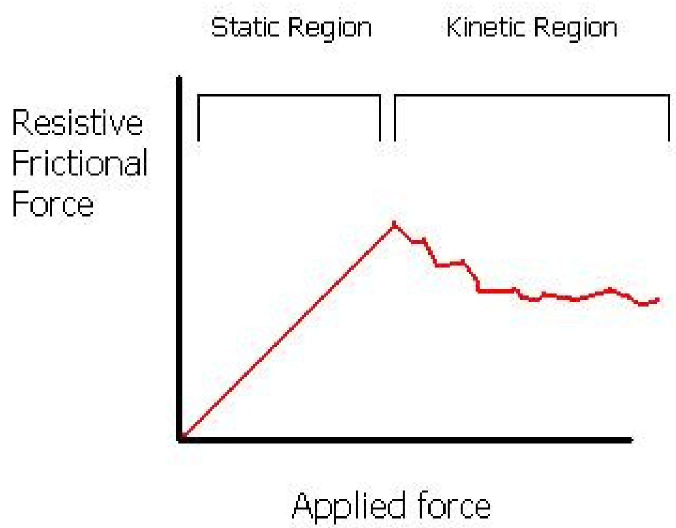
Newton's Laws - continued

Friction, Inclined Planes, N.T.L., Law of Gravitation

TWO types of Friction

- Static – Friction that keeps an object at rest and prevents it from moving
- Kinetic – Friction that acts during motion



Force of Friction

- The Force of Friction is directly related to the Force Normal.
  - Mostly due to the fact that BOTH are surface forces

$$F_f \; \alpha \; F_N$$

$$\mu = \text{constant of proportionality}$$

$$\mu = \text{coefficient of friction}$$

$$F_{sf} = \mu_s F_N$$

$$F_{kf} = \mu_k F_N$$

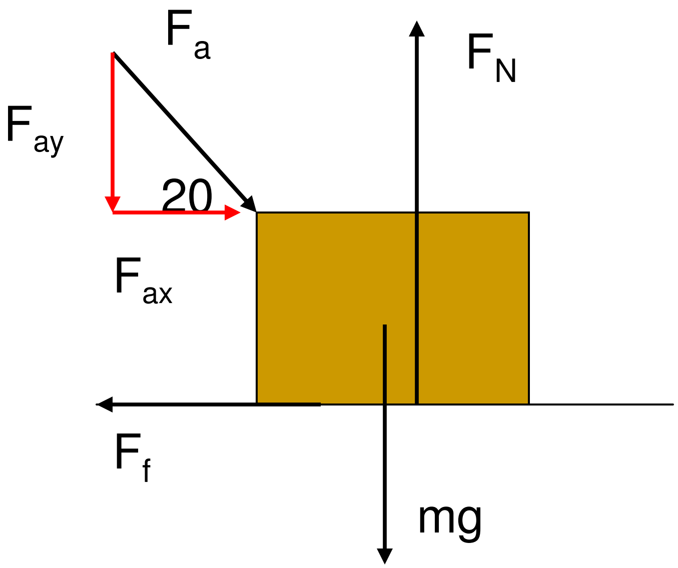
The coefficient of friction is a unitless constant that is specific to the material type and usually less than one.

Note: Friction ONLY depends on the MATERIALS sliding against each other, NOT on surface area.

Example

A 1500 N crate is being pushed across a level floor at a constant speed by a force F of 600 N at an angle of 20° below the horizontal as shown in the figure.

a) What is the coefficient of kinetic friction between the crate and the floor?



$$F_f = \mu_k F_N$$

$$F_f = F_{ax} = F_a \cos\theta = 600(\cos 20) = 563.82N$$

$$F_N = F_{ay} + mg = F_a \sin\theta + 1500$$

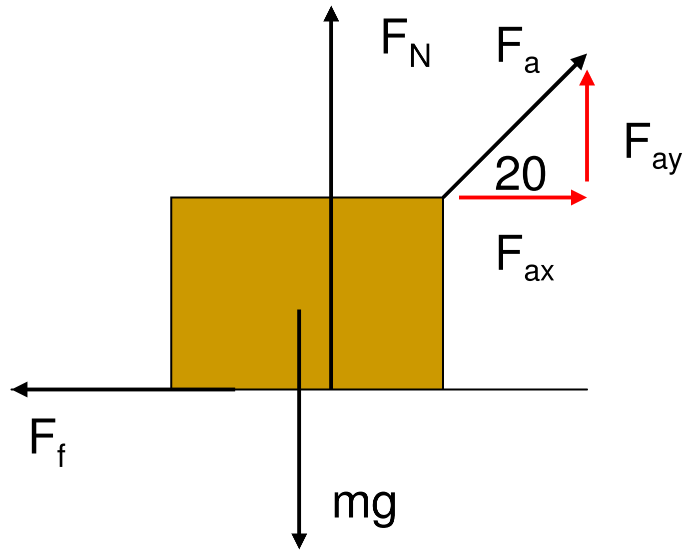
$$F_N = 600(\sin 20) + 1500 = 1705.21N$$

$$563.82 = \mu_k 1705.21$$

$$\mu_k = 0.331$$

Example

If the 600 N force is instead pulling the block at an angle of 20° above the horizontal as shown in the figure, what will be the acceleration of the crate. Assume that the coefficient of friction is the same as found in (a)



$$F_{Net} = ma$$

$$F_{ax} - F_f = ma$$

$$F_a \cos\theta - \mu F_N = ma$$

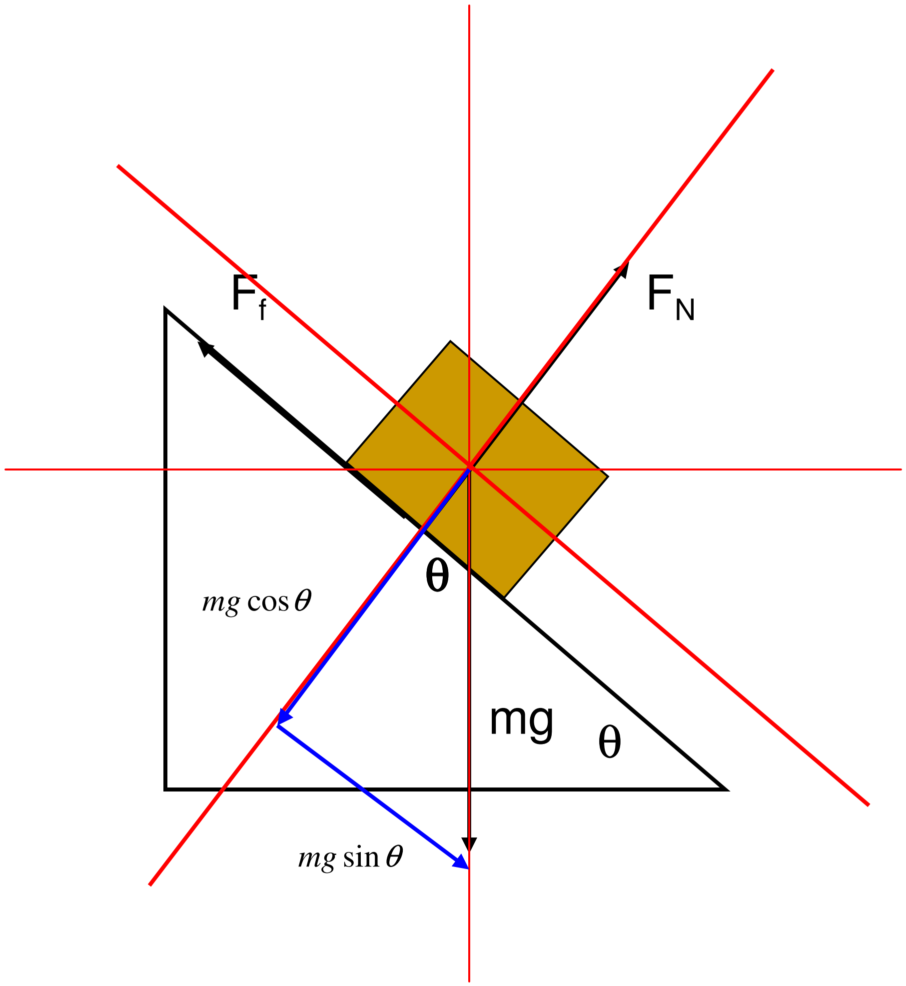
$$F_a \cos\theta - \mu(mg - F_a \sin\theta) = ma$$

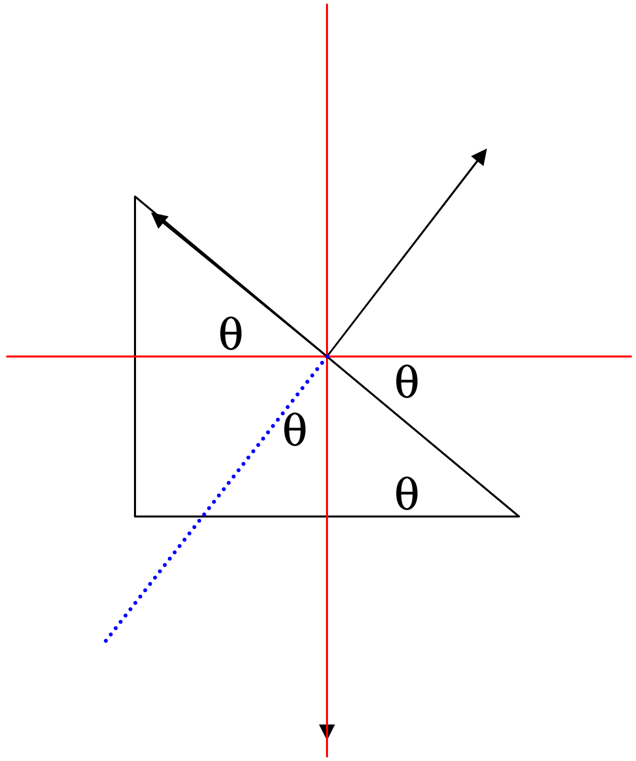
$$600\cos 20 - 0.331(1500 - 600\sin 20) = 153.1a$$

$$563.8 - 428.57 = 153.1a$$

$$a = 0.883\, m/s^2$$

Inclines

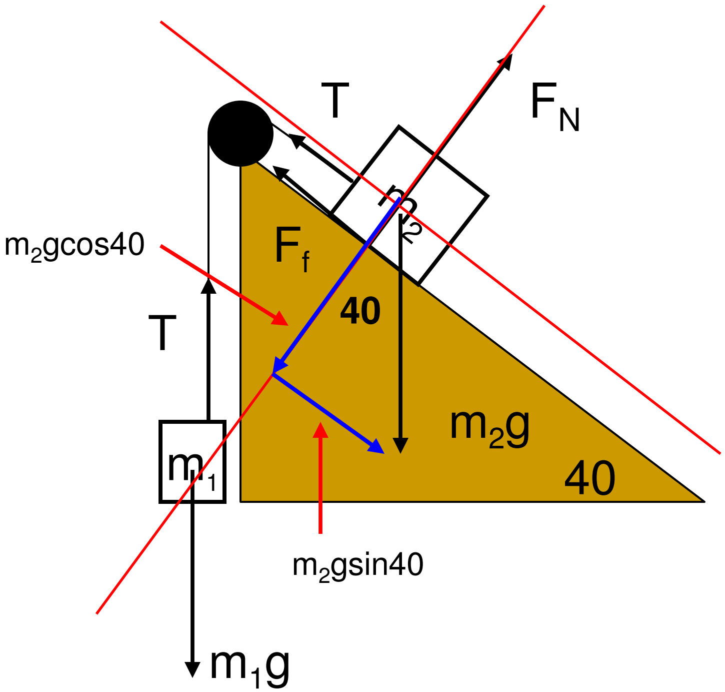




Tips
•Rotate Axis
•Break weight into components
•Write equations of motion or equilibrium
•Solve

Example

Masses m_1 = 4.00 kg and m_2 = 9.00 kg are connected by a light string that passes over a frictionless pulley. As shown in the diagram, m_1 is held at rest on the floor and m_2 rests on a fixed incline of angle 40 degrees. The masses are released from rest, and m_2 slides 1.00 m down the incline in 4 seconds. Determine (a) The acceleration of each mass (b) The coefficient of kinetic friction and (c) the tension in the string.



$$F_{NET} = ma$$

$$T - m_1 g = m_1 a \rightarrow T = m_1 a + m_1 g$$

$$m_2 g \sin\theta - (F_f + T) = m_2 a$$

Example

$$F_{NET} = ma$$

$$T - m_1 g = m_1 a \rightarrow T = m_1 a + m_1 g$$

$$m_2 g \sin\theta - (F_f + T) = m_2 a$$

$$x = v_{ox} t + \tfrac{1}{2} a t^2$$

$$1 = 0 + \tfrac{1}{2} a (4)^2$$

$$a = 0.125\ m/s^2$$

$$T = 4(.125) + 4(9.8) = 39.7N$$

$$m_2 g \sin\theta - F_f - T = m_2 a$$

$$m_2 g \sin\theta - F_f - (m_1 a + m_1 g) = m_2 a$$

$$m_2 g \sin\theta - \mu_k F_N - m_1 a - m_1 g = m_2 a$$

$$m_2 g \sin\theta - \mu_k m_2 g \cos\theta - m_1 a - m_1 g = m_2 a$$

$$m_2 g \sin\theta - m_1 a - m_1 g - m_2 a = \mu_k m_2 g \cos\theta$$

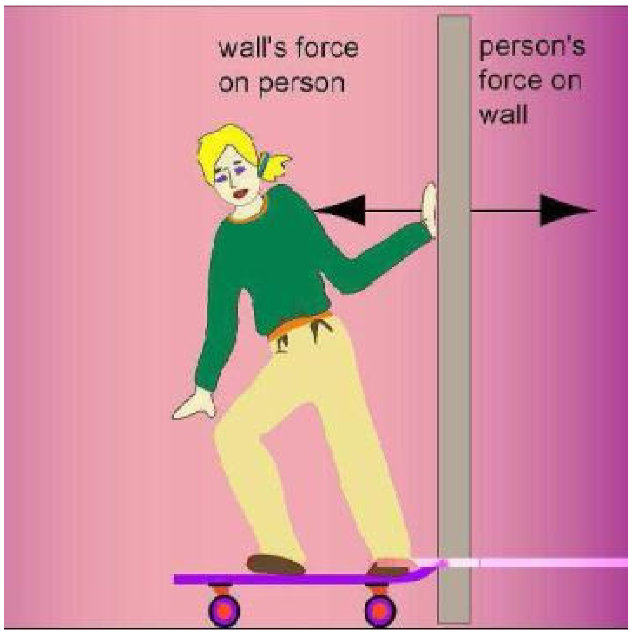
$$\mu_k = \frac{m_2 g \sin\theta - m_1 a - m_1 g - m_2 a}{m_2 g \cos\theta}$$

$$\mu_k = \frac{56.7 - 0.5 - 39.2 - 1.125}{67.57} = 0.235$$

Newton's Third Law

"For every action there is an EQUAL and OPPOSITE reaction.

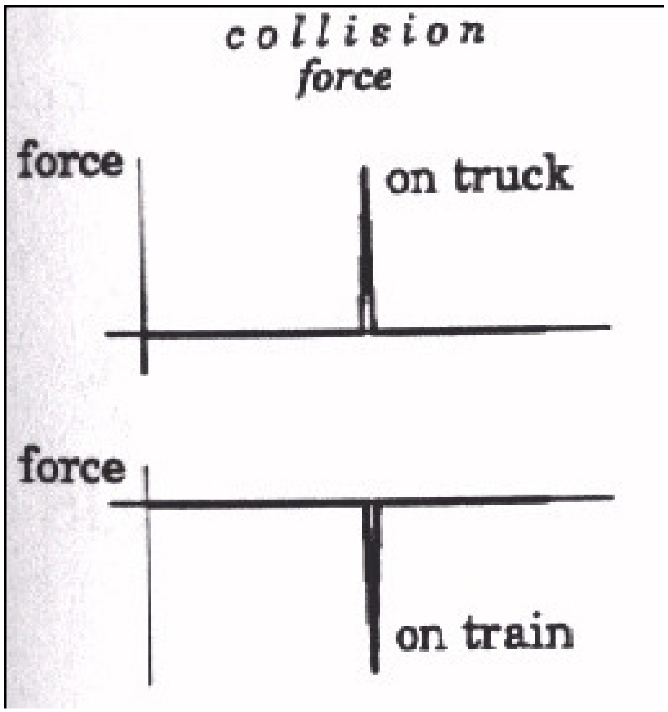
- This law focuses on action/reaction pairs (forces)
- They NEVER cancel out



All you do is SWITCH the wording!

- PERSON on WALL
- WALL on PERSON

N.T.L



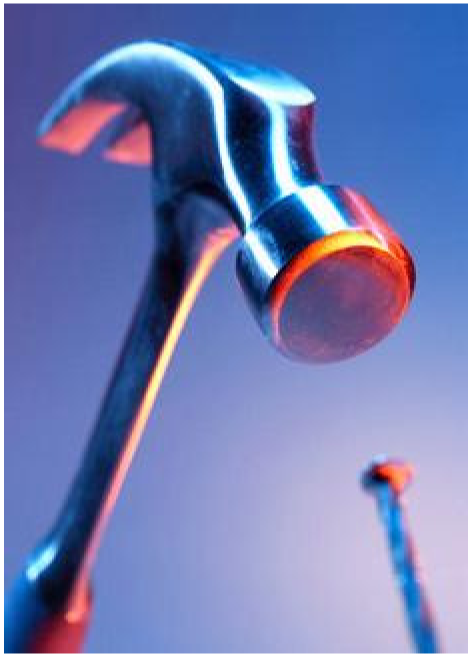
This figure shows the force during a collision between a truck and a train. You can clearly see the forces are EQUAL and OPPOSITE. To help you understand the law better, look at this situation from the point of view of Newton's Second Law.

$$F_{Truck} = F_{Train}$$

$$m_{Truck} A_{Truck} = M_{Train} a_{Train}$$

There is a balance between the mass and acceleration. One object usually has a LARGE MASS and a SMALL ACCELERATION, while the other has a SMALL MASS (comparatively) and a LARGE ACCELERATION.

N.T.L Examples

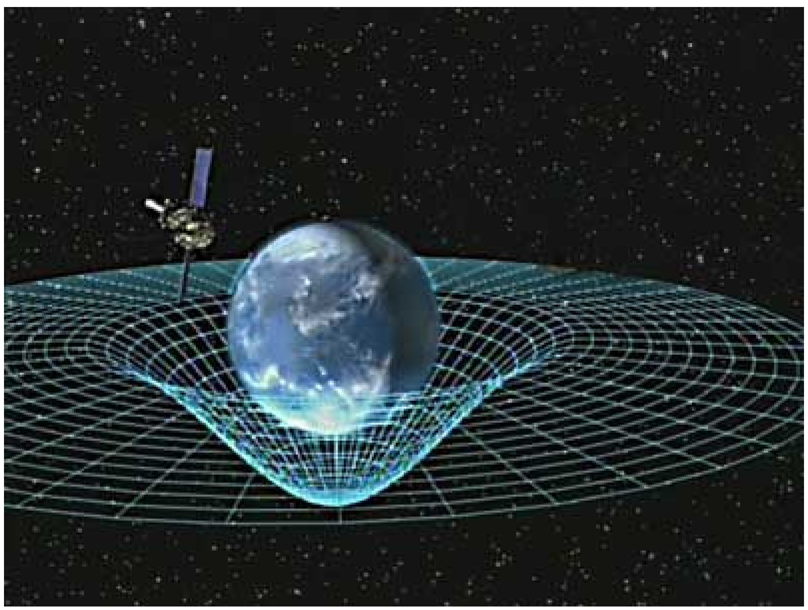


Action: HAMMER HITS NAIL
Reaction: NAIL HITS HAMMER

Action: Earth pulls on YOU
Reaction: YOU pull on the earth

Newton's Law of Gravitation

What causes YOU to be pulled down? THE EARTH….or more specifically…the EARTH'S MASS. Anything that has MASS has a gravitational pull towards it.



$$F_g \, \alpha \, Mm$$

What the proportionality above is saying is that for there to be a FORCE DUE TO GRAVITY on something there must be at least 2 masses involved, where one is larger than the other.

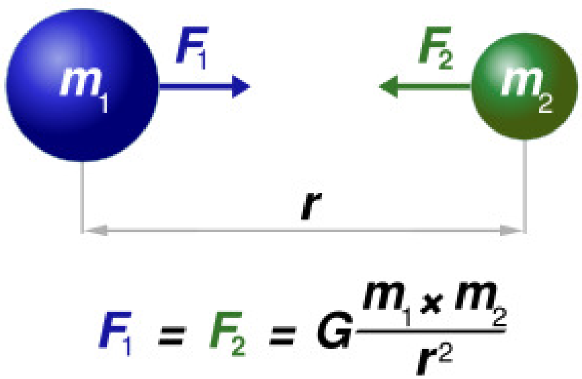
N.L.o.G.

As you move AWAY from the earth, your DISTANCE increases and your FORCE DUE TO GRAVITY decrease. This is a special INVERSE relationship called an Inverse-Square.

$$F_g \, \alpha \frac{1}{r^2}$$

The “r” stands for SEPARATION DISTANCE and is the distance between the CENTERS OF MASS of the 2 objects. We us the symbol “r” as it symbolizes the radius. Gravitation is closely related to circular motion as you will discover later.

N.L.o.G – Putting it all together



$$F_g \;\alpha\; \frac{m_1 m_2}{r^2}$$

$G =$ constant of proportionality

G = Universal Gravitational Constant

$$G = 6.67x10^{-27}\ Nm^2/kg^2$$

$$F_g = G\frac{m_1 m_2}{r^2}$$

$F_g = mg \rightarrow$ Use this when you are on the earth

$F_g = G\frac{m_1 m_2}{r^2} \rightarrow$ Use this when you are LEAVING the earth

Try this!

Let's set the 2 equations equal to each other since they BOTH represent your weight or force due to gravity

$$F_g = mg \rightarrow \text{Use this when you are on the earth}$$

$$F_g = G\frac{m_1 m_2}{r^2} \rightarrow \text{Use this when you are LEAVING the earth}$$

SOLVE FOR g!

$$mg = G\frac{Mm}{r^2}$$

$$g = G\frac{M}{r^2}$$

$$M = \text{Mass of the Earth} = 5.97x10^{24} - kg$$

$$r = \text{radius of the Earth} = 6.37x10^{6} - m$$

$$g = \frac{(6.67x10^{-27})(5.97x10^{24})}{(6.37x10^{6})^2} = 9.81 m/s^2$$