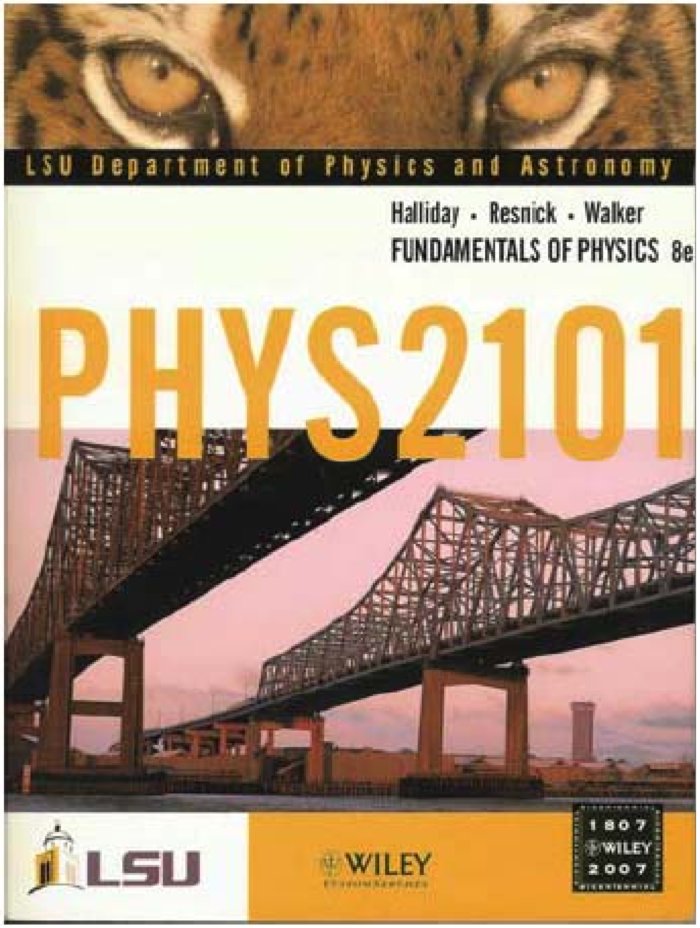


Announcements:

- ***Quiz on Friday the 29th***
- ***First Midterm 6 pm Feb. 3rd***
- ***Help session on Mondays 12:30 until 4:30 pm in 102***

- Special "extended time" Exams

  The Examination will be given in Room E-134 Howe-Russell from 6 pm to 8 pm for all sections.

  Each student gets 90 minutes.

- **Web Homework Statistics:**
  There are 73 students registered in section 3 of 2102
  70 recorded scores on HW #1

Keep your momentum !

Chapter 5: Force and Motion-I

Force and Motion - I (Chapt 5)
- gravitational force
- tension force
- normal force

Force and Motion - II (Chapt. 6)
- friction force
- "centripetal force" force

Newton's laws

1st Law - $\vec{F}_{net} = \sum \vec{F}_i$ $\quad$ $INERTIA -$ stay in motion (rest)

2nd Law - $\vec{F}_{net} = m\vec{a}$ $\quad$ vector $\rightarrow$ $\left\{ \begin{array}{l} F_{net,x} = ma_x \\ F_{net,y} = ma_y \\ F_{net,z} = ma_z \end{array} \right\}$

3rd Law - $\vec{F}_{A\rightarrow B} = -\vec{F}_{B\rightarrow A}$ $\quad$ (i.e. interaction pairs)

Newton's First Law

Before Newton Scientists thought that a **force** was required in order to keep an object moving at constant velocity.

An object was thought to be in it's **"natural state"** when at rest. For example, if we slide an object on a floor with an initial speed v_0 very soon the object will come to rest—**Because of Friction.**

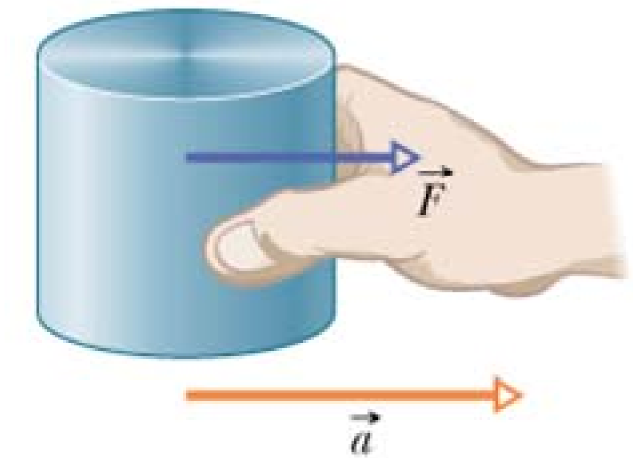
Newton checked his ideas on the motion of the moon and the planets. In space there is no friction, therefore he was able to determine the correct form of what is since known as "**Newton's first law**":

> **If no force acts on a body, the body's velocity cannot change; that is, the body cannot accelerate.**

Note: If several forces act on a body (say $\vec{F}_A,\ \vec{F}_B,$ and $\vec{F}_C$) the net force $\vec{F}_{\text{net}}$ is defined as $\vec{F}_{\text{net}} = \vec{F}_A + \vec{F}_B + \vec{F}_C$, i.e., $\vec{F}_{\text{net}}$ is the vector sum of $\vec{F}_A, \vec{F}_B,$ and $\vec{F}_C$.

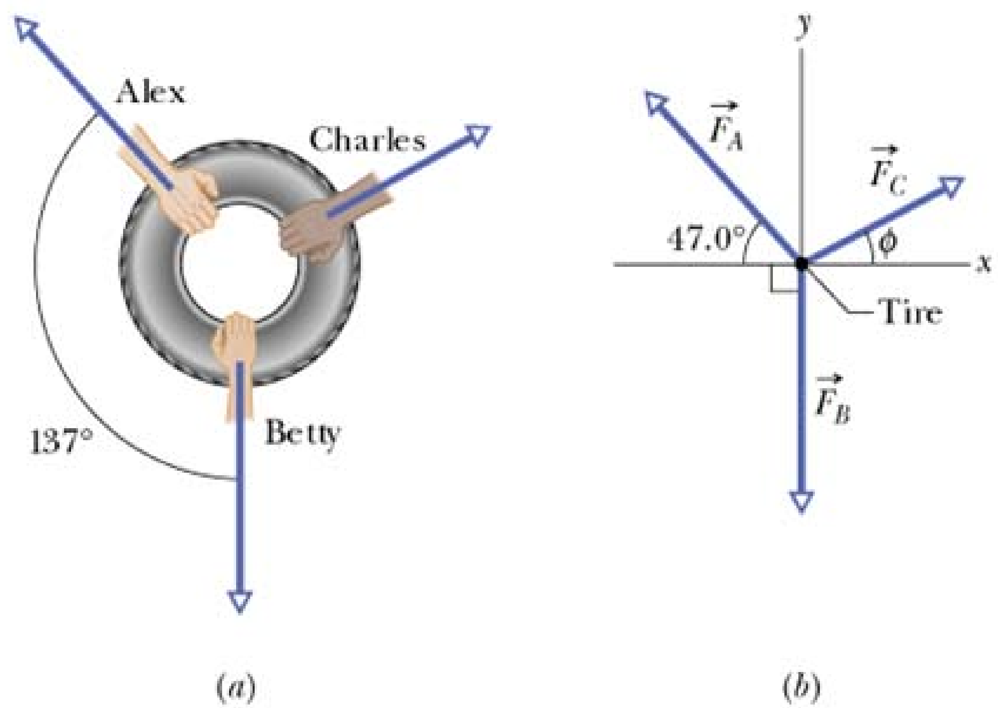
> **If no NET force acts on a body, the body's velocity cannot change; that is, the body cannot accelerate.**

Force: The concept of force was tentatively defined as a push or pull exerted on an object. We can define a force exerted on an object quantitatively by measuring the acceleration it causes using the following procedure.

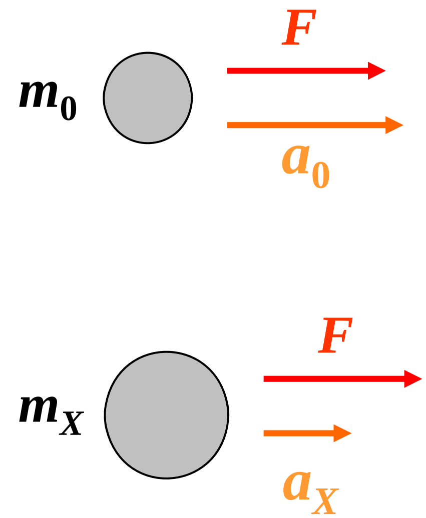


We place an object of mass m = 1 kg on a frictionless surface and measure the acceleration $\boldsymbol{a}$ that results from the application of a force $\boldsymbol{F}$. The force is adjusted so that a = 1 m/s^2. We then say that $\boldsymbol{F}$ **= 1 newton** (symbol: N).

Note: If several forces act on a body (say $\vec{F}_A$, $\vec{F}_B$, and $\vec{F}_C$) the net force $\vec{F}_{\text{net}}$ is defined as $\vec{F}_{\text{net}} = \vec{F}_A + \vec{F}_B + \vec{F}_C$, i.e., $\vec{F}_{\text{net}}$ is the vector sum of $\vec{F}_A, \vec{F}_B$, and $\vec{F}_C$.



Mass: Mass is an ***intrinsic*** characteristic of a body that automatically comes with the existence of the body. But what is it exactly? It turns out that the mass of a body is the characteristic that relates a force F applied on the body and the resulting ***acceleration a.***



Consider that we have a body of mass m_0 = 1 kg on which we apply a force F = 1 N. According to the definition of the newton , F causes an acceleration a_0 = 1 m/s^2. We now apply F on a second body of unknown mass m_X, which results in an acceleration a_X . The ratio of the accelerations is inversely proportional to the ratio of the masses:

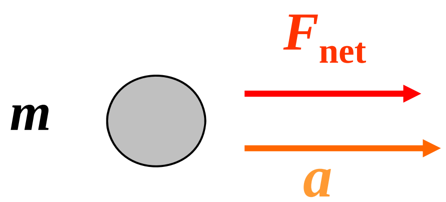
$$\frac{m_X}{m_0} = \frac{a_0}{a_X} \rightarrow m_X = m_0 \frac{a_0}{a_X}$$

Thus by measuring a_X we are able to determine the mass m_X of any object.

Mass gives a quantitative measurement of the inertia of an object

Newton's Second Law

The results of the discussions on the relations between the net force F_{net} applied on an object of mass m and the resulting acceleration a can be summarized in the following statement known as "**Newton's second law**":



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

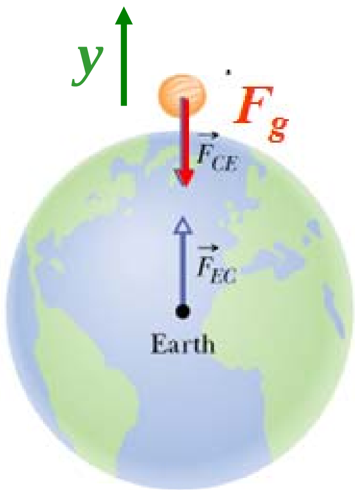
In equation form Newton's second law can be written as:

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

The above equation is a compact way of summarizing three separate equations, one for each coordinate axis:

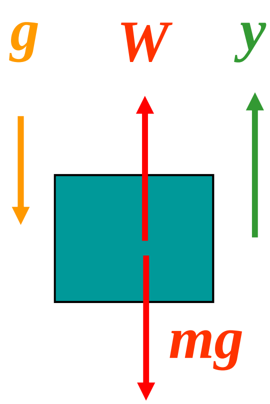
$$F_{\text{net},x} = ma_x \qquad F_{\text{net},y} = ma_y \qquad F_{\text{net},z} = ma_z$$

Common Examples



The Gravitational Force: It is the force that the Earth exerts on any object (in the picture a cantaloupe). It is directed toward the center of the Earth. Its magnitude is given by Newton's second law.

$$\vec{F}_g = m\vec{a} = -mg\hat{j} \qquad \left|\vec{F}_g\right| = mg$$

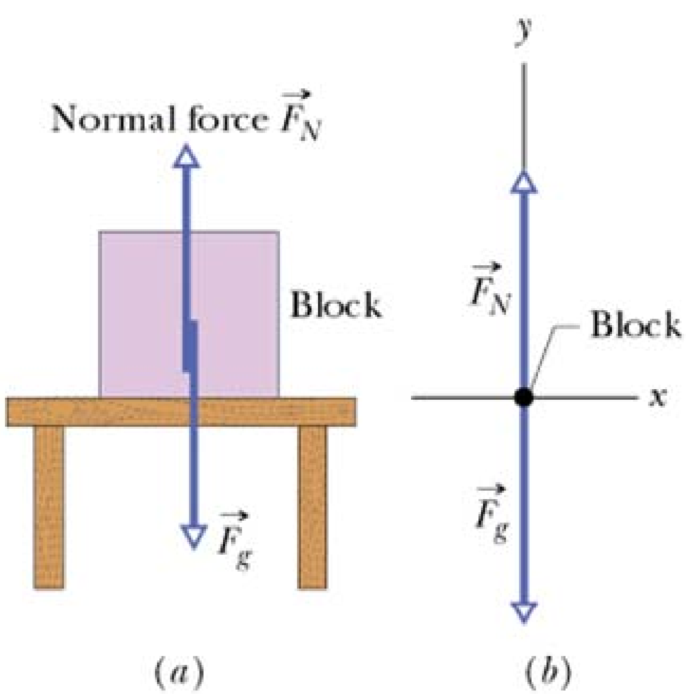


Weight: The weight of a body is defined as the magnitude of the force required to prevent the body from falling freely.

$$F_{\text{net},y} = ma_y = W - mg = 0 \rightarrow W = mg$$

Note: The weight of an object is NOT its mass. If the object is moved to a location where the acceleration of gravity is different (e.g., the moon, where $g_m = 1.7\ \text{m/s}^2$), the mass does not change but the weight does.

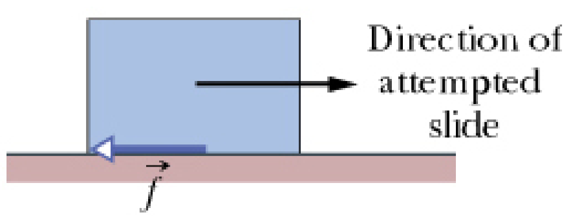
Contact Forces: These forces act between two objects that are in contact. The contact forces have two components: one that is acting along the normal to the contact surface **(normal force)** and a second component that is acting parallel to the contact surface **(frictional force)**.



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. An example is shown in the picture to the left. A block of mass *m* rests on a table.

$$F_{\text{net},y} = ma_y = F_N - mg = 0 \rightarrow F_N = mg$$

Note: In this case $F_N = mg$. This is not always the case.



Friction: If we slide or attempt to slide an object over a surface, the motion is resisted by a bonding between the object and the surface. This force is known as "friction." (Ch. 6).

Tension: This is the force exerted by a rope or a cable attached to an object. Tension has the following characteristics:

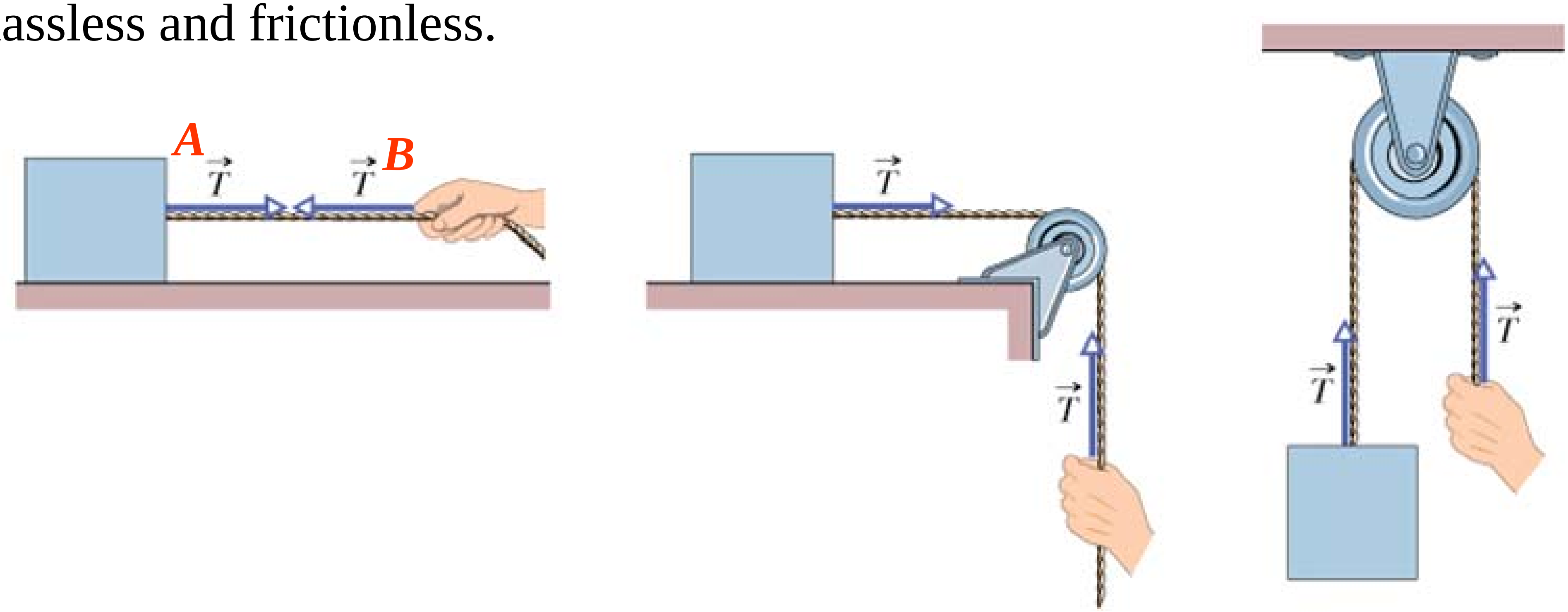
1. It is always directed along the rope.
2. It is always pulling the object.
3. It has the same value along the rope (for example, between points *A* and *B*).

The following assumptions are made:

a. The rope has negligible mass compared to the mass of the object it pulls.

b. The rope does not stretch.

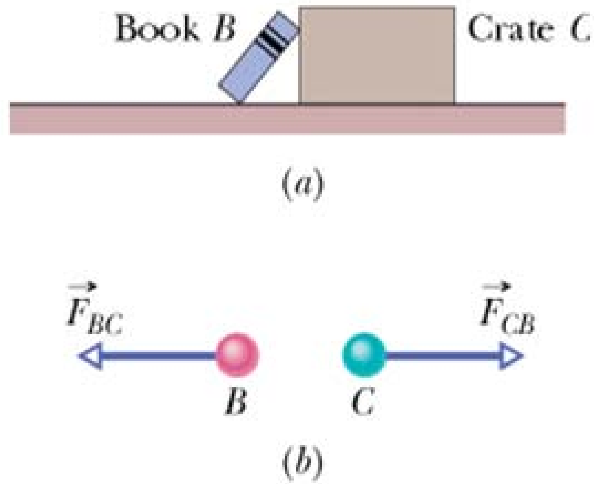
If a pulley is used as in Fig.(b) and Fig.(c), we assume that the pulley is massless and frictionless.



(a) (b) (c)

Newton's Third Law:

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



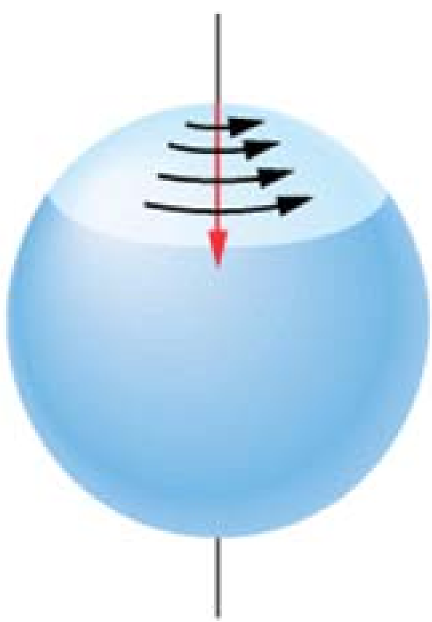
For example, consider a book leaning against a bookcase. We label $\vec{F}_{BC}$, the force exerted on the book by the case. Using the same convention we label $\vec{F}_{CB}$, the force exerted on the case by the book. Newton's third law can be written as $\vec{F}_{BC} = -\vec{F}_{CB}$. The book together with the bookcase are known as a "third-law force pair."

A second example is shown in the picture to the left. The third-law pair consists of the Earth and a cantaloupe. Using the same convention as above we can express Newton's third law as $\vec{F}_{CE} = -\vec{F}_{EC}$.

Inertial Reference Frames:

We define a reference frame as "**inertial**" if Newton's three laws of motion hold. In contrast, reference frames in which Newton's law are not obeyed are labeled "**noninertial.**"

Newton believed that at least one such inertial reference frame R exists. Any other inertial frame R' that moves with **constant velocity** with respect to R is also an inertial reference frame. In contrast, a reference frame R'' that **accelerates** with respect to R is a noninertial reference frame.



The Earth rotates about its axis once every 24 hours and thus it is accelerating with respect to an inertial reference frame.

It is an approximation to consider the Earth to be an inertial reference frame. This approximation is excellent for most small-scale phenomena, but not for large scale phenomena.

Applying Newton's Laws: Free-Body Diagrams

Newton's laws are implements by drawing a free-body diagram.

Define a "**system.**"

Choose axes and enter **all** the forces that are acting on the system and omit those acting on objects that were not included in the system.

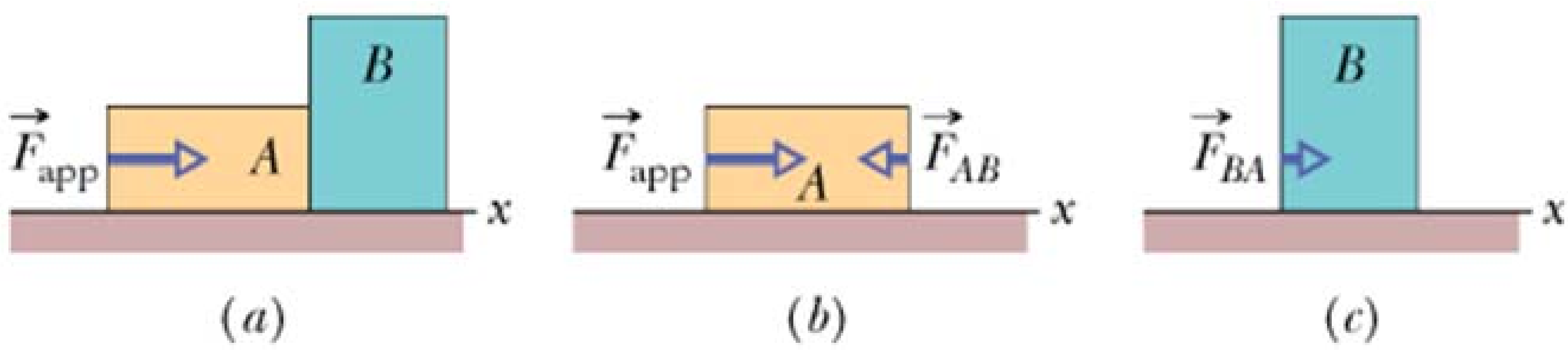
This is a problem that involves two blocks labeled *A* and *B* on which an external force $\vec{F}_{\text{app}}$ is exerted.

We have the following "system" choices:

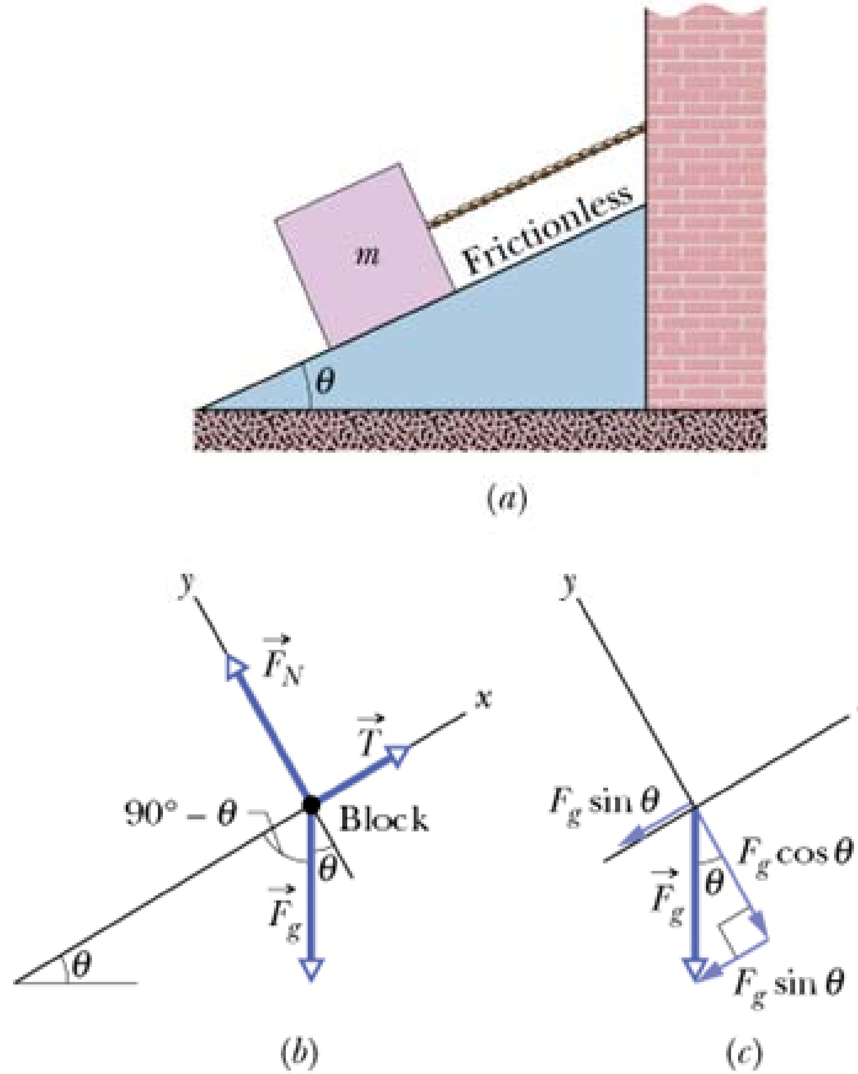
a. System = block *A* + block *B*. The only horizontal force is $\vec{F}_{\text{app}}$.

b. System = block *A*. There are now two horizontal forces: $\vec{F}_{\text{app}}$ and $\vec{F}_{AB}$.

c. System = block *B*. The only horizontal force is $\vec{F}_{BA}$.



Recipe for the Application of Newton's Laws of Motion



- **Choose the system to be studied.**
- **Make a simple sketch of the system.**
- **Choose a convenient coordinate system.**
- **Identify all the forces that act on the system. Label them on the diagram.**
- **Apply Newton's laws of motion to the system.**

Solving Force Problems:

1) **Read the problem and draw a picture.**

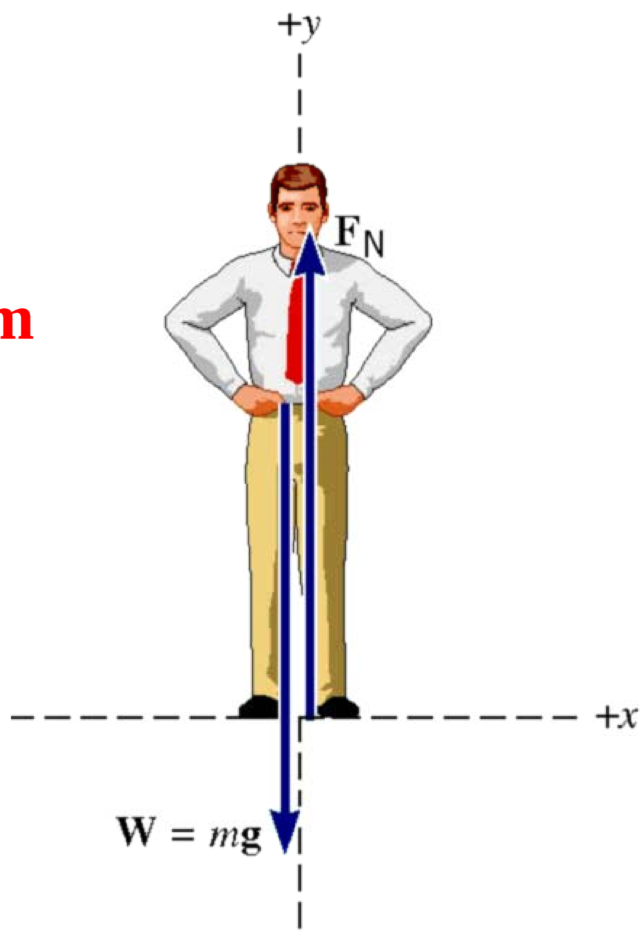
2) **Draw a free-body diagram showing all forces acting on body.**

3) **Draw a convenient coordinate system and resolve forces into components.**

4) **Define direction of acceleration, if any**

5) **Subdivide into differing systems if needed**

6) **Write Force equations for each direction…**
   Solve Newton's 2nd law (vector) for each system



Accelerating Masses

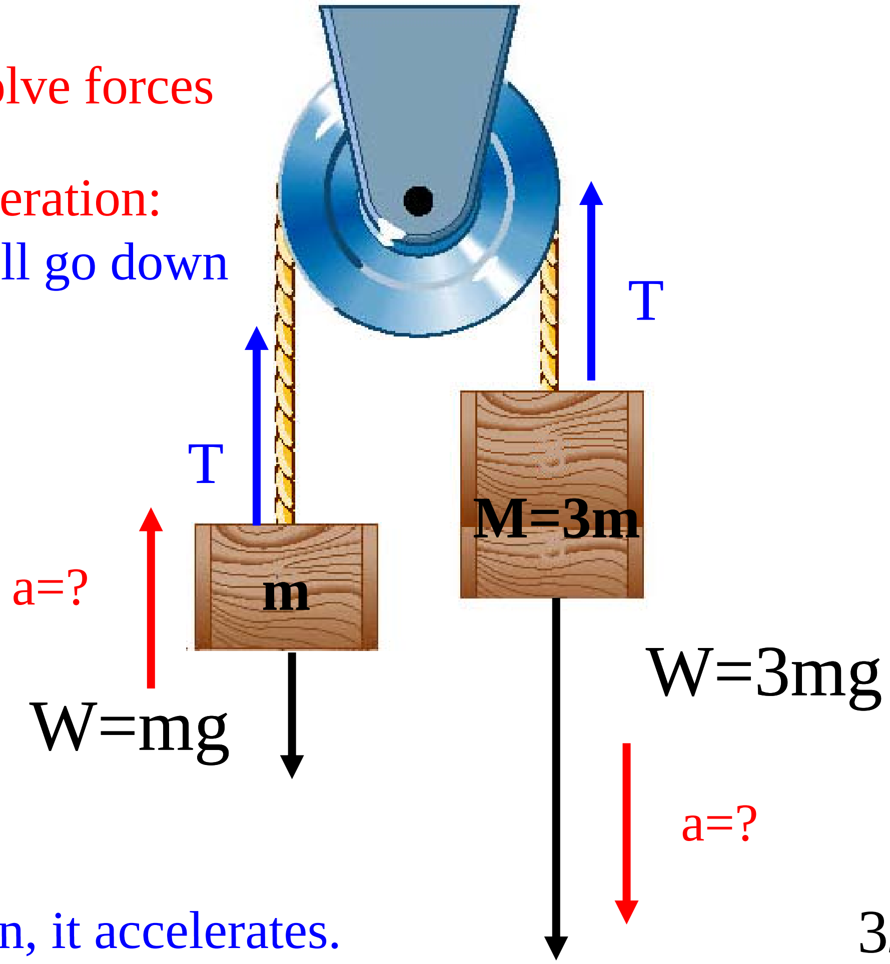
The forces don't balance. What is the acceleration, a?

1) Draw a **free-body diagram**

2) Draw coordinates & resolve forces

3) Define direction of acceleration:

I think the heavier block will go down



If the block M goes down, it accelerates.

Now write your force equations for both masses:

for mass m:

$$ma = T - mg$$

for mass M=3m:

$$Ma = Mg - T$$

$$3ma = 3mg - T$$

$$3ma = 3mg - T$$
$$ma = T - mg$$

$$4ma = 2mg$$

$$a = \tfrac{1}{2} g$$

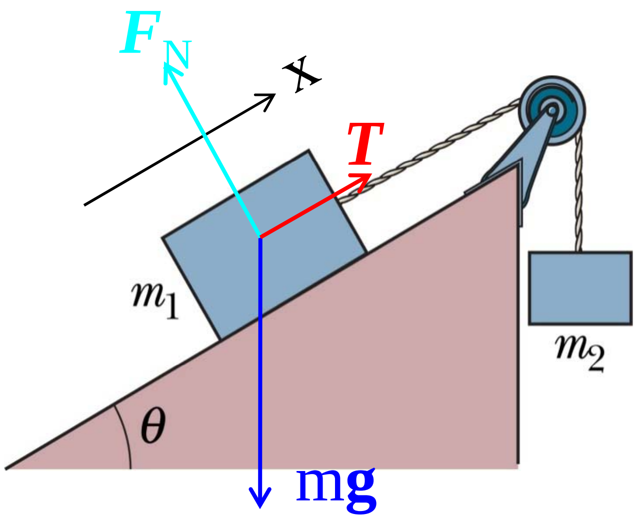
Mass on Inclined Plane

I want to lower a 5 kg mass down a frictionless plane that is inclined 30° from the horizontal. I can provide 20 N tension on the string connected to the mass. What is the net acceleration along the plane?

Solution: We know m_1=5 kg, T=20N, and θ=30^0.

Set up a coordinate system:

Draw Free Body Diagram.



$$\sum F_x = T - m_1 g \sin\theta = m_1 a$$

$$\sum F_y = F_N - m_1 g \cos\theta = 0$$

Only need x equation:

$$\sum F_x = 20 - 5(9.8)(0.866) = -22.4N$$

$$a_x = -4.5 m/s^2$$