Universal Law of Gravitation

Guided Problems on Newton’s Law of Gravitation:

1. Gravitational Force Between Earth and Moon

Problem: The mass of the Earth is $5.97 \times 10^{24}\,\text{kg}$ and the mass of the Moon is $7.35 \times 10^{22}\,\text{kg}$. The average distance between Earth and Moon is $3.84 \times 10^{8}\,\text{m}$. Calculate the gravitational force between the Earth and the Moon.

Solution: Using the formula:

$$F = G\frac{m_1 m_2}{r^2}$$

Where:

- $G = 6.674 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$
- $m_1 = 5.97 \times 10^{24}\,\text{kg}$
- $m_2 = 7.35 \times 10^{22}\,\text{kg}$
- $r = 3.84 \times 10^{8}\,\text{m}$

$$F = \frac{(6.674 \times 10^{-11})(5.97 \times 10^{24})(7.35 \times 10^{22})}{(3.84 \times 10^{8})^2}$$

Calculate the result:

$$F = 1.98 \times 10^{20}\,\text{N}$$

So, the gravitational force between the Earth and the Moon is $1.98 \times 10^{20}\,\text{N}$.

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2. Gravitational Force Between Two Spheres

Problem: Two spheres, each of mass 10 kg, are placed 2 m apart. Find the gravitational force between them.

Solution: Using the formula:

$$F = G\frac{m_1 m_2}{r^2}$$

Where:

- $G = 6.674 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$
- $m_1 = 10\,\text{kg}$
- $m_2 = 10\,\text{kg}$
- $r = 2\,\text{m}$

$$F = \frac{(6.674 \times 10^{-11})(10)(10)}{(2)^2}$$

$$F = 1.6685 \times 10^{-10}\,\text{N}$$

So, the gravitational force is $1.6685 \times 10^{-10}\,\text{N}$.

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3. Gravitational Force on a Satellite

Problem: A satellite of mass 1000 kg orbits the Earth at a distance of $4.2 \times 10^7\,\text{m}$ from the center of the Earth. Calculate the gravitational force exerted on the satellite.

Solution: Using the formula:

$$F = G\frac{m_1 m_2}{r^2}$$

Where:

- $G = 6.674 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$
- $m_1 = 5.97 \times 10^{24}\,\text{kg}$ (mass of Earth)
- $m_2 = 1000\,\text{kg}$ (mass of satellite)
- $r = 4.2 \times 10^7\,\text{m}$

$$F = \frac{(6.674 \times 10^{-11})(5.97 \times 10^{24})(1000)}{(4.2 \times 10^7)^2}$$

$$F = 226.56\,\text{N}$$

So, the gravitational force on the satellite is $226.56\,\text{N}$.

Practice Problems:

1. **Problem:** Two objects of mass $2\,\text{kg}$ and $3\,\text{kg}$ are placed 5 meters apart. Calculate the gravitational force between them.

2. **Problem:** The mass of the Sun is $1.989 \times 10^{30}\,\text{kg}$ and the mass of Jupiter is $1.898 \times 10^{27}\,\text{kg}$. The average distance between them is $7.78 \times 10^{11}\,\text{m}$. Calculate the gravitational force between the Sun and Jupiter.

3. **Problem:** A satellite is orbiting at a distance of $3 \times 10^7\,\text{m}$ from the Earth's center. The satellite's mass is $1500\,\text{kg}$. Find the gravitational force between the Earth and the satellite.

4. **Problem:** Two lead spheres, each of mass $15\,\text{kg}$, are placed 1.5 meters apart. Calculate the gravitational force between them.

5. **Problem:** The mass of Mars is $6.42 \times 10^{23}\,\text{kg}$ and the mass of Phobos, one of its moons, is $1.08 \times 10^{16}\,\text{kg}$. If Phobos orbits at a distance of $9.4 \times 10^6\,\text{m}$, calculate the gravitational force between Mars and Phobos.

6. **Problem:** Two asteroids with masses $8 \times 10^{12}\,\mathrm{kg}$ and $6 \times 10^{12}\,\mathrm{kg}$ are separated by $1 \times 10^{5}\,\mathrm{m}$. What is the gravitational force between them?