

## March 30: Gravity

### Objectives

- Determine the gravitational attraction between objects.
- Interpret a diagram of gravitational field lines.

### What's the point?

- Gravity is a universal force that brings order to the cosmos!

### Universal gravitation

Isaac Newton (was there anything he didn't do?) unified the study of Earth and the heavens with his **law of universal gravitation**, which explained the gravitational force between any two objects: the force on one object is directed toward the center of mass of the other, and has a magnitude

$$F = G \frac{m_1 m_2}{d^2},$$

where  $m_1$  and  $m_2$  are the masses of the interacting objects,  $d$  is the distance between their centers of mass, and  $G$ , the **universal gravitational constant**, is  $6.670 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ .

The gravitational potential energy of two objects is defined as the work needed to bring them from being infinitely far apart to their separation distance  $d$ . Since this displacement is in the direction of the force of gravity, the potential energy is a negative number:  $PE = -G m_1 m_2 / d$ .

### Gravitational fields

The force of gravity extends throughout all space, far from any object that creates it. It is convenient to think of the force as carried by a **gravitational field** that describes the force on one object encountering another. The force on any object in a gravitational field is just the object's mass multiplied by the gravitational field. For instance, the Earth's gravitational field at the surface of the Earth is  $g = 9.8 \text{ N/kg}$ . Consequently, a 1-kg object at the surface of the Earth experiences a gravitational field of 9.8 N.

Since force is a vector, a gravitational field is a vector field. It can be illustrated as vectors in space showing the field's strength and direction at selected locations. Another convenient way to illustrate a vector field is to show continuous **field lines**. Field lines are in the direction of the field vectors, and the magnitudes of the field vectors are greatest in regions where the field lines are close together.

### Escape speed

Although "what goes up must come down" makes a nice line in a song, it is not always true for a gravitational field. The gravitational field of the Earth or any object extends forever, but it is not always able to pull everything to the Earth. The work needed to move an object against the Earth's gravity all the way out to infinite distance is *not* infinite; if an object's kinetic energy is greater than its gravitational potential energy, it can go up forever and *never* come down!