

Preview of Period 4: Gravity, Mass, and Weight

4.1 Center of Gravity

Where does the force of gravity appear to act on an object?

4.2 Center of Mass

How can you find the **center of mass** of an object?

Why is the location of the center of mass useful?

4.3 and 4.4 The Acceleration of Gravity

How does the gravitational force act upon objects?

How large is the acceleration of gravity

4.5 Mass and Weight

What is the difference between mass and weight?

Act. 4.2: The Center of Mass

The center of mass of an object is the point at which the force of gravity acts on the object.



The center of mass of an object **with a uniform distribution of mass** is at its center:

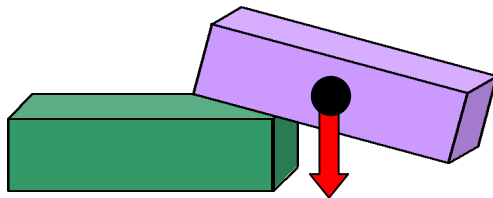
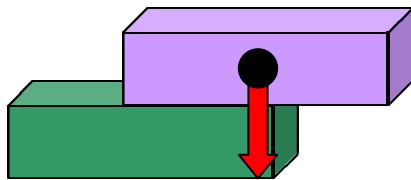
How can you find the center of mass of an irregularly shaped object?



Where is your center of mass?

Act. 4.1: The Center of Mass

What happens when the center of mass of an object is not supported?

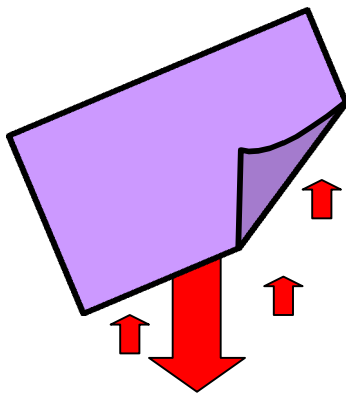


Act. 4.3: The Gravitational Force and the Acceleration of Gravity

Experience tells you that a book falls much faster than a sheet of paper. How can you make them fall at the same rate?

The trick is to reduce **air resistance**.

- ◆ As an object moves through air, it collides with air molecules.
- ◆ Each molecule exerts a force on the object, slowing its velocity slightly.
- ◆ How can you reduce air resistance on the sheet of paper?



The **force of gravity** pulls the paper **down**.

Collisions with air molecules exert a force **up** on the paper.

Act. 4.3: Forces on Falling Objects

- ◆ A falling object accelerates due to the force of gravity pulling it downward.
- ◆ Objects near the Earth accelerate at the rate of 9.8 m/s^2 (or 32 ft/s^2).

Drop two balls to the floor at the same time.

Neglecting air resistance, which one will reach the floor first - the larger, heavier ball, or the smaller, lighter ball?

Make a prediction before you drop the balls!

Neglecting air resistance, does the velocity of a falling object depend upon...

- Its size?
- Its mass (how much matter it contains)?
- How long it falls?

Newton's Law of Gravitational Force

$$\text{Gravitational force} = F = \frac{G M_1 M_2}{D^2}$$

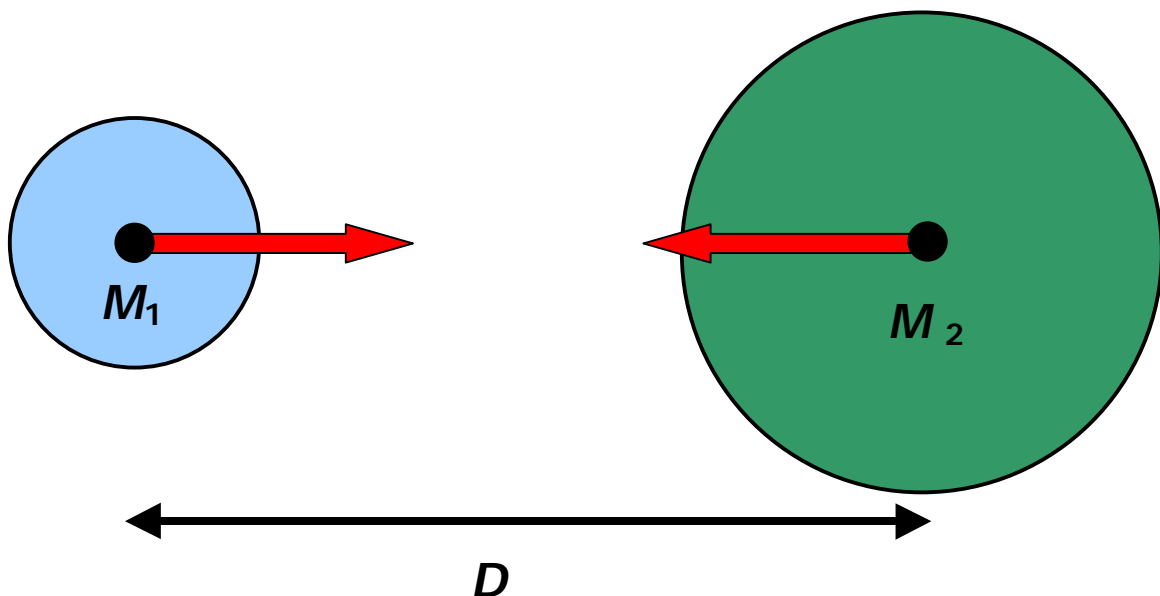
F = Gravitational force (newtons)

M_1 = Mass of object 1 (kilograms)

M_2 = Mass of object 2 (kilograms)

D = Distance between the centers mass of the objects (meters)

G = Gravitational constant of the universe = 6.67×10^{-11} (N m²/kg²)



The gravitational force acts along the line connecting the centers of mass of the objects.

The acceleration of gravity, g , and the universal gravitational constant G

g = the acceleration of gravity.

- The value of g differs for each planet.
- Near Earth, $g = 9.8 \text{ m/s}^2$ or 32 ft/s^2 .

G = the Universal Gravitational constant

- The value of G is constant throughout the Universe.
- $G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$

How is g related to G ?

$$\text{Gravitational force} = F = \frac{G M_1 M_2}{D^2}$$

Three of the quantities in the gravitational force equation **are constants** - their values do not change for objects near the Earth:

$$M_1 = \text{mass of the Earth} = 5.98 \times 10^{24} \text{ kg}$$

$$D = \text{Earth's radius} = 6.3712 \times 10^6 \text{ meters}$$

$$G = \text{Grav. constant} = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$$

We can simplify calculations by combining these 3 terms into one:

$$g = \frac{G M_1}{D^2}$$

$$g = \frac{(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2) \times (5.98 \times 10^{24} \text{ kg})}{(6.3712 \times 10^6 \text{ m})^2}$$

$$g = 9.8 \text{ m/s}^2 \text{ near the Earth.}$$

Since the mass and diameter of planets vary, the value of g is different for each planet.

How does **g** simplify calculations?

We can find the attractive gravitational force between two objects near the Earth by substituting **g** into the gravitational force equation:

$$F = \frac{G M_1 M_2}{D^2}$$

substitute: $g = \frac{G M_1}{D^2}$

$$F = M g$$

Near the Earth, the force of gravity =

$$F = M g = M \times 9.8 \text{ m/s}^2$$

Scientific Notation on Your Calculator

Using the gravitational force equation requires squaring a number written in scientific notation:

$$(6.3712 \times 10^6 \text{ m})^2$$

On many calculators, you must enclose the number to be squared in parentheses before pressing the X^2 key. Try this on your calculator.

$$(6.3712 \times 10^6 \text{ m})^2 = ?$$

$$\text{Answer: } 4.0592 \times 10^{13} \text{ m}^2$$

Act. 4.5: Mass and Weight

How is the **force** an object exerts on a scale **related to the object's weight?**

$$\text{Force} = \text{Mass} \times g = \text{Weight}$$

How is weight related to mass?

$$\text{Mass} = \frac{\text{Weight}}{g} = \frac{\text{Weight}}{9.8 \text{ m/s}^2}$$

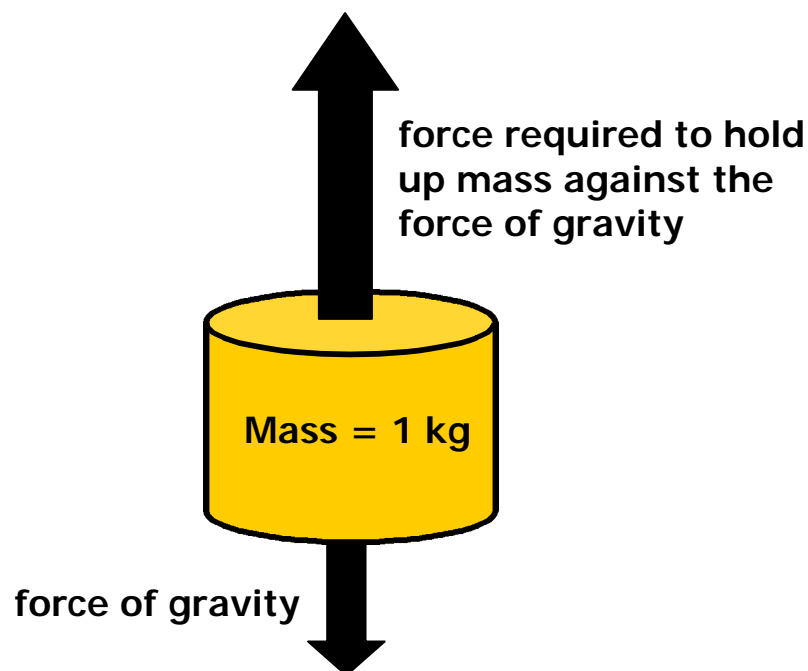
Would a person **weigh** more, less, or the same when standing on the Earth as compared to standing on the Moon?

Would the person's **mass** be more, less, or the same on the Earth as compared to the Moon?

Act. 4.5: Measuring Mass and Force

- ◆ Attach a 1 kg mass to the force scale.
- ◆ The force of gravity exerts a downward force on the 1 kg mass.
- ◆ The force scale measures the force required to hold up the 1 kg mass against the force of gravity.
- ◆ The scale measures force in units of newtons. A newton (N) has units of mass (kg) times acceleration (m/s^2)

$$1 \text{ N} = 1 \text{ kg} \times 1 \text{ m/s}^2$$



Period 4 Summary

4.1: The **center of mass** of an object is the point on which gravity pulls it in a straight line toward the center of the Earth.

The attractive gravitational force acts between the centers of mass of all objects.

4.2: The **strength of the gravitational force** between two objects depends on their masses and the square of the distance between them.

$$F = \frac{G M_1 M_2}{D^2}$$

4.3: Mass and weight are different concepts.

An object's **mass** is a measure of how much matter it contains.

An object's **weight** is a measure of the gravitational force between it and the planet it is near.

An object's **weight = mass x g**, where g = the acceleration of gravity

Near the Earth, g = 9.8 m/s² or 32 ft/ s²

4.4: The acceleration of a falling object, g, is independent of the mass of the object.

Period 4 Review Questions

- R.1** Explain why we were able to raise a large metal rod in class using only strips of paper.
- R.2** Is there a gravitational attraction between you and this piece of paper? If so, why doesn't the piece of paper fall towards you?
- R.3** Where is the center of mass of the Moon? Where is the center of mass of a bagel?
- R.4** A penny and a feather placed inside of a vacuum jar with no air. If the penny and feather are dropped at the same time, which one reaches the bottom of the jar first?
Now the penny and feather are removed from the vacuum jar. If they are dropped at the same time, which one reaches the ground first? Explain any differences in your answers.
- R.5** A 6 kg rock and a 12 kg rock are dropped from a roof. If the 6 kg rock reaches a velocity of 36 m/s just before hitting the ground, what velocity will the 12 kg rock reach just before hitting the ground? (Neglect air resistance.)
- R.6** What are the advantages to driving a high profile vehicle, such as a sports utility vehicle? What are the disadvantages?