Extra Newton’s Law of Gravitation Practice Problems - Answers

1. Two spherical objects have masses of 200 kg and 500 kg. Their centers are separated by a distance of 25 m. Find the gravitational attraction between them.

\[
F = \frac{Gm_1m_2}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(200 \text{ kg})(500 \text{ kg})}{(25 \text{ m})^2} = 1.1 \times 10^{-8} \text{ N}
\]

2. Two spherical objects have masses of 1.5 \times 10^6 \text{ kg} and 8.5 \times 10^2 \text{ kg}. Their centers are separated by a distance of 2500 m. Find the gravitational attraction between them.

\[
F = \frac{Gm_1m_2}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(1.5 \times 10^5 \text{ kg})(8.5 \times 10^2 \text{ kg})}{(2500 \text{ m})^2} = 1.4 \times 10^{-11} \text{ N}
\]

3. Two spherical objects have masses of 3.1 \times 10^6 \text{ kg} and 6.5 \times 10^3 \text{ kg}. The gravitational attraction between them is 65 N. How far apart are their centers?

\[
r = \sqrt{\frac{Gm_1m_2}{F}} = \sqrt{\frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(3.1 \times 10^5 \text{ kg})(6.5 \times 10^3 \text{ kg})}{65 \text{ N}}} = 4.5 \times 10^{-2} \text{ meters}
\]

4. Two spherical objects have equal masses and experience a gravitational force of 25 N towards one another. Their centers are 36 cm apart. Determine each of their masses.

\[
F = \frac{Gm_1m_2}{r^2}, \text{ need to solve for the masses, } m_1 = m_2 = m; \quad F = \frac{Gm^2}{r^2}
\]

NOTE: \( r \) is given in cm and MUST be converted to meters!!!

\[
m = \sqrt{\frac{Fr^2}{G}} = r \sqrt{\frac{F}{G}} = (0.36 \text{ m}) \sqrt{\frac{25 \text{ N}}{6.67 \times 10^{-11} \frac{Nm^2}{kg^2}}} = 2.2 \times 10^5 \text{ kg}
\]

5. A 1 kg object is located at a distance of 6.4 \times 10^6 \text{ m} from the center of a larger object whose mass is 6.0 \times 10^{24} \text{ kg}.

a. What is the size of the force acting on the smaller object?

\[
F = \frac{Gm_1m_2}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(6.0 \times 10^{24} \text{ kg})(1 \text{ kg})}{(6.4 \times 10^6 \text{ m})^2} = 9.8 \text{ N}
\]

b. What is the size of the force acting on the larger object?

Newton’s Third Law – the forces are equal so the answer is 9.8 N.
c. What is the acceleration of the smaller object when it is released?

The force acting on the object is the net force. According to Newton’s Second Law, net force is equal to mass times acceleration.

\[ F = ma; \quad a = \frac{F}{m} \]

\[ a = \frac{9.8 \text{ N}}{1 \text{ kg}} = 9.8 \frac{\text{m}}{\text{s}^2} \]

d. What is the acceleration of the larger object when it is released?

\[ F = ma; \quad a = \frac{F}{m} \]

\[ a = \frac{9.8 \text{ N}}{6.0 \times 10^{24} \text{ kg}} = 1.6 \times 10^{-24} \frac{\text{m}}{\text{s}^2} \]

6. Two spherical objects have masses of 8000 kg and 1500 kg. Their centers are separated by a distance of 1.5 m. Find the gravitational attraction between them.

\[ F = \frac{Gm_1m_2}{r^2} = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(8000 \text{ kg})(1500 \text{ kg})}{(1.5 \text{ m})^2} = 3.6 \times 10^{-4} \text{ N} \]

7. Two spherical objects have masses of 7.5 \times 10^6 kg and 9.2 \times 10^7 kg. Their centers are separated by a distance of 2.5 \times 10^3 m. Find the gravitational attraction between them.

\[ F = \frac{Gm_1m_2}{r^2} = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(7.5 \times 10^5 \text{ kg})(9.2 \times 10^7 \text{ kg})}{(2.5 \times 10^3 \text{ m})^2} = 7.4 \times 10^{-4} \text{ N} \]

8. Two spherical objects have masses of 8.1 \times 10^8 kg and 4.5 \times 10^8 kg. The gravitational attraction between them is 1.9 \times 10^{-3} N. How far apart are their centers?

\[ F = \frac{Gm_1m_2}{r^2}, \text{ need to solve for the radius} \]

\[ r = \sqrt{\frac{Gm_1m_2}{F}} = \sqrt{\frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(8.1 \times 10^8 \text{ kg})(4.5 \times 10^8 \text{ kg})}{1.9 \times 10^{-3} \text{ N}}} = 110 \text{ meters} \]

9. Two spherical objects have equal masses and experience a gravitational force of 85 N towards one another. Their centers are 36 mm apart. Determine each of their masses.

\[ F = \frac{Gm_1m_2}{r^2}, \text{ need to solve for the masses, } m_1 = m_2 = m; \quad F = \frac{Gm^2}{r^2} \]

NOTE: \( r \) is given in mm and MUST be converted to meters!!!

\[ m = \sqrt{\frac{Fr^2}{G}} = r \sqrt{\frac{F}{G}} = (0.036 \text{ m}) \sqrt{\frac{85 \text{ N}}{6.67 \times 10^{-11} \frac{Nm^2}{kg^2}}} = 4.1 \times 10^4 \text{ kg} \]
10. A 1 kg object is located at a distance of $7.0 \times 10^8$ m from the center of a larger object whose mass is $2.0 \times 10^{30}$ kg.

a. What is the size of the force acting on the smaller object?

\[ F = \frac{G m_1 m_2}{r^2} = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(2.0 \times 10^{30} \text{ kg})(1 \text{ kg})}{(7.0 \times 10^8 \text{ m})^2} = 272 \text{ N} \]

b. What is the size of the force acting on the larger object?

Newton's Third Law - the forces are equal so the answer is 272 N.

c. What is the acceleration of the smaller object when it is released?

\[ F = ma; \ a = \frac{F}{m} \]
\[ a = \frac{272 \text{ N}}{1 \text{ kg}} = 272 \frac{\text{m}}{\text{s}^2} \]

d. What is the acceleration of the larger object when it is released?

\[ F = ma; \ a = \frac{F}{m} \]
\[ a = \frac{272 \text{ N}}{2.0 \times 10^{30} \text{ kg}} = 1.4 \times 10^{-28} \frac{\text{m}}{\text{s}^2} \]

11. Two spherical objects have masses of 8000 kg and 5.0 kg. Their centers are separated by a distance of 1.5 m. Find the gravitational attraction between them.

\[ F = \frac{G m_1 m_2}{r^2} = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(8000 \text{ kg})(5.0 \text{ kg})}{(1.5 \text{ m})^2} = 1.2 \times 10^{-6} \text{ N} \]

12. Two spherical objects have masses of $9.5 \times 10^8$ kg and 2.5 kg. Their centers are separated by a distance of $2.5 \times 10^8$ m. Find the gravitational attraction between them.

\[ F = \frac{G m_1 m_2}{r^2} = \frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(9.5 \times 10^8 \text{ kg})(2.5 \text{ kg})}{(2.5 \times 10^8 \text{ m})^2} = 2.5 \times 10^{-18} \text{ N} \]

13. Two spherical objects have masses of $6.3 \times 10^3$ kg and $3.5 \times 10^4$ kg. The gravitational attraction between them is $6.5 \times 10^{-8}$ N. How far apart are their centers?

\[ F = \frac{G m_1 m_2}{r^2}, \text{ need to solve for the radius} \]
\[ r = \sqrt{\frac{G m_1 m_2}{F}} = \sqrt{\frac{(6.67 \times 10^{-11} \frac{Nm^2}{kg^2})(6.3 \times 10^3 \text{ kg})(3.5 \times 10^4 \text{ kg})}{6.5 \times 10^{-3} \text{ N}}} = 1.5 \text{ meters} \]
14. Two spherical objects have equal masses and experience a gravitational force of 25 N towards one another. Their centers are 36 cm apart. Determine each of their masses.

\[ F = \frac{Gm_1m_2}{r^2}, \text{need to solve for the masses, } m_1 = m_2 = m; F = \frac{Gm^2}{r^2} \]

\[ m = \sqrt{\frac{Fr^2}{G}} = r \sqrt{\frac{F}{G}} = (0.36 \text{ m}) \sqrt{\frac{25 \text{ N}}{6.67 \times 10^{-11} Nm^2/kg^2}} = 2.2 \times 10^5 \text{ kg} \]

15. A 1 kg object is located at a distance of 1.7 x10⁶ m from the center of a larger object whose mass is 7.4 x 10²² kg.
   a. What is the size of the force acting on the smaller object?

\[ F = \frac{Gm_1m_2}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(7.4 \times 10^{22} \text{ kg})(1 \text{ kg})}{(1.7 \times 10^6 \text{ m})^2} = 1.7 \text{ N} \]

b. What is the size of the force acting on the larger object?

Newton’s Third Law – the forces are equal so the answer is 1.7 N.

c. What is the acceleration of the smaller object when it is released?

\[ F = ma; \quad a = \frac{F}{m} \]

\[ a = \frac{1.7 \text{ N}}{1 \text{ kg}} = 1.7 \frac{\text{m}}{\text{s}^2} \]

d. What is the acceleration of the larger object when it is released?

\[ F = ma; \quad a = \frac{F}{m} \]

\[ a = \frac{1.7 \text{ N}}{7.4 \times 10^{22} \text{ kg}} = 2.3 \times 10^{-23} \frac{\text{m}}{\text{s}^2} \]

16. Compute g at a distance of 4.5 x 10⁷m from the center of a spherical object whose mass is 3.0 x 10²³ kg.

\[ g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(3.0 \times 10^{23} \text{ kg})}{(4.5 \times 10^7 \text{ m})^2} = 0.0099 \frac{\text{m}}{\text{s}^2} \]

17. Compute g for the surface of the moon. Its radius is 1.7 x10⁸ m and its mass is 7.4 x 10²⁵ kg.

\[ g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(7.4 \times 10^{22} \text{ kg})}{(1.7 \times 10^6 \text{ m})^2} = 1.7 \frac{\text{m}}{\text{s}^2} \]
18. Compute $g$ for the surface of a planet whose radius is twice that of the Earth and whose mass is the same as that of the Earth.

The radius is now $2R_E$ (double the radius of the Earth). The radius has increased by a factor of two. If the radius increases by a factor of two then $g$ decreases by a factor of 4 because $g$ is inversely proportional the square of the radius.

$g$ at the surface of the Earth is $9.8 \text{ m/s}^2$

$$\frac{9.8 \text{ m}}{4} = 2.45 \text{ m/s}^2$$

19. Compute $g$ for the surface of the sun. Its radius is $7.0 \times 10^8 \text{ m}$ and its mass is $2.0 \times 10^{30} \text{ kg}$.

$$g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(2.0 \times 10^{30} \text{ kg})}{(7.0 \times 10^8 \text{ m})^2} = 270 \text{ m/s}^2$$

20. Compute $g$ for the surface of Mars. Its radius is $3.4 \times 10^6 \text{ m}$ and its mass is $6.4 \times 10^{23} \text{ kg}$.

$$g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(6.44 \times 10^{23} \text{ kg})}{(3.4 \times 10^6 \text{ m})^2} = 3.7 \text{ m/s}^2$$

21. Compute $g$ at a height of $6.4 \times 10^6 \text{ m} (R_E)$ above the surface of Earth.

Need to first determine the $r$ to use. It will be the radius of the Earth plus the height above the Earth. The height above the Earth is the same as the radius of the Earth. Thus, the distance separating the objects is $2R_E$. The radius has increased by a factor of two. If the radius increases by a factor of two then $g$ decreases by a factor of 4 because $g$ is inversely proportional the square of the radius.

$g$ at the surface of the Earth is $9.8 \text{ m/s}^2$

$$\frac{9.8 \text{ m}}{4} = 2.45 \text{ m/s}^2$$

22. Compute $g$ at a height of $2R_E$ above the surface of Earth.

The radius is now $2R_E + R_E$ which equals $3R_E$. The radius has increased by a factor of three. If the radius increases by a factor of three then $g$ decreases by a factor of 9 because $g$ is inversely proportional the square of the radius.

$g$ at the surface of the Earth is $9.8 \text{ m/s}^2$

$$\frac{9.8 \text{ m}}{9} = 1.1 \text{ m/s}^2$$
23. Compute \( g \) for the surface of a planet whose radius is half that of the Earth and whose mass is double that of the Earth.

The radius is now \( \frac{1}{2} R_E \). The radius has decreased by a factor of one-half. This increases \( g \) by a factor of 4 because \( g \) is inversely proportional to the square of the radius. The mass is now \( 2M_E \). The mass has increased by a factor of 2. This increases \( g \) by a factor of 2 because \( g \) is directly proportional to \( M \). These two factors are multiplied together. Thus, \( g \) is increased by a factor of 8.

\[ g \text{ at the surface of the Earth is } 9.8 \text{ m/s}^2 \]

\[
\frac{9.8 \text{ m}}{s^2} \times 8 = 78.4 \text{ m/s}^2
\]

24. Compute \( g \) at a distance of \( 8.5 \times 10^9 \) m from the center of a spherical object whose mass is \( 5.0 \times 10^{28} \) kg.

\[
g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(5.0 \times 10^{28} \text{ kg})}{(8.5 \times 10^9 \text{ m})^2} = 0.046 \text{ m/s}^2
\]

25. Compute \( g \) at a distance of \( 7.3 \times 10^8 \) m from the center of a spherical object whose mass is \( 3.0 \times 10^{27} \) kg.

\[
g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(3.0 \times 10^{27} \text{ kg})}{(7.3 \times 10^8 \text{ m})^2} = 0.38 \text{ m/s}^2
\]

26. Compute \( g \) for the surface of Mercury. Its radius is \( 2.4 \times 10^6 \) m and its mass is \( 3.3 \times 10^{23} \) kg.

\[
g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(3.3 \times 10^{23} \text{ kg})}{(2.4 \times 10^6 \text{ m})^2} = 3.8 \text{ m/s}^2
\]

27. Compute \( g \) for the surface of Venus. Its radius is \( 6.0 \times 10^6 \) m and its mass is \( 4.9 \times 10^{24} \) kg.

\[
g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(4.9 \times 10^{24} \text{ kg})}{(6.0 \times 10^6 \text{ m})^2} = 9.1 \text{ m/s}^2
\]

28. Compute \( g \) for the surface of Jupiter. Its radius is \( 7.1 \times 10^7 \) m and its mass is \( 1.9 \times 10^{27} \) kg.

\[
g = \frac{GM}{r^2} = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right)(1.9 \times 10^{27} \text{ kg})}{(7.1 \times 10^7 \text{ m})^2} = 25 \text{ m/s}^2
\]

29. Compute \( g \) at a height of \( 4 \) \( R_E \) above the surface of Earth.

The radius is now \( 4R_E + R_E \) which equals \( 5R_E \). The radius has increased by a factor of five. If the radius increases by a factor of five then \( g \) decreases by a factor of 25 because \( g \) is inversely proportional the square of the radius.

\[ g \text{ at the surface of the Earth is } 9.8 \text{ m/s}^2 \]

\[
\frac{9.8 \text{ m}}{25} = 0.39 \text{ m/s}^2
\]
30. Compute $g$ at a height of $5 \, R_E$ above the surface of Earth.

The radius is now $5R_E + R_E$ which equals $6R_E$. The radius has increased by a factor of six. If the radius increases by a factor of five then $g$ decreases by a factor of 36 because $g$ is inversely proportional to the square of the radius.

$g$ at the surface of the Earth is $9.8 \, \text{m/s}^2$

$$\frac{9.8 \, \text{m}}{36} = 0.27 \, \text{m/s}^2$$

31. Compute $g$ for the surface of a planet whose radius is double that of the Earth and whose mass is also double that of the Earth.

The radius is increased by a factor of 2. This decreases $g$ by a factor of 4 because $g$ is inversely proportional to the square of the radius. Double the mass then $g$ increases by a factor of 2. These two factors are multiplied together. Thus, $g$ is decreased by a factor of 2.

$g$ at the surface of the Earth is $9.8 \, \text{m/s}^2$

$$\frac{9.8 \, \text{m}}{2} = 4.9 \, \text{m/s}^2$$