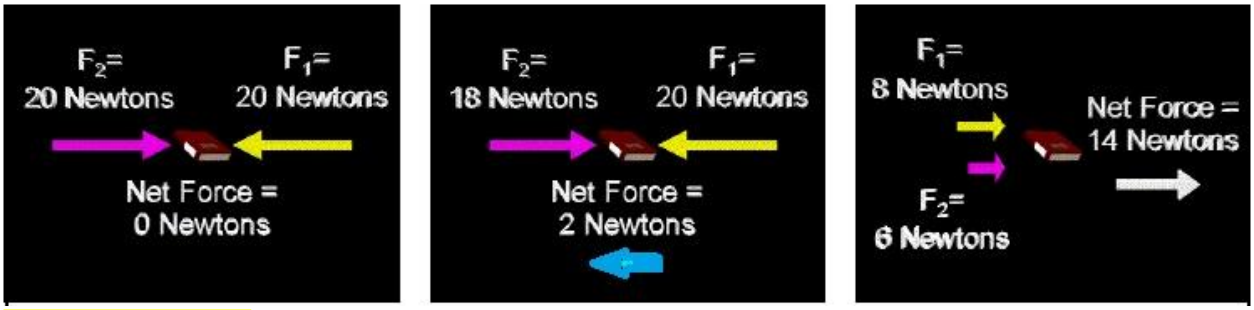
Newton's Laws of Motion

Net force = the combination of all forces acting on an object.



Balanced Force⇒ Produce no change in motion of the object

Unbalanced Force⇒ Make object start to move, speed up, slow down, or change direction.

Newton's First Law:

Every object persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.

Newton's first law of motion

- Gives a definition of (zero) force
- Defines an *inertial frame.*

Zero Force: When a body moves with *constant velocity in a straight line,* either there are no forces present or the net force acting on the body is zero. If the body changes its velocity, then there must be an acceleration, and hence a total non-zero force must be present. Velocity can change due to change in its magnitude or due to change in its direction or change in both.

Inertial frame: If the relative velocity between the two reference frames is constant, then the relative acceleration between the two reference frames is zero, and the reference frames are considered to be *inertial reference frames.* The inertial frame is then simply a frame of reference in which the first law holds. Newton's First Law is called Law of inertia.,

Tendency of a body to remain at rest or in uniform linear motion is called inertia. All objects have inertia. The **greater** the object's mass, the **greater** its inertia and the **larger** the force needed to overcome inertia.

Weight vs. Mass

Mass is the amount of matter. It is a measure of inertia. Weight of an object is a result of the Earth's attraction downward. Weight is a downward force. w=mg

***** Apparent Weight, Normal Force, Tension*****

Newton's Second Law:

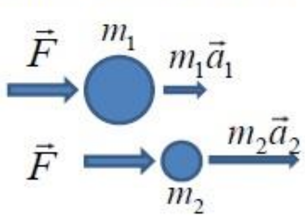
The change of momentum of a body is proportional to the impulse impressed on the body, and happens along the straight line on which that impulse is impressed.

Change of motion is described by the change in momentum of body. For a point mass particle, the momentum is defined as p=mv

Suppose that a force is applied to a body for a time interval Δt. The impressed force or impulse produces a change in the momentum of the body,

$$\vec{\mathbf{I}} = \vec{\mathbf{F}}\Delta \mathbf{t} = \Delta\vec{\mathbf{p}}$$

The instantaneous action of the total force acting on a body at a time *t is defined by taking the mathematical limit as the time interval Δt becomes smaller and smaller,*



$$\frac{m_1}{m_2} = \frac{a_2}{a_1}$$

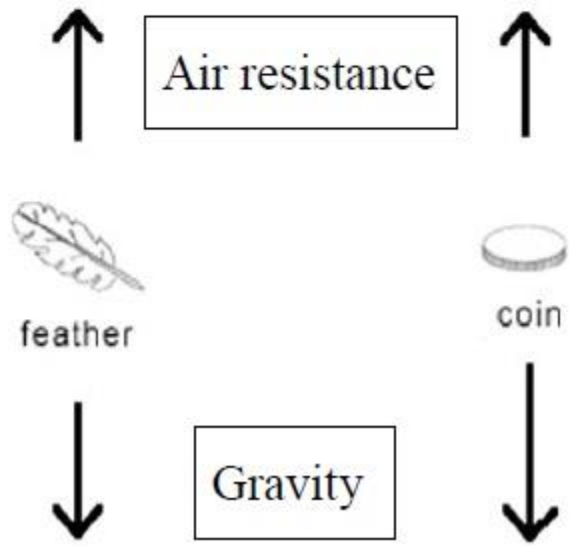
$$\vec{\mathbf{F}}^{\text{total}} = \lim_{\Delta t \to 0} \frac{\Delta\vec{\mathbf{p}}}{\Delta t} \equiv \frac{d\vec{\mathbf{p}}}{dt} \qquad \vec{F}^{\text{total}} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt}$$

Inertial mass

$$\vec{\mathbf{F}}^{\text{total}} = m\vec{\mathbf{a}}$$

Inertial mass $\equiv$ Gravitational mass

- Air resistance and falling objects The force of gravity if pulling down on the feather and coin. The force of air resistance is pushing up on the feather and coin.



The net force of the feather and coin is equal to the force of air resistance subtracted from the force of gravity

- Falling objects don't accelerate through their whole fall. Eventually, the force of air resistance pushing up against the object equals the force of gravity pulling down on the object. When that happens, the net force on the falling object becomes zero, and so the object stops accelerating. The final speed is called terminal speed.

Newton's Third Law: When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction.

Consider two bodies engaged in a mutual interaction. Label the bodies 1 and 2 respectively. Let $\vec{F}_{1,2}$ be the force on body 1 due to the interaction with body 2, and $\vec{F}_{2,1}$ be the force on body 2 due to the interaction with body 1.

$$\vec{\mathbf{F}}_{1,2} = -\vec{\mathbf{F}}_{2,1}$$

Gravitational force: $\vec{F}_{12} = -G\dfrac{m_1 m_2}{r^2}\hat{r}_{12}$ $\qquad \hat{r}_{12} = -\hat{r}_{21}$

Coulomb force: $\vec{F}_{12} = k\dfrac{q_1 q_2}{r^2}\hat{r}_{12}$ $\qquad \vec{F}_{12} = -\vec{F}_{21}$

All real Forces arise due to interaction!

If the acceleration of a body is the result of an outside force, then somewhere in the universe there must be an equal and opposite force acting on another body. The interaction may be a complicated one, but as long as the forces are equal and opposite, Newton's laws are satisfied.

Mathematical problem:

1. Fig:1 gives the free-body diagram for four situations in which an object is pulled by several forces across a frictionless floor, as seen from overhead. In which situations does the object's acceleration have (a) an *x* component and (b) a *y* component? (c) In each situation, give the direction of by naming either a quadrant or a direction along an axis.

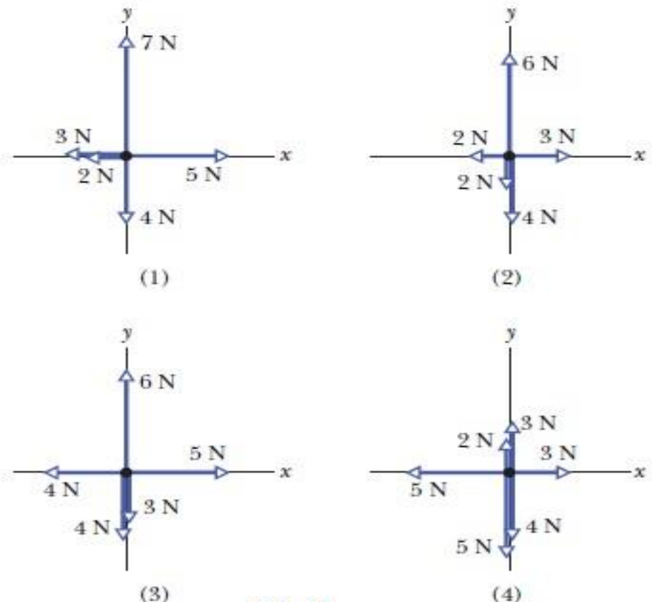


Fig:1

2. An elevator weighing 6000lb is pulled upward by a cable with an accelerator of 4ft/sec^2.
   a. What is the tension in the cable?
   b. What is the tension when the elevator is accelerating downward at 4.0ft/sec^2?

3. Consider a block of mass m pulled along a smooth horizontal surface by a horizontal force P, as shown in Fig:2. N is the normal force exerted on the block by the frictionless surface and W is the weight of the block.
   a. If the block has a mass of 2.0 kg, what is the normal force?
   b. What force P is required to give the block a horizontal velocity of 4.0 m/s in 2.0 sec starting from rest?

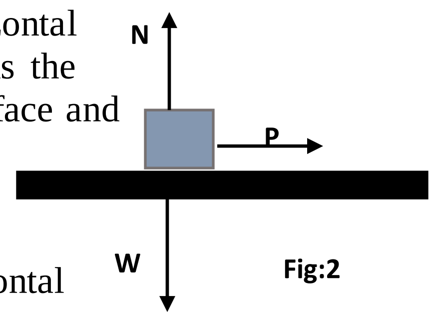


Fig:2

4. Fig: 3 shows an object of weight 100lb hang by strings. The object remains at rest under the action of the three forces. Find the magnitudes of the forces.

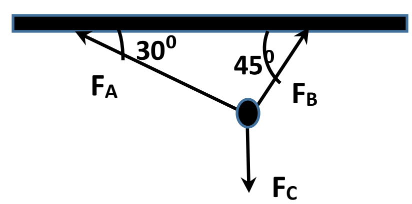


Fig:3