

Chapter 5

Newton's Laws of Motion

4.1) The Concept of Force & net Force: A force is defined in terms of what it does.

Definition:

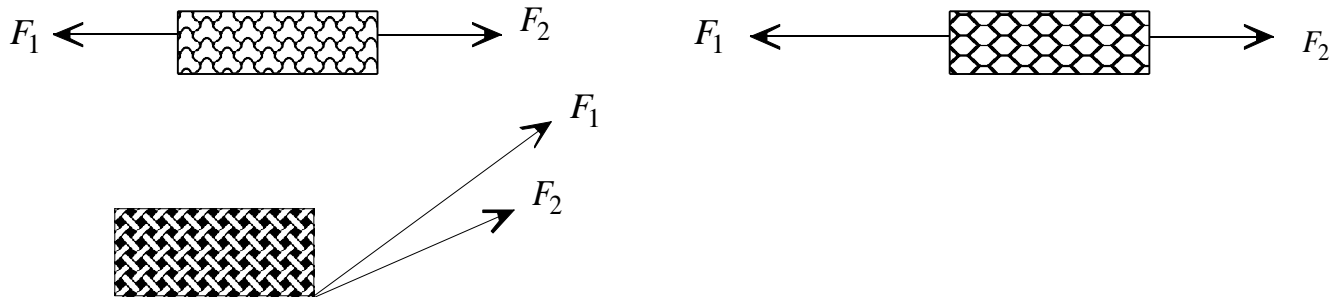
A force is something capable of changing an object's state of motion, i.e., capable of changing its velocity. Hence when a force is acting alone on an object, it will cause the object's velocity to change, hence produces acceleration.

Force is a vector quantity. When several forces act on an object, their combined effect is important. This combined effect is called **the Sum, the Net Force, or the Resultant**. Let $\vec{F}_1, \vec{F}_2, \dots, \vec{F}_n$ be forces acting on an object. Then

$$\text{Resultant} = \text{net force} = \vec{F}_1 + \vec{F}_2 + \dots + \vec{F}_n.$$

If the net force is 0 then we call these forces **balanced forces**. If the net force is not 0 then we call these forces **unbalanced forces**.

Example:



Example:

There are two types of forces: **Contact Forces, Action-at-a distance.**

Inertia & Newton's 1st Law of Motion:

According to Aristotle, the normal state of an object was at rest. According to Galileo, bodies in motion exhibit the behavior of maintaining that motion: if the body is at rest it remain at rest unless something cause it to move.

Definition:

Inertia is the natural tendency of an object to maintain a state of rest or remain indefinitely at uniform motion in straight line.

Examples:

Try to stop a rolling car, try to move a car in neutral, a moving object slams to a wall. Try to move a car and a truck parked on ice, try to punch two different size punching bags, try to move a bucket of water and a bucket of cotton,.....

Definition:

Mass is a measure of inertia. This means that an object with bigger mass has a bigger inertia.

Newton's First Law of Motion:

In the absence of an unbalances applied force, a body at rest remains at rest and a body already in motion remains im motion with a constant velocity. This means that if the net force acting on the objet is zero, then its acceleration is zero (constant speed and direction).

Newton's Second Law of Motion:

Experiment shows that the acceleration of a body is proportional to the applied force:

$$\vec{a} \equiv \vec{F}_{\text{net}}$$

Also for a fixed applied force, the more massive the object is the smaller its acceleration would be. This means that acceleration is inversely proportional to the mass.

$$\vec{a} \equiv \frac{1}{m}$$

So it follows that

$$\vec{a} \equiv \frac{\vec{F}_{\text{net}}}{m} \quad \text{Or} \quad \vec{F}_{\text{net}} \equiv m\vec{a}$$

It turns out that the constant of proportionality is 1, so we get:

$$\vec{F}_{\text{net}} = m\vec{a}.$$

And this formula is what we call Newton's second law of motion.

Weight:

The weight of an object is the gravitational force W exerted on a body. For us, this force is the force of attraction by the earth: when you drop an object, it falls and accelerates. The acceleration is called the gravitational acceleration \vec{g} which is about 9.8m/s^2 directed downward. So if m is the mass of an object, the weight of it is

$$\vec{W} = m\vec{g}.$$

Example:

Newton's Third Law of Motion:

For every force (action), there is an equal and opposite force (reaction). In symbol:

$$\vec{F}_{12} = -\vec{F}_{21}.$$

This means that the force \vec{F}_{12} exerted on object 2 by object 1, is equal and opposite of force \vec{F}_{21} exerted on object 1 by object 2

Remark:

The action and the reaction forces do not act on the same object.

Definition:

The **Normal Force** \vec{N} is the force a surface exerts on an object placed on it.

See the computation of the normal force in various situations on page 110 of the text.

Example:

Definition:

We say an object is in **Transnational Equilibrium** if the net force exerted on it is zero: $\sum \vec{F} = \mathbf{0}$. In general we have:

$$\sum \vec{F}_x = \mathbf{0} \quad \text{and} \quad \sum \vec{F}_y = \mathbf{0}$$

If $\sum \vec{F} = \mathbf{0}$ and the object remains at rest, then we call it **Static Transnational Equilibrium**.

Example:

Definition:

The force of friction is a force with

1. Always in the opposite direction of motion,
2. The magnitude of it depends on the material of the surfaces in touch.

We have three type of friction forces:

1. Static Friction: all the forces sufficient to prevent relative motion between surfaces.
2. Kinetic Friction: is the amount of force needed to keep the object on a surface in uniform motion (constant velocity).
3. Rolling Friction: is the force between two surfaces where one rotates as it moves over the other surface, but it does not slip or slide at the point of contact.

Formulas: It can be shown that if N is the normal force, then

$$f_s \leq \mu_s N, \text{ where } \mu_s = \text{coefficient of static friction}$$

Clearly

$$f_{s \max} = \mu_s N$$

Also, we have:

$$f_k = \mu_k N, \text{ where } \mu_k = \text{coefficient of kinetic friction.}$$

Example: