The Moon does not fall to Earth because

1. It is in Earth's gravitational field.
2. The net force on it is zero.
3. It is beyond the main pull of Earth's gravity.
4. It is being pulled by the Sun and planets as well as by Earth.
5. All of the above.
6. None of the above.

Announcements

- Next week's Lab is not in the lab manual. Pick up a packet during lab this week or download it from the course website
- No office hours on Thursday 1-3pm

Bernoulli's Equation

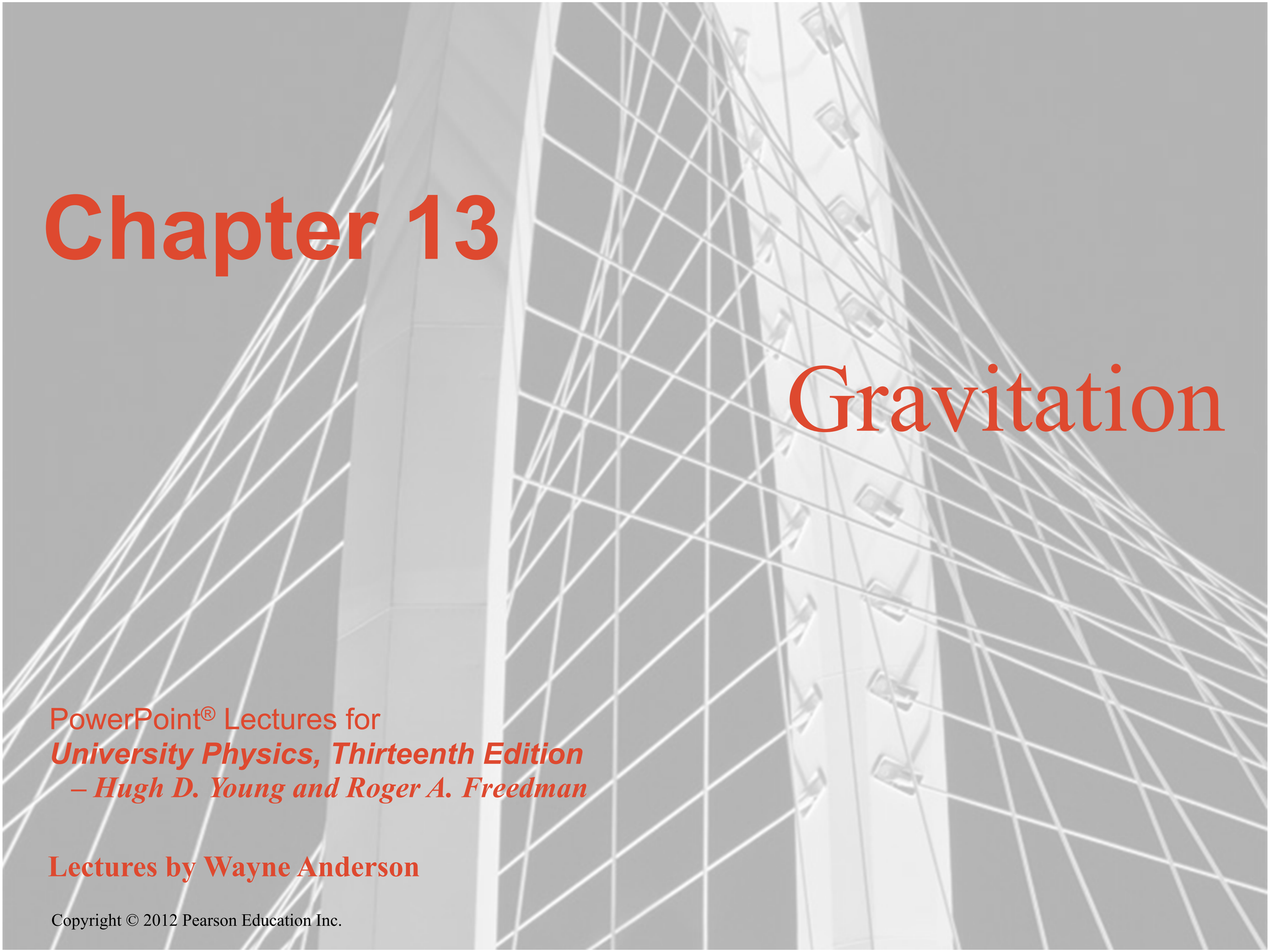
$$p_1 + \rho g y_1 + 1/2\ \rho v_1{}^2$$

$$=$$

$$p_2 + \rho g y_2 + 1/2\ \rho v_2{}^2$$

Ch 13.1-3
Gravitation

PHYS 1210 - Prof. Jang-Condell



Chapter 13

Gravitation

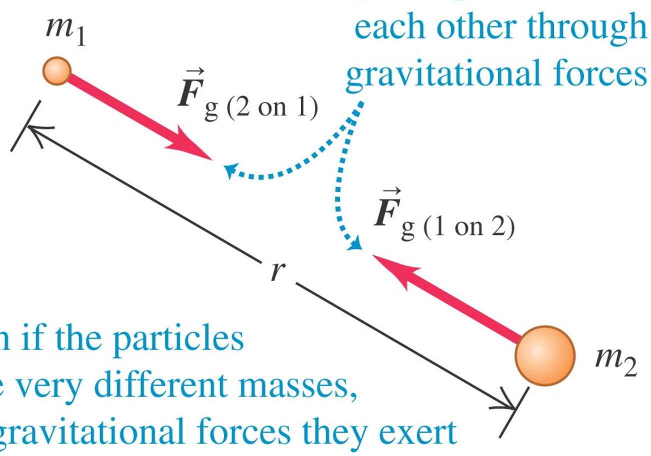
PowerPoint® Lectures for
University Physics, Thirteenth Edition
– Hugh D. Young and Roger A. Freedman

Lectures by Wayne Anderson

Goals for Chapter 13

- To calculate the gravitational forces that bodies exert on each other
- To relate weight to the gravitational force
- To use the generalized expression for gravitational potential energy
- To study the characteristics of circular orbits
- To investigate the laws governing planetary motion
- To look at the characteristics of black holes

Newton's Law of Gravitation



Any two particles attract each other through gravitational forces.

Even if the particles have very different masses, the gravitational forces they exert on each other are equal in strength:
$F_{g\,(1\text{ on }2)} = F_{g\,(2\text{ on }1)}$

$$F_g = Gm_1m_2/r^2$$

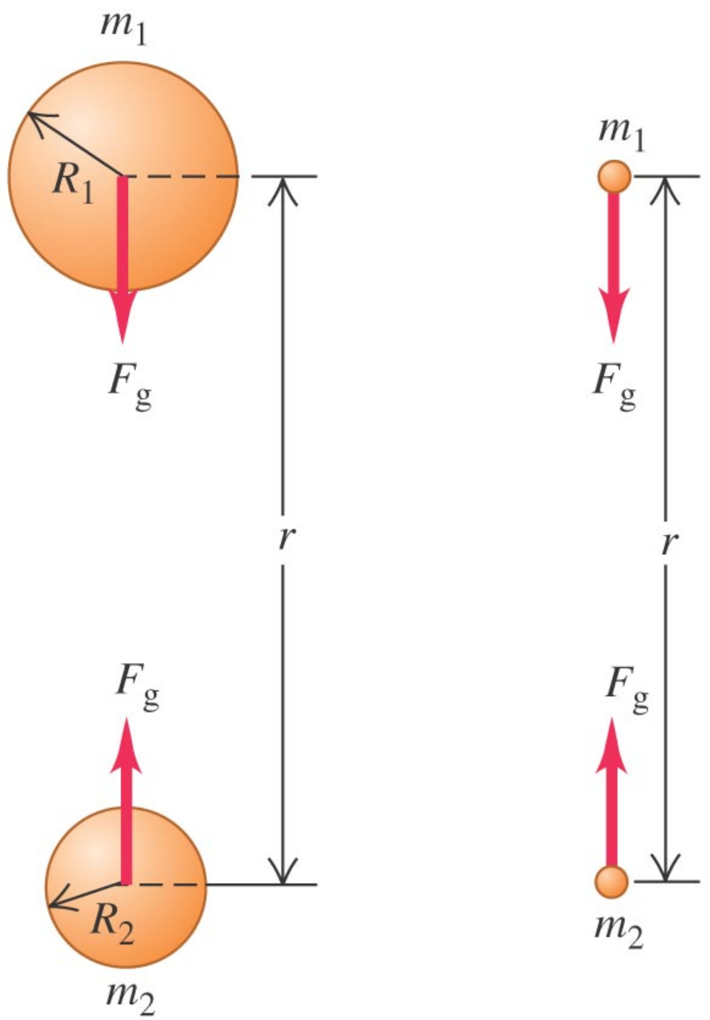
$$G = 6.67 \times 10^{-11}\ \text{N-m}^2/\text{kg}^2$$

Gravitation and spherically symmetric bodies

- The gravitational interaction of bodies having *spherically symmetric* mass distributions is the same as if all their mass were concentrated at their centers. (See Figure 13.2 at the right.)

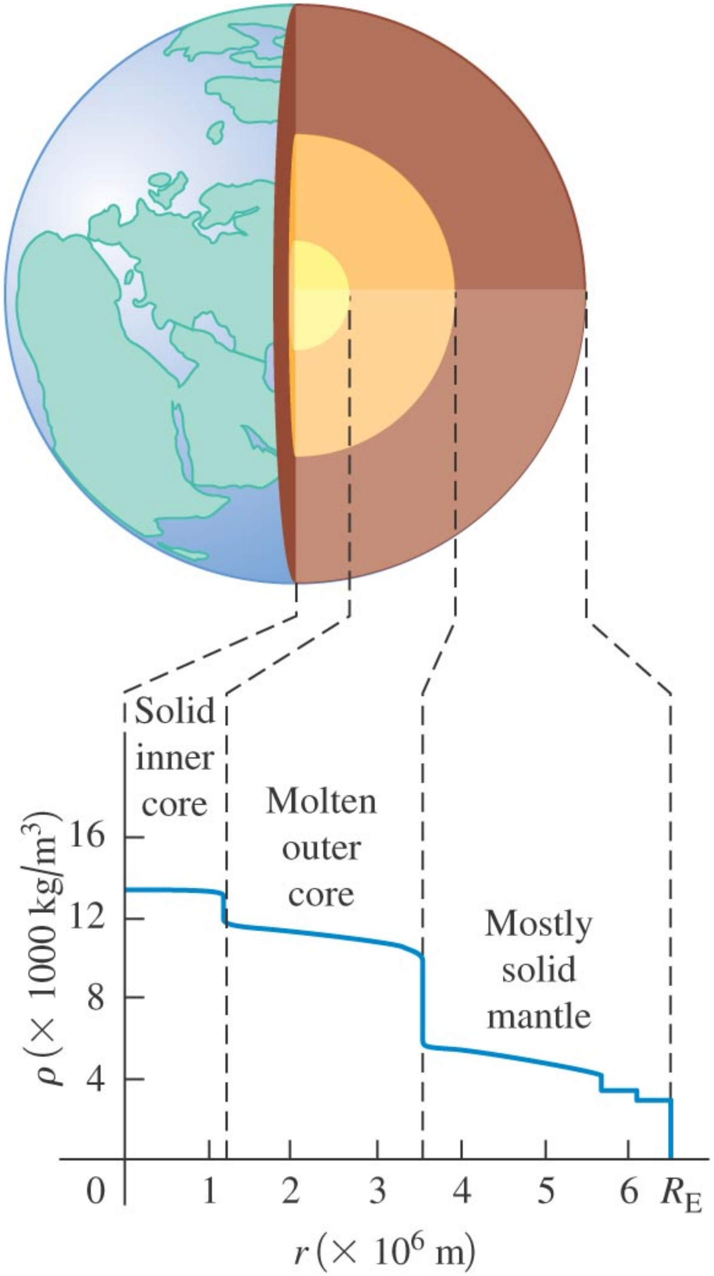
(a) The gravitational force between two spherically symmetric masses m_1 and m_2 ...

(b) ... is the same as if we concentrated all the mass of each sphere at the sphere's center.



Interior of the earth

- The earth is approximately spherically symmetric, but it is *not* uniform throughout its volume, as shown in Figure 13.9 at the right.



Q14.1

The mass of the Moon is 1/81 of the mass of the Earth.

Compared to the gravitational force that the Earth exerts on the Moon, the gravitational force that the Moon exerts on the Earth is

A. $81^2 = 6561$ times greater.

B. 81 times greater.

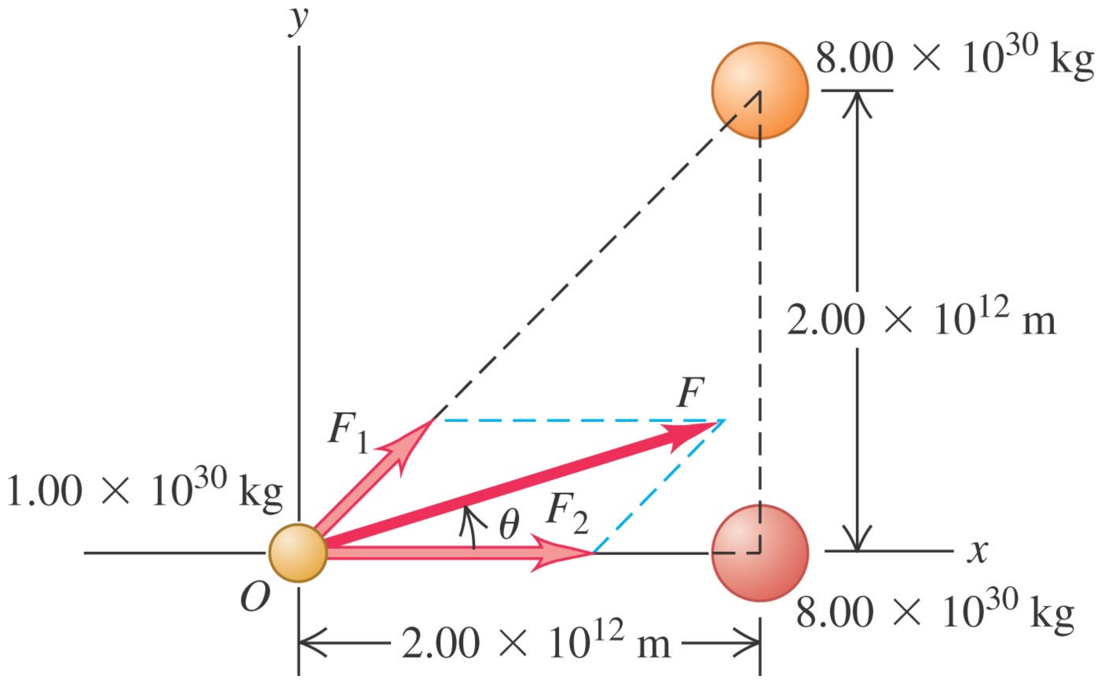
C. equally strong.

D. 1/81 as great.

E. $(1/81)^2 = 1/6561$ as great.

Some gravitational calculations

- Example 13.3 illustrates the *superposition of forces*, meaning that gravitational forces combine vectorially. (See Figure 13.5 below.)



Weight

The **weight** of a body is the total gravitational force exerted on it by all other bodies in the universe.

At the surface of the Earth, the gravitational force of the Earth dominates. So a body's weight is

$$w = Gm_{\mathrm{E}}m/R_{\mathrm{E}}^2$$

The acceleration due to gravity at the earth's surface is

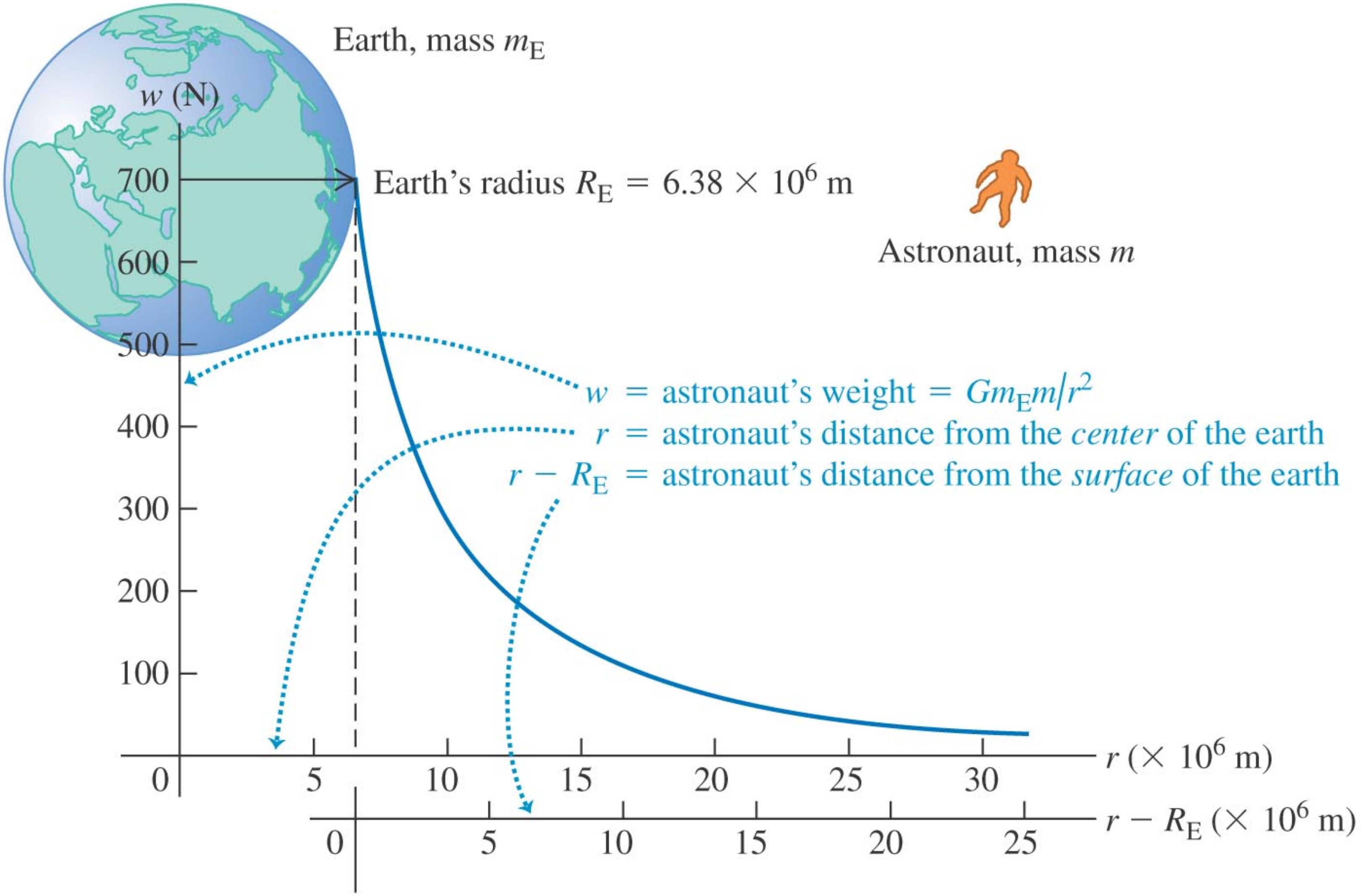
$$g = Gm_{\mathrm{E}}/R_{\mathrm{E}}^2$$

Suppose the Sun were suddenly replaced with a black hole of the same mass as the Sun. What effect would this have on the Earth's orbit?

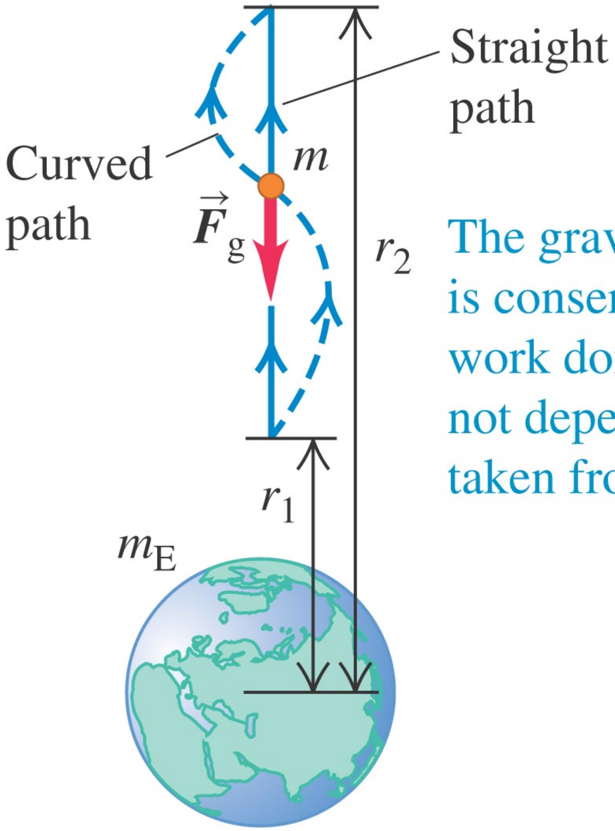
1. The size of the orbit would decrease and the orbital period would increase.
2. The size of the orbit would decrease and the orbital period would decrease.
3. The size of the orbit would increase and the orbital period would decrease.
4. The size of the orbit would increase and the orbital period would increase.
5. The Earth would fall into the black hole.
6. None of the above.

Weight

- The *weight* of a body decreases with its distance from the earth's center, as shown in Figure 13.8 below.



Gravity is a conservative force



The gravitational force is conservative: The work done by $\vec{F}_g$ does not depend on the path taken from r_1 to r_2.

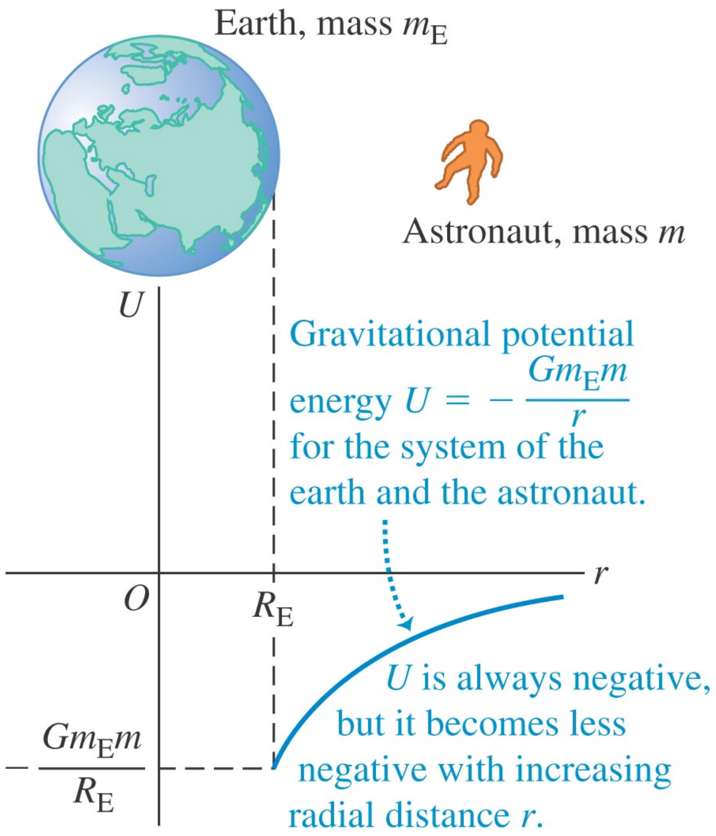
Gravitational Potential Energy

$$U_{\text{grav}} = -\frac{GMm}{r}$$

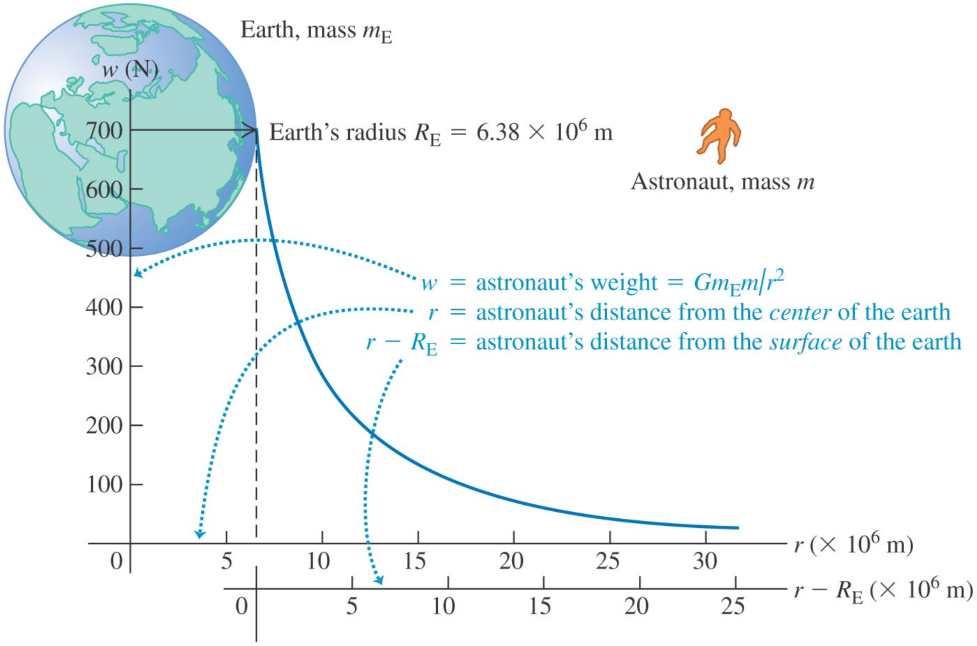
- M = mass of planet
- m = mass of particle
- r = distance between

Gravitational potential energy depends on distance

- The gravitational potential energy of the earth-astronaut system *increases* (becomes less negative) as the astronaut moves away from the earth, as shown in Figure 13.11 at the right.



Gravitational Force

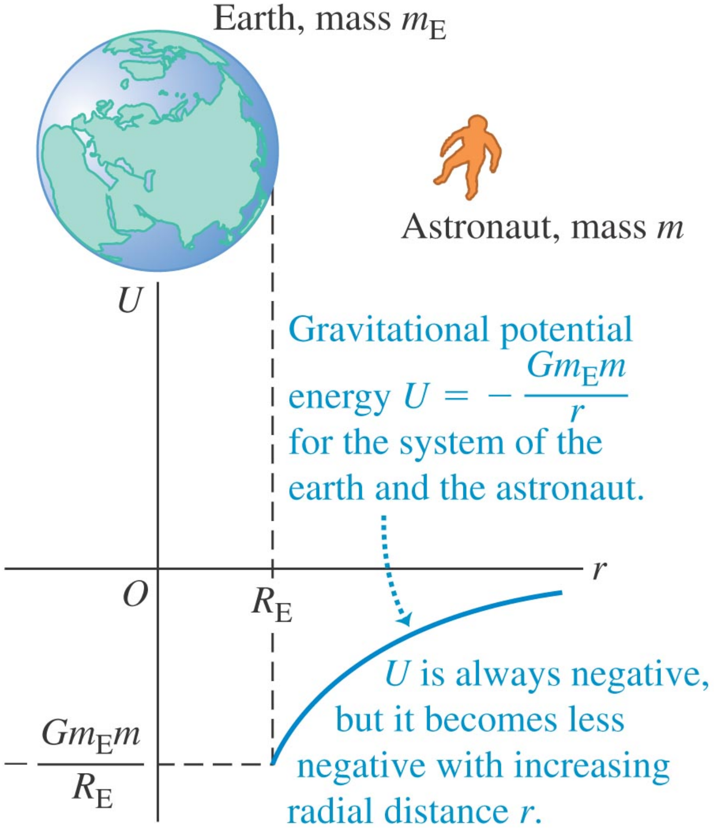


w = astronaut's weight = Gm_Em/r^2

r = astronaut's distance from the *center* of the earth

$r - R_E$ = astronaut's distance from the *surface* of the earth

Gravitational Potential

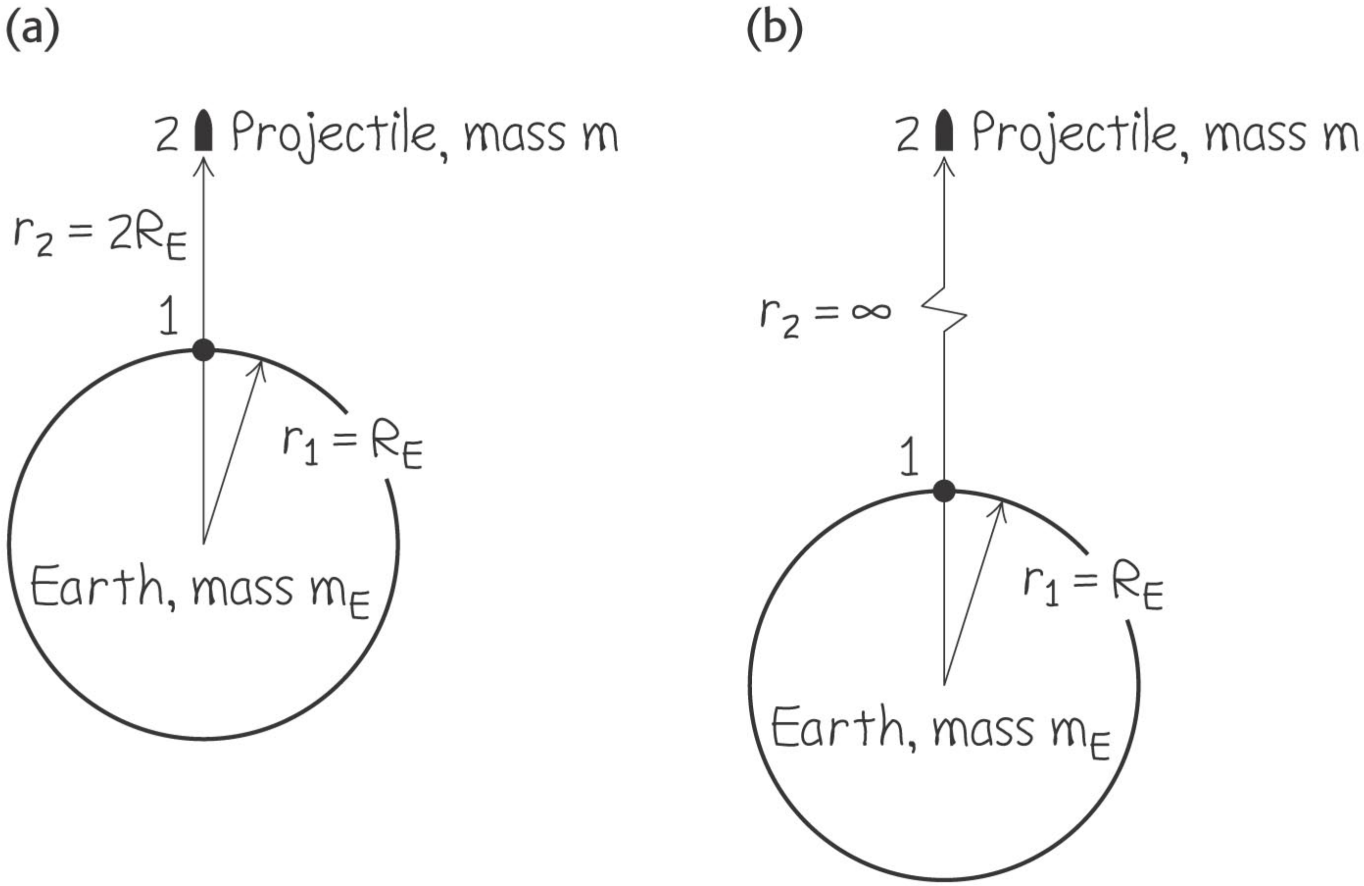


Gravitational potential energy $U = -\frac{Gm_Em}{r}$ for the system of the earth and the astronaut.

U is always negative, but it becomes less negative with increasing radial distance r.

From the earth to the moon

- To escape from the earth, an object must have the *escape speed*.
- Follow Example 13.5 using Figure 13.12 below.

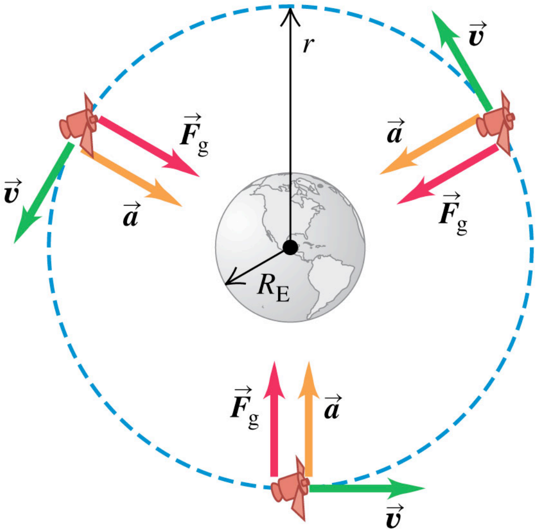


Escape speed

$$v_{\mathrm{esc}} = \sqrt{\frac{2GM}{R}}$$

Circular satellite orbits

- For a circular orbit, the speed of a satellite is just right to keep its distance from the center of the earth constant.
- A satellite is constantly falling *around* the earth. Astronauts inside the satellite in orbit are in a state of *apparent weightlessness* because they are falling with the satellite.



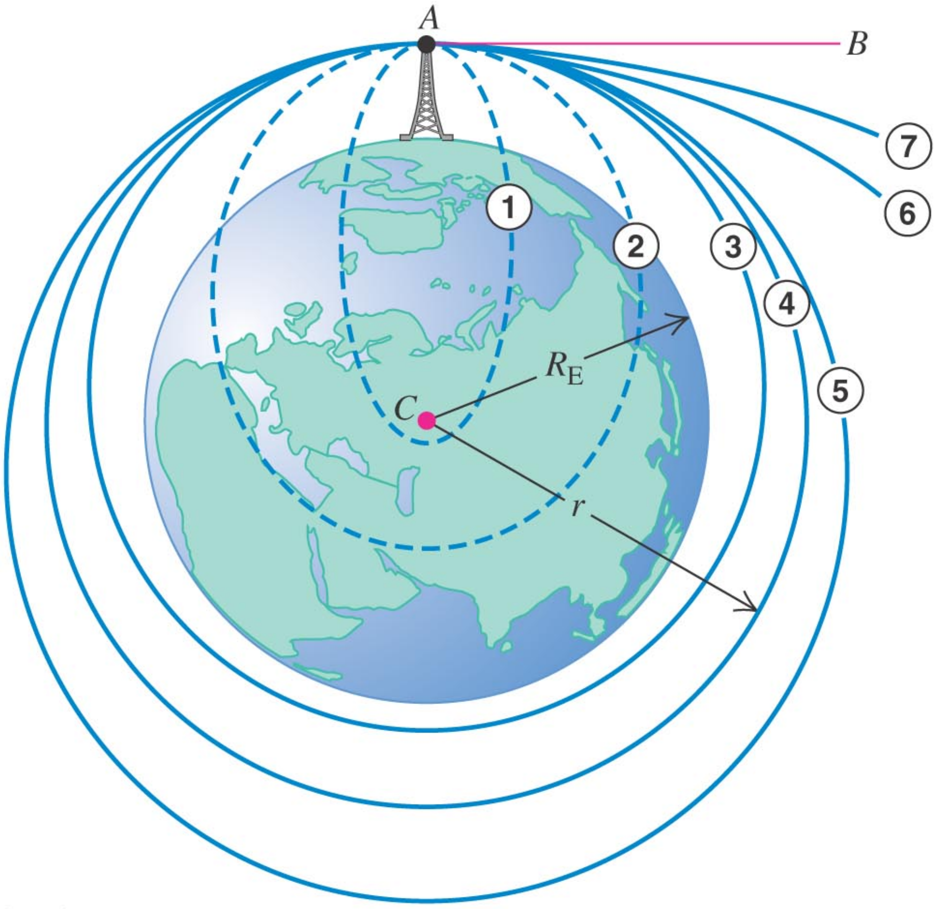
The satellite is in a circular orbit: Its acceleration $\vec{a}$ is always perpendicular to its velocity $\vec{v}$, so its speed v is constant.

Circular Orbits

$$v_{circ} = \left(\frac{GM}{r} \right)^{1/2}$$

The motion of satellites

- The trajectory of a projectile fired from *A* toward *B* depends on its initial speed. If it is fired fast enough, it goes into a *closed elliptical orbit* (trajectories 3, 4, and 5 in Figure 13.14 below).



A projectile is launched from *A* toward *B*. Trajectories ① through ⑦ show the effect of increasing initial speed.