FYI Gravitational Force

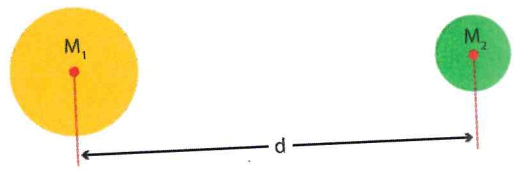
What is gravity? **Gravity** is an informal word for what scientists call **gravitational force**. It is the attractive force, or pulling, in which one object acts upon another object because of the masses of both objects. Or, put another way, since a **force** is a push or pull that causes an object to move, gravity is a pull between objects.

Newton's Law of Universal Gravitation

Newton's law of universal gravitation states:
Every object in the universe attracts every other object with a force directed along the line of centers of mass for the two objects. This force is proportional to the product of their masses and inversely proportional to the square of the separation between the centers of the two masses.

$$\text{Gravitational Force} = \frac{\text{Gravitational Constant x Mass 1 x Mass 2}}{(\text{Distance between Centers of Mass})^2}$$

$$F_g = \frac{G M_1 M_2}{d^2}$$



- F_g is the gravitational force between the two objects.
- G is the gravitational constant, 6.67×10^{-11} $N{\cdot}m^2/kg^2$. It is a fundamental constant of physics.
- M_1 and M_2 are the masses of the two objects.
- d is the distance between the centers of the two objects.

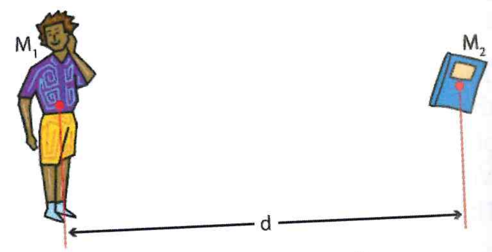


Figure 1-16: Diagrams illustrating the factors involved in Newton's law of universal gravitation. All objects attract each other, and the force of gravitational attraction between any two objects depends upon the masses of the objects and the inverse square of the distance between the centers of the objects.

This may seem complicated, but it basically says three important things:

1. There is a gravitational force between all objects.

   For example, there is a gravitational force between you and this book; there is a gravitational force between you and Earth; and there is even a gravitational force between you and the sun!

2. The larger the masses of the objects involved, the greater the gravitational force.

   For example, Earth has a much, much larger mass than this book does. Hence, while there is a gravitational force between you and this book, the gravitational force between you and Earth is much stronger. So you are pulled down toward Earth but not sideways toward the book!

3. The gravitational force between the objects decreases rapidly with increasing distance between those objects. Specifically, the gravitational force between any two objects is inversely proportional to the square of the distance between those objects.

   For example, the distance between you and the sun's center is incredibly large, while the distance between you and Earth's center is very small, comparatively. So though the sun has a much greater mass than Earth does, the gravitational force between you and Earth is much stronger. Thus, you aren't pulled off Earth by the sun!

Surface Gravitation

The gravitational force experienced on a planet's surface can be calculated by using the planet's mass for M_1 (kg) and the planet's radius for d (m). Thus, both the mass of a planet and the size of a planet, as defined by the planet's radius, determine the surface gravitation of that planet.

The gravitational acceleration experienced on Earth's surface is about 9.8 m/s^2.

$$g = 9.8\ m/s^2$$

Other planets and moons, each with their own mass and radius, have differing values for g. The value of g on our moon is about 1/6 that of Earth—about 1.6 m/s^2.

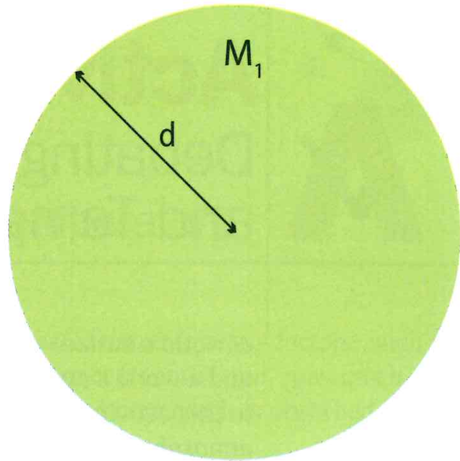


Figure 1-17: Diagram illustrating the factors involved in calculating surface gravitation. The gravitational force (F_g) experienced on the surface of a planet depends on the mass of the planet (M_1) and the radius of the planet (d).

Weight

Weight depends on a planet's surface gravitation. This means that objects weigh different amounts on different planets. On Earth, weight is equal to the mass of the object multiplied by g.

$$F_g = mg$$

- F_g is the weight of an object as experienced on Earth. It is the force acting on the object.
- m is the mass of the object—the amount of matter in the object.
- g is the acceleration of gravity experienced on Earth.

  Note: This is a version of Newton's 2nd Law: force equals mass times acceleration, or

$$F = ma.$$

An object's weight on another planet can be calculated by multiplying the object's mass by the surface gravitational acceleration on that planet.

An object's weight on another planet can also be calculated using that object's weight on Earth and the surface gravitational acceleration experienced on the other planet IF it is defined relative to the surface gravitational acceleration experienced on Earth (1 gee).

Figure 1-18: Drawing of scales and a balance—instruments used to measure weight. Weight depends on the gravitational acceleration experienced on the surface of a planet.

Checking In

1. Describe Newton's law of universal gravitation in your own words.
2. What planetary characteristics affect surface gravitation?