

Chapter 4:Dynamics: Newton's Laws of Motion

Lecture 3

(First Sem 20/21)

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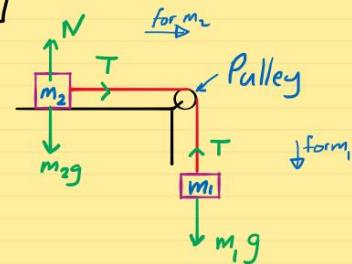
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Solving problems using Newton's Laws

Example 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.

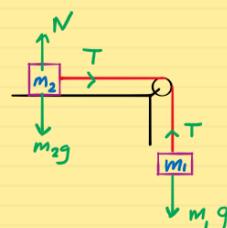


The system can only move such that m_1 moves down and m_2 moves to the right.

For m_1 :

m_1 moves downwards \Rightarrow take downward direction as positive.

$$\nabla \sum F_y \text{ (net force on } m_1) = m_1 a \quad -\textcircled{1}$$

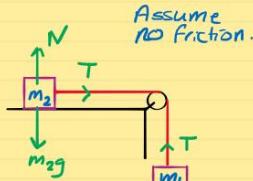


For m_2 : it moves to the right \Rightarrow

$$\rightarrow + \sum F_x \text{ on mass } m_2 = m_2 a \quad \text{--- ②}$$

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

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

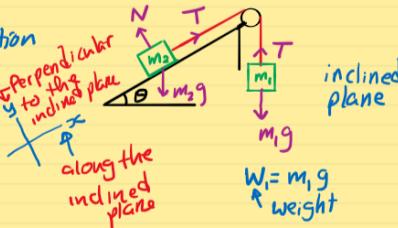


NOTE: $a < g$ is m_1 is NOT in free fall as it has the tension T acting on it.

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

for m_2 :
 $\uparrow \sum F_y = m \text{ (acceleration)}$
 $N - m_2 g = 0$
 $N = m_2 g$

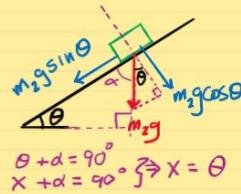
Example: Find the acceleration of the system and the tension in the string.



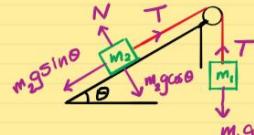
Need to draw a free-body diagram for each mass.

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.

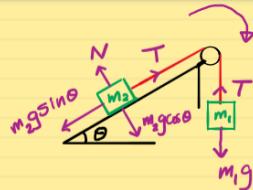


The direction of motion of the system depends on the values of m_1 , m_2 and θ .



- # 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].



$$\text{For } m_1: \downarrow \text{ net force acting on } m_1 \\ m_1 g - T = m_1 a \quad \text{--- (1)}$$

For m_2 : $\nearrow +$

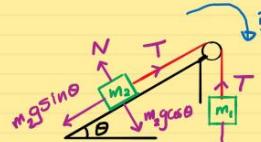
$$T - m_2 g \sin \theta = m_2 a \quad \text{--- (2)}$$

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

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

If $m_1 - m_2 \sin\theta > 0$
 $\Rightarrow a > 0$ and our guessed direction is correct.

If $m_1 - m_2 \sin\theta < 0 \Rightarrow a < 0$
 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
 $m_1 = 3\text{kg}$, $m_2 = 4\text{kg}$
 $\theta = 30^\circ$
 $m_2 \sin 30^\circ = 4 \times \frac{1}{2} = 2$

Apparent 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 $m=40\text{ kg}$.



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 (\uparrow) to be positive.



$$\uparrow : N - mg = ma \quad \text{greater than the true weight of 400 Newtons.}$$

$$N = m(g+a) = 40(10+3) = 520 \text{ Newtons.}$$

Note $N > W$
 \uparrow called apparent weight.

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

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

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

elevator is moving down $\Rightarrow \downarrow$

$$\therefore mg - N = ma$$

$$N = m(g-a) = 40(10-3) = 280 \text{ Newtons.}$$

$$\underline{N < mg} \quad \text{less than the true weight.}$$



Consider the case where the elevator is moving down and decelerating at 3 m/s².

Find N .

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

$$N = m(g-a) \quad \text{since decelerating}$$

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

$$= 40(13) = 520 \text{ Newtons.}$$

$N > W$ weight



Question 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 apparent weight equals the reading of the balance which equals the tension in the spring.

