Forces
What is a force?

- A force can be defined as a push or pull on something.
- A tow truck pulls a car by applying a force on it.
- The force of gravity causes a fly ball in a baseball game to return to earth by pulling downward on the ball.
There are four fundamental forces in nature. The four forces are as follows:

- Gravitational Force
- Electromagnetic Force
- Weak Nuclear Force
- Strong Nuclear Force

These forces are fundamental because all the other forces that are encountered in nature can be shown to be different aspects of these four forces.
• In the middle part of the sixteen hundreds and first part of the seventeen hundreds lived a man viewed now by many as the greatest scientist of all time.
• Isaac Newton was a mathematician, philosopher, and probably the first true physicist.
• Using the work of Galileo and Kepler, Newton formulated his three laws of motion and the law of universal gravitation.
The Law of Inertia

• Newton's first law states that an object tends to maintain a constant velocity until acted on by a net force.
• This is sometimes call the law of inertia.
Example

• If we slide an object across the floor it eventually stops.
• If we lubricate the surfaces of the floor and the object then it will continue in a straight line for a greater amount of time before it comes to rest.
• If we keep making the two surfaces slicker and slicker then the object, once set in motion, will continue in a straight path for a greater and greater distance.
• If we can remove all the forces that resist the motion then the object will continue to move in a straight line forever.
Newton's Second Law

• Newton's second law states that when a net force acts on an object the acceleration of that object as a result of the force is directly proportional to the net force and has a magnitude that is inversely proportional to the mass.
Newton's Second Law

- Mathematically stated:

\[ \vec{a} = \frac{\sum \vec{F}}{m} \]

Or

\[ \sum \vec{F} = m \ddot{a} \]
• In the previous equation "a" is acceleration, "F" is the applied force, and "m" is the mass of the object.
• In SI the unit for force is the Newton "N".
• Note the net force is the vector sum of all the forces on a mass.
Example

- Two people are pushing on a stalled car.
- The mass of the car is 1850 kg.
- One person applies a force of 275 N to the car, while the other person pushes with a force of 395 N.
- Both forces act in the positive x direction.
- A third force due to friction from the cars tires and the road opposes the push of the two people and has a magnitude of 560 N.
- What is the acceleration of the car?
Solution

\[ \sum \vec{F} = 250N \hat{i} + 395N \hat{i} - 560N \hat{i} \]

\[ \sum \vec{F} = 110N \hat{i} \]
Solution cont.

• The acceleration can now be obtained by dividing the net force by the mass:

\[
\vec{a} = \frac{\sum \vec{F}}{m} = \frac{110N \hat{i}}{1850kg} = (0.059m/s^2) \hat{i}
\]
Newton's Third Law

• Newton's third law of motion states that whenever one object exerts a force on a second object, the second object exerts an oppositely directed force of equal magnitude on the first body.

• Newton's third law tells us that all forces come in pairs.
• There is no such thing as an isolated force acting all by itself. The third law is sometimes known as the law of action - reaction.
Example:

• Suppose that the mass of a spacecraft is \( m_s = 11000 \text{ kg} \) and the mass of an astronaut is \( m_A = 92 \text{ kg} \).
• If the astronaut is outside of the spacecraft and she exerts a force of 36 N on the spacecraft then what will be the accelerations of the spacecraft and the astronaut?
Solution

- The acceleration of the spacecraft is:

\[ a_s = \frac{F}{m_s} = \frac{36N}{1.1 \times 10^4 \text{ kg}} = 3.3 \times 10^{-3} \text{ m} / \text{s}^2 \]
Solution

• The acceleration of the astronaut is:

\[ a_A = \frac{-F}{m_A} = \frac{-36N}{92kg} = -0.39 m/s^2 \]
Example

- Two people push on a stuck vehicle.
- If each person applies a force of 700 N in the positive x direction and the retarding force of the vehicle plus the force supplied by the tires is 950 N, determine the acceleration of the vehicle.
- The mass of the vehicle is 2000 kg.
Free-Body Diagram
Solution

- According to Newton’s second law the acceleration of the vehicle is:
Example

- Two people engaged in an argument begin to fight.
- One person pushes against the other with a force of 250.0 N.
- If the people are standing on a very slick surface, determine the magnitude of the acceleration of each person if their masses are 45.0 kg and 55.0 kg.
Free-Body Diagram

-250N 45kg 55kg 250N
Solution

• According to Newton’s third law the forces must be of equal magnitude and opposite direction.
• From Newton’s second law we get:
Example

• A person is dragging a trunk containing a dead body, up an incline with a slope of 15°.
• The rope that pulls the crate makes an angle of 25° with respect to the incline.
• What force must the person exert on the rope if she is to just pull the trunk up the hill.
• Assume the weight is $F_{\text{crate}} = 200\text{N}$, on the crate.
Free-Body Diagram

- We first draw a picture labeling the forces.
Solution

• We place the $x$-axis along the incline for convince.

• Note: we are assuming that there is no friction between the trunk and the incline.
Solution cont.

• We break the forces up into components and set them equal to zero since there is no acceleration.
Solution cont.

• The magnitude of the force is then:
Solution cont.

• The $x$ and $y$ components are:
Solution cont.

• The force is then:

\[ \vec{F} = (50.0N)\hat{i} + (23.0N)\hat{j} \]
Example

• Determine the magnitude of the normal force exerted on the crate by the incline plane in the previous example.
Solution

- The sum of the forces on the crate in the $y$-direction was:
• Now that we know the applied force we can determine the normal force on the crate.