CUBE NOTES
Class 11/12 | AP Physics | IIT JEE | NEET

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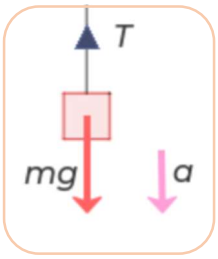
Free body diagrams

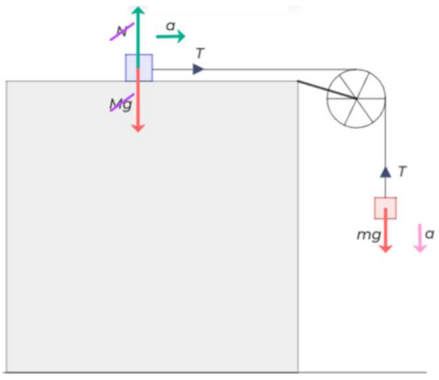
A Free Body Diagram is a graphical representation used primarily to visualize the forces acting on a single object. It simplifies the analysis of an object's motion by isolating it and representing all the external forces acting upon it.

Key Components of a Free Body Diagram:



- *Isolated Object:* The object of interest is typically represented as a dot or a simple geometric shape (like a rectangle or circle)
- *Force Vectors:* Arrows are drawn to represent the forces. The direction of each arrow indicates the direction of the force, while its length can represent the magnitude of the force.
- *Labels:* Each force vector is labelled to identify its type (e.g., gravitational force, tension, normal force).

Steps to Draw a Free Body Diagram:



- *Isolate the Object:* Remove the object from its environment
- *Identify All External Forces:* Determine all the forces acting on the object.
- *Draw the Object:* Represent the object as a simple shape or point.
- *Draw Force Vectors:* Represent each force with an arrow, pointing in the direction the force acts.
- *Label Each Force:* Clearly label each force (e.g., F_{gravity}, T or tension)

Common Forces in Free Body Diagrams:

- *Weight* (Gravitational Force): This force acts vertically downward and is due to the Earth's gravity. It's given by $F_{\text{gravity}} = mg$, where m is the object's mass and g is the acceleration due to gravity. This force acts on all objects with mass, regardless of whether they are in contact with another object or in free fall.
- *Normal Force:* This is the perpendicular force exerted by a surface that supports an object against gravity
- *Tension:* This force is exerted by strings or ropes when they're stretched. Always acts away from the object and along the direction of the string or rope.
- *Friction:* This acts parallel to surfaces in contact and opposes the motion or potential motion of an object.
- *Applied Forces:* These are forces applied to the object by an external source.

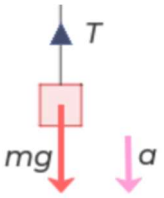
Applying the Ideas in a Problem

Problem Setup:

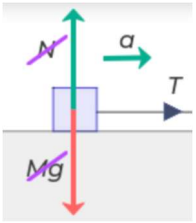
- We have two blocks:
  - A sliding block of mass M = 3.3 kg on a frictionless table.
  - A hanging block of mass m = 2.1 kg.
- Assumptions:
  - Pulley and cord are frictionless and massless.
  - Cord is un-stretchable.
- Questions:
  - Acceleration of the sliding block?
  - Acceleration of the hanging block?
  - Tension in the cord?

Solving the Problem:

- Step 1: Label All Forces: Only consider external forces.
  - For the hanging block ($mass\ m$):
    - Gravitational force: $mg(downward)$.
    - Tension in the string: $T(upward)$.
    - Acceleration: a downward (this is not a force therefore marked away from the body)



  - For the sliding block ($mass\ M$):
    - Tension in the cord: $T(totheright)$.
    - Gravitational force: $Mg(downward)$.
    - Normal force from the table: $N(upward)$.
    - Acceleration: a to the right



- Step 2: Apply Newton's Second Law ($F = ma$)
  - Sign notation:
    - Downward & left: negative (-)
    - Upward & right: positive (+)
      1. For mass m: T - mg = -ma
      2. For mass M: T = Ma

- Step 3: Solve the Equations

From the above equations, we derive:

$$a = \frac{mg}{M+m} \quad (1)$$

$$T = \frac{Mmg}{M+m} \quad (2)$$

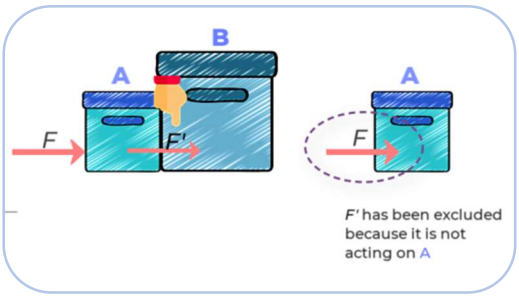
Plugging in the given values:

$$a = 3.8 m/s^2$$

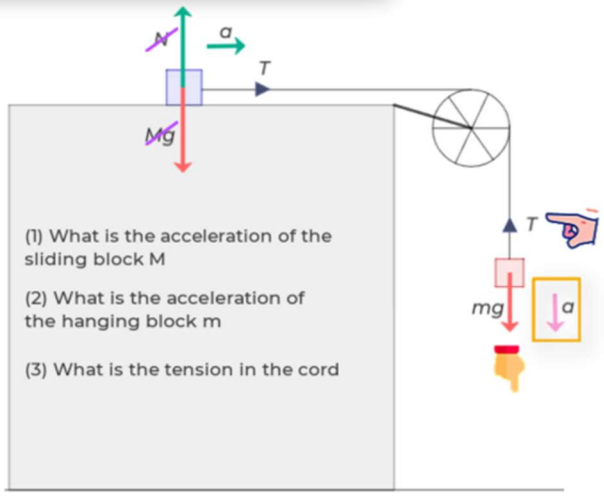
$$T = 13\ N$$

Common Mistakes 🔍

- In FBDs, it's crucial to include only external forces. Internal forces, like intermolecular forces, aren't considered because they don't affect the object's external motion.
- Incorrectly marking forces, the mass is impressing on other masses.
- Mixing up the direction of forces and accelerations.
- Not considering tension as a pulling force



Free Body Diagrams



(1) What is the acceleration of the sliding block M

(2) What is the acceleration of the hanging block m

(3) What is the tension in the cord

M = 3.3 Kg m = 2.1 Kg

$F_{net} = ma$ *(Newton's 2nd Law)*

$T - mg = m(-a)$ (1)

$T = Ma$ (2)

$mg = a(M+m)$

$a = \frac{m}{(M+m)} g = 3.8\ m/s^2$

$T = M \frac{mg}{(M+m)} = 13\ N$

STEP 3: Solve the Equations
STEP 2: Apply Newton's 2nd Law
STEP 1: Label all the Forces