Is Heisenberg's uncertainty principle universal? A thought experiment by Shubham

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Abstract

Heisenberg's uncertainty principle is a founding pillar of quantum mechanics. This paper questions the foundations of the quantum mechanics with a thought experiment. The author has come up with this experiment and have found out that there are some anomalies in quantum measurement.

Quantum Mechanics: Is Heisenberg's uncertainty principle universal?

Every physics student must have come across with Heisenberg's uncertainty principle when studying quantum mechanics which states that we cannot measure position and momentum of a particle at the same time [1]. I also came across with this in my masters and have been fascinated by this phenomenon and being a dynamic young physicist wanted to see if it holds true. I have come up with a thought experiment which questions its validity.

Consider, a photon passing from one medium (vacuum) to a denser medium. At the boundary of the medium, it has wavelength λ_1 and as it passes its speed changes because of refractive index of the medium. Its wavelength changes to λ_2.

Now, suppose we know the thickness of the medium and the particle travels through this thickness Δx. Also, we can calculate the change in momentum of the particle Δp with the relation p= h/ λ. Then this means we know both Δx and Δp. Does this violate Heisenberg's uncertainty principle?

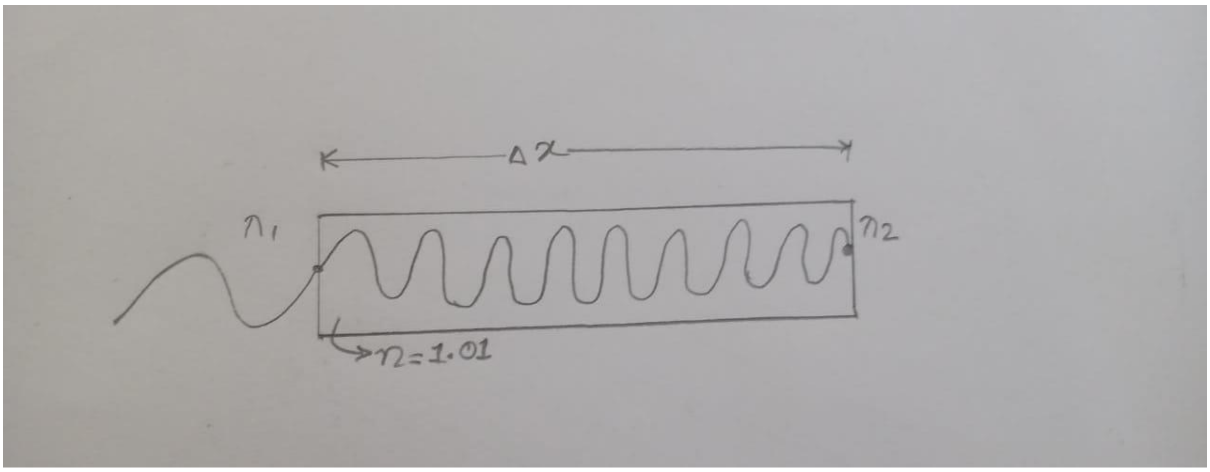

Figure 1. Thought experiment setup, photon travelling from one medium to another.

Well, I have taken some values and have put it into the formula:

$$\Delta x \Delta p \geq \frac{h}{4\pi} \qquad \dots (1)$$

Now,

Let the thickness of the medium, $\Delta x = 10^{-6}$m

Wavelength of the photon at entry, $\lambda_1 = 8650$ Å $= 8650 \times 10^{-10}$ m.

Let the refractive index of the medium, n = 1.1

The wavelength of the photon at medium can be found out by the relation:

$\lambda_2 = \lambda_1 / n$

Now, change in momentum, $\Delta p = \Delta(\frac{h}{\lambda}) = h\,\Delta(\frac{1}{\lambda}) = h(\frac{1}{\lambda_2} - \frac{1}{\lambda_1})$

Now, (1) ⇒

$$\Delta x \Delta p \geq^{?} \frac{h}{4\pi}$$

$$\Delta x h(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}) \geq^{?} \frac{h}{4\pi}$$

$$\Delta x \left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) \geq^{?} \frac{1}{4\pi}$$

$$\Delta x \left(\frac{\lambda_1 - \lambda_2}{\lambda_2 \lambda_1}\right) \geq^{?} \frac{1}{4\pi}$$

$$\Delta x \left(\frac{\lambda_1 - \lambda_1/n}{\lambda_1 \lambda_1/n}\right) \geq^{?} \frac{1}{4\pi}$$

$$\Delta x \left(\frac{\mathrm{n}\lambda_1 - \lambda_1}{{\lambda_1}^2}\right) \geq^{?} \frac{1}{4\pi}$$

$$\Delta x \left(\frac{n-1}{\lambda_1}\right) \geq^{?} \frac{1}{4\pi}$$

Substituting the values:

$$\frac{10^{-6}(1.01 - 1)}{8650 \times 10^{-10}} \geq^{?} 0.079577$$

$$1.156 \times 10^{-4} \times 10^{-6} \times 10^{-2} \times 10^{10} \geq^{?} 0.079577$$

$$0.1156 \geq^{?} 0.079577$$

This is not true, ‘0.1156 is not greater than or equal to 0.079577’.

Does this mean Heisenberg’s uncertainty principle is getting violated? Does this not hold for this set of values? Is it incomplete? Or quantum mechanics needs reform? I have just come up with this hypothesis. I call this as ‘Shubham’s hypothesis’. I may be wrong as Heisenberg’s principle is the pillar of quantum mechanics and I may have made a mistake but values show the converse. I am a physics student at Cardiff University who just wants to unravel the mysteries of the cosmos and understand the world around us.

With my sincere gratitude I welcome any criticism and reviews for this hypothesis and will be delighted to discuss with others. Feel free to contact me. I would like to thank my professors at Cardiff University for their lectures which helped me to explore and come up with this thought experiment.

Conclusion

The paper gives a thought experiment which questions the Heisenberg's uncertainty principle and theoretically tries to disprove the inequality and make position and momentum measurement at the same time. The author endorses any review.

References

[1] "Uncertainty principle - Wikipedia." https://en.wikipedia.org/wiki/Uncertainty_principle (accessed May 17, 2022).