individual (10 marks): Two identical heavy blocks (M_2 = 1500 kg) are resting on a frictionless flat surface (see figure). A wedge (θ = 5º, see figure) is used to separate the 2 blocks. If the wedge has a mass M_1 = 5 kg, and a constant downward force F is applied at the top of the wedge (see figure), what should the magnitude of that force be in order for the 2 large blocks to move away from their original positions with acceleration a = 0.5 m/s^2. There is no friction at the contact surfaces between the 3 blocks.

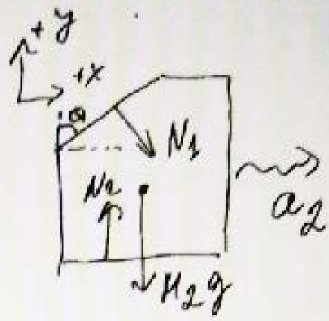


Solution approach:

1. Prepare Free Body Diagram diagrams (FBD) for the 3 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 the wedge (M_1), each of the blocks (M_2) and the angle θ of the wedge.



$\theta = \frac{\phi}{2} = \frac{10^\circ}{2} = 5^\circ$



$\Sigma F_y = M_1 a_1$

$M_1 g + F - 2N_1 \sin\theta = M_1 a_1$ (1)

$\Sigma F_x = M_2 a_2$

$N_1 \cos\theta = M_2 a_2$ (2)

$N_1 = \frac{M_2 a_2}{\cos\theta}$ (3)

Substitute (3) in (1) =>

$F = M_1 a_1 + 2 M_2 a_2 \frac{\sin\theta}{\cos\theta} - M_1 g$ (4)

As M_1 moves down a distance Δy, M_2 moves to the right a distance Δx, where $\tan\theta = \frac{\Delta x}{\Delta y}$ => $\tan\theta = \frac{a_2}{a_1}$ (5)

Substitute (5) in (4) =>

~~[illegible]~~

$F = \frac{M_1 a_2}{\tan\theta} + 2M_2 a_2 \tan\theta - M_1 g = \frac{5 \times 0.5}{0.09} + 1500 \times 2 \times 0.5 \times 0.09 - 5 \times 9.8$

$F \simeq 111$ N

Group work:

6. As the 3 objects are moving, how many normal forces are acting on one of the objects of mass M_2?
   a. None – Normal forces do not act on frictionless surfaces.
   b. 2 – one from the floor and one from the contact surface with M_1; **X**
   c. 1 – from the floor;
   d. 3 - one from the floor, one from the contact surface with M_1 and one from the contact surface with the other object M_2;

7. What is the direction of the normal force exerted by object M_1 on one of objects M_2?
   a. Parallel to the ground;
   b. Perpendicular to the ground;
   c. Inclined at angle θ with respect to the horizontal axis (parallel to ground) **X**
   d. 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. $\frac{1}{2} M_1 g$
   b. $\frac{1}{2} M_1 g / \cos(\theta)$
   c. $M_1 a_1 / \cos(\theta)$
   d. $M_2 a_2 / \cos(\theta)$ **X**

9. Is the displacement Δy of M_1 related to the displacement Δx of M_2 and how?
   a. $\Delta x = \Delta y \tan(\theta)$ **X**
   b. $\Delta y = \Delta x \tan(\theta)$
   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. $a_2 = a_1 \tan(\theta)$ **X**
    b. $a_1 = a_2 \tan(\theta)$
    c. $a_2 = 2a_1 \tan(\theta)$
    d. $a_2 = \frac{1}{2} a_1 \tan(\theta$