

15 Physics Problems: Gravitational Force

Medium to slightly above medium difficulty. Unless a problem states otherwise, use $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$ and $g = 9.81 \text{ m/s}^2$. Do not assume that an object's mass changes when it is moved to another planet.

1. Two satellites

Two artificial satellites are orbiting Earth. Satellite A has a mass of 850 kg and satellite B has a mass of 1,200 kg. At a particular moment, the distance between their centers is $4.50 \times 10^5 \text{ m}$. Calculate the gravitational force each satellite exerts on the other.

2. Earth and the Moon

The Earth has a mass of $5.97 \times 10^{24} \text{ kg}$ and the Moon has a mass of $7.35 \times 10^{22} \text{ kg}$. Their centers are separated by $3.84 \times 10^8 \text{ m}$. Determine the gravitational attraction between them. Compare this force with the gravitational force that would act between two 1,000 kg spacecraft separated by the same distance.

3. A spacecraft above Earth

A spacecraft of mass 2,500 kg is located $2.00 \times 10^6 \text{ m}$ above Earth's surface. Take Earth's mass as $5.97 \times 10^{24} \text{ kg}$ and its radius as $6.37 \times 10^6 \text{ m}$. Determine the gravitational force acting on the spacecraft.

4. How does distance affect attraction?

A 900 kg satellite is initially at a distance of $7.00 \times 10^6 \text{ m}$ from Earth's center. It is then moved so that its distance from Earth's center becomes $1.40 \times 10^7 \text{ m}$. By what factor does the gravitational force on the satellite change? Calculate both forces using Earth's mass of $5.97 \times 10^{24} \text{ kg}$.

5. Weight on another planet

A planet has twice the mass of Earth and twice Earth's radius. An astronaut has a mass of 72 kg. Determine the astronaut's weight on Earth and on this planet. Take Earth's mass as $5.97 \times 10^{24} \text{ kg}$ and radius as $6.37 \times 10^6 \text{ m}$.

6. A compact planet

Planet X has 0.40 times Earth's mass and 0.50 times Earth's radius. A scientific instrument has a mass of 18 kg. Determine the gravitational force acting on the instrument at the surface of Planet X. Compare its weight with its weight on Earth.

7. Finding a planet's mass

An astronaut has a weight of 420 N on the surface of a planet whose radius is 3.20×10^6 m. The astronaut's mass is 70 kg. Determine the mass of the planet. Ignore the rotation of the planet.

8. Finding a planet's radius

A 60 kg explorer weighs 480 N on the surface of Planet Y. Planet Y has a mass of 6.00×10^{24} kg. Determine the radius of Planet Y. Give your answer in kilometers.

9. Density of a spherical planet

A spherical planet has a radius of 4.00×10^6 m and a uniform density of 5.50×10^3 kg/m³. Use the volume of a sphere, $V = 4\pi r^3/3$, to determine the planet's mass. Then calculate the gravitational force acting on a 75 kg person standing at its surface.

10. Comparing two planets using density

Planet A and Planet B have the same radius of 5.00×10^6 m. Planet A has a density of 4.00×10^3 kg/m³, while Planet B has a density of 8.00×10^3 kg/m³. Determine the gravitational acceleration at the surface of each planet and determine how many times greater a person's weight would be on Planet B than on Planet A.

11. Same mass, different radius

Two spherical planets have the same mass, 8.00×10^{24} kg, but their radii are different. Planet A has a radius of 4.00×10^6 m and Planet B has a radius of 8.00×10^6 m. Determine the gravitational acceleration at each surface. A 65 kg astronaut travels between them. Calculate the astronaut's weight on each planet and explain quantitatively why the values differ.

12. Surface gravity from density

A spherical exoplanet has a uniform density of 7.00×10^3 kg/m³ and a radius of 3.50×10^6 m. First determine its mass using $V = 4\pi r^3/3$. Then determine the gravitational acceleration at its surface. Finally, calculate the weight of a 90 kg astronaut on the planet.

13. Gravitational force between two moons

Two spherical moons have masses of 9.00×10^{21} kg and 3.00×10^{22} kg. Their centers are separated by 2.50×10^8 m. Calculate the gravitational force between them. If their separation becomes three times larger, determine the new force and the percentage decrease in the force.

14. A planet made of two density layers

A simplified planet consists of a spherical core and a surrounding spherical outer layer. The core has radius 2.00×10^6 m and density 9.00×10^3 kg/m³. The planet's total radius is 5.00×10^6 m, and the outer layer has density 3.00×10^3 kg/m³. Treat the core and outer layer as separate volumes, using $V = 4\pi r^3/3$. Determine the total mass and the gravitational acceleration at the surface.

15. Designing a low-gravity world

A spherical planet is designed to have a surface gravitational acceleration equal to 0.60 times Earth's. Its average density is 4.50×10^3 kg/m³. Determine the radius of the planet. Then calculate the weight of a 80 kg astronaut on its surface. Use Earth's mass of 5.97×10^{24} kg and radius of 6.37×10^6 m where needed.