Newton’s First and Second Laws

- Fundamental Forces
- Newton’s First Law
- Newton’s Second Law
- Homework
Fundamental Forces of Nature

- We will see that Newton’s laws give us an operational definition of force as something that changes the momentum of an object

- Until about 30 years ago, physicists believed there were four fundamental forces in nature
  - Gravitational force
  - Electromagnetic force
  - Strong force
  - Weak force
Gravitational Force

- Acts between all objects that have mass
- Attractive
- Proportional to the product of the masses
- Gets weaker as the distance between the masses increases
- Binding force of the solar system and galaxies
- Given by Newton’s law of universal gravitation

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

where \( G = 6.67 \times 10^{-11} \text{N} \cdot \text{m}^2/\text{kg}^2 \)

![Diagram of gravitational force between two masses](image-url)
Electromagnetic Force

- Acts between all objects that have electric charge
- Can be either attractive or repulsive, depending on the charges on the objects
- Holds the atom together
- Coulomb’s law expresses the magnitude of the electrostatic force between two charged particles

\[ F_e = k_e \frac{q_1 q_2}{r^2} \quad where \quad k_e = 8.99 \times 10^9 N \cdot m^2/C^2 \]
**Strong Force**

- Acts between protons and neutrons
- Attractive
- Extremely short ranged
- Holds the nucleus together
- We will see later that the strong force actually acts between quarks and it is what we call the residual strong force that holds protons and neutrons together
Weak Force

- Called the weak force because it is weak compared to the strong force
- Short ranged
- Responsible for nuclear beta decay
Electroweak Force

- In an effort to reduce the number of fundamental forces, in 1967 physicists predicted that the electromagnetic and weak forces were different manifestations of the same force, called the electroweak force.

- The prediction was confirmed experimentally in 1984.
The Concept of Force

Serway/Jewett; Principles of Physics, 3/e
Figure 4.1

<table>
<thead>
<tr>
<th>Contact forces</th>
<th>Field forces</th>
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</thead>
<tbody>
<tr>
<td><img src="image1" alt="Contact forces" /></td>
<td><img src="image2" alt="Field forces" /></td>
</tr>
</tbody>
</table>

(a) 

(b) 

(c) 

(d) 

(e) 

(f)
Newton’s First Law

- Newton’s 1st Law - In the absence of a net external force, an object at rest remains at rest and an object in motion continues in motion with constant velocity (that is, with a constant speed in a straight line).
  - i.e. When no net force acts on a body, its acceleration is zero.

- The tendency of a body to maintain its original state of motion in the absence of a net external force is called inertia.

- Inertial mass is the measure of an object’s resistance to a change in motion in response to a net external force.
**Newton’s Second Law**

- The net external force acting on a body is equal to the product of the mass of the body and its acceleration.

  \[ \sum F_x = ma_x \]

- The SI unit of mass is the kilogram (kg)
- The SI unit of force is the newton (N) and \( 1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2 \)
Example Problem

A loaded sled whose mass is 240 kg is pushed a distance of 2.3 m over the surface of a frozen lake with a horizontal force of 130 N. If the sled starts from rest, what is its final velocity?
Example Solution

A loaded sled whose mass is 240 kg is pushed a distance of 2.3 m over the surface of a frozen lake with a horizontal force of 130 N. If the sled starts from rest, what is its final velocity?

\[ m = 240 \text{ kg} \quad x_i = 0 \quad x_f = 2.3 \text{ m} \quad F_x = 130 \text{ N} \]

\[ v_{xi} = 0 \quad a_x =? \quad v_{xf} =? \]

\[ a_x = \frac{F_x}{m} = \frac{130 \text{ N}}{240 \text{ kg}} = 0.54 \text{ m/s}^2 \]

\[ v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i) \]

\[ v_{xf} = \sqrt{2a_xx_f} = \sqrt{2 (0.54 \text{ m/s}^2) (2.3 \text{ m})} = 1.6 \text{ m/s} \]
Homework Set 3 - Due Wed. Sept. 15

- Read Sections 5.6 & 4.1-4.4
- Do problems 4.1 & 4.6