Exam next Tuesday evening

Today: Newton's Laws and Forces (Ch. 5-6)

Force - an interaction
It's a vector quantity

Newton's Laws:
1st Law: Every object continues to move at a constant velocity if no force acts on it.
2nd Law:
The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

\[ \vec{a} = \frac{\vec{F}_{\text{net}}}{m} \]

OR \[ \vec{F}_{\text{net}} = m \vec{a} \]

Mass is a resistance to change \( \sim \) inertia

\[ \sum \vec{F} = \vec{F}_{\text{net}} \]

\[ F_{\text{net},x} = \sum F_x \quad \text{and} \quad \sum F_{\text{net},y} = \sum F_y \]

\[ F_{\text{net},x} = ma_x, \quad F_{\text{net},y} = ma_y \]

\[ \begin{bmatrix} F \end{bmatrix} = \begin{bmatrix} m \end{bmatrix} \begin{bmatrix} a \end{bmatrix} = \text{kg} \cdot \frac{m}{s^2} \equiv \text{N}\]

Units: "Newton"
Example:
An object (top view) has the following forces acting on it. What is its acceleration?

\[ m = 250 \text{ kg} \]

\[
\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3
\]

\[
F_{\text{net},x} = F_{1x} + F_{2x} + F_{3x} = -300 \text{ N} + 0 + 500 \text{ N} = 200 \text{ N}
\]

\[
F_{\text{net},y} = F_{1y} + F_{2y} + F_{3y} = 0 + 300 \text{ N} + 0 = 300 \text{ N}
\]

\[
a_x = \frac{F_{\text{net},x}}{m} = \frac{200 \text{ N}}{250 \text{ kg}} = 0.8 \text{ m/s}^2
\]

\[
a_y = \frac{F_{\text{net},y}}{m} = \frac{300 \text{ N}}{250 \text{ kg}} = 1.2 \text{ m/s}^2
\]

\[
a = \sqrt{a_x^2 + a_y^2} = 1.44 \text{ m/s}^2
\]

\[
\vec{a} = \frac{a_y}{a_x} = \frac{1.2}{0.8} \approx 1.5 \text{ above the horizontal}
\]

\[ \tan^{-1} \left( \frac{a_y}{a_x} \right) = 56^\circ \text{ above the horizontal} \]
The object is at rest. Find $F_3$.

$\sum F_x = m a_x = 0 \quad a_x = a_y = 0$

$\sum F_y = m a_y = 0$

$\sum F_x = F_{1x} + F_{2x} + F_{3x} = 0$ (mag.)

$F_{3x} = F_1 \cos \theta_1 + F_2 \sin \theta_2 - F_3 \cos \theta_3 = 0$

$F_3 \cos \theta_3 = F_1 \cos \theta_1 + F_2 \sin \theta_2$

$F_3 = \frac{F_1 \cos \theta_1 + F_2 \sin \theta_2}{\cos \theta_3}$

$\sum F_y = F_{1y} + F_{2y} + F_{3y} = 0$ (mag.)

$F_{1y} + F_{2y} \cos \theta_2 - F_3 \sin \theta_3 = 0$

$F_3 = \frac{F_1 \sin \theta_1 + F_2 \cos \theta_2}{\sin \theta_3}$
Types of Forces

Fundamental Forces
1. Gravitational Force \( \vec{F}_g = \vec{W} = m\vec{g} \)
2. Weak Nuclear Force ("Electroweak")
3. Electromagnetic Force
4. Strong Nuclear Force

- Normal force \( \vec{N} \)
- Tension \( \vec{T} \)
- Friction force (Kinetic vs. Static)
The mass on Earth is shown in a horizontal surface. The gravitational force \( \vec{F}_g = \vec{W} = Mg \) is downward.

The net force in the y-direction is \( F_{\text{net},y} = ma_y = 0 \).

The net force in the x-direction is \( \sum F_x = N - F_g \cos \theta = 0 \) with normal force \( N \) and gravitational force \( F_g \) at an angle \( \theta \).

The normal force is always "normal" or perpendicular to the surface.

The normal force in the y-direction is \( N - F_{g,y} = 0 \) implies \( N = F_{g,y} = Mg \cos \theta \).
Tension:  (from past exam)

\[ T_2 \quad T_1 \]

\[ \theta \]

\[ M \]

\[ Mg \]

\[ \vec{T}_2 \]

\[ \vec{T}_1 \]

\[ \vec{mg} \]

"free-body diagram"

\[ \vec{a}_{net} = 0 \quad a_x = 0, \quad a_y = 0 \]

\[ \Sigma F_x = m a_x = 0 \quad \text{and} \quad \Sigma F_y = m a_y = 0 \]

\[ \Sigma F_x = T_1 \cos \theta - T_2 = 0 \]

\[ \Sigma F_y = T_1 \sin \theta - mg = 0 \]

\[ T_1 = \frac{mg}{\sin \theta} \]

Plug back into x-comp eq:

\[ \left( \frac{mg}{\sin \theta} \right) \cos \theta - T_2 = 0 \]

\[ \Rightarrow T_2 = \frac{mg \cot \theta}{\sin \theta} \]