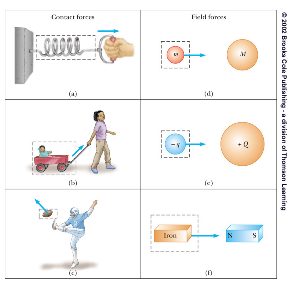
Vectors Lecture-Tutorial

- Work with a partner or two
- Read directions and answer all questions carefully. Take time to understand it now!
- Come to a consensus answer you all agree on before moving on to the next question.
- If you get stuck, ask another group for help.
- If you get really stuck, raise your hand and I will come around.

Forces

- Usually think of a force as a push or pull
- Vector quantity
- May be a **contact force** or a **field force**
  - Contact forces result from physical contact between two objects
  - Field forces act between disconnected objects
- Key idea: Forces act on objects and change their motion.

Contact and Field Forces



Fundamental Forces

- Types
  - Strong nuclear force
  - Electromagnetic force
  - Weak nuclear force
  - Gravity
- Characteristics
  - All field forces
  - Listed in order of decreasing strength
  - Only gravity and electromagnetic in mechanics

External and Internal Forces

- External force
  - Any force that results from the interaction between the object and its environment
- Internal forces
  - Forces that originate within the object itself
  - They cannot change the object's velocity

Inertia vs. Mass

- Inertia is the tendency of an object to continue in its original motion
- Mass is a measure of the resistance of an object to changes in its motion due to a force
  - Scalar quantity
  - SI units are kg

Newton's First Law

- An object moves with a velocity that is constant in magnitude and direction, unless acted on by a nonzero net force
  - The net force is defined as the vector sum of all the external forces exerted on the object

Newton's Second Law

- The acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass.

$$\vec{\mathbf{a}} = \frac{\sum \vec{\mathbf{F}}}{m} \text{ or } \sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

  - F and a are both vectors
- Can also be written in component-form
- Force unit: the newton (1 N = 1 kg m/s^2)

Gravitational Force

- Mutual force of attraction between any two objects
- Expressed by Newton's Law of Universal Gravitation (more later):

$$F_g = G\frac{m_1 m_2}{r^2}$$

Newton's Third Law

- If object 1 and object 2 interact, the force exerted by object 1 on object 2 is equal in magnitude but opposite in direction to the force exerted by object 2 on object 1.
  - $\vec{\mathbf{F}}_{12} = -\vec{\mathbf{F}}_{21}$
  - This is like saying a single isolated force cannot exist in a system

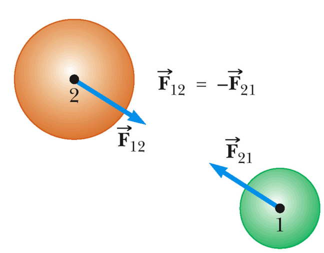
Gravitational Force

- Mutual force of attraction between any two objects
- Expressed by Newton's Law of Universal Gravitation (more later):

$$F_g = G\frac{m_1 m_2}{r^2}$$

Newton's Third Law cont.

- F_{12} may be called the *action* force and F_{21} the *reaction* force
- The action and reaction forces **ALWAYS** act on **DIFFERENT** objects



Weight

- The magnitude of the gravitational force acting on an object of mass *m* near the Earth's surface is called the weight *w* of the object
  - $w = m\,g$ is a special case of Newton's Second Law
  - g is the acceleration due to gravity

More about weight

- Weight is **not** an inherent property of an object
  - mass **is** an inherent property
- Weight depends upon location

Applications of Newton's Laws

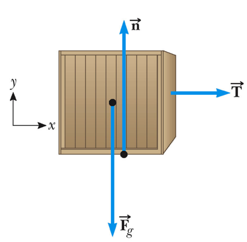
- Assume:
  - Objects behave as particles
    - can ignore rotational motion (for now)
  - Masses of strings or ropes are negligible (i.e., zero)
  - Interested only in the forces acting on the object
    - can neglect reaction forces

Free Body Diagrams

- Must identify all the forces acting on the object of interest
- Choose an appropriate coordinate system
- If the free body diagram is incorrect, the solution will likely be incorrect!

Free Body Diagrams

- The force $\vec{T}$ is the tension acting on the box
  - The tension is the same at all points along the rope
- $\vec{n}$ *and* $\vec{F}_g$ are the forces exerted by the ground and the Earth's gravity



Newton's Laws Lecture-Tutorial Part 1

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Solving Newton's Second Law Problems

- **Read** the problem at least once
- **Draw** a picture of the system
  - Identify the object of primary interest
  - Indicate forces with arrows
- **Label** each force
  - Use labels that bring to mind the physical quantity involved

Solving Newton's Second Law Problems

- **Draw** a free body diagram
  - If additional objects are involved, draw separate free body diagrams for each object
  - Choose a convenient coordinate system for each object
- **Apply Newton's Second Law**
  - The x- and y-components should be taken from the vector equation and written separately
- **Solve** for the unknown(s)

Equilibrium

- An object either at rest or moving with a constant velocity is said to be in *equilibrium*
- The net force acting on the object is zero (since the acceleration is zero)

$$\sum \vec{\mathbf{F}} = 0$$

Equilibrium

- Easier to work with the equation in terms of its components:

$$\sum F_x = 0 \textit{ and } \sum F_y = 0$$

A stoplight is held up by two cords, making a 53-degree and 37-degree angle with the support beam respectively. If the stoplight has a mass of 30 kg, what are the tensions in both cords?

Equilibrium Example – Free Body Diagrams