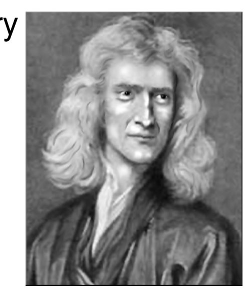
Phy 211: General Physics I

Chapter 5: Force & Motion I
Lecture Notes

Sir Isaac Newton (1642-1727)

- Greatest scientific mind of the late 17th century
- Invented the "calculus" (independently but simultaneously with Gottfried Wilhelm Leibnitz)
- Among his accomplishments included:
  - A Particle Theory Light & Optics
  - A Theory of Heat & Cooling
- Established 3 Laws of Motion
- Proposed the Law of Universal Gravitation (to settle a parlor bet)
  - The bet was actually between Edward Haley & Robert Hooke
  - This theory successfully explained planetary motion and elliptical orbits



"If I have seen further it is by standing on the shoulders of giants."

Newton's 1st Law

Every object continues in its state of rest, or of motion unless compelled to change that state by forces impressed upon it.

- Also known as the "Law of Inertia"
- Key Points:
  - When an object is moving in uniform motion it has no net force acting on it
  - When there is no force acting on an object, it will stay at rest or maintain its constant speed in a straight line

$$\vec{F}_{net}=0 \Rightarrow \vec{a} = 0 \; \{\vec{v} = \text{constant}\}$$

  - Or simply put,

Nature is lazy!

Newton's 2nd Law

- When a net force is exerted on an object its velocity will change: $\vec{F}_{net}=\sum_i \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots \propto \frac{d\vec{v}}{dt}$
- The time rate of change of motion (acceleration) is related to:
  - Proportional to the size of the net force
  - Inversely proportional to the mass of the object (i.e. its inertia)
- The relationship between them is

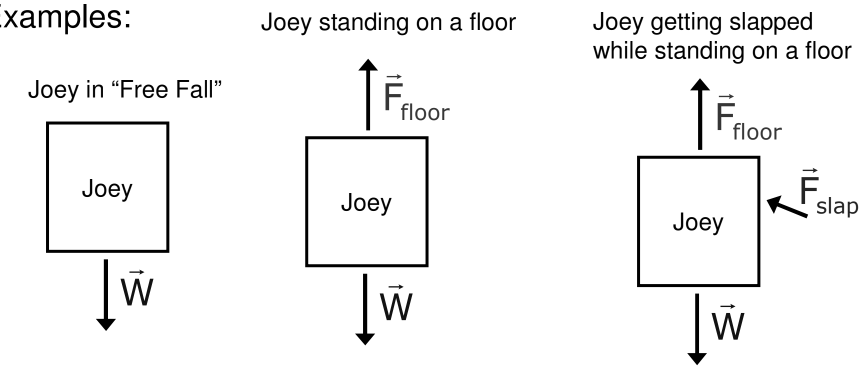
$$\vec{a}=\frac{\vec{F}_{net}}{m}=\frac{1}{m}\left(\vec{F}_{net_x}\hat{i} + \vec{F}_{net_y}\hat{j}\right) \quad \underline{\text{or}} \quad \vec{F}_{net}=m\vec{a}=m\left(a_x\hat{i} + a_y\hat{j}\right)$$

- The direction of $\vec{a}$ will always correspond to the direction of $\vec{F}_{net}$

Free-Body Diagrams

- Simplified drawing of a body with only the forces acting on it specified
- The forces are drawn as vectors
- Free-Body diagrams facilitate the application of Newton's 2nd Law

Examples:



Types of Forces

In our world, forces can be categorized as one of 2 types:

•**Non-Contact:** force is exerted over a distance of space with out direct contact *(a.k.a. "action-at-a-distance" forces)*

•**Contact:** forces is exerted due to direct contact

(Note: at the microscopic level, ALL forces are non-contact)

•In either case, Newton's 3rd law still applies to the forces present

Examples of each type of force:

Non-Contact:
- Gravitational
- Electric
- Magnetic

Contact:
- Normal
- Frictional
- Tension

Weight

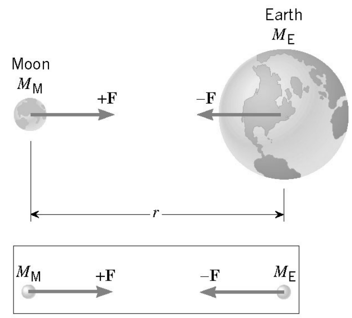
- The "weight" of an object is the gravitational force exerted on it by the gravitational attraction between the object and its environment:

$$\vec{F}_G = m\vec{a}_G = ma_G\hat{j}$$

- On the surface of the Earth, the gravitational force is referred to as weight:

$$\vec{F}_G = \vec{W} = (-mg)\hat{j}$$

- Mass is a measure of an object's inertia (measured in kg)
  - Independent of object location
- Weight is the <u>effect</u> of gravity <u>on</u> an object's mass (measured in N)
  - Determined by the local gravitational acceleration surrounding the object



Notes:

- Mass is a measure of an object's inertia (measured in kg)
  - Independent of object location
- Weight is the <u>effect</u> of gravity <u>on</u> an object's mass (measured in N)
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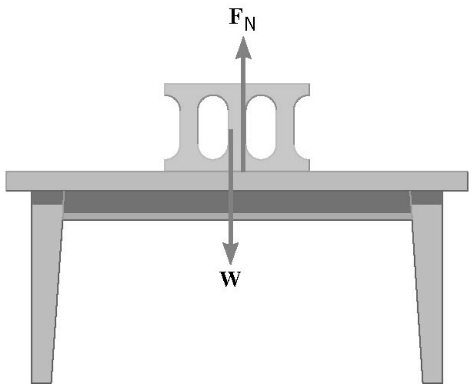
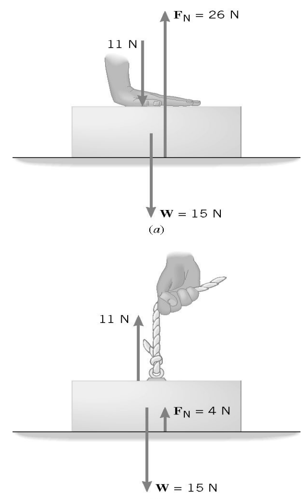
Normal Force

- The "support" force between 2 surfaces in contact
- Direction is always perpendicular (or normal) to the plane of the area of contact
- Example: the force of floor that supports your weight
- Consider standing on a scale on the floor of an elevator. The reading of the scale is equal to the normal force it exerts on you:
- Construct free body diagrams for the scale:
  - At rest
  - Constant velocity
  - Accelerating upward
  - Accelerating downward

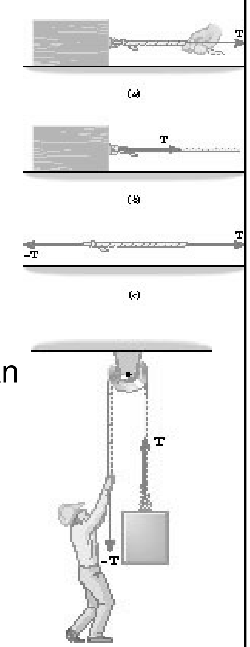
Examples of Normal Force





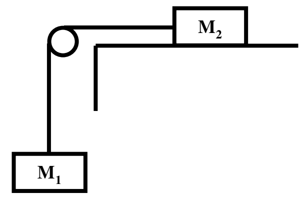
Tension Force

- Force applied through a rope or cable
- When the rope or cable is massless (negligible compared to the bodies it is attached to) it can be treated as a connection between 2 bodies
  - No mass means no force needed to accelerate rope
  - Force of pull transfers unchanged along the rope
  - Action force at one end is the same as the Reaction force at the other end
- When attached to a pulley the tension force can be used to change the direction of force acting on a body
- Calculation of a tension force is usually an intermediate step to connecting the free-body diagrams between 2 attached objects

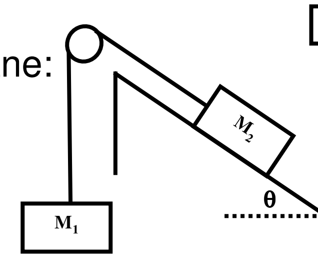


Tension Applications

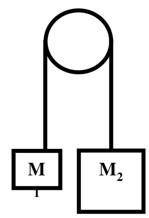
- With Pulley (flat surface):



- Inclined Plane:

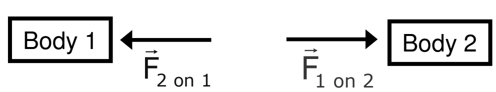


- Atwood Machine:



Newton's 3rd Law

When an object exerts a force on a second object, the second object exerts an equal but oppositely directed force on the first object



where: $\left|\vec{F}_{2\text{ on }1}\right| = \left|\vec{F}_{1\text{ on }2}\right|$

Consequences:

- Forces always occur in action-reaction pairs (never by themselves)
- Each force in an action-reaction pair acts on a <u>different</u> object

<u>Important:</u>

- Newton's 3rd law identifies the forces produced by interactions between bodies
- Newton's 2nd law defines the accelerations that each object undergoes