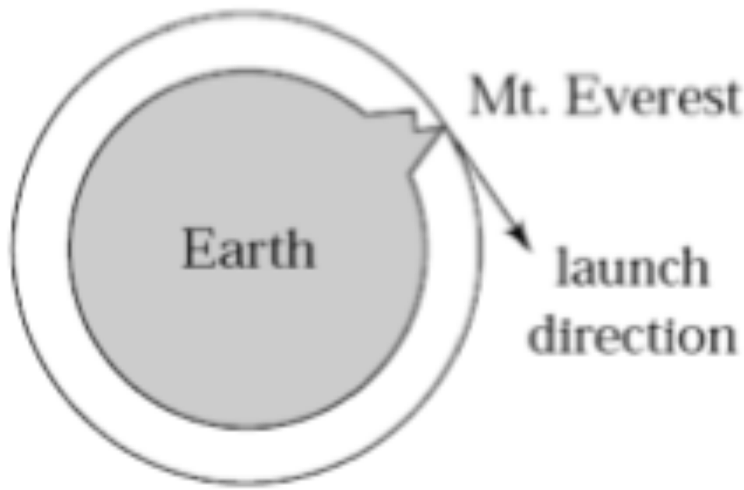
Suppose Earth had no atmosphere and a ball were fired from the top of Mt. Everest in a direction tangent to the ground. If the initial speed were high enough to cause the ball to travel in a circular trajectory around Earth, the ball's acceleration would



A. be much less than *g* (because the ball doesn't fall to the ground).
B. be approximately *g*.
C. depend on the ball's speed.

Ch 13.3-5
Orbits

PHYS 1210 - Prof. Jang-Condell

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

Circular Orbits

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

Two satellites *A* and *B* of the same mass are going around Earth in concentric orbits. The distance of satellite *B* from Earth's center is twice that of satellite *A*. What is the ratio of the centripetal force acting on *B* to that acting on *A*?

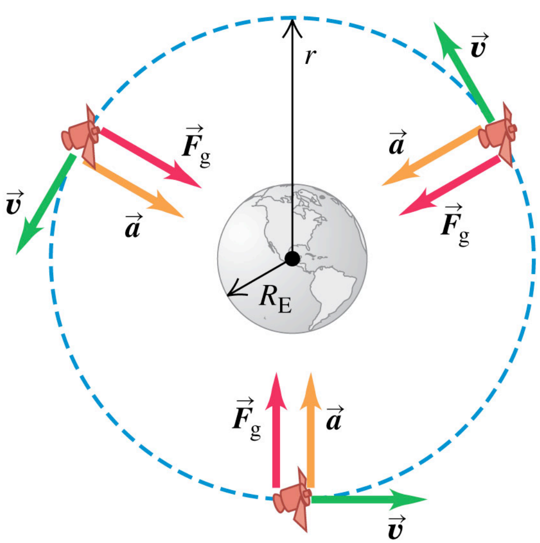
F. 1/8
G. 1/4
H. 1/2
I. $\sqrt{1/2}$
J. 1

Two satellites *A* and *B* of the same mass are going around Earth in concentric orbits. The distance of satellite *B* from Earth's center is twice that of satellite *A*. What is the ratio of the tangential speed of *B* to that of *A*?

K. $1/2$
L. $\sqrt{1/2}$
M. 1
N. $\sqrt{2}$
P. 2

Circular satellite orbits

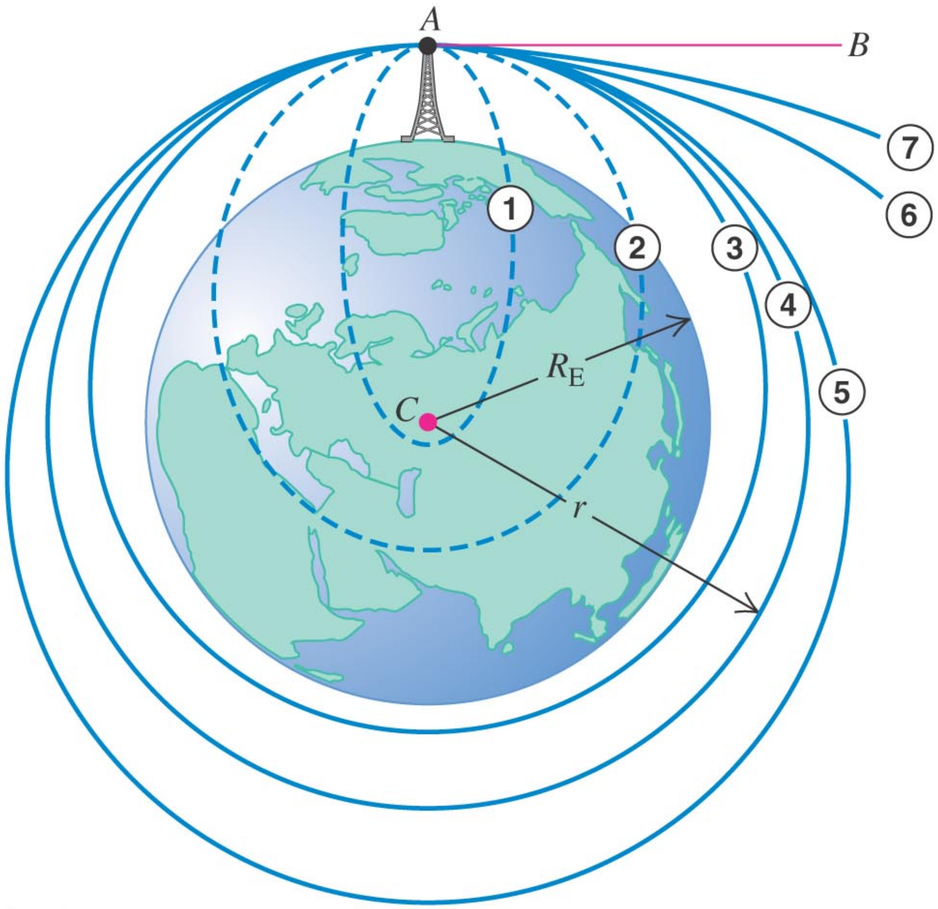
- For a circular orbit, the speed of a satellite is just right to keep its distance from the center of the earth constant.
- A satellite is constantly falling *around* the earth. Astronauts inside the satellite in orbit are in a state of *apparent weightlessness* because they are falling with the satellite.



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.

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).

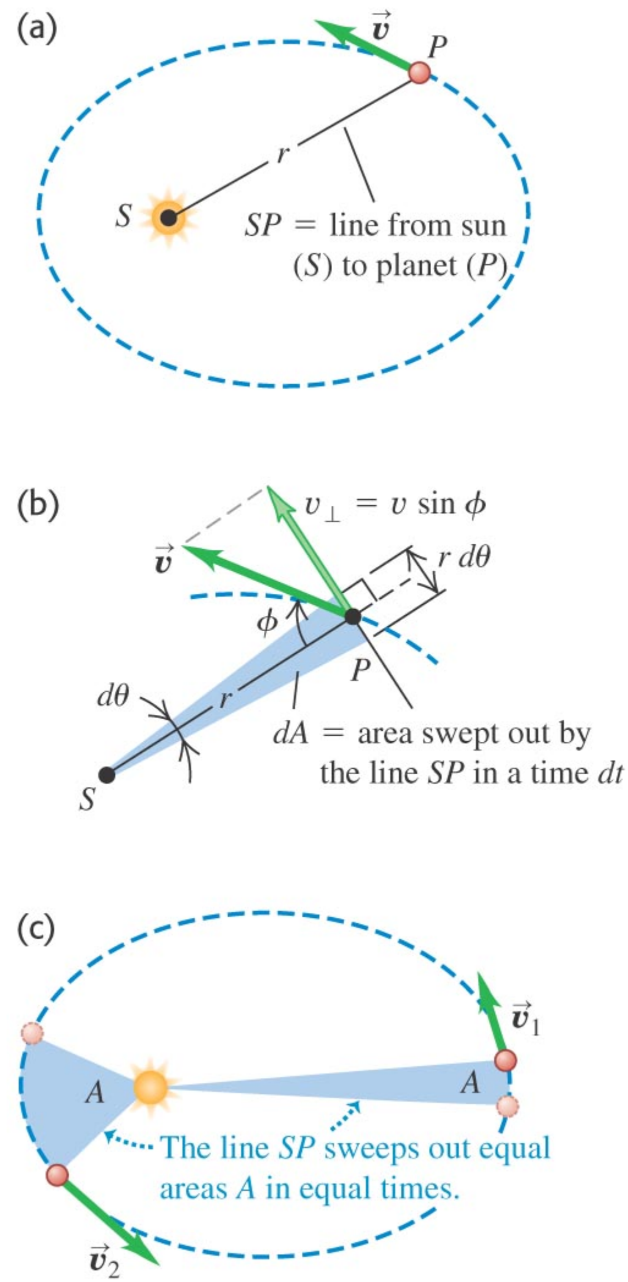


A projectile is launched from *A* toward *B*. Trajectories (1) through (7) show the effect of increasing initial speed.

Planetary Motion Demo

Kepler's laws and planetary motion

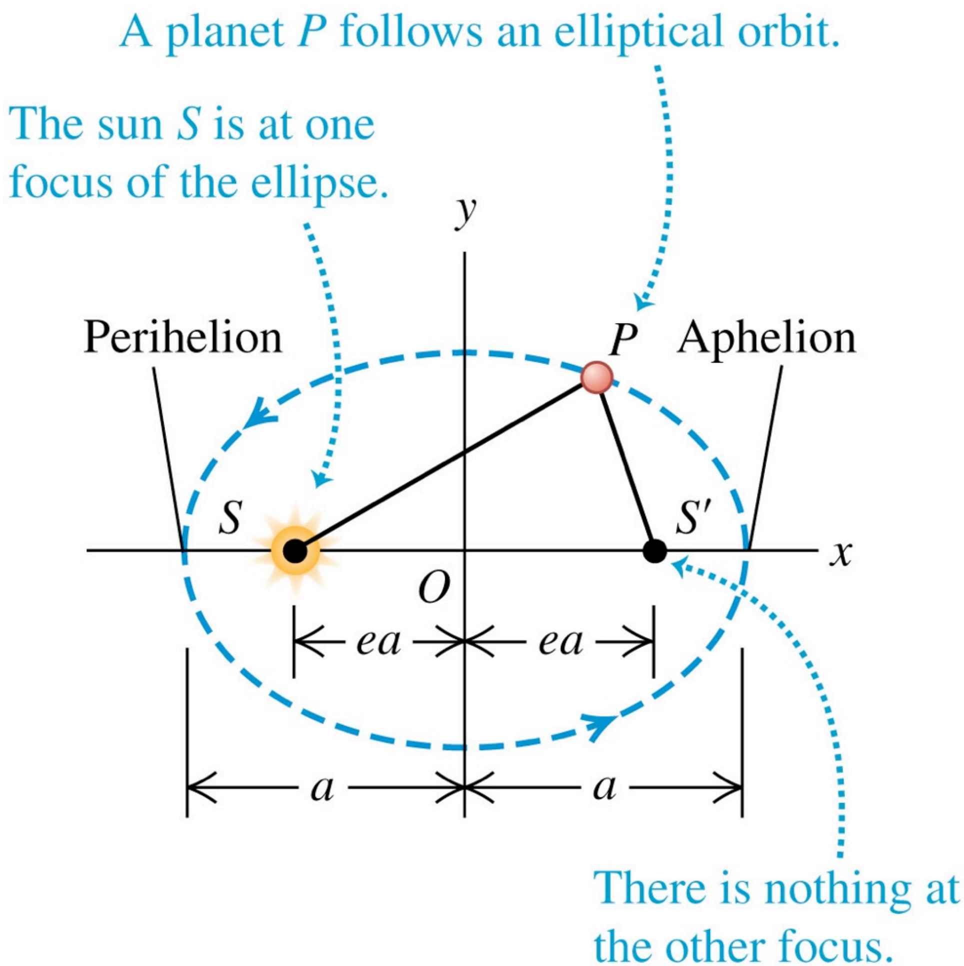
- Each planet moves in an elliptical orbit with the sun at one focus.
- A line from the sun to a given planet sweeps out equal areas in equal times (see Figure 13.19 at the right).
- The periods of the planets are proportional to the $^3/_2$ powers of the major axis lengths of their orbits.



Kepler's First Law

Each planet moves around the sun in an ellipse, with the sun at the focus

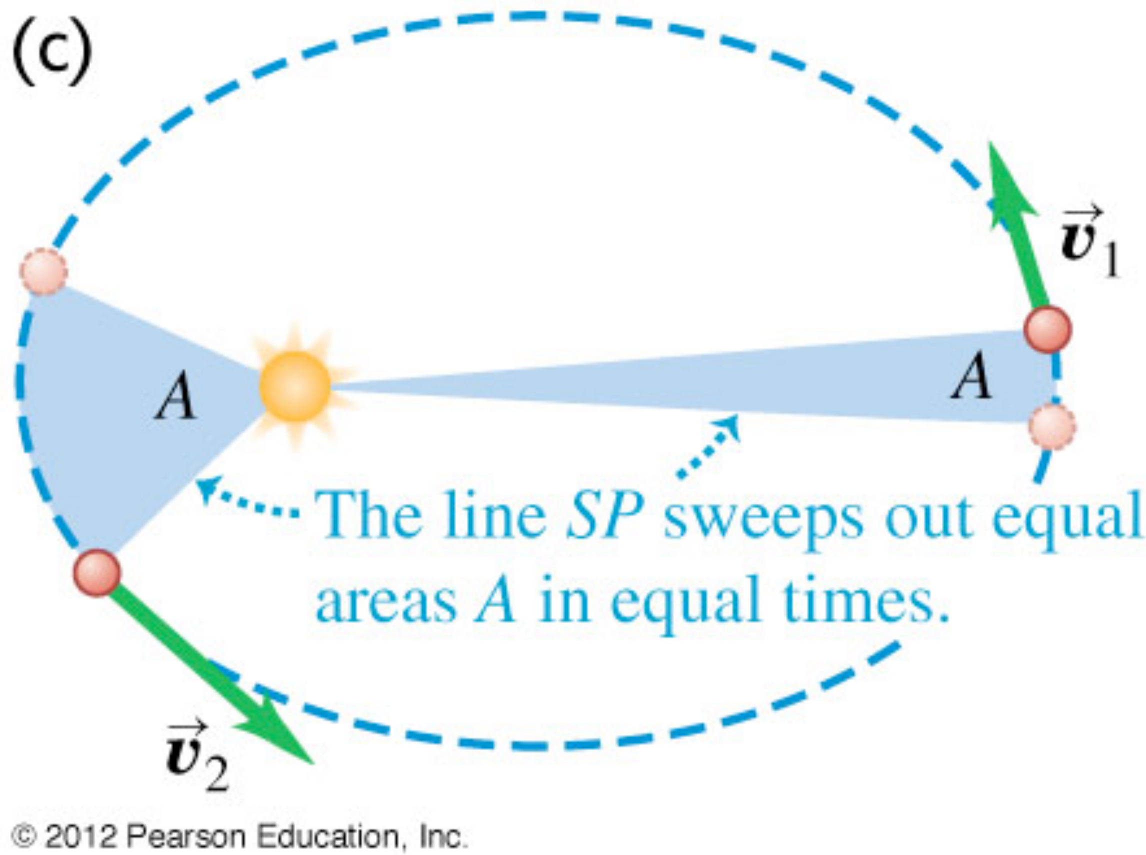
Kepler’s First Law



Kepler’s Second Law

Equal area is swept out in equal time

Kepler's Second Law

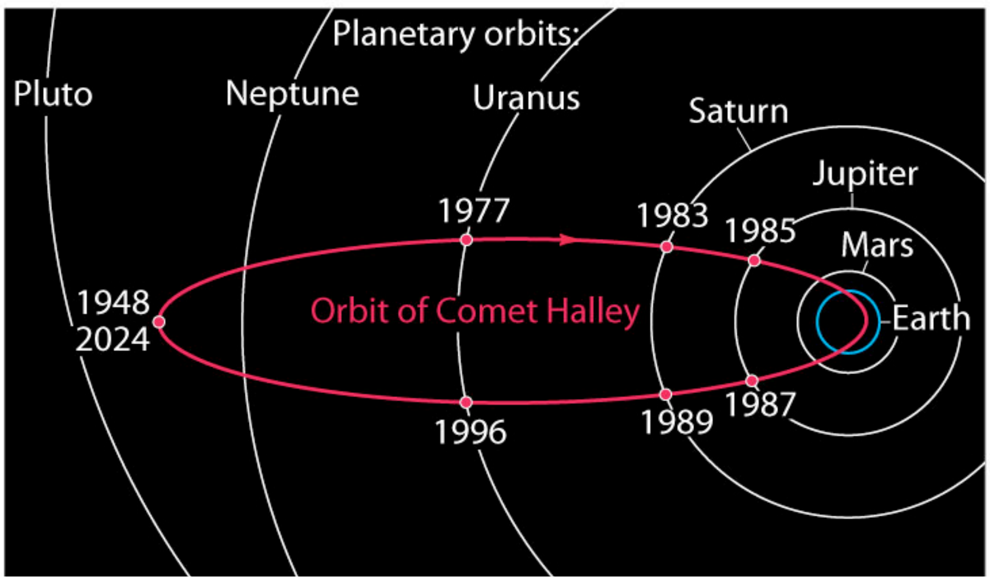


Kepler's Third Law

$$T \propto a^{3/2}$$

Halley's comet

(a)



(b)

Escape speed

(from energy conservation)

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

Black holes

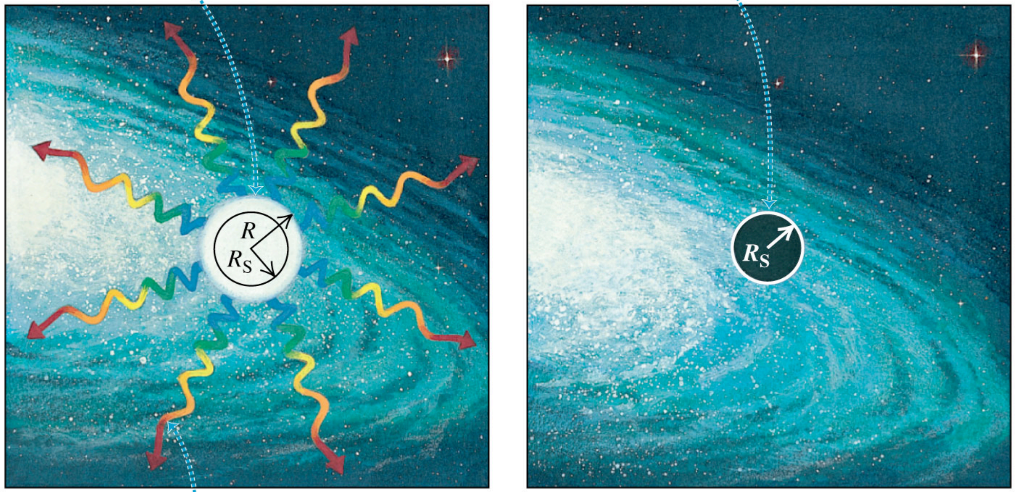
- Imagine a star so dense that its escape speed is the speed of light (c)
- The radius of that star as a function of its mass is $R_S = 2GM/c^2$
- This is the **Schwarzchild radius**

Black holes

The **event horizon** is the surface of the sphere of radius R_S surrounding a black hole.

(a) When the radius R of a body is greater than the Schwarzschild radius R_S, light can escape from the surface of the body.

(b) If all the mass of the body lies inside radius R_S, the body is a black hole: No light can escape from it.



Gravity acting on the escaping light "red shifts" it to longer wavelengths.

Detecting black holes

- We can detect black holes by looking for x rays emitted from their *accretion disks*. (See Figure 13.27 below.)