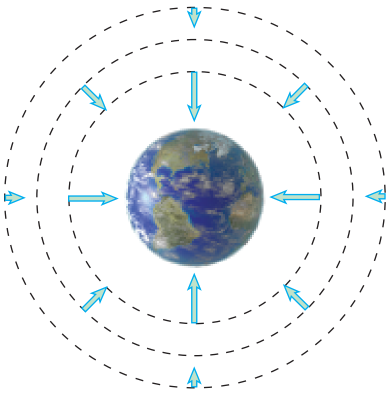

Figure 10
The gravitational field vectors represent Earth's gravitational field at each point. Note that the field has the same strength at equal distances from Earth's center.

Gravitational field strength equals free-fall acceleration

Consider an object that is free to accelerate and is acted on only by gravitational force. According to Newton's second law, $\mathbf{a} = \mathbf{F}/m$. As seen earlier, $\mathbf{g}$ is defined as $\mathbf{F_g}/m$, where $\mathbf{F_g}$ is gravitational force. Thus, the value of g at any given point is equal to the acceleration due to gravity. For this reason, $g = 9.81$ m/s^2 on Earth's surface. Although gravitational field strength and free-fall acceleration are equivalent, they are not the same thing. For instance, when you hang an object from a spring scale, you are measuring gravitational field strength. Because the mass is at rest (in a frame of reference fixed to Earth's surface), there is no measurable acceleration.

Figure 10 shows gravitational field vectors at different points around Earth. As shown in the figure, gravitational field strength rapidly decreases as the distance from Earth increases, as you would expect from the inverse-square nature of Newton's law of universal gravitation.

Weight changes with location

In the chapter about forces, you learned that weight is the magnitude of the force due to gravity, which equals mass times free-fall acceleration. We can now refine our definition of weight as mass times gravitational field strength. The two definitions are mathematically equivalent, but our new definition helps to explain why your weight changes with your location in the universe.

Newton's law of universal gravitation shows that the value of g depends on mass and distance. For example, consider a tennis ball of mass m. The gravitational force between the tennis ball and Earth is as follows:

$$F_g = \frac{Gmm_E}{r^2}$$

Combining this equation with the definition for gravitational field strength yields the following expression for g:

$$g = \frac{F_g}{m} = \frac{Gmm_E}{mr^2} = G\frac{m_E}{r^2}$$

This equation shows that gravitational field strength depends only on mass and distance. Thus, as your distance from Earth's center increases, the value of g decreases, so your weight also decreases. On the surface of any planet, the value of g, as well as your weight, will depend on the planet's mass and radius.

Why it Matters

Conceptual Challenge

1. Gravity on the Moon The magnitude of g on the moon's surface is about $\frac{1}{6}$ of the value of g on Earth's surface. Can you infer from this relationship that the moon's mass is $\frac{1}{6}$ of Earth's mass? Why or why not?

2. Selling Gold A scam artist hopes to make a profit by buying and selling gold at different altitudes for the same price per weight. Should the scam artist buy or sell at the higher altitude? Explain.