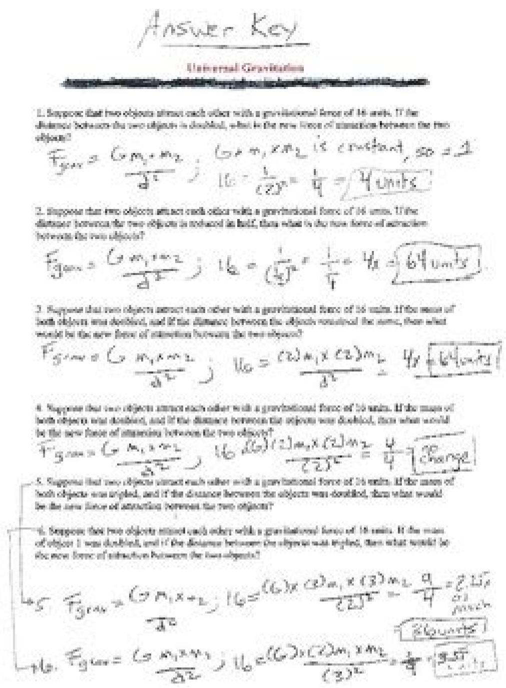
Universal Gravitation Practice Problems


Answer Key

Universal Gravitation

Universal gravitation practice problems are essential for students and enthusiasts of physics to grasp the fundamental concepts of gravitational forces. The law of universal gravitation, formulated by Sir Isaac Newton, states that every point mass attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers. Understanding this principle through practice problems enhances comprehension and application in real-world scenarios. In this article, we will explore various practice problems related to universal gravitation, covering key concepts, example problems, and step-by-step solutions.

Understanding Universal Gravitation

Before diving into practice problems, it's crucial to understand the law of universal gravitation and its mathematical formulation. The equation for universal gravitation is given by:

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

Where:
- F is the gravitational force between two masses,
- G is the gravitational constant, approximately $6.674 \times 10^{-11} \, \text{N(m/kg)}^2$,
- m_1 and m_2 are the masses of the two objects,
- r is the distance between the centers of the two masses.

Key Concepts

1. Gravitational Force: The force that attracts two bodies towards each other.
2. Mass: A measure of the amount of matter in an object, usually in kilograms (kg).
3. Distance: The separation between the centers of two masses, measured in meters (m).
4. Gravitational Constant (G): A key constant in the equation that quantifies the strength of gravity.

Types of Practice Problems

To effectively apply the law of universal gravitation, we can categorize practice problems into the following types:

1. Calculating Gravitational Force: Problems that require calculating the force between two masses.
2. Finding Mass from Gravitational Force: Problems where the gravitational force and distance are given, and the mass of one object needs to be determined.
3. Distance Calculation: Problems that involve finding the distance between two masses when the force and masses are known.
4. Gravitational Field Strength: Problems that require determining the gravitational field strength at a point in space.

Example Problems and Solutions

Problem Type 1: Calculating Gravitational Force

Problem 1: Calculate the gravitational force between two objects with masses $m_1 = 5.0 \, \text{kg}$ and $m_2 = 10.0 \, \text{kg}$ that are $2.0 \, \text{m}$ apart.

Solution:
1. Use the universal gravitation formula:
$$ F = G \frac{m_1 m_2}{r^2} $$
2. Substitute the known values:
$$ F = (6.674 \times 10^{-11}) \frac{(5.0)(10.0)}{(2.0)^2} $$
3. Calculate:
$$ F = (6.674 \times 10^{-11}) \frac{50}{4} $$
$$ F = (6.674 \times 10^{-11}) \times 12.5 $$
$$ F = 8.3425 \times 10^{-10} \, \text{N} $$

Thus, the gravitational force between the two masses is approximately $8.34 \times 10^{-10} \, \text{N}$.

Problem Type 2: Finding Mass from Gravitational Force

Problem 2: If the gravitational force between two objects is \(1.0 \times 10^{-9} \, \text{N} \), and one of the masses is \(4.0 \, \text{kg} \) while the distance between them is \(3.0 \, \text{m} \), find the other mass.

Solution:
1. Rearrange the universal gravitation formula to solve for \(m_2 \):
\[m_2 = \frac{F \cdot r^2}{G \cdot m_1} \]
2. Substitute the known values:
\[m_2 = \frac{(1.0 \times 10^{-9}) \cdot (3.0)^2}{(6.674 \times 10^{-11}) \cdot (4.0)} \]
3. Calculate:
\[m_2 = \frac{(1.0 \times 10^{-9}) \cdot 9}{(6.674 \times 10^{-11}) \cdot 4} \]
\[m_2 = \frac{9.0 \times 10^{-9}}{2.6696 \times 10^{-10}} \]
\[m_2 \approx 33.7 \, \text{kg} \]

Thus, the other mass is approximately \(33.7 \, \text{kg} \).

Problem Type 3: Distance Calculation

Problem 3: Two objects with masses \(m_1 = 20 \, \text{kg} \) and \(m_2 = 50 \, \text{kg} \) exert a gravitational force of \(6.67 \times 10^{-9} \, \text{N} \) on each other. What is the distance between them?

Solution:
1. Rearrange the universal gravitation formula to solve for \(r \):
\[r = \sqrt{G \frac{m_1 m_2}{F}} \]
2. Substitute the known values:
\[r = \sqrt{(6.674 \times 10^{-11}) \frac{(20)(50)}{6.67 \times 10^{-9}}} \]
3. Calculate:
\[r = \sqrt{(6.674 \times 10^{-11}) \frac{1000}{6.67 \times 10^{-9}}} \]
\[r = \sqrt{(6.674 \times 10^{-11}) \cdot 150.15} \]
\[r = \sqrt{1.003 \times 10^{-8}} \]
\[r \approx 0.00317 \, \text{m} \]

Thus, the distance between the two objects is approximately \(0.00317 \, \text{m} \) or \(3.17 \, \text{mm} \).

Problem Type 4: Gravitational Field Strength

Problem 4: Calculate the gravitational field strength at a distance of \(10 \, \text{m} \) from a mass of \(100 \, \text{kg} \).

Solution:
1. The gravitational field strength \(g \) is given by:
\[g = G \frac{m}{r^2} \]
2. Substitute the known values:
\[g = (6.674 \times 10^{-11}) \frac{100}{(10)^2} \]
3. Calculate:
\[g = (6.674 \times 10^{-11}) \frac{100}{100} \]
\[g = 6.674 \times 10^{-11} \, \text{N/kg} \]

Thus, the gravitational field strength at a distance of \(10 \, \text{m} \) from a mass of \(100 \, \text{kg} \) is approximately \(6.67 \times 10^{-11} \, \text{N/kg} \).

Conclusion

Universal gravitation practice problems serve as an excellent way to understand and apply the law of gravitation in various contexts. By working through different types of problems, students can develop a deeper comprehension of gravitational forces and their implications in physics. The examples provided illustrate the versatility and broad application of Newton's law, allowing for further exploration in fields such as astrophysics, engineering, and beyond. Regular practice will enhance problem-solving skills and help students prepare for exams and real-world applications of gravitational concepts.

Frequently Asked Questions

What is the formula for calculating the gravitational force between two objects?

The formula for calculating the gravitational force (F) between two objects is $F = G (m1\ m2) / r^2$, where G is the gravitational constant (6.674×10^{-11} $N(m/kg)^2$), m1 and m2 are the masses of the objects, and r is the distance between their centers.

How does the distance between two objects affect the gravitational force between them?

The gravitational force between two objects decreases with the square of the distance between them. This means that if the distance doubles, the gravitational force becomes one-fourth of its original value.

If the mass of one object is increased, what happens to the gravitational force between it and another object?

If the mass of one object increases, the gravitational force between it and another object also increases proportionally. Specifically, if the mass of one object is doubled, the gravitational force will also double, assuming the distance remains constant.

How would you determine the gravitational force acting on a satellite orbiting Earth?

To determine the gravitational force acting on a satellite orbiting Earth, use the formula $F = G (m\ M) / r^2$, where m is the mass of the satellite, M is the mass of Earth, and r is the distance from the center of Earth to the satellite. The distance r is equal to the radius of Earth plus the altitude of the satellite.

What would be the gravitational force between two 1 kg masses separated by 1 meter?

Using the formula $F = G (m1\ m2) / r^2$, where G is 6.674×10^{-11} $N(m/kg)^2$, m1 = 1 kg, m2 = 1 kg, and r = 1 m, the gravitational force would be $F = 6.674 \times 10^{-11}\ N(m/kg)^2 (1\ kg\ 1\ kg) / (1\ m)^2 = 6.674 \times 10^{-11}\ N$.

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