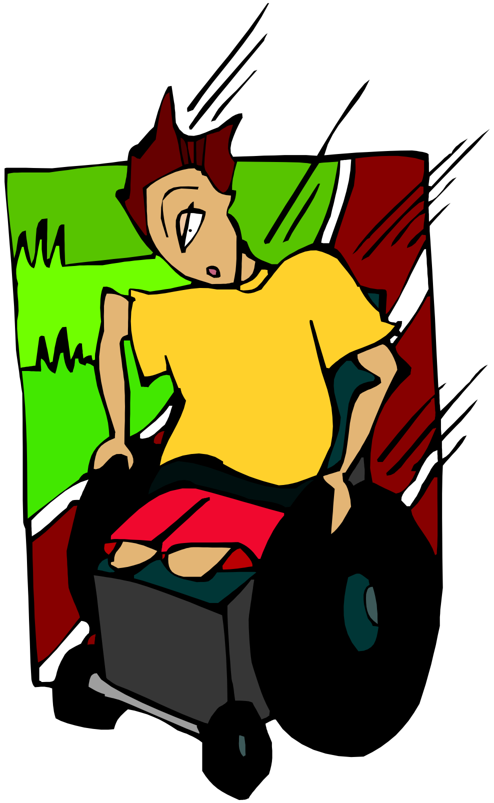
Applied Physics NS (1001)

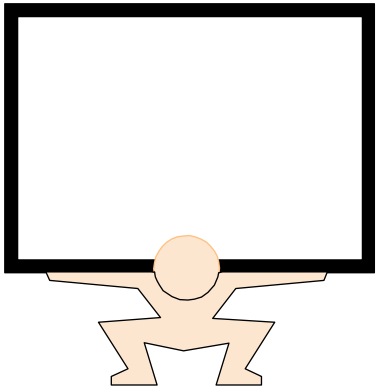
Forces and Motion

Forces can create changes in motion (acceleration or deceleration).

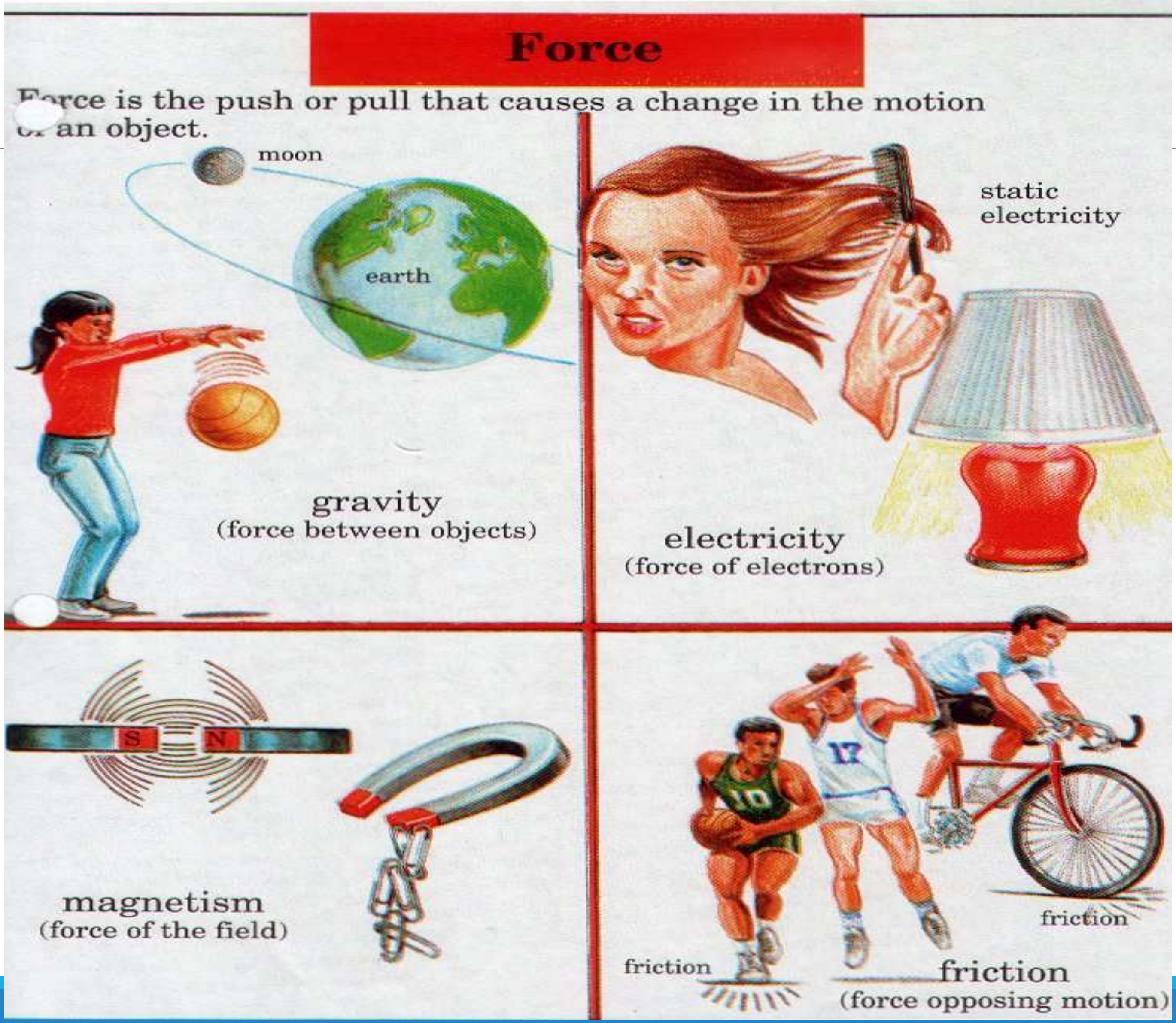


Definition of a Force

A force is a push or a pull.



THE CONCEPT OF FORCE



➢Four Fundamental Forces.

So practically there are just four fundamental forces in the Universe.

Two of them are very familiar to us which we experience in our every day life,

- **The electromagnetic force, and**
- **The gravitational force.**

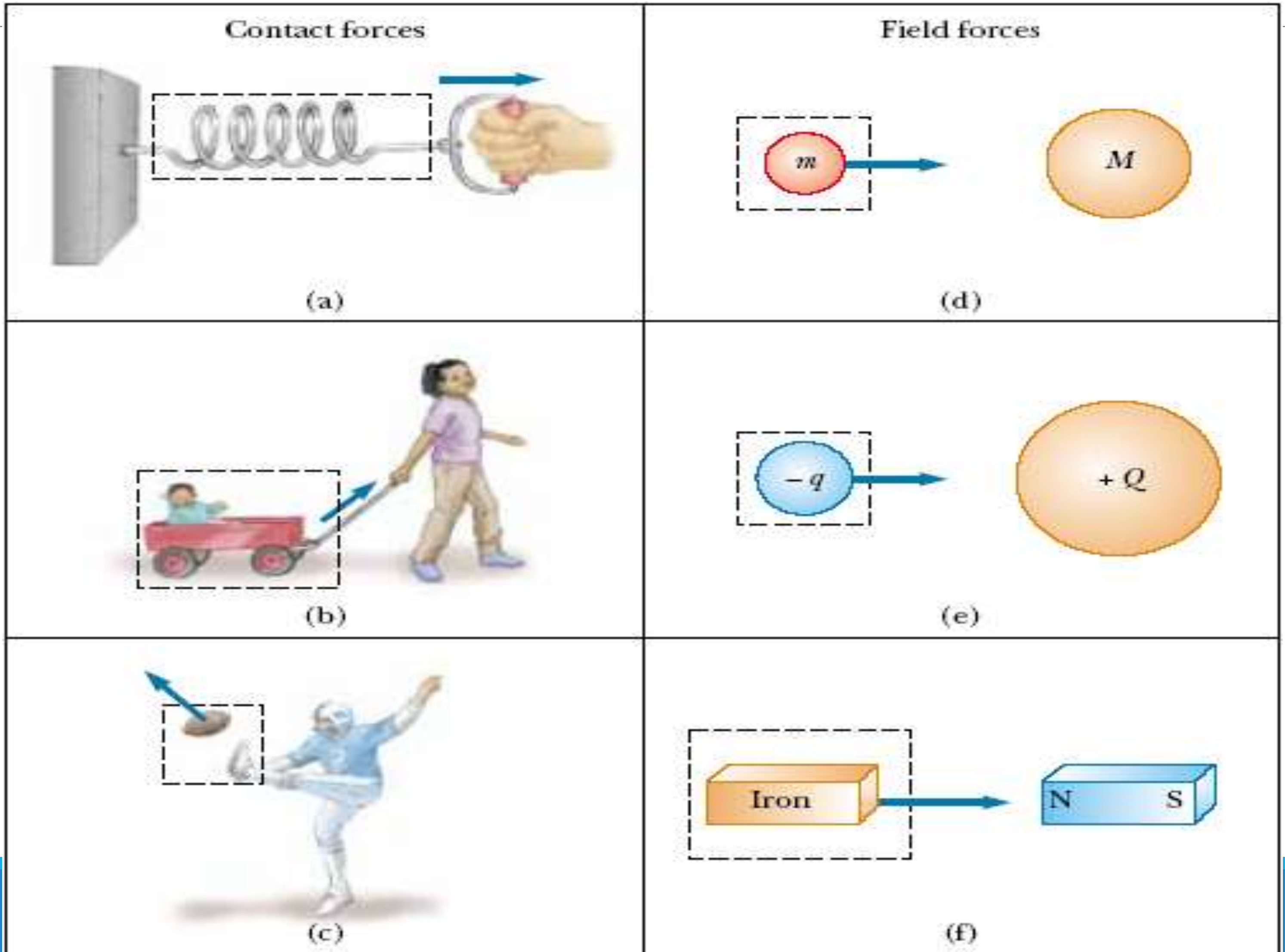
The other two are invisible unless we probe deep inside the nucleus of the atom. They are called “

- **Strong nuclear force** and the “
- **Weak nuclear force**.

Classes of forces

Contact forces :

Field Force / Action at a distance force

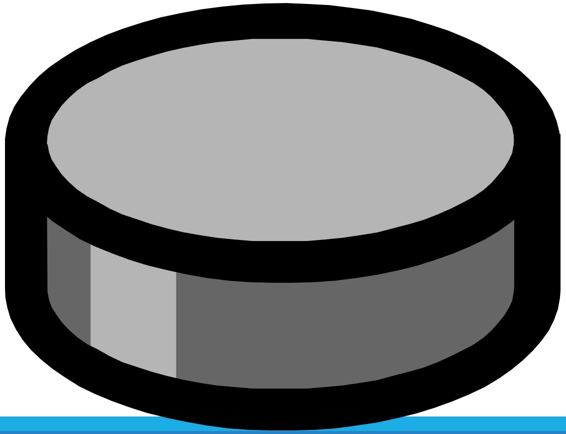


Friction

A force that opposes, or works against, motion of two objects that are touching.

Friction

- Friction causes an object to slow down and stop.
- Since the amount of energy stays constant, the energy becomes heat.



Frictional Forces

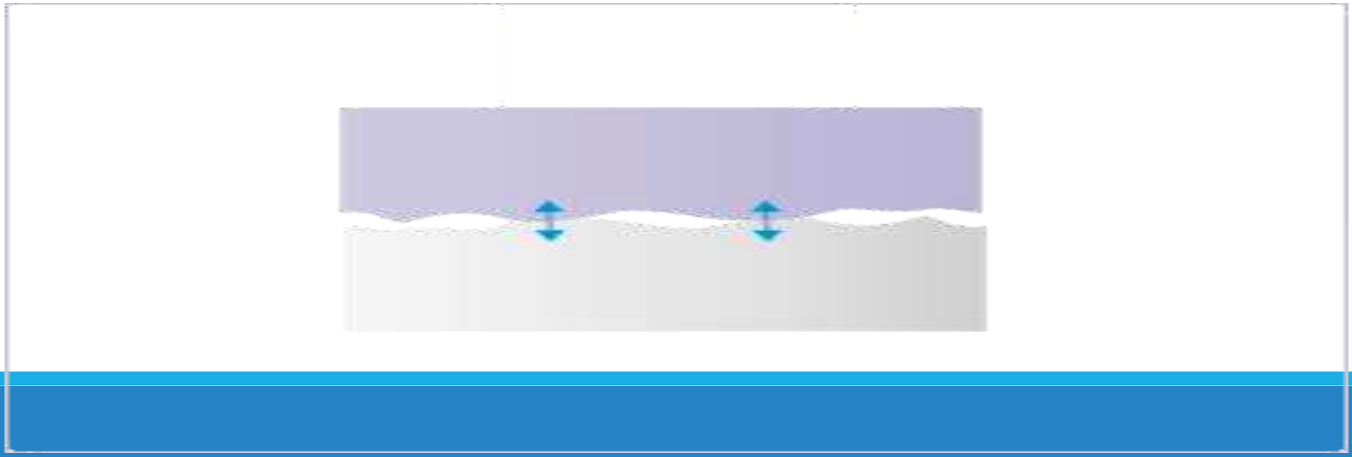
Friction: a contact force *parallel* to the contact surfaces.

Static friction acts to prevent objects from sliding.

$$f_s^{max} = \mu_s N$$

Kinetic friction acts to make sliding objects slow down. Sometimes called Dynamic friction.

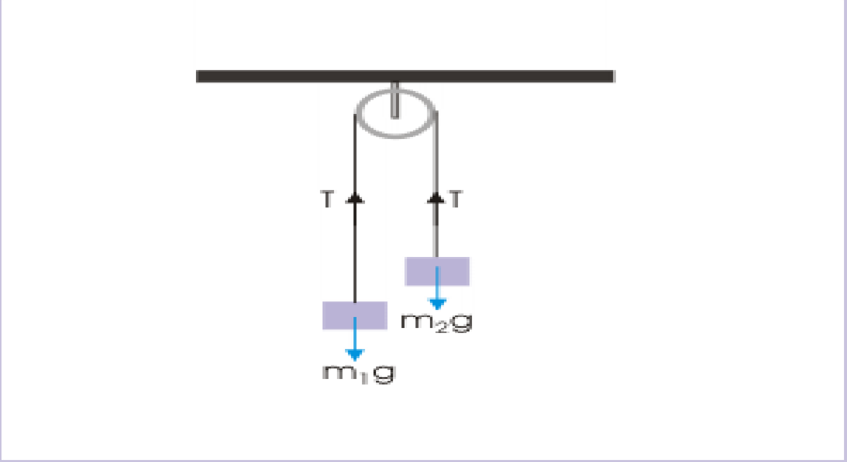
$$f_d = \mu_d N$$

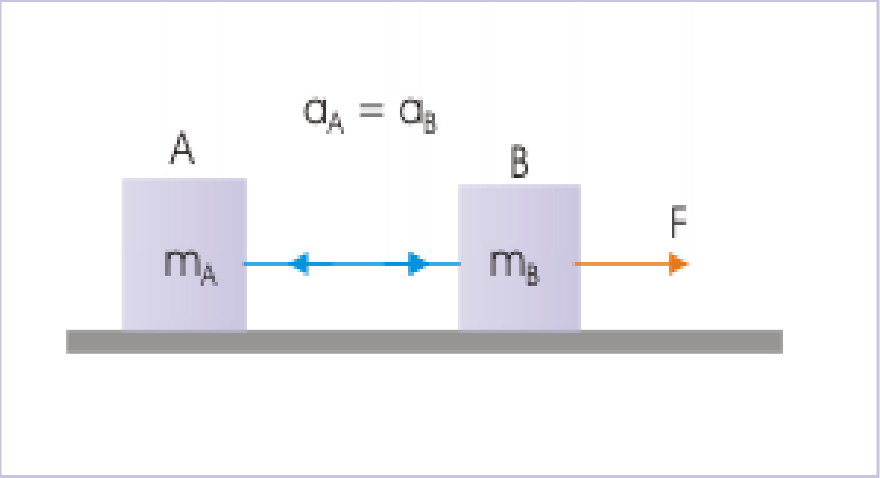


Tension

This is the force transmitted through a “rope” from one end to the other.

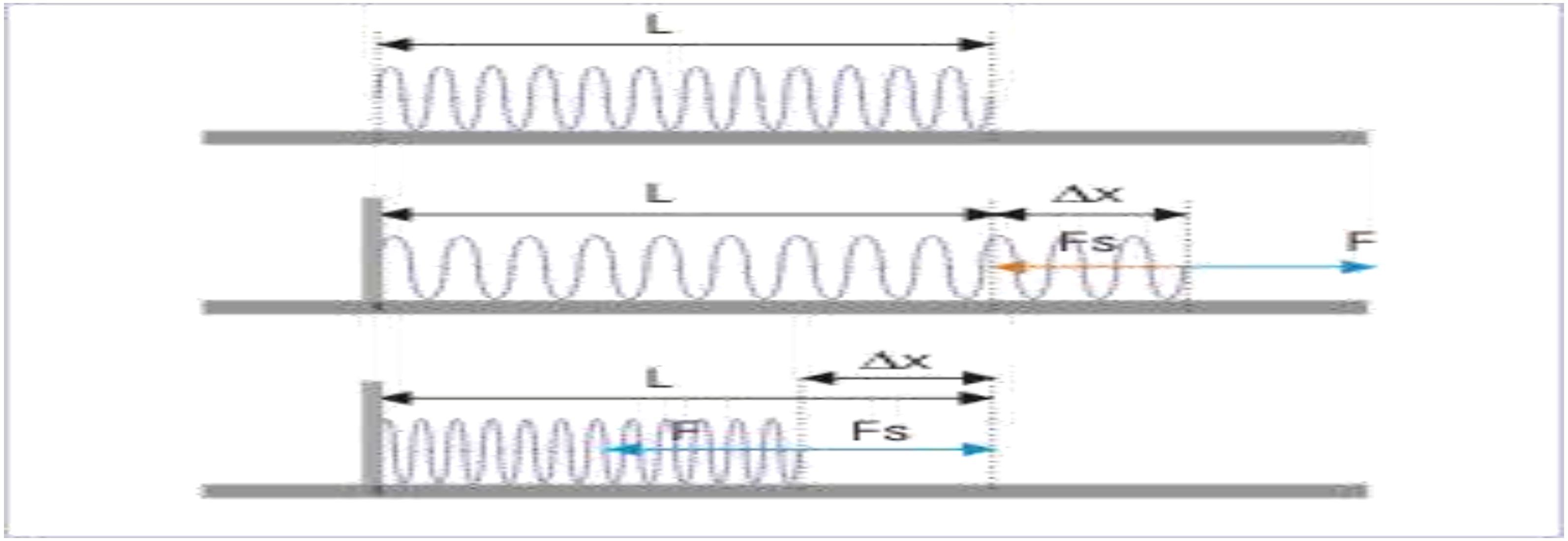
An **ideal** cord has zero mass, does not stretch, and the tension is the same throughout the cord.





Spring Force

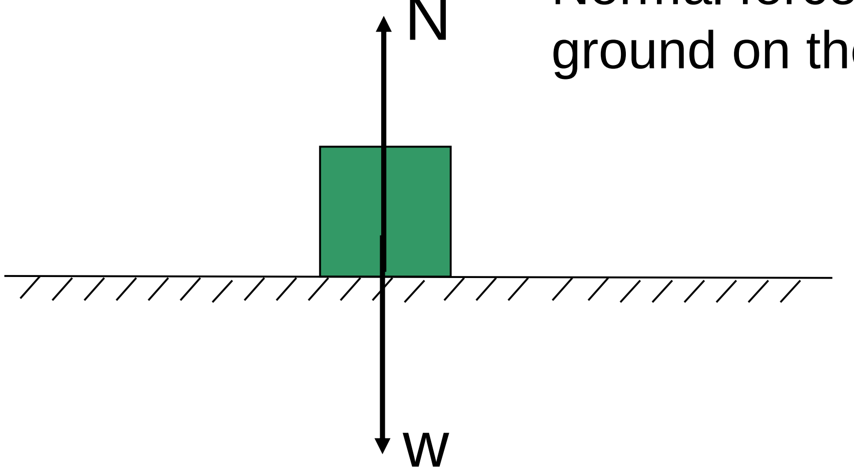
The spring force is the force exerted by a compressed or stretched spring upon any object that is attached to it. An object that compresses or stretches a spring is always acted upon by a force that restores the object to its rest or equilibrium position.



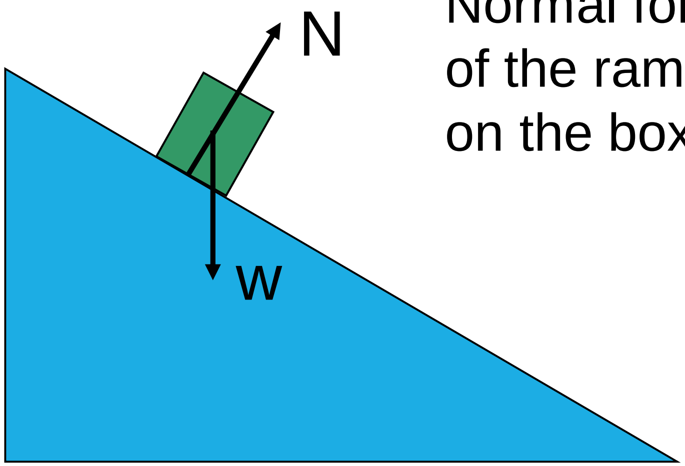
Normal Forces

Normal force: this force acts in the direction perpendicular to the contact surface.

Normal force of the ground on the box

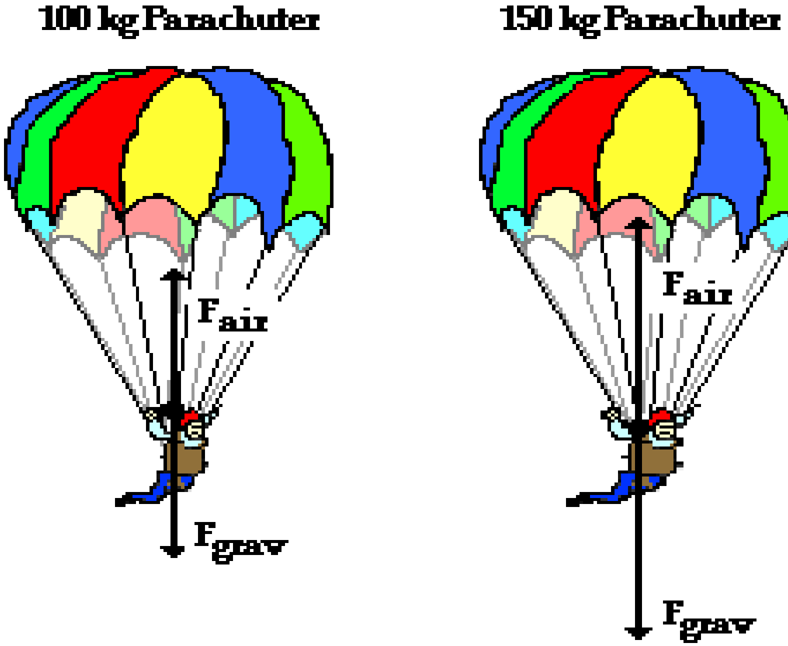


Normal force of the ramp on the box



Air Resistance Force

The air resistance is a special type of frictional force that acts upon objects as they travel through the air. The force of air resistance is often observed to oppose the motion of an object. This force will frequently be neglected due to its negligible magnitude (and due to the fact that it is mathematically difficult to predict its value). It is most noticeable for objects that travel at high speeds (e.g., a skydiver or a downhill skier) or for objects with large surface areas.



Applied Force

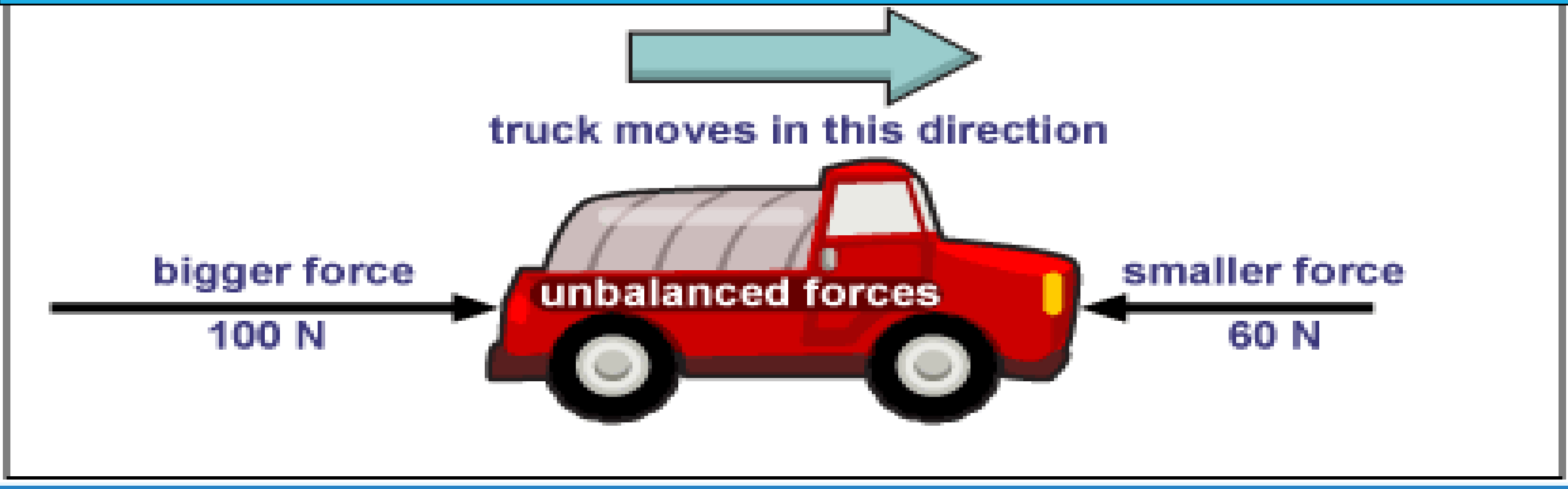
An applied force is a force that is applied to an object by a person or another object. If a person is pushing a desk across the room, then there is an applied force acting upon the object. The applied force is the force exerted on the desk by the person.

Balanced Force

Equal forces in opposite directions produce no motion

Unbalanced Forces

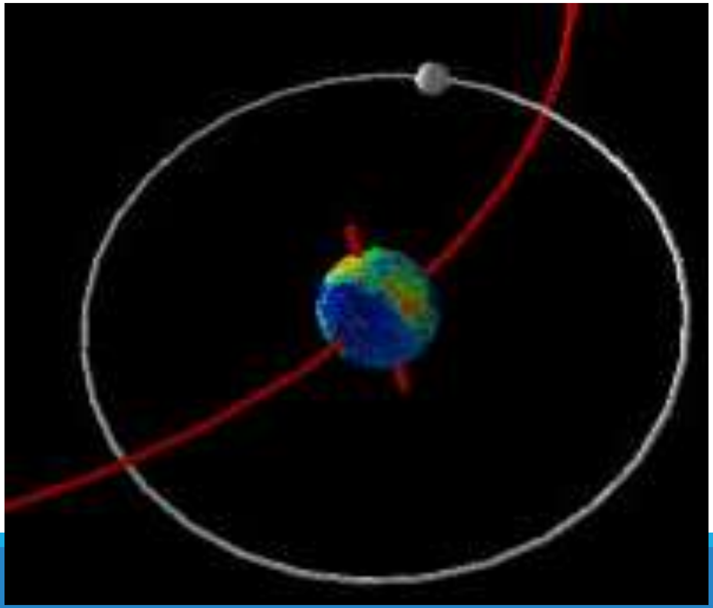
Unequal opposing forces produce an unbalanced force causing motion

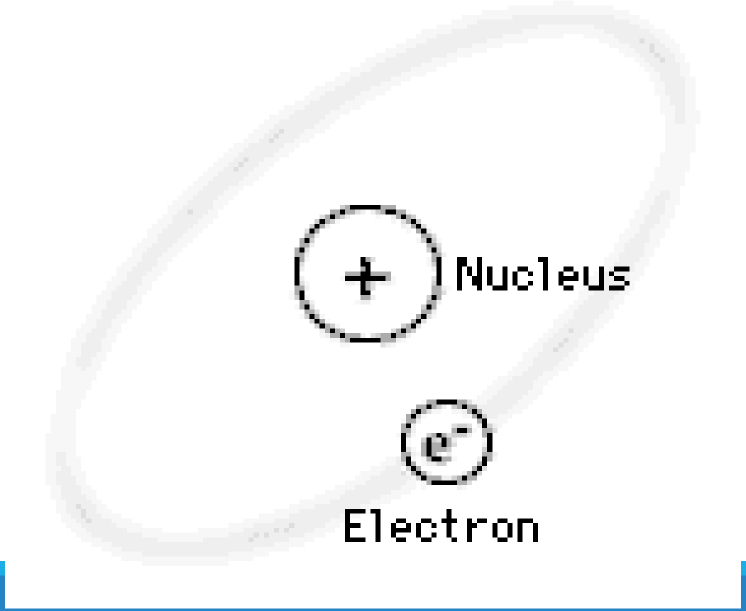


Laws of Motion

If an object moves with uniform motion (constant velocity),no force is required for the motion to be maintained.

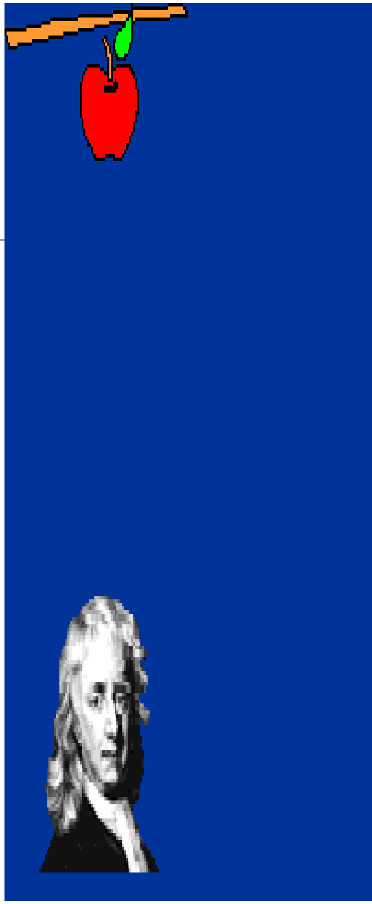
Moon-Earth system , Electron revolves around nucleus





Laws of Motion

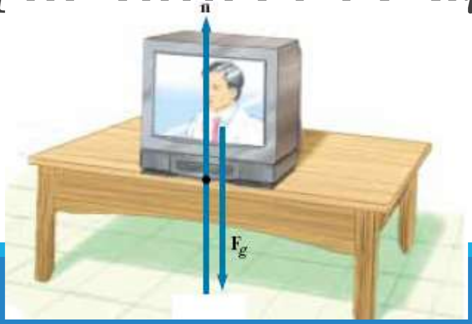
What happens when several forces act simultaneously on an object?



The object accelerates only if the net force(total/resultant/unbalance), acting on it is not equal to zero.

If the net force exerted on an object is zero, then the acceleration of the object is zero and its velocity remains constant.

The object is said to be in equilibrium.



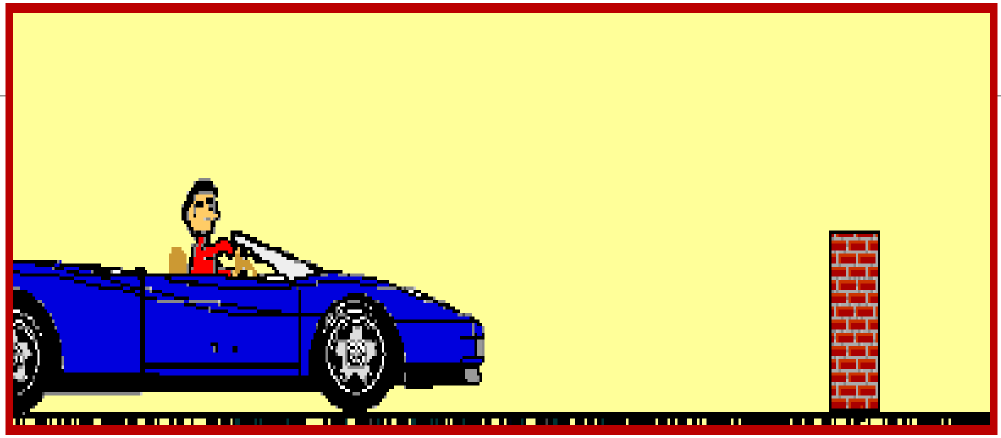
Newton's First Law

An object at rest will stay at rest, and an object in motion will stay in motion at constant velocity, unless acted upon by an unbalanced force.

Once airborne, unless acted on by an unbalanced force (gravity and air – fluid friction), it would never stop!
Unless acted upon by an unbalanced force, this golf ball would sit on the tee forever.

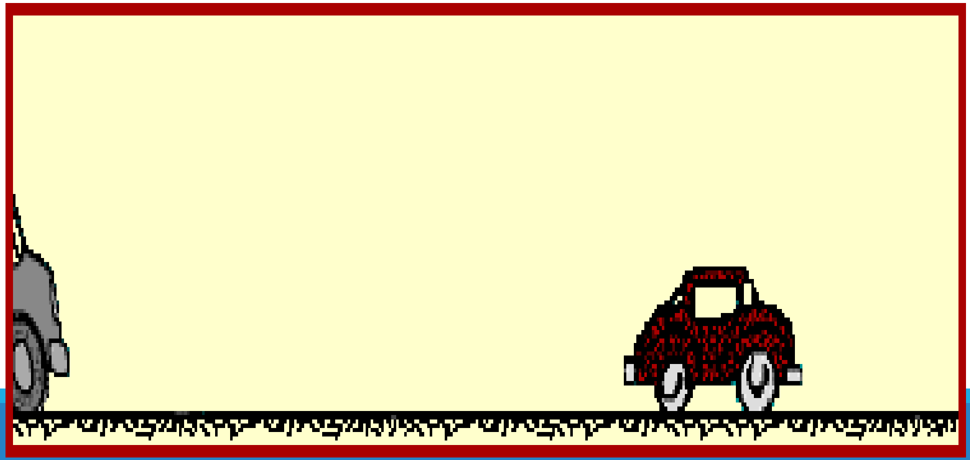
Inertia

The tendency of an object to resist any attempt to change its velocity is called the inertia of the object.



Don't let this be you. Wear seat belts.

Because of inertia, objects (including you) resist changes in their motion. When the car going 80 km/hour is stopped by the brick wall, your body keeps moving at 80 m/hour.



Mass:

Mass is that property of an object that specifies how much inertia the object has.

The greater the mass of an object, the less that object accelerates under the action of an applied force.

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

Mass is an inherent property of an object and is independent of the object's surroundings and of the method used to measure it. Mass is a scalar quantity.

Weight :

The weight of an object is equal to the magnitude of the gravitational force exerted on the object and varies with location.

$$F = mg$$

For example, a person who weighs 180 lb on the Earth weighs only about 30 lb on the Moon. On the other hand, the mass of a body is the same everywhere: an object having a mass of 2 kg on the Earth also has a mass of 2 kg on the Moon. Weight is a vector quantity .

What causes "weightlessness"?

Even in the space shuttle, there is a force of attraction exerted by the earth on the shuttle and its contents.

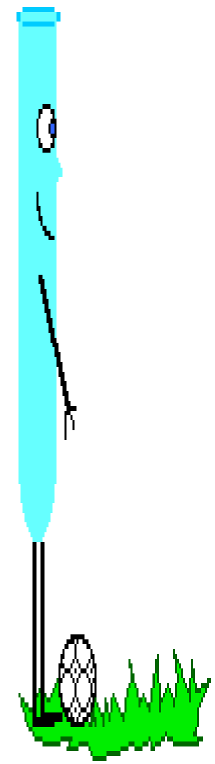
When the space shuttle temporarily "falls" toward the earth, the contents of the space shuttle appear to be weightless, but in fact they are falling with the space shuttle. This is called "freefall".

Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

$$\sum \mathbf{F} = m\mathbf{a}$$

$$\sum F_x = ma_x \qquad \sum F_y = ma_y \qquad \sum F_z = ma_z$$

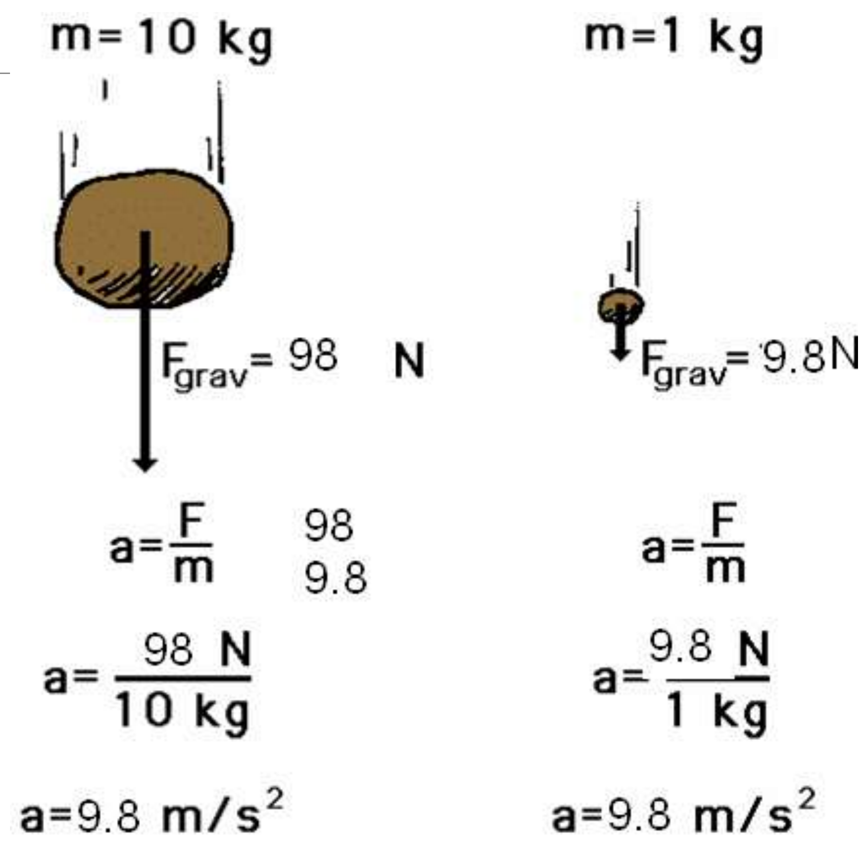


- ***When mass is in kilograms and acceleration is in m/s/s, the unit of force is in Newtons (N).***
- ***One Newton is equal to the force required to accelerate one kilogram of mass at one meter/second/second***

Newton's 2nd Law proves that different masses accelerate to the earth at the same rate, but with different forces.

We know that objects with different masses accelerate to the ground at the same rate.

However, because of the 2nd Law we know that they don't hit the ground with the same force.



F = ma

98 N = 10 kg x 9.8 m/s/s

F = ma

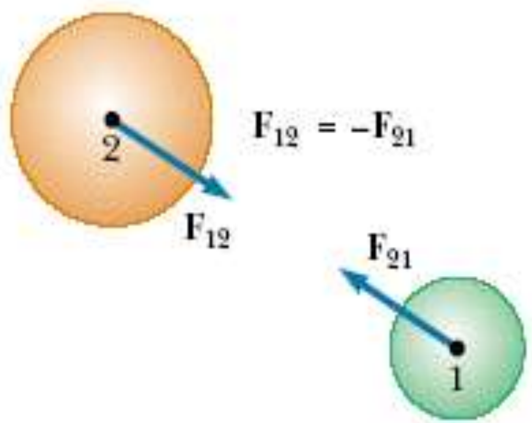
9.8 N = 1 kg x 9.8 m/s/s

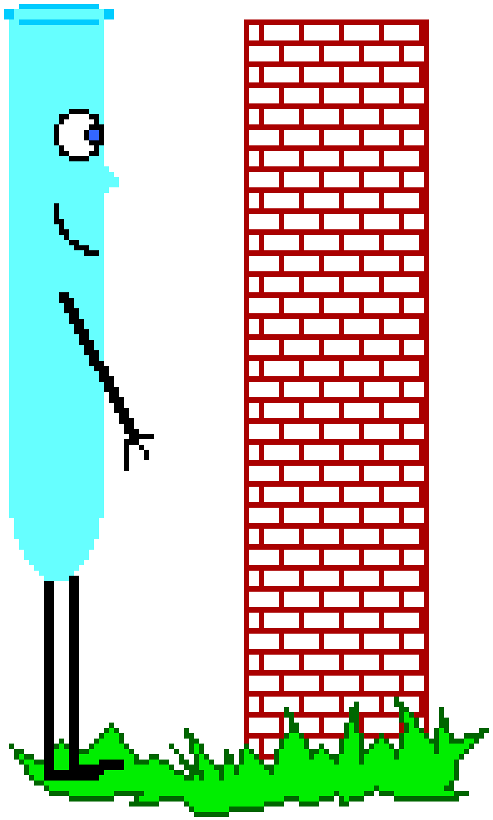
Newton's Third Law

If two objects interact, the force $\mathbf{F}_{12}$ exerted by object 1 on object 2 is equal in magnitude to and opposite in direction to the force $\mathbf{F}_{21}$ exerted by object 2 on object 1:

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

For every action, there is an equal and opposite reaction.





Newton's 3rd Law in Nature

Consider the propulsion of a fish through the water. A fish uses its fins to push water backwards. In turn, the water *reacts* by pushing the fish forwards, propelling the fish through the water.

The size of the force on the water equals the size of the force on the fish; the direction of the force on the water (backwards) is opposite the direction of the force on the fish (forwards).

3rd Law

Flying gracefully through the air, birds depend on Newton’s third law of motion. As the birds push down on the air with their wings, the air pushes their wings up and gives them lift.

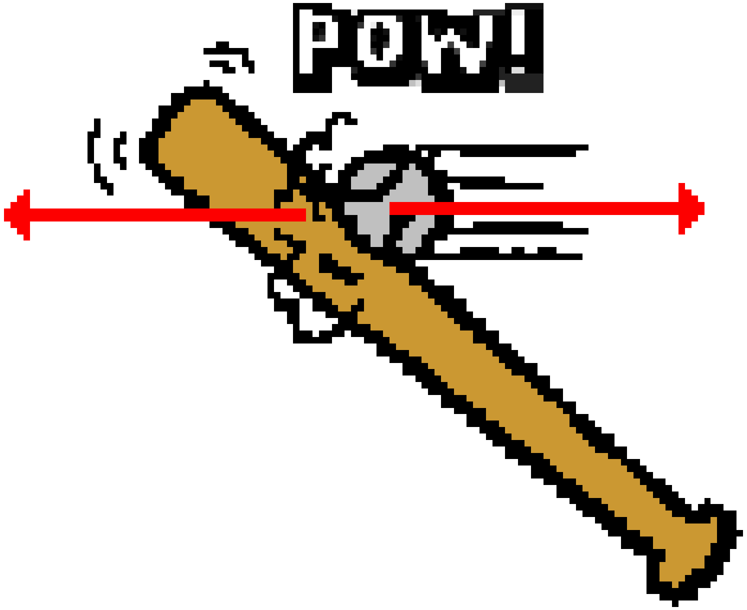
Consider the flying motion of birds. A bird flies by use of its wings. The wings of a bird push air downwards. In turn, the air reacts by pushing the bird upwards.

The size of the force on the air equals the size of the force on the bird; the direction of the force on the air (downwards) is opposite the direction of the force on the bird (upwards).

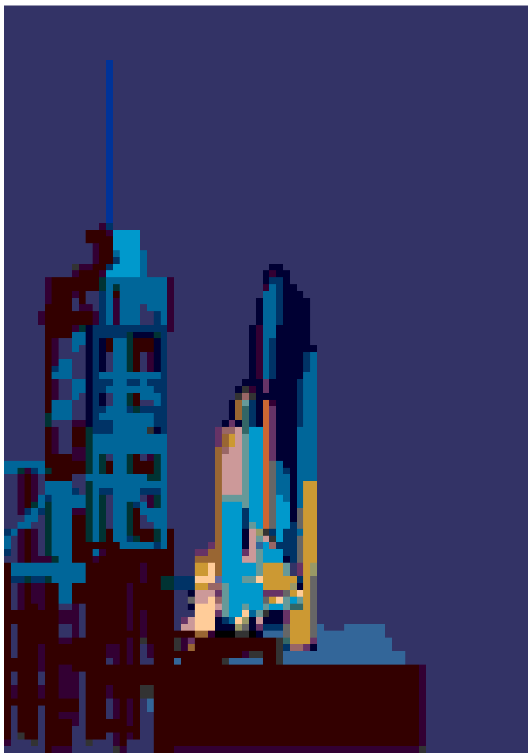
Action-reaction force pairs make it possible for birds to fly.

Other examples of Newton's Third Law

The baseball forces the bat to the left (an action); the bat forces the ball to the right (the reaction).



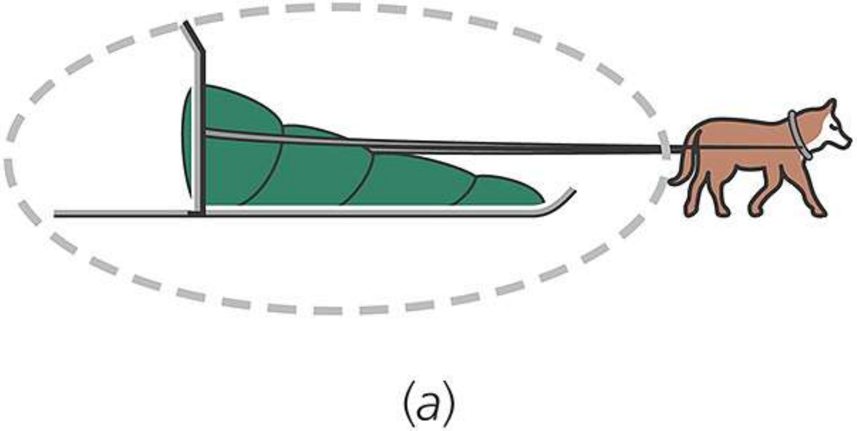
3^{rd} Law

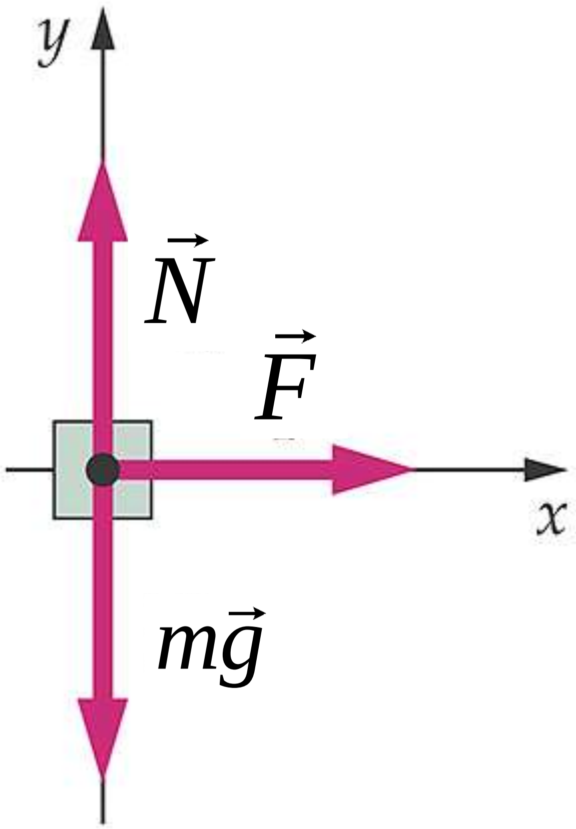


The reaction of a rocket is an application of the third law of motion. Various fuels are burned in the engine, producing hot gases.

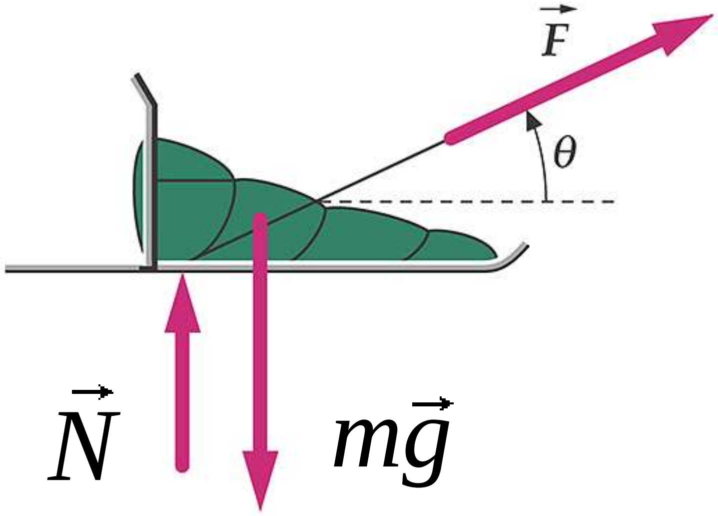
The hot gases push against the inside tube of the rocket and escape out the bottom of the tube. As the gases move downward, the rocket moves in the opposite direction.

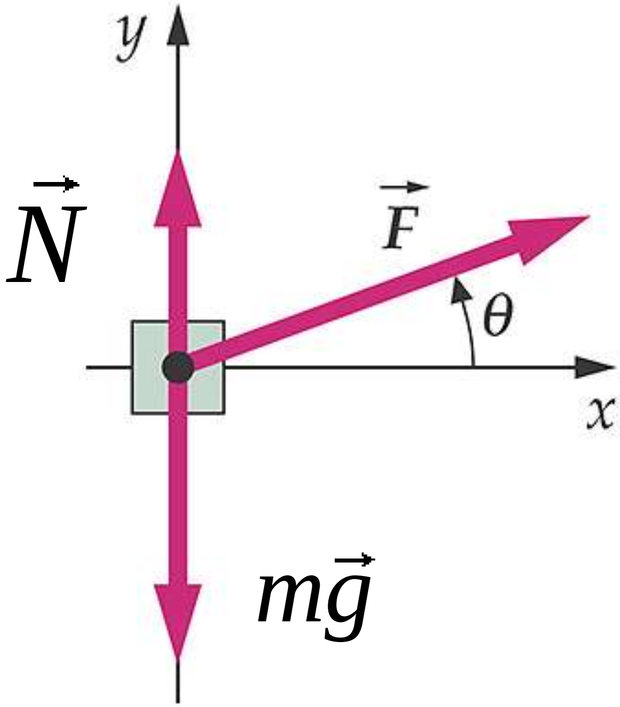
Free Body Diagram





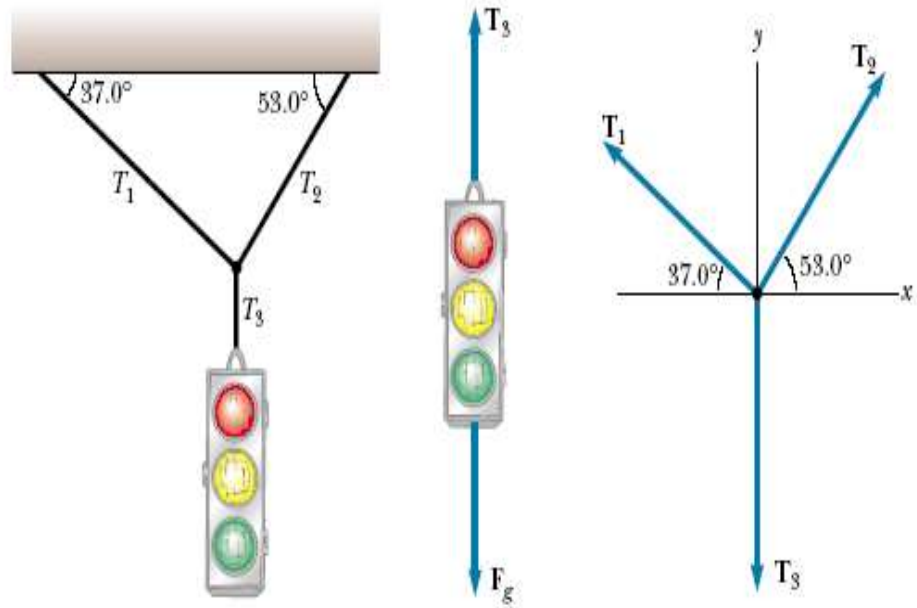
Same problem but the applied force is angled up





A Traffic Light at Rest

A traffic light weighing 125 N hangs from a cable tied to two other cables fastened to a support. The upper cables make angles of 37.0° and 53.0° with the horizontal. Find the tension in the three cables.



Force	x Component	y Component
$\mathbf{T}_1$	$-T_1 \cos 37.0°$	$T_1 \sin 37.0°$
$\mathbf{T}_2$	$T_2 \cos 53.0°$	$T_2 \sin 53.0°$
$\mathbf{T}_3$	0	-125 N

$$\sum F_x = -T_1 \cos 37.0° + T_2 \cos 53.0° = 0$$

$$\sum F_y = T_1 \sin 37.0° + T_2 \sin 53.0° + (-125\ N) = 0$$

$$T_1 \sin 37.0° + (1.33T_1)(\sin 53.0°) - 125\text{ N} = 0$$

$$T_2 = T_1\left(\frac{\cos 37.0°}{\cos 53.0°}\right) = 1.33T_1$$

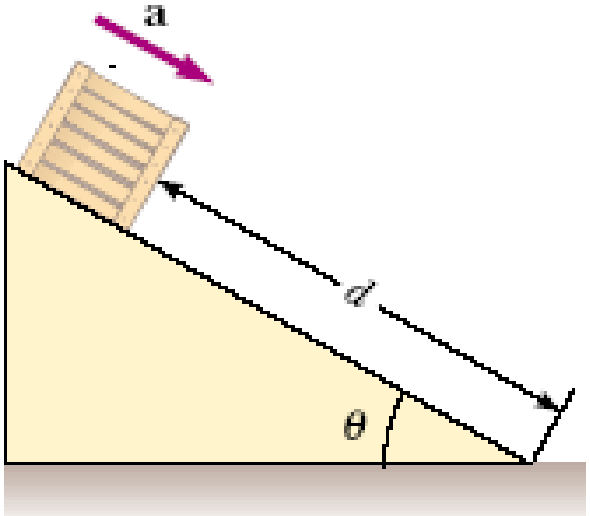
$$T_1 = \boxed{75.1\text{ N}}$$

$$T_3 = F_g = \boxed{125\text{ N.}}$$

$$T_2 = 1.33T_1 = \boxed{99.9\text{ N}}$$

Crate on a Frictionless Incline

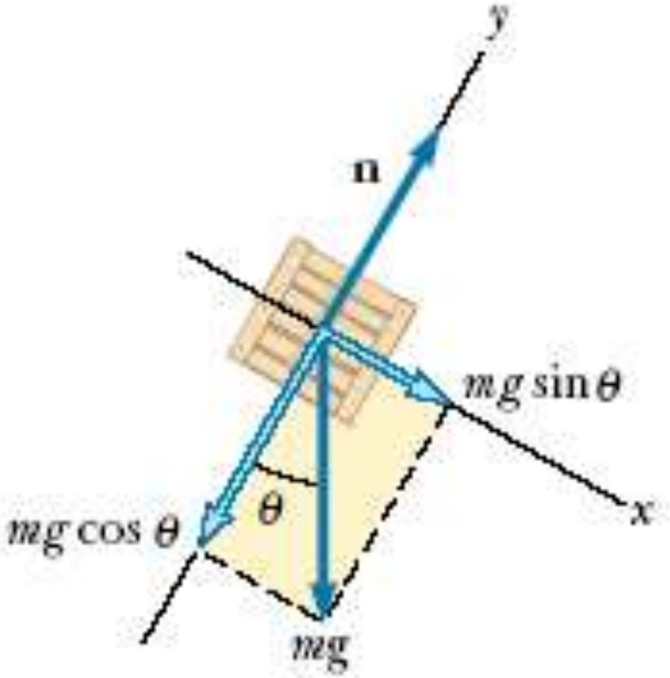
A crate of mass m is placed on a frictionless inclined plane of angle θ. (a) Determine the acceleration of the crate after it is released.



$$\sum F_x = mg\sin\theta = ma_x$$

$$\sum F_y = n - mg\cos\theta = 0$$

$$a_x = g\sin\theta$$



Weighing a Fish in an Elevator

A person weighs a fish of mass *m on a spring scale attached to* the ceiling of an elevator, as illustrated in Figure. Show that if the elevator accelerates either upward or downward, the spring scale gives a reading that is different from the weight of the fish.

If the elevator is either at rest or moving at constant velocity, the fish is not accelerating, and so or (remember that the scalar *mg*
is the weight of the fish).$T = mg$

$$\sum F_y = T - mg = 0$$

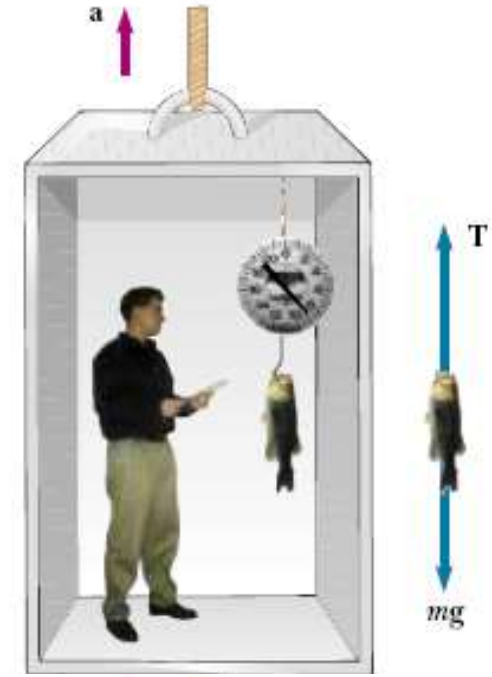
If the elevator moves upward with an acceleration a relative to an observer standing outside the elevator in an inertial frame.

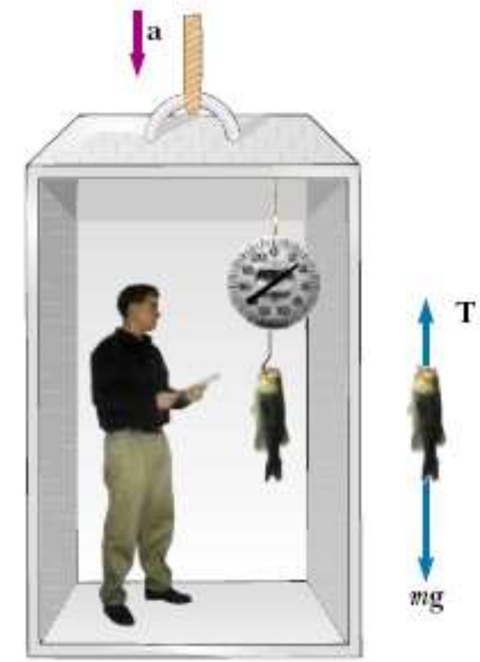
$$\sum F_y = T - mg = ma_y$$

The scale reading *T is greater than* the weight *mg if a is upward, so that ay is positive, and that* the reading is less than *mg if a is downward, so that ay is* negative.

$$T = ma_y + mg = mg\left(\frac{a_y}{g} + 1\right)$$
$$= (40.0\ \text{N})\left(\frac{2.00\ \text{m/s}^2}{9.80\ \text{m/s}^2} + 1\right)$$
$$= \boxed{48.2\ \text{N}}$$

$$T = mg\left(\frac{a_y}{g} + 1\right) = (40.0\ \text{N})\left(\frac{-2.00\ \text{m/s}^2}{9.80\ \text{m/s}^2} + 1\right)$$
$$= \boxed{31.8\ \text{N}}$$





Atwood's Machine

When two objects of unequal mass are hung vertically over a frictionless pulley of negligible mass, Determine the magnitude of the acceleration of the two objects and the tension in the lightweight cord.

$$\sum F_y = m_2 g - T = m_2 a_y$$

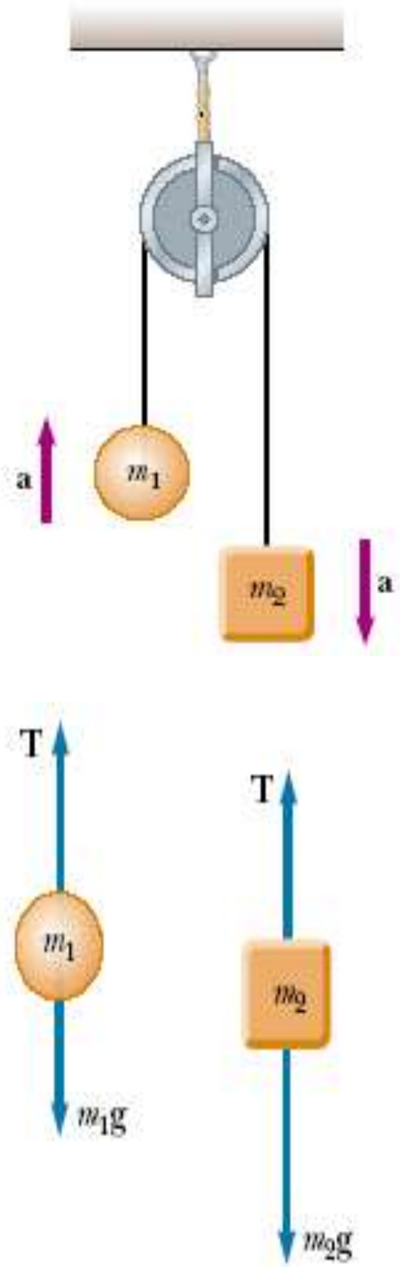
$$\sum F_y = T - m_1 g = m_1 a_y$$

$$-m_1 g + m_2 g = m_1 a_y + m_2 a_y$$

$$a_y = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g$$

$$T = \left(\frac{2 m_1 m_2}{m_1 + m_2}\right) g$$

Special Cases When $m_1 = m_2$, then $a_y = 0$ and $T = m_1 g$, as we would expect for this balanced case. If $m_2 \gg m_1$, then $a_y \approx g$ (a freely falling body) and $T \approx 2 m_1 g$.



Acceleration of Two Objects Connected by a Cord

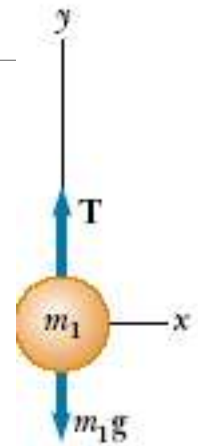
A ball of mass *m1 and a block of mass m2 are attached by a* lightweight cord that passes over a frictionless pulley of negligible mass, as shown in Figure. The block lies on a frictionless incline of angle . Find the magnitude of the acceleration of the two objects and the tension in the cord.

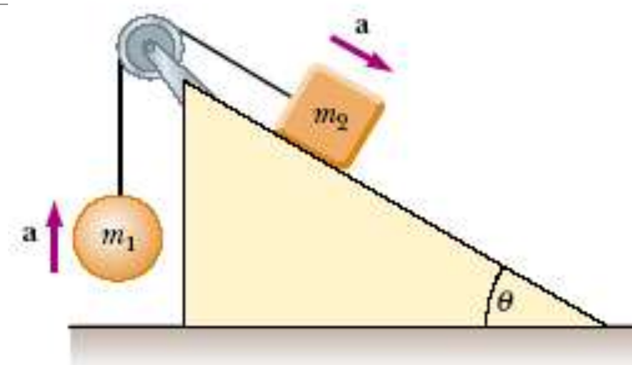
$$\sum F_x = 0$$

$$\sum F_y = T - m_1 g = m_1 a_y = m_1 a$$

$$\sum F_{x'} = m_2 g \sin\theta - T = m_2 a_{x'} = m_2 a$$

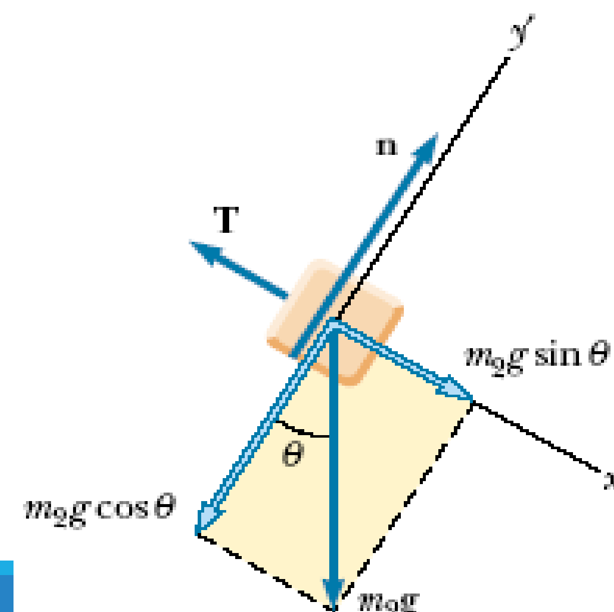
$$\sum F_{y'} = n - m_2 g \cos\theta = 0$$





$$a = \frac{m_2 g \sin\theta - m_1 g}{m_1 + m_2}$$

$$T = \frac{m_1 m_2 g(\sin\theta + 1)}{m_1 + m_2}$$



In Fig let the mass of the block be 8.5 kg and the angle be 30 .Find (a) the tension in the cord and (b) the normal force acting on the block. (c) If the cord is cut, find the magnitude of the resulting acceleration of the block.