Chapter 4:Dynamics: Newton's Laws of Motion

Lecture 3

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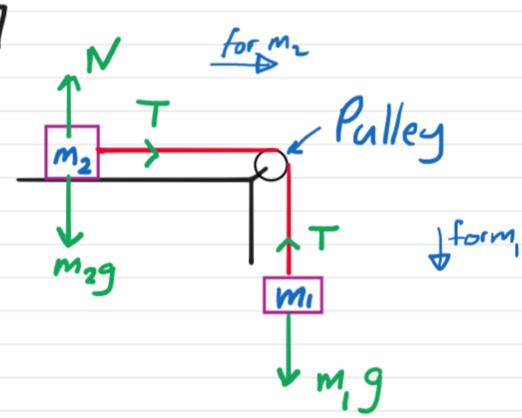
Solving problems using Newton's Laws

<u>Example</u> In the figure, find the acceleration of the system and the tension in the strings. [Ignore the masses of the string and pulley]

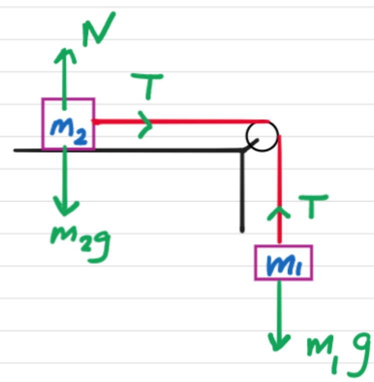


- Draw a free-body diagram for each mass.
- Apply Newton's second law to each mass separately.

The system can only move such that m_1 moves down and m_2 moves to the right.

For m_1:

m_1 moves downwards $\Rightarrow$ take downward direction as positive.

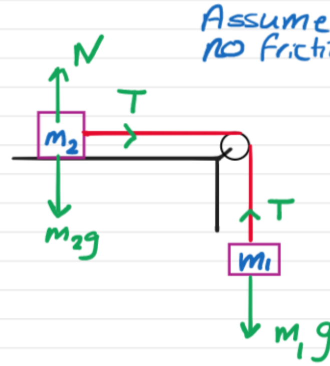


$$\overset{\downarrow}{+} \quad \underbrace{m_1 g - T}_{\Sigma F_y \text{ (net force on } m_1)} = m_1 a \quad -① $$

For m_2: it moves to the right $\Rightarrow$

$$\rightarrow + \quad \underbrace{T}_{\Sigma F_x \text{ on mass } m_2} = m_2 a \quad -②$$

Assume no friction.



① + ② $\Rightarrow$ $m_1 g = (m_1 + m_2) a$

$$\therefore \quad a = \left(\frac{m_1}{m_1 + m_2}\right) g$$

NOTE: $a < g$ is m_1 is NOT in free fall as it has the tension T acting on it.

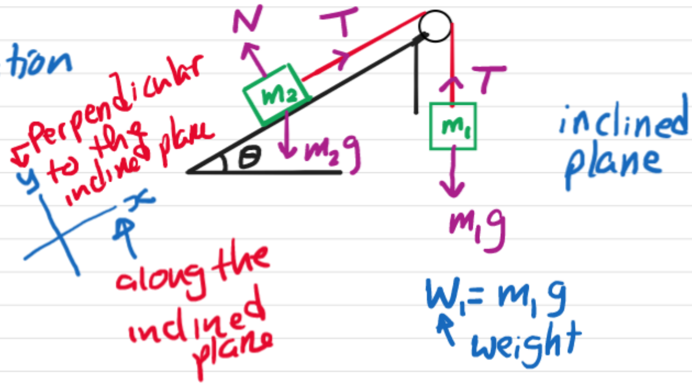
For m_2: $\overset{+}{\uparrow}$ $\Sigma F_y = m$(acceleration) $\overset{\text{0 no motion along}}{\downarrow\, y}$

$N - m_2 g = 0$

$N = m_2 g$.

Using ② $\quad T = m_2 a = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g$

Example: Find the acceleration of the system and the tension in the string.

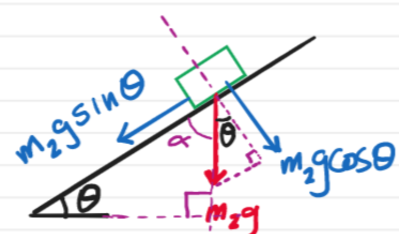


Need to draw a free-body diagram for each mass.

For m_2 we need to resolve the weight $W_2 = m_2 g$ into two components:

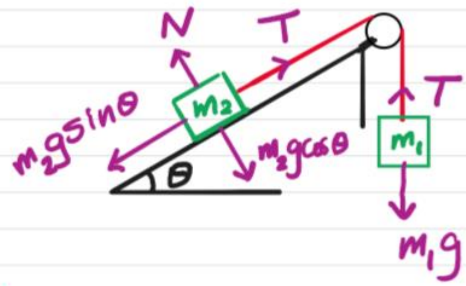
along the inclined plane
perpendicular to the inclined plane.

How to resolve $W_2 = m_2 g$ into two components.



$$\left.\begin{array}{l}\theta + \alpha = 90^\circ \\ x + \alpha = 90^\circ\end{array}\right\} \Rightarrow x = \theta$$

The direction of motion of the system depends on the values of m_1, m_2 and θ.

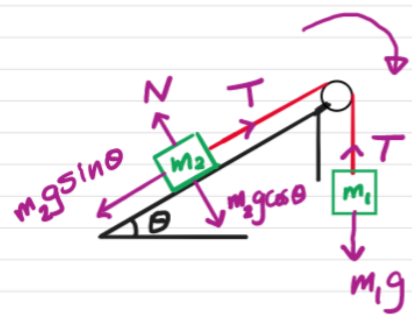


\# Guess a direction of motion.

\# Draw a free-body diagram for each mass.

\# Apply Newton's second law to each mass.

Suppose m_2 moves up the incline while m_1 moves down [You can assume the opposite].



For m_1: $\downarrow +$

$$\underbrace{m_1 g - T}_{\text{net force acting on } m_1} = m_1 a \quad — ①$$

For m_2: $\nearrow +$

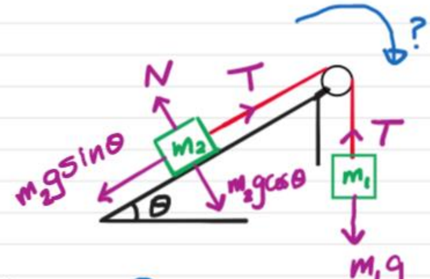
$$T - m_2 g \sin\theta = m_2 a \quad — ②$$

$$① + ② \Rightarrow \quad m_1 g - m_2 g \sin\theta = (m_1 + m_2) a$$

$$\therefore \quad a = \left(\frac{m_1 - m_2 \sin\theta}{m_1 + m_2}\right) g$$

If $m_1 - m_2 \sin\theta > 0$

$\Rightarrow a > 0$ and our guessed direction is correct.



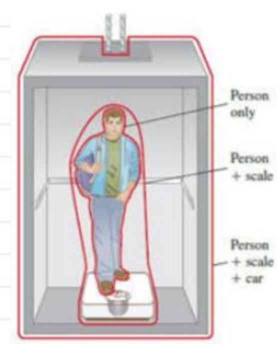
If $m_1 - m_2 \sin\theta < 0 \Rightarrow a<0 \Rightarrow$ system moves in the opposite direction, which means m_1 moves up while m_2 moves down the inclined plane. Note the magnitude of the acceleration $|a|$ is correct and the sign is for direction only.

Suppose
$m_1 = 3\,kg$, $m_2 = 4\,kg$
$\theta = 30^\circ$.

$m_2 \sin 30^\circ = 4 \times \frac{1}{2}$
$= 2$

Apparant Weight (الوزن الظاهري)

The figure shows a boy of mass m in an elevator that is accelerating upwards at $3\ m/s^2$. Find the normal force acting on the boy. Assume $m = 40\ kg$.



Draw a free-body diagram.

N is the force exerted on the boy by the floor of the elevator.
(or by the balance if he is standing on a balance)

Take direction of motion (↑) to be positive.

$\overset{+}{\uparrow}$: $N - mg = ma$.

$N = m(g+a) = 40(10+3) = 520$ Newtons.

greater than the true weight of 400 Newtons.

Note $N > W$

called apparant weight.

If the boy was standing on a scale placed on the floor of the elevator ⇒ N is the reading of the scale.

Now consider the same system, but the elevator is moving down and accelerating at 3 m/s².

elevator is moving down ⇒ $\overset{\downarrow}{+}$

$\therefore$ $mg - N = ma$

$N = m(g-a) = 40(10-3) = 280$ Newtons.

$N < mg$.

less than the true weight.

Conider the case where the elevator is moving down and decelerating at 3 m/s². Find N.

$\downarrow +$: $mg - N = ma$

$N = m(g-a)$ since decelerating

$= 40(10 - (-3))$

$= 40(13) = 520$ Newtons.

$N >$ Weight

<u>Question</u> When does the scale read the true weight?

Answer: When $a=0$ i.e when the elevator moves at constant velocity or when it is at rest.

We can apply the same analysis to a fish hung by a spring balance. The apparant weight equals the reading of the balance which equals the tension in the spring.