# Force And Motion I

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# First Law

- Newton's First Law
  - A body at rest remains at rest --
  - A body in uniform linear motion (constant velocity) continues to move with the same velocity (ie, same magnitude and direction on that straight line) --
  - UNLESS ACTED UPON BY A FORCE
- Newton's Laws do NOT hold good for all frames
  - need a reference frame does NOT accelerate (also called the inertial reference frame)
- First Law defines Inertia of an object
- If the body is at rest OR in uniform linear motion
  - then the net (vector sum) of all the forces acting on the body is ZERO

# Second Law

- Newton's Second Law
  - If a net (non-zero) force acts on a body, it accelerates in the direction of the net force. Acceleration of the object is proportional to the net force
  - If the object has a mass m and acceleration a, the net force is given by

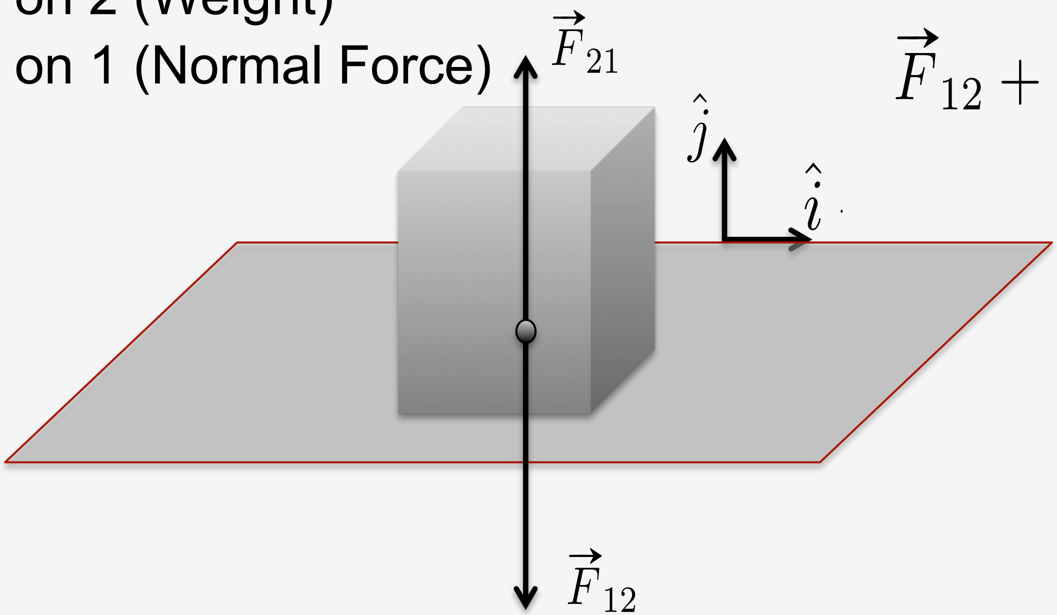
$$\vec{F}_1 + \vec{F}_2 + \cdots + \vec{F}_N = \sum_{i=1}^{i=N} \vec{F}_i = \vec{F}_{net} = m\vec{a}$$

- If the acceleration is zero, then
  - The net force is zero
  - If there are say 5 forces, each may (or not) be zero, but their vector sum is zero
  - The body could be at rest OR the body could be in a uniform linear motion
  - F1, F2, F3 … FN are a SYSTEM of forces on that body

# Third Law

- Defines "contact" force or the force of "interaction"
  - The forces of interaction between two bodies are equal in magnitude and opposite in direction.
  - Force of Action + Force of Reaction = 0
  - The two forces form an "action/reaction pair"
  - 1 = Bottom Surface of the box
  - 2 = Top surface of a table (for example)
  - $F_{12}$ = Force of 1 on 2 (Weight)
  - $F_{21}$ = Force of 2 on 1 (Normal Force)

$$\vec{F}_{12} + \vec{F}_{21} = 0$$

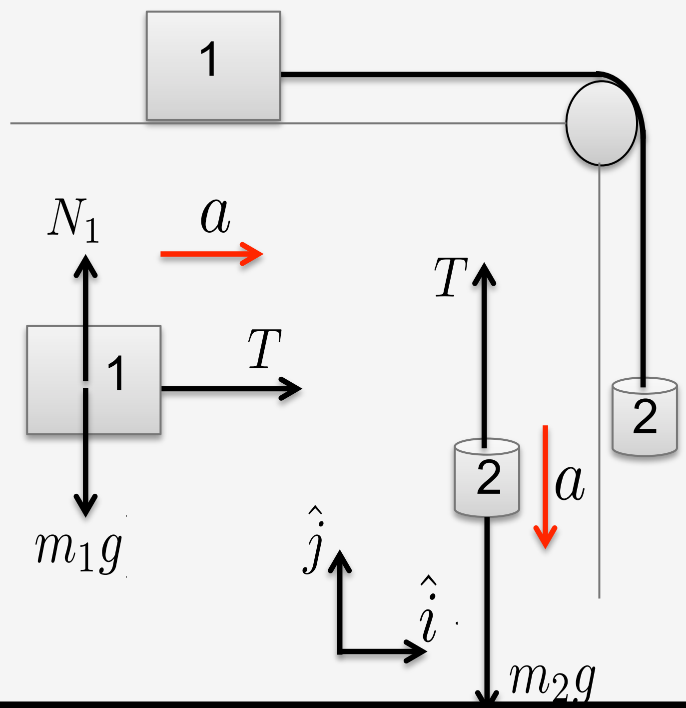


# Some Forces

- Force
  - due to Earth's gravitational pull – weight
  - due to surfaces in contact – normal force
  - due to relative motion between surfaces of contact – friction
  - due to rope/string holding (in suspension) a heavy object – tension
- Setting up and solving problems
  - Identify all objects in the system
  - Setup a reference frame
  - Identify forces acting on each object using a Free Body Diagram (FBD)
    - remove/isolate the object from the system
    - indicate forces acting ON the object due to all other objects
  - Apply Newton's Laws (usually 2$^{nd}$ and 3$^{rd}$ laws)
  - Solve for the unknown (forces, acceleration, mass etc)

# Example 1

- Assume
  - Friction between contact surfaces can be ignored, rope is massless and does not slip on the pulley, pulley's mass is negligible compared to 1 and 2 and 2 is falling (moving downward) with an acceleration




$$T\,\hat{i} + (N_1 - m_1 g)\,\hat{j} = m_1 a\,\hat{i}$$

$$(T - m_2 g)\,\hat{j} = -m_2 a\,\hat{j}$$

$$T = m_1 a\ , \quad (N_1 - m_1 g) = 0\ , \quad (T - m_2 g) = -m_2 a$$

$$\Rightarrow \boxed{a = \frac{m_2 g}{(m_1 + m_2)} \quad T = \frac{m_1 m_2 g}{(m_1 + m_2)}}$$