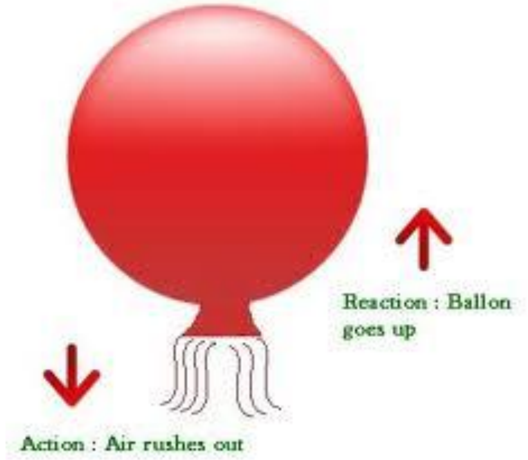
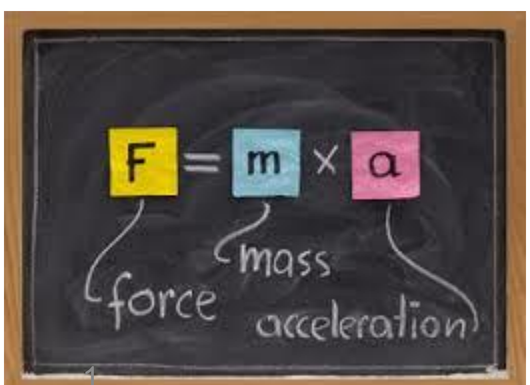


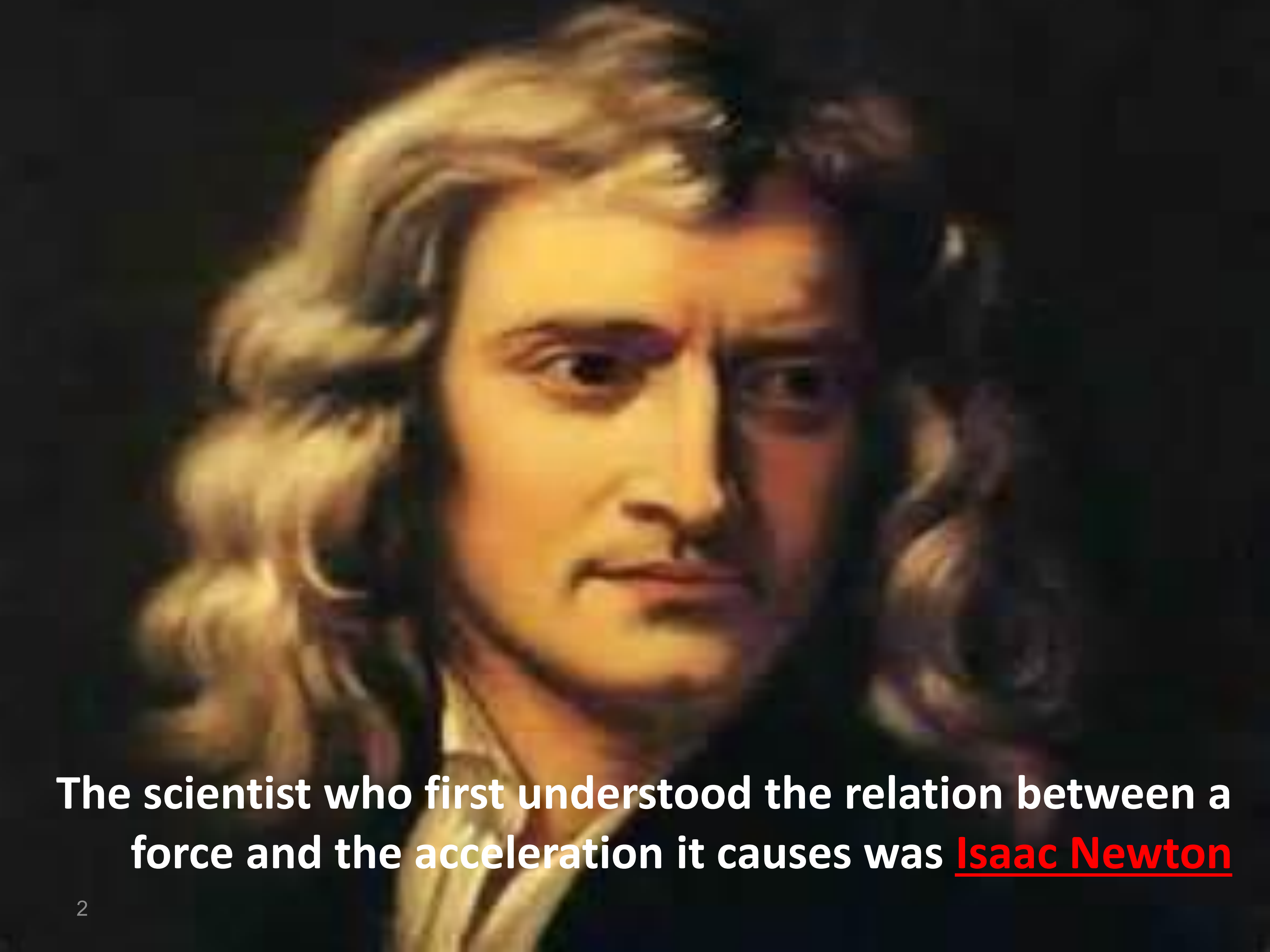
Force and Motion I

Newton's First Law of Motion

- Newton's first law is often called the law of inertia
- Newton's First Law of Motion states—An object at rest will remain at rest, or an object in motion will remain in motion in a straight line at constant speed, unless an external force is applied to it and changes its state motion



By: Dr. Wajood Diery


The scientist who first understood the relation between a force and the acceleration it causes was Isaac Newton

5-1 Newton's First and Second Law

What is Physics?

To study the motion of an object

↓

We usually study the acceleration of this object

↓

Acceleration is the changing in velocity

↓

The cause of this changing is a **Force**

Newton's First Law

If No Force acts on a body, the body's velocity cannot change; that is, the body cannot Accelerate.

or

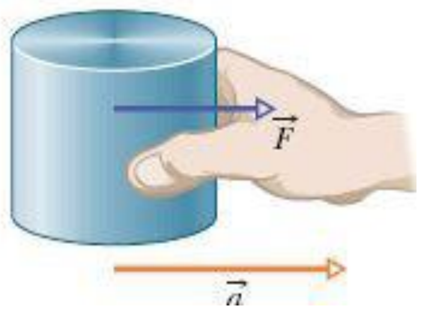
If there is **No Force** that acts on the body

if the body is at rest , it stays at rest

if the body is in motion, it stays in motion with the same velocity (same speed and direction)

Force

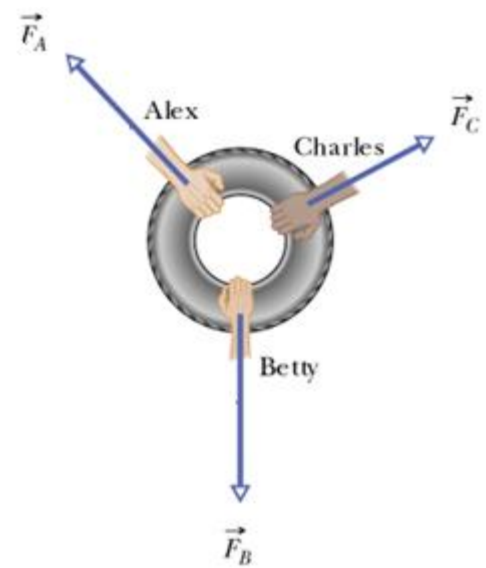
Thus, a force is measured by the acceleration it produces.



- Its Unit is Newton N .
- It is a Vector. $\vec{F}$

If several forces act on a body

$$\vec{F}_{net} = \vec{F}_A + \vec{F}_B + \vec{F}_C$$



Newton's First Law: If no *net* force acts on a body ($\vec{F}_{net} = 0$), the body's velocity cannot change; that is, the body cannot accelerate.

Mass

- Mass is an ***intrinsic*** characteristic of a body that relates a ***force F*** applied on the body and the resulting ***acceleration a*.**

- **SI Unit is Kg.**

- **It is a scalar.**

$$\frac{m_X}{m_0} = \frac{a_0}{a_X} \rightarrow \boxed{m_X = m_0 \frac{a_0}{a_X}}$$

Newton's second Law

The net force on a body is equal to the product of the body's mass and its acceleration.

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

$$F_{\text{net},x} = ma_x \qquad F_{\text{net},y} = ma_y \qquad F_{\text{net},z} = ma_z$$

The acceleration component along a given axis is caused *only by* the sum of the force components along that *same* axis, and not by force components along any other axis.

$$1\ \text{N} = (1\ \text{kg})(1\ \text{m/s}^2) = 1\ \text{kg}\cdot\text{m/s}^2$$

$$\text{If } \vec{F}_{net} = 0 \Rightarrow a = 0 \Rightarrow v \text{ is constant.}$$
$$\qquad\quad \Leftarrow \qquad\quad \Leftarrow$$

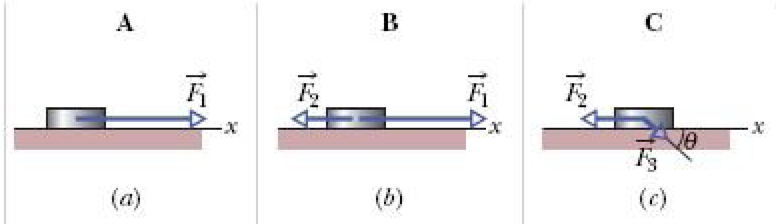
At rest, constant velocity, equilibrium $\Rightarrow \quad F_{net} = 0$

Free body diagram

1. Draw x and y coordinates.
2. The body is represented by a dot at the origin.
3. Each Force on the body is drawn as a vector arrow with its tail on the body.

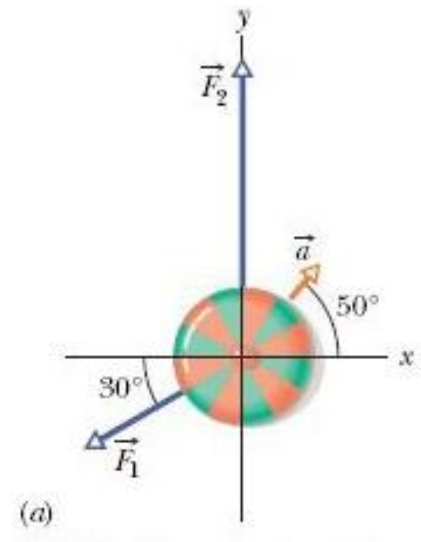
Sample Problem (5.01)

Figures 5-3*a* to *c* show three situations in which one or two forces act on a puck that moves over frictionless ice along an x axis, in one-dimensional motion. The puck's mass is $m = 0.20$ kg. Forces $\vec{F}_1$ and $\vec{F}_2$ are directed along the axis and have magnitudes $F_1 = 4.0$ N and $F_2 = 2.0$ N. Force $\vec{F}_3$ is directed at angle $\theta = 30°$ and has magnitude $F_3 = 1.0$ N. In each situation, what is the acceleration of the puck?



Sample Problem (5.02)

In the overhead view of Fig. 5-4*a*, a 2.0 kg cookie tin is accelerated at 3.0 m/s^2 in the direction shown by $\vec{a}$, over a frictionless horizontal surface. The acceleration is caused by three horizontal forces, only two of which are shown: $\vec{F}_1$ of magnitude 10 N and $\vec{F}_2$ of magnitude 20 N. What is the third force $\vec{F}_3$ in unit-vector notation and in magnitude-angle notation?



5-2 Some particular forces

Gravitational force

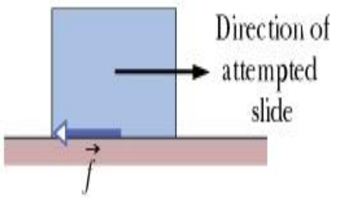
It is the force that the Earth exerts on any object. It is directed toward the center of the Earth.

Normal force

When a body presses against a surface, the surface deforms and pushes on the body with a normal force perpendicular to the contact surface.

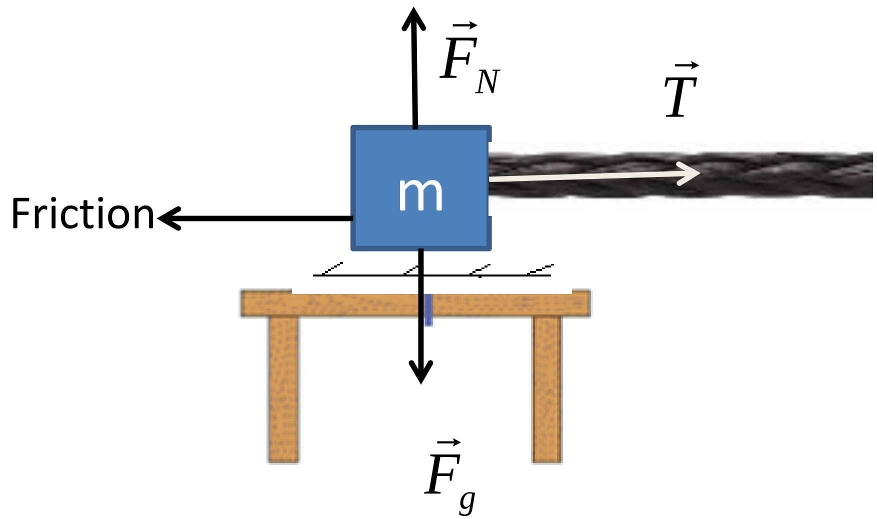
Friction

The force that opposes the motion.



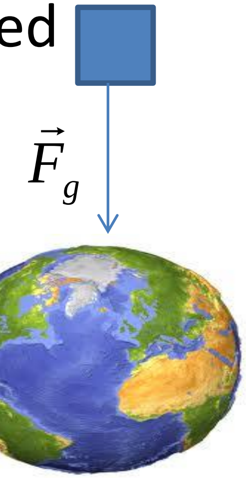
Tension

This is the force exerted by a rope or a cable attached to an object.



Gravitational force

- It is the force that the Earth exerts on any object .It is directed toward the center of the Earth.



$$F_{net,y} = ma_y \qquad -F_g = m(-g) \qquad F_g = mg$$

$$\vec{F}_g = -F_g\hat{j} = -mg\hat{j} = m\vec{g}$$

The weight W of a body is equal to the magnitude F_g of the gravitational force on the body.

$$w = \left|\vec{F}_g\right| = mg$$

mass	**weight**
• mass is constant.	• weight is changeable, It depends on g.
• Unit: kg.	• Unit: N.

Normal force

The body at rest or moving with constant velocity.

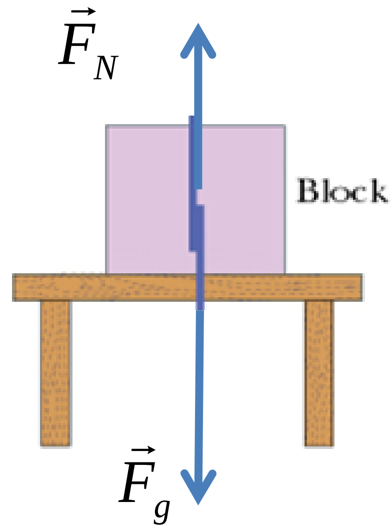
$$a = 0$$

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

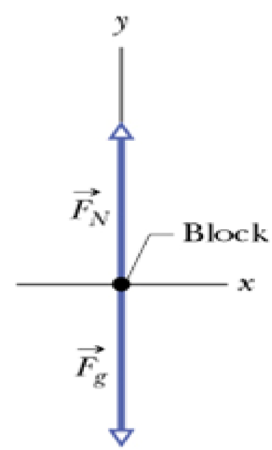
$$F_{net,y} = ma_y$$

$$F_N - F_g = 0$$

$$\boxed{F_N = F_g = mg}$$



Direction of motion



Direction of motion

The body is moving with acceleration

$$a = a_y$$

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

$$F_{net,y} = ma_y$$

$$F_N - F_g = ma_y$$

$$F_N = F_g + ma_y$$

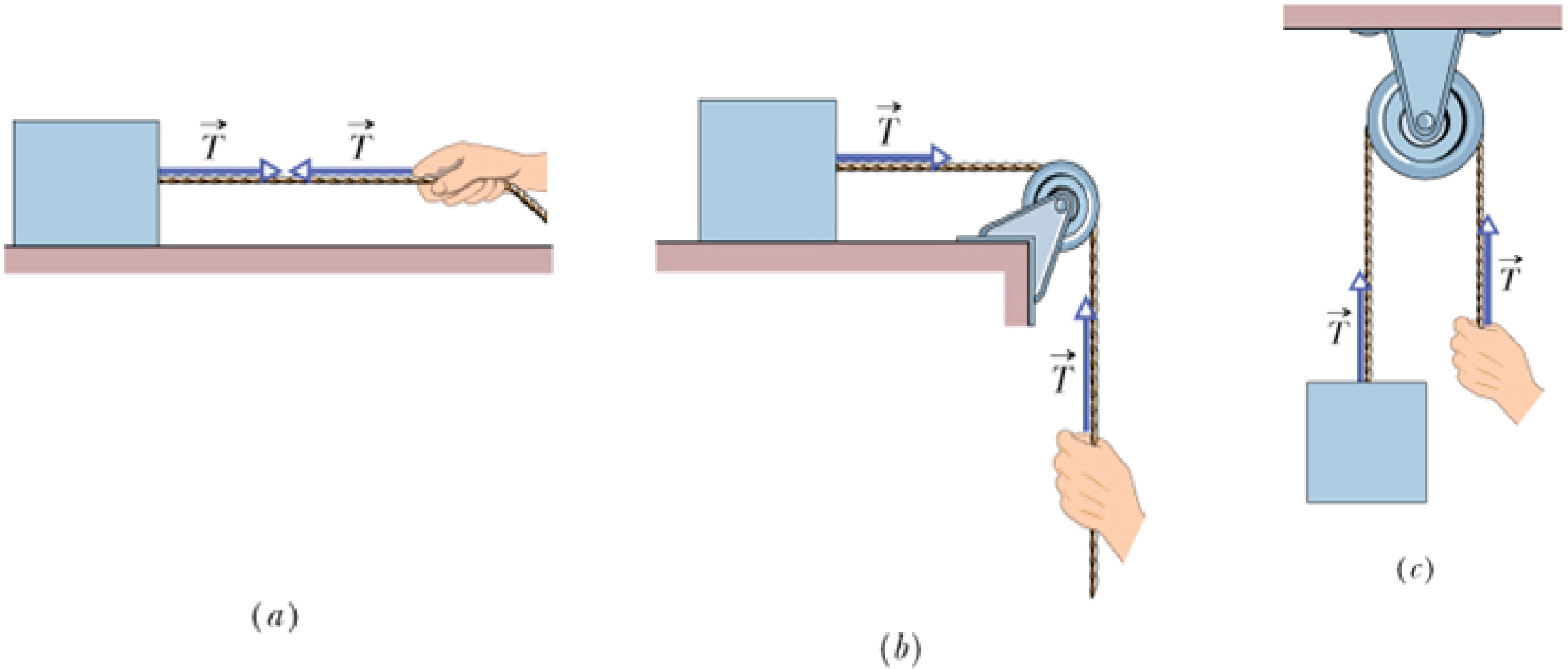
$$= mg + ma_y$$

$$\boxed{F_N = (g + a_y)m}$$

Tension

Tension has the following characteristics:

1. It is always directed along the rope.
2. It is always pulling the object.
3. It has the same value along the rope.



5-3 Applying Newton's Laws

Newton's Third Law

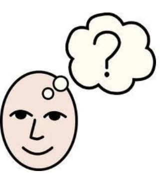
When two bodies interact by exerting forces on each other, the forces are equal in magnitude and opposite in direction.

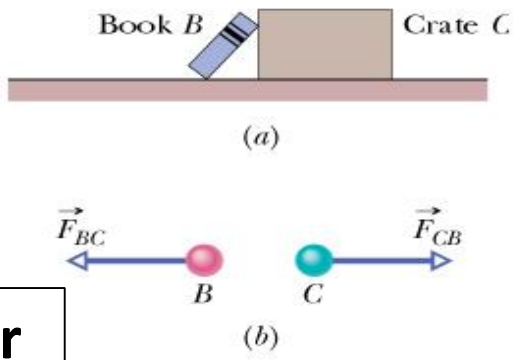
There is a horizontal force on the book from the crate denoted by $\vec{F}_{BC}$

and a horizontal force on the crate from the book denoted by $\vec{F}_{CB}$

$$F_{BC} = F_{CB} \quad \text{(equal magnitude)}$$

$$\vec{F}_{BC} = -\vec{F}_{CB} \quad \text{(equal magnitude and opposite direction)}$$



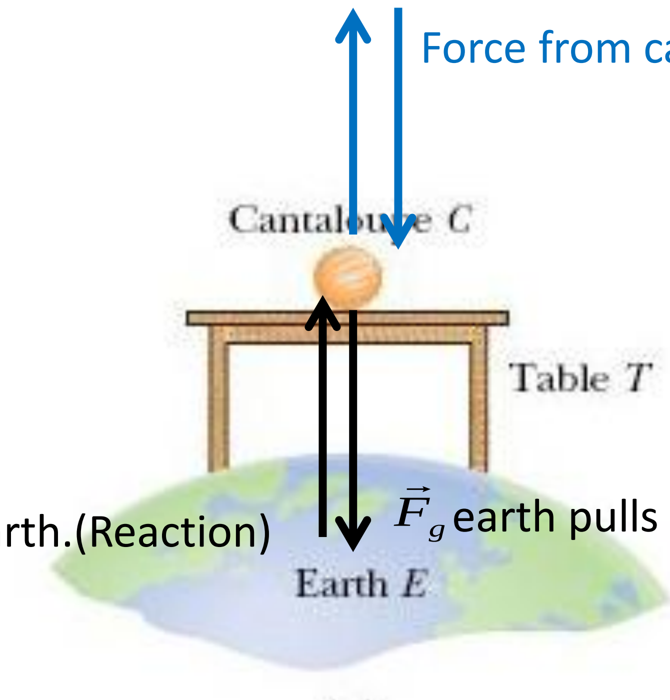


Why the action and reaction force do not cancel each other?

Action and reaction are called third-law force pair

F_n :force from table on the Cantaloupe(action)

Force from cantaloupe on the table (reaction)

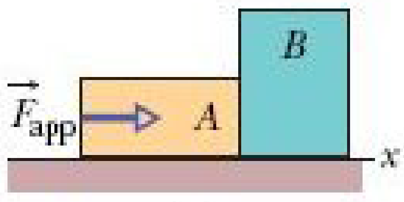


$\vec{F}_g$ earth pulls on Cantaloupe .(Action)

Cantaloupe pulls on the earth.(Reaction)

Sample Problem (5.07): Acceleration of Block pushing on Block

In Fig. 5-20*a*, a constant horizontal force $\vec{F}_{app}$ of magnitude 20 N is applied to block *A* of mass $m_A = 4.0$ kg, which pushes against block *B* of mass $m_B = 6.0$ kg. The blocks slide over a frictionless surface, along an *x* axis.



(a) What is the acceleration of the blocks?

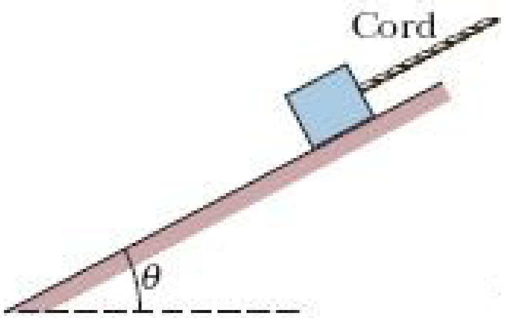
(b) What is the (horizontal) force $\vec{F}_{BA}$ on block *B* from block *A* (Fig. 5-20*c*)?

Recipe for the Application of Newton's Laws of Motion for a single particle

1. Identify all the forces that act on the particle. Label them on the diagram and the direction of motion of the object if it is moving.
2. Draw a free-body diagram for the object.
3. Check if there is any force needs to be resolved.
4. Write Newton 2ed law.
5. decide how many equations do you need, if its one-dimension, need one equation, two-dimension ,you need two equations.
6. If the object at rest or moving with constant velocity, then the acceleration is zero (a=0) along that axis, otherwise it a has a value.
7. Add the forces along each axis Geometrically(i.e along x-axis: to the right (+), to the left (-). Along y-axis :upward (+), downward (-).
8. solve the equation to find the unknown.

Sample Problem 5.04: Cord accelerates box up a ramp

In Fig. 5-16*a*, a cord pulls on a box of sea biscuits up along a frictionless plane inclined at $\theta = 30°$. The box has mass $m = 5.00$ kg, and the force from the cord has magnitude $T = 25.0$ N. What is the box's acceleration component a along the inclined plane?



Sample Problem (5.06): Forces within an elevator cab

In Fig. 5-19a, a passenger of mass $m = 72.2$ kg stands on a platform scale in an elevator cab. We are concerned with the scale readings when the cab is stationary and when it is moving up or down.

(a) Find a general solution for the scale reading, whatever the vertical motion of the cab.

(b) What does the scale read if the cab is stationary or moving upward at a constant 0.50 m/s?

(c) What does the scale read if the cab accelerates upward at 3.20 m/s^2 and downward at 3.20 m/s^2?

Recipe for the Application of Newton's Laws of Motion for a system of particles

1. Identify all the forces that act on the system. Label them on the diagram and the direction of motion of each object if they are moving.

2. Remember that the system of two objects moves with the **same acceleration.**

3. Choose one object to start with and follow the steps below:

a) Draw a free-body diagram for the object.

b) Check if there is any force need to be resolved.

c) Write Newton 2ed law.

d) decide how many equations do you need, if its one-dimension, need one equation, two-dimension ,you need two equations.

e) If the object at rest or moving with constant velocity, then (a=0) the acceleration is zero along that axis, otherwise a has a value.

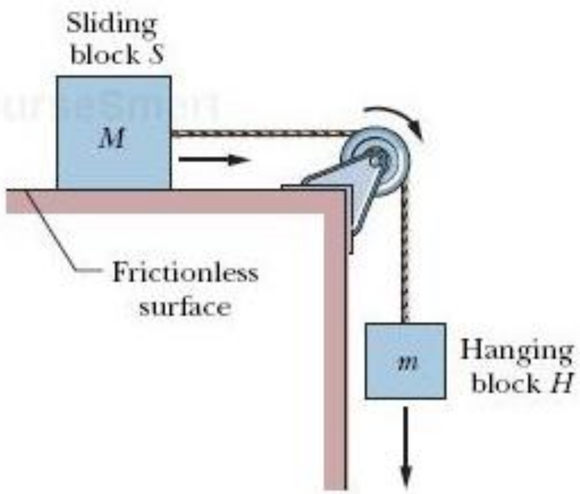
f) simplify the equation you get and label it (1)

4.Now Apply step(3) to the other object till you get another equation and label (2).

5. Solve the two Equations to find the unknown.

Sample Problem 5.03: Block on table, block hanging

Figure 5-13 shows a block S (the *sliding block*) with mass $M = 3.3$ kg. The block is free to move along a horizontal frictionless surface and connected, by a cord that wraps over a frictionless pulley, to a second block H (the *hanging block*), with mass $m = 2.1$ kg. The cord and pulley have negligible masses compared to the blocks (they are "massless"). The hanging block H falls as the sliding block S accelerates to the right. Find (a) the acceleration of block S, (b) the acceleration of block H, and (c) the tension in the cord.

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