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Understanding the relationship between weight, mass, and gravity is fundamental in physics. When analyzing how objects behave on different celestial bodies, it's essential to understand how gravity influences weight. This article explores a specific problem: determining the mass of a stone that weighs 490 N on a planet where the acceleration due to gravity is half that of Earth's gravity. We will delve into the physics principles involved, outline the calculation process, and discuss related concepts to deepen your understanding.

Introduction to Weight and Gravity

Before diving into the problem, let's clarify some key concepts.

What is Weight?

Weight is the force exerted by gravity on an object. It is dependent on two factors:

- The mass of the object (m)
- The acceleration due to gravity at the location (g)

Mathematically, weight (W) is expressed as:

$$W = m \times g$$

Where:

- W is the weight (in Newtons, N)
- m is the mass (in kilograms, kg)
- g is the acceleration due to gravity (in meters per second squared, m/s^2)

Gravity and Its Variability

Gravity varies across different planets and celestial bodies based on:

- The mass of the planet
- The radius of the planet

Earth's average acceleration due to gravity is approximately $9.8 m/s^2$. When comparing other planets, their g values can be higher or lower depending on their physical characteristics.

The Given Problem: Key Data and Objective

The problem states:

- The weight of the stone on the planet: $W = 490 \text{ N}$
- The acceleration due to gravity on the planet: $g_{\text{planet}} = \frac{1}{2} g_{\text{earth}}$

Objective:

Calculate the mass of the stone.

Understanding the Relationship Between Weight and Gravity

Given:

- Weight on Earth: $(W_{\text{earth}} = m \times g_{\text{earth}})$
- Weight on the planet: $(W_{\text{planet}} = m \times g_{\text{planet}})$

Since the weight on the planet is provided, and the gravity on the planet is half of Earth's gravity, we can relate these quantities to find the mass.

Step-by-Step Calculation

Let's outline the calculation process.

Step 1: Express the gravitational acceleration on the planet

Given:

$$g_{\text{planet}} = \frac{1}{2} g_{\text{earth}}$$

and

$$g_{\text{earth}} \approx 9.8, \text{ m/s}^2$$

Therefore:

$$g_{\text{planet}} = \frac{1}{2} \times 9.8, \text{ m/s}^2 = 4.9, \text{ m/s}^2$$

Step 2: Use the weight on the planet to find the mass

Given the weight:

$$W_{\text{planet}} = 490, \text{ N}$$

Using the relation:

$$W_{\text{planet}} = m \times g_{\text{planet}}$$

Rearranged to solve for mass:

$$m = \frac{W_{\text{planet}}}{g_{\text{planet}}}$$

Substituting the known values:

$$m = \frac{490 \text{ N}}{4.9 \text{ m/s}^2}$$

Calculating:

$$m = 100 \text{ kg}$$

Result:

The mass of the stone is 100 kilograms.

Implications and Related Concepts

Understanding this calculation sheds light on several important physics concepts.

1. Mass vs. Weight

- Mass is an intrinsic property of matter; it remains constant regardless of location.
- Weight is a force that depends on the local gravity.

This distinction explains why the same object weighs less on the Moon than on Earth, even though its mass remains unchanged.

2. Calculating Weight on Different Planets

Knowing the mass and the gravity of various planets allows us to compute the weight of objects elsewhere in the solar system or universe.

For example:

- On Mars, with gravity approximately 3.71 m/s^2 , an object with a mass of 100 kg would weigh:

$$W_{\text{Mars}} = 100 \text{ kg} \times 3.71 \text{ m/s}^2 = 371 \text{ N}$$

3. Significance in Space Missions and Engineering

Understanding weight and gravity is critical in:

- Designing spacecraft and landers
- Calculating payload capacities
- Planning extraterrestrial exploration missions

Additional Considerations and Applications

Let's explore some related practical aspects and calculations.

Adjusting for Different Gravitational Fields

Suppose you want to determine the weight of the same stone on a different planet with a known gravity. The formula is straightforward:

$$W_{\text{new}} = m \times g_{\text{new}}$$

Where:

- $m = 100$, kg
- g_{new} is the gravity of the new planetary body.

Example: Weight on the Moon

Given:

$$g_{\text{moon}} \approx 1.62, \text{ m/s}^2$$

Calculate:

$$W_{\text{moon}} = 100, \text{ kg} \times 1.62, \text{ m/s}^2 = 162, \text{ N}$$

This illustrates how weight diminishes significantly in lower gravity environments, impacting everything from human movement to structural engineering.

Summary and Key Takeaways

- The weight of an object depends on both its mass and the local acceleration due to gravity.
- When given the weight and the gravity, you can find the mass using the formula $m = \frac{W}{g}$.
- If gravity is known to be half of Earth's, the weight of an object will be half if the mass remains constant.
- The calculated mass of the stone in this problem is 100 kg.

Conclusion

Understanding the relationship between weight, mass, and gravity is essential for physics students, engineers, astronauts, and anyone interested in space science. This problem exemplifies how to approach such calculations systematically, applying fundamental principles to real-world scenarios. By mastering these concepts, you can analyze and predict the behavior of objects

across different gravitational environments, which is vital for space exploration, satellite deployment, and understanding the universe's physical laws.

FAQs

Q1: Why does the weight of the stone change on different planets but its mass remains the same?

A1: Because mass is an intrinsic property of matter, it doesn't change regardless of location. Weight, however, depends on the local gravitational acceleration, which varies across planets.

Q2: How do scientists measure gravity on other planets?

A2: Gravity on other planets is measured using spacecraft, orbiters, and landers equipped with accelerometers and other instruments, which analyze the gravitational pull based on the motion of the spacecraft or the behavior of the lander.

Q3: Can the weight of an object be zero?

A3: In free fall, an object experiences apparent weightlessness, but technically, the gravitational force still acts on it. Zero apparent weight occurs in orbit when the object is in continuous free fall.

Q4: How does understanding gravity help in designing space habitats?

A4: Engineers need to account for reduced gravity's effects on human health, structural integrity, and equipment operation. This knowledge informs the design of habitats that can support life in low-gravity environments.

Q5: What is the significance of knowing the mass of objects in space missions?

A5: Precise mass measurements are vital for navigation, fuel calculations, and ensuring the safety and efficiency of space missions.

By mastering the principles demonstrated in this problem, you'll be better equipped to analyze gravitational effects in various contexts, from classroom exercises to advanced space exploration scenarios.

Frequently Asked Questions

What is the weight of a stone on a planet where gravity is half of Earth's gravity if the stone

weighs 490 N on Earth?

The weight of the stone on the planet is 245 N, since weight is proportional to gravity. Therefore, it weighs half of its Earth weight.

How do you calculate the weight of an object on a different planet with reduced gravity?

You multiply the object's weight on Earth by the ratio of the planet's gravity to Earth's gravity. If the gravity is half, multiply by 0.5.

If a stone weighs 490 N on Earth, what is its mass and how does it change on a planet with half gravity?

The mass of the stone is 50 kg (since weight = mass $\times$ gravity, $490\text{ N} = 50\text{ kg} \times 9.8\text{ m/s}^2$). On the planet with half gravity, its weight becomes 245 N, but its mass remains unchanged at 50 kg.

Why does the weight of a stone decrease on a planet with lower gravity?

Weight depends on the gravitational acceleration; if gravity decreases, the force exerted on the object decreases, resulting in a lower weight.

What is the formula used to find the weight of an object on any planet given Earth's weight and the planet's gravity?

The formula is: Weight on planet = (Weight on Earth) $\times$ (Gravity on planet / Gravity on Earth).

Additional Resources

A Stone Weight 490 N On A Planet Whose Acceleration Due To Gravity Is Half That Of The Earth: An In-Depth Analysis

Understanding the relationship between weight, mass, and gravitational acceleration is fundamental in physics. When considering an object on a planet different from Earth, the variations in gravity significantly impact the object's weight, even if its mass remains unchanged. This article explores a scenario where a stone weighs 490 N on a planet with gravitational acceleration half that of Earth's. We delve into the physics principles involved, perform detailed calculations, and analyze the implications of such a situation.

Understanding the Concept of Weight and Its Dependence on Gravity

What Is Weight?

Weight is the force exerted by gravity on an object. It differs from mass, which is the measure of the amount of matter in an object. While mass remains constant regardless of location, weight varies depending on the gravitational field strength.

Mathematically, weight (W) is expressed as:

$$W = m \times g$$

Where:

- W = weight of the object (in newtons, N)
- m = mass of the object (in kilograms, kg)
- g = acceleration due to gravity at the location (in meters per second squared, m/s^2)

Key Point: The weight of an object is directly proportional to the local acceleration due to gravity.

Scenario Setup and Given Data

In this scenario:

- The weight of the stone on the planet, W_{planet} , is 490 N.
- The acceleration due to gravity on the planet, g_{planet} , is half of Earth's gravity, g_{earth} .

Knowing that:

- Earth's standard gravity, g_{earth} , is approximately 9.8 m/s^2 .
- The planet's gravity, g_{planet} , is therefore:

$$g_{\text{planet}} = \frac{1}{2} g_{\text{earth}} = \frac{1}{2} \times 9.8, \text{ m/s}^2 = 4.9, \text{ m/s}^2$$

The primary goal is to determine:

1. The mass of the stone.
2. The weight of the stone on Earth.

3. Any additional insights into the physics of gravity and weight.

Calculating the Mass of the Stone

Given the weight on the planet:

$$W_{\text{planet}} = m \times g_{\text{planet}}$$

Rearranged to solve for mass:

$$m = \frac{W_{\text{planet}}}{g_{\text{planet}}}$$

Plugging in known values:

$$m = \frac{490 \text{ N}}{4.9 \text{ m/s}^2}$$

$$m = 100 \text{ kg}$$

Interpretation:

The stone has a mass of 100 kg. This value is consistent regardless of location; mass is invariant under gravitational changes.

Calculating the Weight of the Stone on Earth

Having determined the mass, we can now compute what the weight of the same stone would be on Earth:

$$W_{\text{earth}} = m \times g_{\text{earth}}$$

$$W_{\text{earth}} = 100 \text{ kg} \times 9.8 \text{ m/s}^2$$

$$W_{\text{earth}} = 980 \text{ N}$$

Key Point:

The stone would weigh 980 N on Earth, which is exactly double its weight on the other planet with half of Earth's gravity.

Physical Implications and Real-World Analogies

Gravity's Influence on Weight

This calculation vividly illustrates how gravity influences weight. The same object, with a fixed mass, can have vastly different weights depending on the gravitational acceleration. For example:

- On the Moon, with gravity approximately 1.62 m/s^2 (about $1/6$ of Earth's), an object with a mass of 100 kg would weigh:

$$W_{\text{moon}} = 100 \text{ kg} \times 1.62 \text{ m/s}^2 = 162 \text{ N}$$

- On Mars, with gravity approximately 3.71 m/s^2 , the weight would be:

$$W_{\text{Mars}} = 100 \text{ kg} \times 3.71 \text{ m/s}^2 = 371 \text{ N}$$

This comparison emphasizes how gravitational variations directly impact the force objects exert on surfaces, which has significant implications for engineering, space exploration, and understanding planetary environments.

Practical Implications of Reduced Gravity

- Human Motion and Weight: Reduced gravity environments, like that on the Moon or Mars, allow astronauts to perform jumps and movements that are impossible on Earth, owing to the decreased weight.
- Structural Engineering: Buildings and structures must be designed considering the local gravity to ensure stability and safety.
- Transportation: Vehicles and machinery designed for Earth might need modifications to operate efficiently in different gravitational fields.

Broader Context: Gravitation and Planetary Physics

The Role of Planetary Mass and Radius

While gravity depends on the planet's mass and radius, the simplified calculation here assumes uniform gravitational acceleration. In reality, the gravitational acceleration (g) at a planet's surface is given by:

$$g = \frac{GM}{R^2}$$

Where:

- G = gravitational constant ($6.674 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$)
- M = mass of the planet
- R = radius of the planet

Thus, a planet's gravity depends on both its mass and radius, and variations in these parameters lead to different gravitational environments.

Implication:

A planet with a larger radius but similar mass would have lower gravity, affecting how objects weigh and move there.

Significance for Space Missions and Astrophysics

Understanding how gravitational acceleration varies across different celestial bodies is vital for mission planning, landing site selection, and designing equipment suited to local gravity conditions. It also enriches our comprehension of planetary formation and evolution.

Concluding Remarks and Future Perspectives

The simple yet profound calculation presented—determining the weight of a stone on a planet with half Earth's gravity—serves as a gateway to understanding fundamental physics concepts. It highlights the direct proportionality between weight and gravitational acceleration and underscores the importance of precise measurements in astrophysics and engineering.

Summary of Key Findings:

- The stone's mass is 100 kg, a constant regardless of location.
- Its weight on the planet is 490 N, owing to the reduced gravity.
- On Earth, the same stone would weigh 980 N.
- Variations in planetary gravity influence the force objects exert, impacting everything from human activity to structural stability.

Looking Ahead:

As space exploration advances, understanding gravitational differences will be essential for establishing colonies on other planets and moons. Technologies that can adapt to these environments will be crucial for future missions.

Final Thought:

Gravity shapes our universe, dictating the behavior of celestial bodies and influencing every object within them. By understanding these principles through calculations like this, we deepen our appreciation of the universe's intricate workings and prepare ourselves for the challenges of exploring new worlds.

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