Newton’s first law: inertia

- An object at rest or in uniform motion (velocity in a straight line) will maintain its state, unless it is acted upon by a net outside force.

\[ \Sigma \vec{F} = 0, \text{ then } \vec{v} \text{ is constant and } \vec{a} = 0. \]

- The tendency for an object to maintain its state of rest or motion is known as **inertia**.

- A **force** is a push or a pull on an object as a result of its *interaction* with another object. The force of object A on object B is often denoted \( \vec{F}_{AB} \).

- **Net force** is the sum of all the forces acting upon an object. If the sum of all forces acting on an object is zero, all forces acting on the object are balanced and the object will maintain its state.

- This also means that an object will not accelerate if the net force acting on it is zero.
Newton’s second law: dynamics

- The net force acting on an object is directly proportional to its acceleration with the constant of proportionality equal to the object’s mass. The direction of acceleration is the same as the direction of the net force.

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

- This law gives us knowledge of the dynamics of objects, or the effect of forces on the motion of objects.

- Mass is the measure of the inertia of an object. Roughly, how difficult it is to change the object’s motion.

- A net force acting on an object with greater mass will experience a lesser acceleration than the same net force acting on an object with lesser mass.

- The Newton (N) is a unit that measures force. It is defined as the force required to accelerate a mass of 1 kg by 1 m/s². This means that 1 N = 1 kg \cdot m/s².

- In general, the dimensions of force are \([M][L][T]^{-2}\) and other units are sometimes used, such as the familiar pound: 1 pound = 1 slug \cdot ft/s².
Newton’s third law: reaction

- Whenever one object exerts a force on a second object, the second exerts on the first object an equal force in the opposite direction.

\[ \vec{F}_{AB} = -\vec{F}_{BA} \]

- An important aspect of this law is that the reaction force of the second is applied to the first as shown below. This ensures that a net force on an object is still possible!

- Consider the situation of pulling a wagon. You are exerting a pulling force on the wagon’s handle. The handle’s reaction is a pulling force acting on you in the opposite direction with the same magnitude.
Gravity and normal forces

- The acceleration we are most familiar with so far is acceleration due to gravity. Newton’s second law implies that some force acts upon these objects to impart acceleration on them. This is known as the gravitational force $\vec{F}_G$ and has this form near the earth’s surface:

$$\vec{F}_G = mg$$

- Objects standing on the earth’s surface do not accelerate, yet they continue to experience the gravitational force. Newton’s first law implies that some force is opposing the gravitational force and is pointed upward, perpendicular to the earth’s surface. This is known as the normal force $\vec{F}_N$.

$$\vec{F}_N + \vec{F}_G = 0$$

- Newton’s third law implies that the surface an object is resting upon is exerting the normal force onto the object. This means that the ground exerts a force resting on objects lying on it. Likewise, the object exerts an equal and opposite force on the ground as illustrated.
Free-body diagrams

- A **free-body diagram** is a drawing of an object with every force acting on it. This is a useful technique to account for all the forces in a physics problem and ensure that the correct net force is calculated.

- The diagram also helps to visualize the directions of force vectors and aid understanding their decomposition into component parts.

- Consider the example of a box on an incline. The force of gravity is oriented downwards. However, the normal force exerted on the block by the incline is perpendicular to the incline, and the component of gravity accelerating the block down the incline is parallel to its surface.
**Friction**

- The force of **friction** arises when two solid surfaces are touching each other. The roughness in the two surfaces interact and exerts a force.

- The friction force exerted on your feet by the ground enables walking. Remember that your feet also exert an equal and opposite force on the ground!

- The magnitude of the friction force $F_{fr}$ is proportional the magnitude of the normal force $F_N$ and is directed perpendicularly to the normal force.

- The two *magnitudes* are related by the proportionality constant $\mu$, the **coefficient of friction**:

  $$F_{fr} = \mu F_N$$

  Notice that only the magnitudes of the vectors are described by this relation, their directions are perpendicular!

- The coefficient of friction is affected by the characteristics of the two surfaces that are interacting. For example, a rough steel box will have a different coefficient of friction with ice than with wood.

- The coefficient of friction has a different value in static conditions (no motion) than in dynamic conditions. We denote the coefficient of static friction $\mu_s$ and the coefficient of dynamic friction $\mu_k$. Pay careful attention to the dynamics of the situation before selecting which $\mu$ to use.