Chapter 4. Gravity, Projectiles, and Satellites

Think and Solve (Mathematica Application)

42. Suppose you stood atop a ladder that was so tall that you were three times as far from Earth's center as you presently are. Show that your weight would be one-ninth of its present value.

43. Show that the gravitational force between two planets is quadrupled if the masses of both planets are doubled but the distance between them stays the same.

44. Show that there is no change in the force of gravity between two objects when their masses are doubled and the distance between them is also doubled.

45. Find the change in the force of gravity between two planets when their distance apart is decreased by a factor of 10.

46. Consider a pair of planets in which the distance between them is decreased by a factor of 5. Show that the force between them becomes 25 times as strong.

47. Many people mistakenly believe that the astronauts who orbit Earth are "above gravity." Earth's mass is 6×10^{24} kg, and its radius is 6.38×10^{6} m (6380 km). Use the inverse-square law to show that in "space shuttle territory," 200 kilometers above Earth's surface, the force of gravity on a shuttle is about 94% that at Earth's surface.

48. Newton's universal law of gravity tells us that $F = G\frac{m_1 m_2}{d^2}$. Newton's second law tells us that $a = \frac{F_{net}}{m}$. (a) With a bit of algebraic reasoning, show that your gravitational acceleration toward any planet of mass M a distance d from its center is $a = G\frac{M}{d^2}$.

(b) How does this equation tell you whether or not your gravitational acceleration depends on your mass?

49. An airplane is flying horizontally with speed 1000 km/h (~280 m/s) when an engine falls off. Neglecting air resistance, assume that it takes 30 s for the engine to hit the ground.
(a) Show that the altitude of the airplane is 4.4 km. (Use g=9.8 m/s^2)

(b) Show that the horizontal distance that the airplane engine travels during its fall is 8.4 km.

(c) If the airplane somehow continues to fly as though nothing had happened, where is the engine relative to the airplane at the moment the engine hits the ground?

50. A ball is thrown horizontally from a cliff at a speed of 10 m/s. Show that its speed one second later is about 14 m/s.

51. A satellite at a particular point along an elliptical orbit has a gravitational potential energy of 5000 MJ with respect to Earth's surface and a kinetic energy of 4500 MJ. Later in its orbit the satellite's potential energy is 6000 MJ. Use the conservation of energy to find its kinetic energy at that point.

52. A rock thrown horizontally from a bridge hits the water below. The rock travels a smooth parabolic path in time t. (a) Show that the height of the bridge is $\frac{1}{2}gt^2$.

(b) What is the height of the bridge if the time the rock is airborne is 2 s?

(c) To solve this problem, what information is assumed here that wasn't in Chapter 2?

53. A baseball is tossed at a steep angle into the air and makes a smooth parabolic path. Its time in the air is t, and it reaches a maximum height h. Assume that air resistance is negligible.

(a) Show that the height reached by the ball is $\frac{gt^2}{8}$.

(b) Show that if the ball is in the air for 4 s, it reaches a height of nearly 20 m.

(c) If the ball reached the same height as it did when it was tossed at some other angle, would the time of flight be the same?

54. A penny on its side moving at speed v slides off the horizontal surface of a table a vertical distance y from the floor.

(a) Show that the penny lands a distance $v.\sqrt{\frac{2y}{g}}$ from the base of the coffee table.

(b) Show that if the speed is 3.5 m/s and the coffee table is 0.4 m tall, the distance the coin lands from the base of the table is 1.0 m. (Use g = 9.8 m/s^2 .)

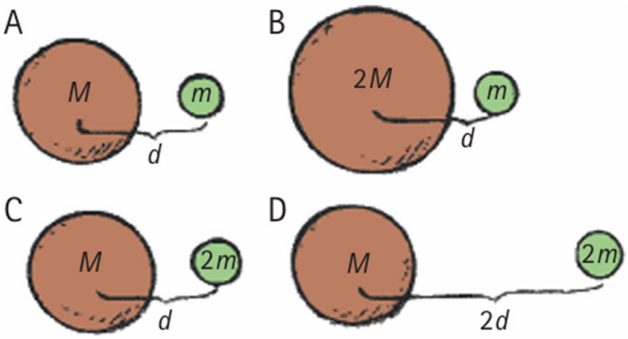
55. Students in a lab measure the speed of a steel ball launched horizontally from a tabletop to be v. The tabletop is distance y above the floor. They place a tin coffee can of height $0.1y$ on the floor to catch the ball.

(a) Show that the can should be placed a horizontal distance from the base of the table of $v.\sqrt{\frac{2(0.9)y}{g}}$

(b) Show that if the ball leaves the tabletop at a speed of 4.0 m/s, the tabletop is 1.5 m above the floor, and the can is 0.15 m tall, then the center of the can should be placed a horizontal distance of 2.1 m from the base of the table.

Think and rank

56. The planet and its moon gravitationally attract each other. Rank, from greatest to least, the force of attraction between the members of each pair.



58. Rank, from greatest to least, the average gravitational forces between:

(a) The Sun and Mars.

(b) The Sun and the Moon.

(c) The Sun and Earth.

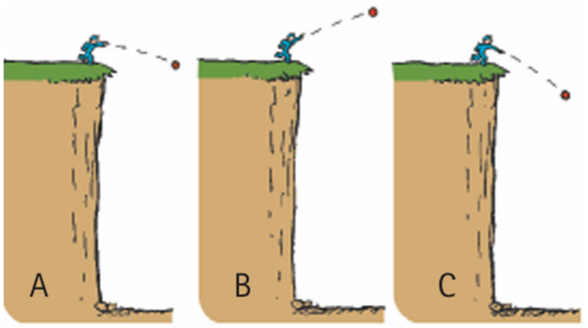
59. A ball is tossed off the edge of a cliff with the same speed, but at different angles as shown. Rank, from greatest to least:

(a) The initial PEs of the balls relative to the ground below.

(b) The initial KEs of the balls when tossed.

(c) The KEs of the balls when hitting the ground below.

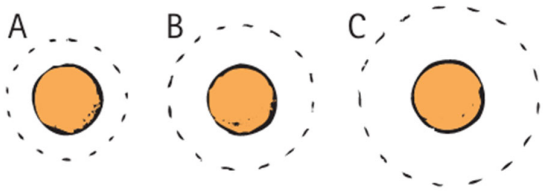
(d) The times of flight while airborne.



60. The dashed lines show three circular orbits about Earth. Rank the following quantities from greatest to least:

(a) Their orbital speed.

(b) Their time to orbit Earth.



61. The positions of a satellite in elliptical orbit are indicated. Rank the following quantities from greatest to least:

(a) Gravitational force.

(b) Speed.

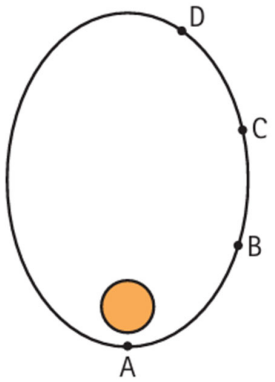
(c) Momentum.

(d) KE.

(e) PE.

(f) Total energy (KE + PE).

(g)Acceleration.



Readiness Assurance Test (RAT)

Choose the BEST way to complete the statement.

1. The Moon falls toward Earth in the sense that it falls

A. with an acceleration of 10 m/s^2, as do apples on Earth.

B. beneath the straight-line path it would follow without gravity.

C. both of these

D. neither of these

2. The force of gravity between two planets depends on

A. their masses. **B.** the square of the distance between their centers.

C. the constant G. **D.** all of these

3. Inhabitants of the International Space Station are weight_less because

A. very little (if any) gravitational attraction to Earth is present. **B.** in outer space one has no mass.

C. they lack a support force. **D.** all of these

4. A spacecraft on its way from Earth to the Moon is pulled equally by Earth and the Moon when it is

A. closer to the Earth's surface. **B.** closer to the Moon's surface.

C. halfway from Earth to Moon. **D.** at no point, since Earth always pulls more strongly.

5. Theoretically, a baseball tossed horizontally in a gravity-free region would continue in a straight line. With gravity, it falls in one second about

A. 1 m below that line. **B.** 5 m below that line.

C. 10 m below that line. **D.** none of these

6. When no air resistance acts on a projectile, its horizontal acceleration is

A. g. **B.** at right angles to g. **C.** centripetal. **D.** zero.

7. Without air resistance, a ball tossed at an angle of 40° with the horizontal goes as far downrange as one tossed at the same speed at an angle of

A. 45°. **B.** 50°. **C.** 60°. **D.** none of these

8. When you toss a projectile sideways, it curves as it falls. It will become an Earth satellite if the curve it makes

A. matches the curve of Earth's surface. **B.** results in a straight line.

C. spirals out indefinitely. **D.** none of these

9. A satellite in elliptical orbit about Earth travels fastest when it moves……

A. closest to Earth. **B.** farthest from Earth.

C. neither of these; that is, it moves at the same speed everywhere.

D. halfway between the near and far points from Earth.

10. A satellite in Earth orbit is mainly above Earth's

A. atmosphere. **B.** gravitational field. **C.** both of these **D.** neither of these