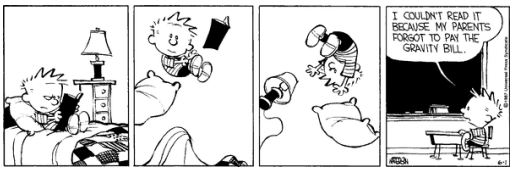
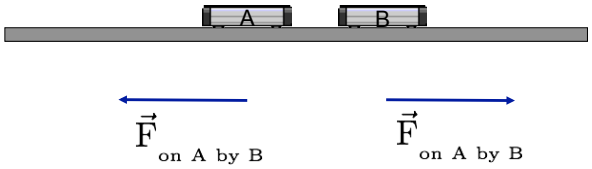


Interactions

A **force** is one side of an *interaction*. When two objects interact, they exert forces on each other.



Newton's third law says that these forces are equal in magnitude and opposite in direction.

What if the objects in an interaction have different masses?

Force is a measure of the strength of the interaction.

What if they have different masses?

The carts exert equal and opposite forces on each other, as is true in any interaction.

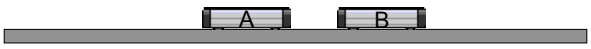
Newton's third law does not depend on their masses or motion. It just tells us about the "two-sided" nature of an interaction.

Poll

If Cart A has twice the mass of Cart B, which cart exerts a larger magnitude force on the other during the collision?

1. Cart A
2. Cart B
3. neither, because they exert equal magnitude forces on each other.

Poll



If Cart A is moving with twice the speed as Cart B when they make a head-on collision, which cart exerts a larger magnitude force on the other during the collision?

1. Cart A
2. Cart B
3. neither, because they exert equal magnitude forces on each other.

Poll

Which cart has a bigger change in momentum as a result of the collision?

1. Cart A
2. Cart B
3. Neither, they have the same change in momentum

Poll

Which cart has a bigger change in velocity as a result of the collision?

1. Cart A
2. Cart B
3. Neither, they have the same change in velocity

Poll

Which cart has a bigger acceleration as a result of the collision?

1. Cart A
2. Cart B
3. Neither, they have the same acceleration

Poll

A certain ball is in free-fall. As it falls, Earth exerts a constant downward force of 5 N on the ball. What is the force of the ball on Earth?

1. zero; (the ball exerts a negligible, almost zero, force on Earth)
2. a small, non-zero, upward force.
3. 5 N, upward
4. an upward force that is greater than 5 N.

Poll

A certain ball is in free-fall. As it falls, Earth exerts a constant downward force of 5 N on the ball. Which object has the bigger magnitude of change in velocity during a certain time interval?

1. The ball
2. Earth
3. Neither, they exert equal forces on each other and therefore will have equal magnitude changes in velocity.

Universal Law of Gravitation

Every particle of mass *m* attracts every other particle in the Universe.

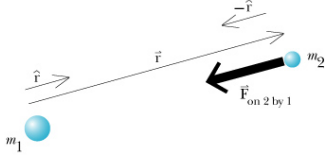
…is consistent with Newton's third law.

Gravitational Force

To find F on 2 by 1:

1. Draw r from m1 to m2.
2. Determine r
3. Calculate mag of r
4. Calculate dir of r
5. Calculate F on 2 by 1.

$$\left|\vec{F}_{\text{grav}}\right| = G\frac{m_1 m_2}{\left|\vec{r}\right|^2}$$



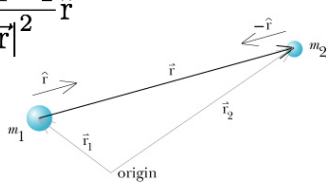
$$\vec{F}_{\text{grav on 2 by 1}} = G\frac{m_1 m_2}{\left|\vec{r}_{\text{of 2 rel 1}}\right|^2}\left(-\hat{r}_{\text{of 2 rel 1}}\right)$$

Gravitational Force

$$\vec{F}_{\text{grav on 2 by 1}} = -G\frac{m_1 m_2}{|\vec{r}|^2}\hat{r}$$

where

$$\vec{r} = \vec{r}_2 - \vec{r}_1$$



Poll

If you double the mass of m_1, the gravitational force on m_2

1. Increases by 2
2. Increases by 4
3. Decreases by 1/2
4. Decreases by 1/4
5. Stays the same

Poll

If you double the distance between m_1 and m_2, the gravitational force on m_2

1. Increases by 2
2. Increases by 4
3. Decreases by 1/2
4. Decreases by 1/4
5. Stays the same

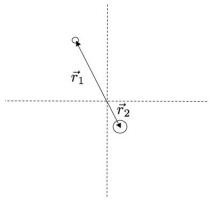
Poll

Sun's mass is 2×10^{30} kg. Earth's mass is 6×10^{24} kg. Thus, Sun is nearly a million times more massive than Earth. Which object "feels" a larger gravitational force? (Assume a two-body system.)

1. Sun
2. Earth
3. Neither, the graviational force on each object has the same magnitude.

Example

A binary star system consists of two stars. Star 1 has a mass of 1×10^{30} kg and at this instant is at the position $< -5\times10^{10}, 8.66\times10^{10}, 0 >$ m. Star 2 has a mass of 5×10^{30} kg and at this instant is at the position $< -1\times10^{10}, 1.73\times10^{10}, 0 >$ m. Sketch the gravitational force of Star 1 on Star 2, and sketch the gravitational force of Star 2 on Star 1. What is the gravitational force on Star 2 by Star 1?



Gravitational Field

A particle of mass M creates a gravitational field everywhere in space around it that is directed toward the particle.

If another particle of mass *m* is at a location in this gravitational field, then the gravitational force on *m* due to the field is

$$\left|\vec{F}_{\text{grav}}\right| = mg$$

This is called the ***weight*** of the particle.

Gravitational Field

The gravitational field due to a particle of mass M is toward the particle and has a magnitude

$$|\vec{\mathrm{g}}| = \frac{GM}{|\vec{\mathrm{r}}|^2}$$

Thus,

$$\vec{\mathrm{g}} = -\frac{GM}{|\vec{\mathrm{r}}|^2}\hat{\mathrm{r}}$$

Example

Calculate the magnitude of the gravitational field of Earth near its surface. What assumption did you make?

Example

What is the weight of a 90-kg astronaut if she is orbiting Earth at an altitude of 200 km? Is she weightless? If not, then why does she seem to "float around" in the space shuttle?

Poll

You drop a 4 kg object and a 1 kg object from the roof of this building. On which object is the gravitational force by Earth the greatest?

1. 4-kg object
2. 1-kg object
3. Neither, because the gravitational force on each object is the same.

Poll

You drop a 4 kg object and a 1 kg object from the roof of this building. Which object has the greatest change in velocity during a 1 second time interval?

1. 4-kg object
2. 1-kg object
3. Neither, because the gravitational force on each object is the same.

Poll

Suppose that a certain star has no planets or other "debris" orbiting it. Does the star create a gravitational field around it?

1. Yes
2. No
3. Yes, but it's a field of dreams.