

Universal Gravitation Practice Problems

Universal Gravitation: $F_G = \frac{Gm_1m_2}{r^2}$, $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$

Class Work

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.
2. Two spherical objects have masses of $1.5 \times 10^5 \text{ kg}$ and $8.5 \times 10^2 \text{ kg}$. Their centers are separated by a distance of 2500 m. Find the gravitational attraction between them.
3. Two spherical objects have masses of $3.1 \times 10^5 \text{ kg}$ and $6.5 \times 10^3 \text{ kg}$. The gravitational attraction between them is 65 N. How far apart are their centers?
4. Two spherical objects have equal masses and experience a gravitational force of 25 N towards one another. Their centers are 36cm apart. Determine each of their masses.
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?
 - b. What is the size of the force acting on the larger object?
 - c. What is the acceleration of the smaller object when it is released?
 - d. What is the acceleration of the larger object when it is released?

Homework

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.
7. Two spherical objects have masses of $7.5 \times 10^5 \text{ kg}$ and $9.2 \times 10^7 \text{ kg}$. Their centers are separated by a distance of $2.5 \times 10^3 \text{ m}$. Find the gravitational attraction between them.
8. Two spherical objects have masses of $8.1 \times 10^2 \text{ kg}$ and $4.5 \times 10^8 \text{ kg}$. The gravitational attraction between them is $1.9 \times 10^{-3} \text{ N}$. How far apart are their centers?
9. Two spherical objects have equal masses and experience a gravitational force of 85 N towards one another. Their centers are 36mm apart. Determine each of their masses.
10. A 1 kg object is located at a distance of $7.0 \times 10^8 \text{ m}$ from the center of a larger object whose mass is $2.0 \times 10^{30} \text{ kg}$.
 - a. What is the size of the force acting on the smaller object?
 - b. What is the size of the force acting on the larger object?
 - c. What is the acceleration of the smaller object when it is released?
 - d. What is the acceleration of the larger object when it is released?
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.
12. Two spherical objects have masses of $9.5 \times 10^8 \text{ kg}$ and 2.5 kg. Their centers are separated by a distance of $2.5 \times 10^8 \text{ m}$. Find the gravitational attraction between them.
13. Two spherical objects have masses of $6.3 \times 10^3 \text{ kg}$ and $3.5 \times 10^4 \text{ kg}$. The gravitational attraction between them is $6.5 \times 10^{-3} \text{ N}$. How far apart are their centers?

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.
15. A 1 kg object is located at a distance of 1.7×10^6 m from the center of a larger object whose mass is 7.4×10^{22} kg.
 - a. What is the size of the force acting on the smaller object?
 - b. What is the size of the force acting on the larger object?
 - c. What is the acceleration of the smaller object when it is released?
 - d. What is the acceleration of the larger object when it is released?

***Gravitational Field:** $g = \frac{GM}{r^2}$

Class Work

16. Compute g at a distance of 4.5×10^7 m from the center of a spherical object whose mass is 3.0×10^{23} kg.
17. Compute g for the surface of the moon. Its radius is 1.7×10^6 m and its mass is 7.4×10^{22} kg.
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.
19. Compute g for the surface of the sun. Its radius is 7.0×10^8 m and its mass is 2.0×10^{30} kg.
20. Compute g for the surface of Mars. Its radius is 3.4×10^6 m and its mass is 6.4×10^{23} kg.
21. Compute g at a height of 6.4×10^6 m (R_E) above the surface of Earth.
22. Compute g at a height of $2 R_E$ above the surface of Earth.
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.

Homework

24. Compute g at a distance of 8.5×10^9 m from the center of a spherical object whose mass is 5.0×10^{28} kg.
25. Compute g at a distance of 7.3×10^8 m from the center of a spherical object whose mass is 3.0×10^{27} kg.
26. Compute g for the surface of Mercury. Its radius is 2.4×10^6 m and its mass is 3.3×10^{23} kg.
27. Compute g for the surface of Venus. Its radius is 6.0×10^6 m and its mass is 4.9×10^{24} kg.
28. Compute g for the surface of Jupiter. Its radius of is 7.1×10^7 m and its mass is 1.9×10^{27} kg.
29. Compute g at a height of $4 R_E$ above the surface of Earth.
30. Compute g at a height of $5 R_E$ above the surface of Earth.
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.

****Orbital Motion:** $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$, $v = \sqrt{\frac{GM}{r}}$, $R_E = 6.4 \times 10^6 \text{ m}$

Class Work

32. Compute:

- The velocity of an object orbiting at a distance of $4.5 \times 10^7 \text{ m}$ from the center of a spherical object whose mass is $3.0 \times 10^{23} \text{ kg}$.
- Compute the orbital period of that object.

33. Compute:

- The velocity of an object orbiting at a height of $6.4 \times 10^6 \text{ m}$ above the surface of Earth.
- Compute the orbital period of that object.

34. Mars has two moons, Phobos and Deimos. Phobos has an orbital radius of $9.4 \times 10^6 \text{ m}$ and an orbital period of 0.32 days. Deimos has an orbital radius of $23.5 \times 10^6 \text{ m}$.

- What is the orbital period of Deimos?
- At what height above the surface of Mars would a satellite have to be placed so that it remains above the same location on the surface of Mars as the planet rotates below it. A Martian day is equal to 1.02 Earth days.

Homework

35. Compute:

- The velocity of an object orbiting at a distance of $8.5 \times 10^9 \text{ m}$ from the center of a spherical object whose mass is $5.0 \times 10^{28} \text{ kg}$.
- Compute the orbital period of that object.

36. Compute:

- The velocity of an object orbiting at height of $2 R_E$ above the surface of Earth.
- Compute the orbital period of that object.

37. Earth orbits the sun in 365.25 days and has an orbital radius of $1.5 \times 10^{11} \text{ m}$.

- How many days will it take Mercury to orbit the sun given that its orbital radius is $5.8 \times 10^{10} \text{ m}$.
- How many days will it take Mars to orbit the sun given that its orbital radius is $2.3 \times 10^{11} \text{ m}$.
- It takes Jupiter 4333 days to orbit the sun. What is its average distance from the sun?

38. Compute:

- The velocity of an object orbiting at a distance of $7.3 \times 10^8 \text{ m}$ from the center of a spherical object whose mass is $3.0 \times 10^{27} \text{ kg}$.
- Compute the orbital period of that object.

39. Compute:

- The velocity, both magnitude and direction, of an object orbiting at a height of $5R_E$ above the surface of Earth
- Compute the orbital period of that object.

40. Calculate the orbital velocity and the period, in days, for an object orbiting the sun at distance of $1.5 \times 10^{11} \text{ m}$. Give the period in days (The mass of the Sun is $1.989 \times 10^{30} \text{ kg}$).

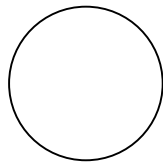
41. Jupiter has 16 moons. One of them, Io, has an orbital radius of $4.2 \times 10^8 \text{ m}$ and an orbital period of 1.77 days.

- What is the mass of Jupiter?

- b. Another moon of Jupiter, Europa, has an orbital radius of 6.7×10^8 m. What is its orbital period?
- c. Another moon of Jupiter, Ganymede, has an orbital period 7.2 days. What is the radius of its orbit?
- d. Jupiter rotates once every 0.41 days. At what orbital radius will a satellite maintain a constant position?

General Problems

42. As shown in the diagram below, a 5.0 kg space rock is located 2.5×10^7 m from the center of the earth. The mass of the earth is 6.0×10^{24} kg.



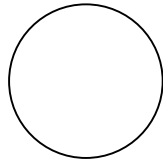
Earth



Space Rock

- a. Determine the force of gravity acting on the space rock, due to the earth. Calculate the magnitude and state the direction.
- b. Compare your answer in a) to the force of gravity acting on the earth, due to the space rock. Indicate that force on the diagram above.
- c. On the diagram above, indicate the direction the space rock would accelerate if released. Label that vector "a".
- d. Calculate the acceleration the rock would experience.
- e. **If instead of falling, the object were in a stable orbit, indicate on the diagram above a possible direction of its velocity. Label that vector "v".
- f. **Calculate the velocity the rock needs to be in a stable orbit.
- g. **Calculate the period of the rock orbiting the earth.

43. As shown in the diagram below, a 2000 kg spacecraft is located 9.2×10^6 m from the center of the earth. The mass of the earth is 6.0×10^{24} kg.



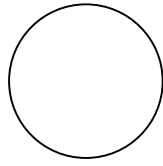
Earth



Spacecraft

- Determine the force of gravity acting on the spacecraft, due to the earth. Calculate the magnitude and state the direction.
- Compare your answer in a) to the force of gravity acting on the earth, due to the spacecraft. Indicate that force on the diagram above.
- On the diagram above, indicate the direction the spacecraft would accelerate if released. Label that vector "a".
- Calculate the acceleration the spacecraft would experience.
- **If instead of falling, the spacecraft were in a stable orbit, indicate on the diagram above a possible direction of its velocity. Label that vector "v".
- **Calculate the velocity the spacecraft needs to be in a stable orbit.
- **Calculate the period of the spacecraft orbiting the earth.

44. As shown in the diagram below, a 1000 kg asteroid is located 6.8×10^6 m from the center of the Mars. The mass of the Mars is 6.4×10^{23} kg.



Mars



Asteroid

- Determine the force of gravity acting on the asteroid, due to the Mars. Calculate the magnitude and state the direction.
- Compare your answer in a) to the force of gravity acting on the Mars, due to the asteroid. Indicate that force on the diagram above.
- On the diagram above, indicate the direction the asteroid would accelerate if released. Label that vector "a".
- Calculate the acceleration the asteroid would experience.
- **If instead of falling, the asteroid were in a stable orbit, indicate on the diagram above a possible direction of its velocity. Label that vector "v".
- **Calculate the velocity the asteroid needs to be in a stable orbit.
- **Calculate the period of the asteroid orbiting the earth.

Answers

1. 1.067×10^{-8} N
2. 1.361×10^{-9} N
3. 0.045 m
4. 220400 kg
5. a) 9.77 N
b) 9.77 N
c) 9.77 m/s^2
d) $1.63 \times 10^{-24} \text{ m/s}^2$
6. 0.000356 N or 3.56×10^{-4} N
7. 0.000736 N or 7.36×10^{-4} N
8. 113.229 m
9. 40640 kg
10. a) 272 N
b) 272 N
c) 272 m/s^2
d) $1.36 \times 10^{-28} \text{ m/s}^2$
11. 1.19×10^{-6} N
12. 2.53×10^{-18} N
13. 1.50 m
14. 220400 kg
15. a) 1.71 N
b) 1.71 N
c) 1.71 m/s^2
d) $2.31 \times 10^{-23} \text{ m/s}^2$
16. 0.0099 m/s^2
17. 1.71 m/s^2
18. 2.44 m/s^2
19. 272 m/s^2
20. 3.69 m/s^2
21. 2.44 m/s^2
22. 1.09 m/s^2
23. 78.2 m/s^2
24. 0.0462 m/s^2
25. 0.375 m/s^2
26. 3.82 m/s^2
27. 9.08 m/s^2
28. 25.13 m/s^2
29. 0.392 m/s^2
30. 0.27 m/s^2
31. 4.89 m/s^2
32. a) 670 m/s
b) 4.2×10^5 s
33. 5591.57 m/s
b) 1.44×10^4 s
34. a) 1.6 days
b) 2.04×10^7 m
35. a) 2.0×10^4 m/s
b) 2.7×10^6 s
36. a) 4560 m/s
b) 5.09×10^3 s
37. a) 88 days
b) 693.5 days
c) 7.8×10^{11} m
38. a) 1.66×10^4 m/s tangential to orbit
b) 2.79×10^5 s
39. a) 3230 m/s tangential to orbit
b) 7.4×10^4 s
40. 3.0×10^4 m/s; 365 days
41. a) 1.90×10^{27} kg
b) 3.57 days
c) 1.07×10^9 m
d) 2.58×10^7 m
42. a) 3.2 N left
b) same force to right
c) (\leftarrow) from rock towards earth
d) 0.64 m/s^2
e) (\uparrow or \downarrow) up or down from rock
f) 4000 m/s
g) 39260 s
43. a) 9457 N left
b) same force to right
c) (\leftarrow) from spacecraft towards earth
d) 4.73 m/s^2
e) (\uparrow or \downarrow) up or down from spacecraft
f) 6595 m/s
g) 8764 s
44. a) 923 N left
b) same force to right
c) (\leftarrow) from asteroid towards mars
d) 0.92 m/s^2
e) (\uparrow or \downarrow) up or down from asteroid
f) 2505 m/s
g) 17052 s