P5_7 The Wavelength of a Cow

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Abstract

In this paper, we explore the de Broglie wavelength of an average cow, and investigate if it is possible for a cow to also act as a wave. It is perfectly viable to calculate the de Broglie wavelength of a macroscopic object, such as in this case a cow, if we consider each atom of the cow to be coherent. The de Broglie wavelength of an average cow was found to be 1.3×10^{-37} m.

Introduction

The de Broglie wavelength of an object describes how these objects can act as both a particle and a wave [1], similar to the wave-particle duality condition of light [2]. Usually only microscopic objects, such as protons and electrons, have a described de Broglie wavelength, however, it is possible for macroscopic objects to also have a de Broglie wavelength [3]. The de Broglie wavelength of macroscopic objects is determined by using its centre of mass, which satisfies the free Schrodinger equation [3]:

$$-\frac{\hbar^2}{2M}\nabla^2\Psi(X) = E\Psi(X) \qquad (1)$$

The solution to Equation 1 can be found; corresponding to the energy which is shown in Equation 2 [3].

$$E = \frac{p^2}{2M} \qquad (2)$$

This solution has the form of [3]:

$$\Psi(X) = exp\left(i\frac{pX}{\hbar}\right) \qquad (3)$$

The de Broglie wavelength is found from the eigenvalue of Equation 3, as written in Equation 4.

Due to this, in this paper, we will calculate and discuss the de Broglie wavelength a cow will achieve if it runs at top speed.

Theory

The average cow weighs around 630 kg [4], and can run up to 7.8 ms^{-1} [5]. At this mass, a cow can be described as a macroscopic object and will have a de Broglie wavelength [3]. The de Broglie wavelength of an object is as follows [6]:

$$\lambda = \frac{2\pi\hbar}{p} \qquad (4)$$

Where λ is the wavelength, h is Planck's constant, and p is the momentum. Momentum can be found using the following equation [7]:

$$p = mv \qquad (5)$$

Where m is the mass of the object, and v is its velocity.

We can first use Equation 4 to find the de Broglie wavelength of an electron, so we can

make a comparison between this and the wavelength of a cow. If we assume the electron has a velocity in the order of 10^6 ms^{-1}, then the wavelength is calculated as 7.3 Å.

Using this equation, along with the values of mass and velocity of an average cow stated previously, we find the wavelength of a cow to be 1.3×10^{-37} m.

For additional comparison, the value of the Planck length is 1.6×10^{-35} m [8], the Planck length being the smallest value of distance between two particles where we can tell their positions apart [8].

Discussion

As shown, the de Broglie wavelength of an average cow travelling at top speed is almost 2 orders of magnitude smaller than the Planck length. This means that, although the cow does have an associated de Broglie wavelength, it is too small for us to observe, due to the laws of physics.

Conclusion

While an average cow does have a de Broglie wavelength, calculated to be 1.3×10^{-37} m, the wavelength is too small to observe, as it is smaller than the Planck length.

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