

Chapter 13 Universal Gravitation

Exercises

13.1 The Falling Apple (page 233)

1. Describe the legend of Newton's discovery that gravity extends throughout the universe.

According to legend, Newton saw an apple fall from a tree and realized that the moon falls toward Earth for the same reason an apple falls from a tree. They are both pulled by Earth's gravity.

2. Newton understood the concept of inertia, developed by Galileo, that without an outside force, moving objects continue to move at constant speed in a straight line.
3. Is the following sentence true or false? Circular motion is accelerated motion, which requires a force. true

13.2 The Falling Moon (pages 233–235)

4. Newton realized that the moon must be falling around Earth.
5. Is the following sentence true or false? The moon falls beneath the straight line it would follow if no force acted on it. true
6. Newton compared motion of the moon to a cannonball fired from the top of a high mountain. Describe the possible paths for the cannonball proposed by Newton.

A cannonball fired with a small horizontal speed would follow a parabolic path and soon hit Earth. If the speed were faster, the path would be less curved and the cannonball would hit Earth farther away. At a fast enough speed, the path would become a circle and the cannonball would circle indefinitely.

7. Circle the letter of the word that best describes the tangential velocity that prevents the moon from hitting Earth.
- a. upward **(b.)** sideways
c. downward d. backward
8. Is the following sentence true or false? Newton believed that the mass of the moon affects how it falls. false
9. Explain Newton's calculation that the moon falls 1.4 millimeters each second.

An apple falls about 5 m in its first second of fall. The moon is about 60 times farther from the center of Earth than an apple at Earth's surface. The moon should fall $1/(60)^2$ of 5 m, or 1.4 millimeters in one second.

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13.3 The Falling Earth (page 236)

10. Is this sentence true or false? Newton's theory of gravity confirmed the Copernican theory of the solar system. true
11. Circle the letter of the sentence that describes the motion of a planet if its tangential velocity were reduced to zero.
- It would drift in space.
 - It would continue in orbit at a slower speed.
 - It would crash into the sun.
 - It would spin away from the solar system.
12. Why are there no large objects in the solar system today with very low tangential velocities?
They long ago crashed into the sun.

13.4 Newton's Law of Universal Gravitation (pages 237–239)

13. Is the following sentence true or false? Isaac Newton discovered gravity.
false
14. State Newton's law of universal gravitation using words.
For any pair of objects, each object attracts the other object with a force that is directly proportional to the product of the masses of the objects and inversely proportional to the square of the distance between their centers of mass.
15. What is the equation for universal gravitation?
 $F = G [m_1 m_2 / d^2]$
16. The constant G in this equation is called the universal gravitational constant and describes the strength of gravity.
17. The English physicist Henry Cavendish first measured G .
18. Is the following sentence true or false? The force of gravity is the strongest of the presently known four fundamental forces. false
19. Is the following sentence true or false? At the top of a mountain, your weight is slightly less than at ground level. true

**13.5 Gravity and Distance:
The Inverse-Square Law** (pages 240–241)

20. Express the inverse square law in words.
If one quantity is multiplied by a factor, another quantity decreases by the square of that factor.
21. Circle the letter of the inverse square of 9.
- $\frac{1}{3}$
 - $\frac{1}{81}$
 - 3
 - 81

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Match each change with the effect it would have on the force of gravity between two objects.

- | Change | Effect |
|---|----------------------------------|
| <u>c</u> 22. The mass of one object doubles. | a. The force is divided by 2. |
| <u>a</u> 23. The mass of one object decreases by half. | b. The force is divided by 4. |
| <u>b</u> 24. The distance between the objects' centers of mass doubles. | c. The force is multiplied by 2. |
| <u>d</u> 25. The distance between the objects' centers of mass decreases by half. | d. The force is multiplied by 4. |
26. Is the following sentence true or false? The gravitational influence of every object is exerted through all space. true

13.6 Gravitational Field (pages 242–243)

27. The pulls that Earth and the moon exert on each other is action at a distance because the bodies interact without being in contact.
28. Define *gravitational field*.
a force field that exists in the space around every massive body
-
29. Earth's gravitational field interacts with objects by causing them to experience gravitational forces.
30. Field lines show the strength and direction of a force field.
31. Field lines are closest together where a field is strongest.
32. How are gravitational field lines related to the acceleration of an object around Earth?
Any mass near Earth will be accelerated in the direction of the field lines at that location.
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13.7 Gravitational Field Inside a Planet (page 244)

33. Circle the letter that identifies the location where Earth's gravitational field is zero.
- a. in a plane above Earth's surface b. at Earth's surface
 c. between Earth's surface and its center **(d.)** at Earth's center
34. Is the following sentence true or false? The weight of a rock at Earth's center is zero. true

13.8 Weight and Weightlessness (pages 245–246)

35. Why are people often unaware that gravity accelerates us?
because we are almost always in contact with Earth
-
36. Pressure against Earth is the sensation we interpret as weight.

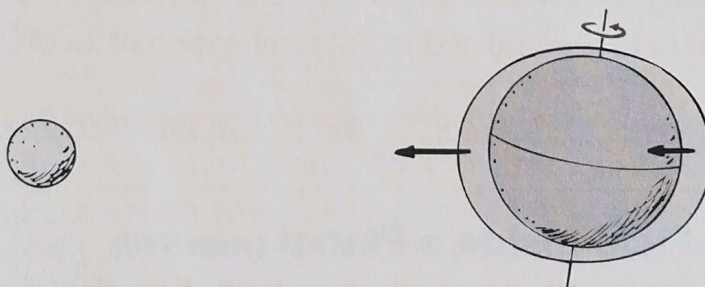
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Match each position or movement of an elevator with your weight if you stepped on a scale in the elevator.

- | Elevator Position or Movement | Weight Reading |
|--|------------------------------|
| <u> b </u> 37. sitting still | a. no weight |
| <u> d </u> 38. accelerating downward | b. normal weight |
| <u> c </u> 39. accelerating upward | c. greater weight than usual |
| <u> a </u> 40. falling freely | d. less weight than usual |
41. Rather than define your weight as the force of gravity that acts on you, it is more practical to define weight as the force you exert against a supporting floor.
42. Is the following sentence true or false? Weightlessness is the absence of gravity. false
43. Explain why rotating giant wheels will likely be used as space habitats in the future.
Rotation will supply a support force for astronauts, giving them a sense of weight.

13.9 Ocean Tides (pages 246–248)

44. How often does a high tide occur? twice per day
45. Is the following sentence true or false? The pull of the moon and Earth on each other causes them both to be slightly elongated rather than spherical. true



46. The figure shows the moon near the spinning Earth. Use the figure to explain the cause of ocean tides on Earth. In your explanation, describe why the arrows in the figure are different lengths.
The arrows show that the gravitational pull of the moon is stronger on the ocean water nearest the moon and weaker on the opposite side, causing a bulge on each side. As Earth spins, a fixed point moves under both bulges each day.
47. Circle the letter of the fraction that compares the sun's contribution to ocean tides to the moon's contribution.
a. one sixteenth b. one fourth
c. one eighth **d. one half**
48. The sun's pull on Earth is 180 times greater than the moon's pull on Earth.

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49. Write *spring* or *neap* on each line to indicate whether the description matches a spring tide or a neap tide.

- neap a. Occurs when the moon is halfway between a new moon and a full moon.
- spring b. High tides are higher than usual, and low tides are lower than usual.
- spring c. Occurs at times of a new or full moon.
- neap d. The pulls of the moon and sun are perpendicular to each other.
- spring e. Occurs when the sun, Earth, and moon are all lined up.
- spring f. The solar and lunar tides coincide.
- neap g. The solar and lunar tides do not overlap.

50. A tidal effect causes the solid surface of Earth to rise and fall as much as one-quarter meter twice each day.

51. Explain why lakes have almost no tides.

There is no significant difference in the moon's pull on different parts of the lake.

13.10 Black Holes (pages 249–251)

52. Explain the effects that the following processes have on stars like our sun.

- a. Gravitation: It tends to crush all solar material toward the center.
- b. Nuclear fusion: It blows solar material outward.

53. If the fusion rate of the sun increases, the sun will get hotter and bigger.

54. If the fusion rate of the sun decreases, the sun will get cooler and smaller.

55. Circle the letter that identifies the fuel for the type of fusion that currently takes place in the sun.

- a. carbon
- (b.) hydrogen**
- c. nitrogen
- d. oxygen

56. Explain what will cause our sun to collapse some 5 billion years from now.

The sun will run out of hydrogen fuel for fusion, and gravitation will dominate.

57. As the sun collapses, a different type of fusion will begin in which helium fuses into carbon.

58. Fusion will eventually cause the sun to expand into a(n) red giant which will extend beyond Earth's orbit and swallow Earth.

59. When our sun no longer gives off heat and light, it will be a(n) black dwarf.

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60. Explain why a star that is at least two to three times more massive than our sun will eventually collapse into a black hole.

It is so massive that its collapse will not stop and its density will become infinite.

61. Circle the letters of the statements that correctly describe a black hole.
- It has significantly more mass than the star from which it collapsed.
 - Its gravitational field beyond the original radius of the star is unchanged.
 - The configuration of the gravitational field around it represents a collapse of space itself.
 - Its volume is unchanged from the star from which it collapsed.

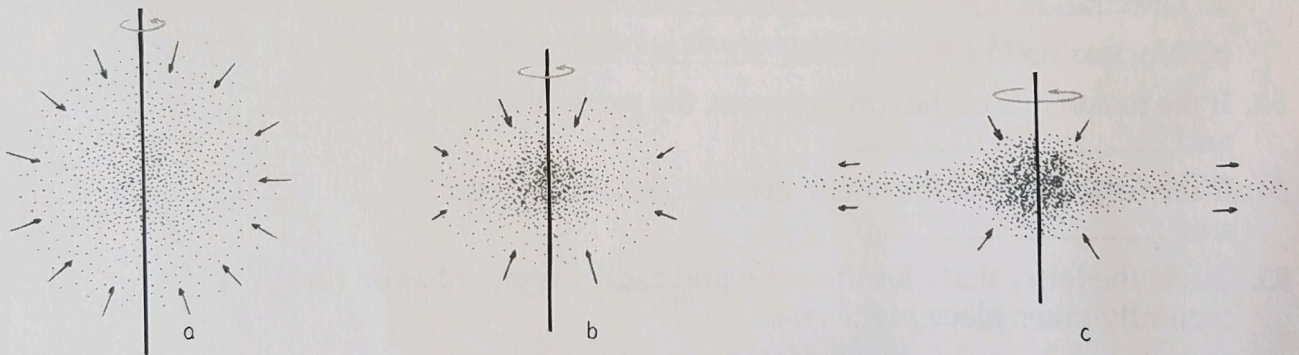
62. Explain how a black hole that is part of a binary pair can be detected, even though it cannot be seen.

Matter streams from the visible star of the binary pair toward the black hole, emitting X-rays that can be detected by telescopes.

63. Black holes are near the centers of most galaxies. How do these black holes affect stars near them?

They cause the stars to speed around in tight orbits.

13.11 Universal Gravitation (pages 251–254)



64. Refer to the figures above to describe the role that gravity played in the formation of the solar system.

A slightly rotating ball of interstellar gas contracted due to mutual gravitation. To conserve angular momentum, the rotational speed of the gas increased, and the particles moved out, producing a disk shape. The greater surface area caused the matter to cool and form clusters that became planets.

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65. Explain why Earth is round.

Gravity caused Earth to attract itself together before it became solid. Any "corners" of Earth have been pulled in so that Earth is a giant sphere.

66. Define *perturbation*.

the deviation of an orbiting object from its path around a center of force, caused by the action of an additional center of force

67. Circle the letter of the orbiting body that was discovered in just half an hour because of a perturbation in the orbit of Uranus.

- a. Jupiter
- b. Neptune
- c. Pluto
- d. Saturn

Match each type of energy or matter with its percent of the universe.

Energy or Matter	Percentage of the Universe
<u>c</u> 68. dark energy	a. 4%
<u>b</u> 69. dark matter	b. 23%
<u>a</u> 70. ordinary matter	c. 73%

71. Is the following sentence true or false? The law of universal gravitation is a complicated law that only describes a few unique instances.

false