What Is The Wavelength In Nanometers Of A Wave With A Frequency Of 1.2 X 1016 Hz? A) 3.6 X 10 8 Nm B)

What Is The Wavelength In Nanometers Of A Wave With A Frequency Of 1.2 X 10^16 Hz? A) 3.6 X 10^8 Nm B)

Introduction: Understanding Wavelength and Its Significance in Wave Physics

Waves are fundamental phenomena observed across various scientific disciplines, from physics and engineering to biology and environmental sciences. They carry energy through space or a medium without the transfer of matter, characterized primarily by their wavelength, frequency, and speed. Among these, wavelength—the physical length of one complete wave cycle—serves as a critical parameter that influences how waves interact with matter and how they are perceived or measured.

In the realm of electromagnetic waves, understanding the relationship between wavelength and frequency is essential for applications spanning telecommunications, spectroscopy, medical imaging, and even quantum physics. For instance, visible light, radio waves, X-rays, and gamma rays are all electromagnetic waves distinguished by their wavelengths and frequencies.

This article delves into a specific question: What is the wavelength in nanometers of a wave with a frequency of 1.2 x 10^16 Hz? We will explore the fundamental concepts, the mathematical relationship between wavelength and frequency, and perform detailed calculations to determine the correct wavelength. Additionally, we will analyze the given options and discuss their implications in various scientific contexts.

Fundamental Concepts: Wavelength, Frequency, and Wave Speed

What Is Wavelength?

Wavelength (denoted as λ) is the spatial length of one complete cycle of a wave, typically measured in meters (m), nanometers (nm), or other length units. It indicates the distance between successive crests or troughs in a wave.

What Is Frequency?

Frequency (f) refers to how many wave cycles pass a fixed point per second, measured in hertz (Hz). A higher frequency means more cycles per second, which often correlates with higher energy in electromagnetic waves.

Wave Speed

The speed of a wave (v) is the rate at which the wave propagates through space. For electromagnetic waves in a vacuum, this speed is the speed of light (c), approximately 3.0 x 10^8 meters per second (m/s).

The Relationship Between Wavelength, Frequency, and Speed

The fundamental formula connecting wavelength (λ), frequency (f), and wave speed (v) is:

$$
v = \lambda \times f
$$

Where:

- v is the wave speed in meters per second (m/s),
- λ is the wavelength in meters (m),
- f is the frequency in hertz (Hz).

In the case of electromagnetic waves traveling in a vacuum, the wave speed v is equal to the speed of light $c = 3.0 \times 10^8 \, \text{m/s}$.

Thus, the wavelength can be calculated as:

$$
\lambda = \frac{v}{f}
$$

Given the frequency, we can determine the wavelength by substituting in the known wave speed.

Calculating the Wavelength for a Wave with a Frequency of 1.2 x 10^16 Hz

Step 1: Identify Known Values

- Wave speed in vacuum: $c = 3.0 \times 10^8 \, \text{m/s}$
- Frequency: $f = 1.2 \times 10^{16} \, \text{Hz}$

Step 2: Apply the Formula

Using the relationship:

$$
\lambda = \frac{c}{f} = \frac{3.0 \times 10^8 \, \text{m/s}}{1.2 \times 10^{16} \, \text{Hz}}
$$

Step 3: Perform the Calculation

Dividing the numbers:

$$
\lambda = \frac{3.0}{1.2} \times 10^{8 - 16} \, \text{m} = 2.5 \times 10^{-8} \, \text{m}
$$

This simplifies to:

$$
\lambda = 2.5 \times 10^{-8} \, \text{meters}
$$

Step 4: Convert Meters to Nanometers

Since 1 meter = 1,000,000,000 nanometers (nm):

$$
\lambda = 2.5 \times 10^{-8} \, \text{m} \times 10^{9} \, \text{nm/m} = 25 \, \text{nm}
$$

Result: The wavelength is approximately 25 nanometers.

Analyzing the Given Option: 3.6 x 10^8 Nm

The calculation above indicates that the wavelength corresponding to the given frequency is approximately 25 nm, which falls within the extreme ultraviolet (EUV) region of the electromagnetic spectrum, often associated with high-energy photon emissions.

The option provided in the question, A) 3.6 x 10^8 Nm, is vastly different from the calculated value. To understand its significance, let's analyze what this wavelength represents.

- 3.6 x 10^8 nm equals 360 meters, which is an enormous wavelength, characteristic of extremely low-frequency waves, such as very long radio waves or even seismic waves, not electromagnetic waves in the visible or ultraviolet spectrum.

Implication:

- This discrepancy suggests that Option A is incorrect if the question pertains to electromagnetic waves in the context of high frequency (~10^16 Hz).
- Alternatively, if the question involves a different medium or wave type, the context would need to be clarified.

Understanding the Electromagnetic Spectrum and Relevant Wavelengths

The electromagnetic spectrum encompasses a vast range of wavelengths and frequencies, with specific regions characterized by their properties and applications.

Spectrum Region	Wavelength Range (nm)	Frequency Range (Hz)	Typical Uses
Radio Waves	> 1,000,000 nm (> 1 km)	< 3 x 10^8 Hz	Radio communication, TV, radar
Microwaves	1,000,000 nm – 1 nm	3 x 10^8 – 3 x 10^11	Microwave ovens, Wi-Fi
Infrared	700 nm – 1 nm	3 x 10^11 – 4.3 x 10^14	Remote controls, thermal imaging
Visible Light	380 – 750 nm	4.3 x 10^14 – 7.9 x 10^14	Human vision
Ultraviolet	10 – 380 nm	7.9 x 10^14 – 3 x 10^16	Sterilization, black lights
X-Rays	0.01 – 10 nm	3 x 10^16 – 3 x 10^19	Medical imaging
Gamma Rays	< 0.01 nm	> 3 x 10^19	Cancer treatment, nuclear physics

Given our calculated wavelength (~25 nm), the wave falls within the ultraviolet spectrum, which has significant implications in various scientific and technological applications.

Real-World Applications and Significance of Wavelength Calculations

Understanding and accurately calculating wave wavelengths is essential for numerous practical applications:

- Spectroscopy: Identifying materials based on their absorption or emission at specific wavelengths.
- Medical Imaging: X-ray machines operate at wavelengths around 0.01 to 10 nm, requiring precise wavelength control.
- Communication Technologies: Radio and microwave systems depend on specific wavelength ranges to optimize signal transmission.
- Astronomy: Determining the properties of celestial objects based on their emitted electromagnetic radiation.
- Nanotechnology: Wavelengths in the UV range are critical for nanofabrication and surface analysis.

Accurate wavelength calculations also underpin the development of new materials and devices, enabling scientists and engineers to harness electromagnetic radiation effectively.

Summary and Conclusion

To summarize:

- The relationship between wavelength, frequency, and wave speed is fundamental in wave physics.
- For electromagnetic waves traveling in a vacuum, the wave speed is approximately 3.0 x 10^8 m/s.
- Using the given frequency of 1.2 x 10^16 Hz, the calculated wavelength is approximately 25 nanometers.
- The option A) 3.6 x 10^8 Nm does not align with this calculation and likely represents a different context or is incorrect within the scope of electromagnetic wave calculations.

Final note: When solving wavelength-related questions, always ensure to convert units appropriately and consider the nature of the wave and medium involved. Precise calculations facilitate better understanding and application across scientific disciplines.

Keywords: wavelength, nanometers, frequency, wave speed, electromagnetic spectrum, UV light, wave calculation, physics, nanotechnology, spectroscopy, wave physics

Frequently Asked Questions

What is the wavelength in nanometers of a wave with a frequency of 1.2 × 10¹⁶ Hz?

The wavelength is approximately 25 nm.

How do you calculate the wavelength of a wave given its frequency?

Wavelength (λ) is calculated using the formula λ = c / f, where c is the speed of light (~3.0 × 10⁸ m/s) and f is the frequency.

Given a frequency of 1.2 × 10¹⁶ Hz, what is the wavelength in nanometers?

Using λ = c / f, the wavelength is approximately 25 nm.

What is the significance of the wavelength in nanometers for electromagnetic waves?

Wavelength in nanometers helps classify the type of electromagnetic radiation, such as UV, visible, or X-rays.

Is a wavelength of about 25 nm in the ultraviolet or X-ray spectrum?

A wavelength of approximately 25 nm falls within the extreme ultraviolet or soft X-ray range.

Why is understanding the wavelength important in physics?

Wavelength determines the wave's energy, penetration ability, and interaction with matter, essential in fields like optics and medical imaging.

What is the approximate wavelength in meters for a wave with this frequency?

The wavelength is approximately 2.5 × 10⁻⁸ meters.

How does increasing the frequency affect the wavelength of a wave?

Increasing the frequency decreases the wavelength, since they are inversely related.

What is the relation between wavelength in nanometers and

frequency in Hz?

The relation is λ (nm) = (c / f) × 10⁹, where c is the speed of light in m/s.

Is the given wavelength in the options consistent with the calculation for the given frequency?

Yes, the approximate wavelength of 25 nm aligns with the typical calculations for a frequency of 1.2 × 10¹⁶ Hz.

Additional Resources

What Is The Wavelength In Nanometers Of A Wave With A Frequency Of 1.2 X 10^16 Hz? A) 3.6 X 10^8 Nm B

Understanding the fundamental properties of electromagnetic waves is essential for many fields—from physics and engineering to telecommunications and astronomy. One key property that characterizes these waves is their wavelength, which describes the distance between successive peaks or troughs of the wave. When given a wave's frequency, calculating its wavelength in nanometers provides insight into the wave's nature and applications. In this article, we will explore how to determine the wavelength of a wave with a frequency of 1.2 × 10^16 Hz, analyze the options provided, and delve into the broader implications of such calculations.

Fundamentals of Wave Properties: Frequency and Wavelength

Before diving into the calculation, it's crucial to understand what frequency and wavelength represent and how they relate to each other.

What Is Frequency?

- Definition: Frequency (f) refers to the number of wave cycles that pass a fixed point per second, measured in hertz (Hz).
- Range: Electromagnetic waves span a vast range of frequencies—from very low radio waves to extremely high gamma rays.
- Example: Visible light typically ranges from about 4 × 10^14 Hz (red light) to 7.5 × 10^14 Hz (violet light).

What Is Wavelength?

- Definition: Wavelength (λ) is the physical distance between successive crests or troughs of a wave, usually measured in meters (m), nanometers (nm), or other length units.

- Significance: Wavelength determines the wave’s behavior, interaction with matter, and its role in various technologies.

The Relationship Between Frequency and Wavelength

The fundamental relationship connecting frequency (f), wavelength (λ), and the speed of light (c) is expressed as:

$$ \lambda = \frac{c}{f} $$

where:
- c is the speed of light in a vacuum, approximately 3.0×10^8 meters per second (m/s).
- f is the frequency in Hz.
- λ is the wavelength in meters.

This formula indicates that as the frequency increases, the wavelength decreases, and vice versa.

Calculating the Wavelength for a Frequency of 1.2 × 10^16 Hz

Given:
- $f = 1.2 \times 10^{16}$ Hz
- $c = 3.0 \times 10^8$ m/s

Applying the formula:

$$ \lambda = \frac{3.0 \times 10^8 \, \text{m/s}}{1.2 \times 10^{16} \, \text{Hz}} $$

Calculating step-by-step:

1. Divide the coefficients:

$$ \frac{3.0}{1.2} = 2.5 $$

2. Subtract the exponents:

$$ 10^{8} / 10^{16} = 10^{8 - 16} = 10^{-8} $$

3. Combine:

$$ \lambda = 2.5 \times 10^{-8} \, \text{meters} $$

To express this wavelength in nanometers, recall that:

$$ 1\, \text{meter} = 10^{9} \, \text{nanometers} $$

Thus:

$$\lambda = 2.5 \times 10^{-8} \, \text{m} \times 10^{9} \, \text{nm/m} = 2.5 \times 10^{1} \, \text{nm} = 25 \, \text{nm}$$

Result: The wavelength is approximately 25 nanometers.

Interpreting the Result and the Given Option

The calculation yields a wavelength of approximately 25 nm, which is in the ultraviolet (UV) range of the electromagnetic spectrum. UV light spans wavelengths roughly from 10 nm to 400 nm, and 25 nm falls well within this category.

The question also presents an option labeled:

- A) 3.6×10^8 Nm

This figure appears to be an attempt at a wavelength expression, but it is inconsistent with the correct calculation. To interpret this:

- 3.6×10^8 Nm equals 360 million nanometers or 360 meters, which is not plausible for a wave with such a high frequency (~10^{16} Hz). Such a wavelength would be characteristic of radio waves, not gamma rays or UV light.

Given the calculation, the correct wavelength in nanometers is approximately 25 nm, not 360 million nanometers. The option provided seems to be either a typographical error or an incorrect choice.

Understanding the Spectrum and Practical Implications

The high frequency of 1.2×10^{16} Hz places this electromagnetic wave in the extreme ultraviolet or soft X-ray region. Let’s explore what that means:

Electromagnetic Spectrum Context

- Radio Waves: Wavelengths > 1 meter (10^9 nm)
- Microwaves: 1 mm to 1 meter (10^6 to 10^9 nm)
- Infrared: 700 nm to 1 mm (0.7 to 10^6 nm)
- Visible Light: 400 to 700 nm
- Ultraviolet: 10 to 400 nm
- X-rays: 0.01 to 10 nm
- Gamma Rays: < 0.01 nm

Since our calculated wavelength (~25 nm) falls within the ultraviolet to soft X-ray range, it has significant implications:

- Medical Imaging: Ultraviolet and X-ray wavelengths are used in imaging technologies.
- Material Science: These wavelengths can penetrate various materials, making them useful for non-destructive testing.
- Astrophysics: High-frequency waves help observe high-energy cosmic phenomena.

Technological and Scientific Relevance

- The precise wavelength informs the design of optical systems, detectors, and filters.
- It influences the safety protocols for exposure, as UV and X-ray radiation can be harmful.
- Understanding wave properties informs the development of spectroscopy tools, which analyze material composition.

Conclusion: The Significance of Accurate Wavelength Calculation

Calculating the wavelength of an electromagnetic wave based on its frequency is a fundamental skill in physics, underpinning many technological applications. For a wave with a frequency of 1.2 × 10^16 Hz, the wavelength is approximately 25 nanometers, placing it within the ultraviolet spectrum. This insight not only enhances our understanding of wave behavior but also informs practical applications in medicine, industry, and astrophysics.

Regarding the options provided in the question, the correct wavelength is nowhere near 3.6 × 10^8 nanometers, which would be an unreasonably large value for such a high-frequency wave. Instead, recognizing the correct calculation underscores the importance of precision and understanding in scientific inquiry.

In sum, mastering the relationship between frequency and wavelength empowers scientists and engineers to harness electromagnetic waves effectively, advancing technology and expanding our understanding of the universe.

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