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A2_2 Dodging a Bullet

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Abstract

This paper discusses the possibility of a person being able to dodge a bullet through a quantum tunnelling event. A quantum mechanical approach was taken, modelling the bullet as a collection of individual atoms with identical wavelengths. The probability of tunnelling was then taken to be the collective probability of each atom tunnelling individually. The result obtained was $\left(\left(5.11\times10^{-19}\right)\exp(-4.48\times10^{24})\right)^{3.21\times10^{19}}$ which is effectively zero.

Introduction

Wave-particle duality dictates that every piece of matter has a de Broglie wavelength associated with it due to its momentum. This means that there is always the possibility of matter quantum tunnelling through classically forbidden regions (potential barrier). This paper concentrates on a scenario where a bullet tunnels through a person causing no damage to them. Due to the macroscopic nature of this situation, we are unable to model the bullet as a single particle and therefore will focus on its individual atoms.

Discussion

In order to calculate a probability of tunnelling, the bullet concerned was modelled as a collection of atoms. It was assumed that the bullet will have tunnelled once each atom has tunnelled successfully. In the scope of this paper we will not consider inter-particle interactions. Due to wave-particle duality we model the atoms as plane waves. To calculate the wavelength of the particles the de Broglie wavelength was used

$$\lambda = \frac{h}{p} = \frac{h}{mv}\ ; \qquad (1)$$

where; λ is the wavelength, h is Planck's constant, p is the momentum, m is the mass of the atom, and v is the speed of the atom. The bullet considered was a .40 Smith & Wesson (S&W) calibre bullet, taken to be travelling at 350ms^{-1}[1]. The bullet has a mass of 11g [1] and is assumed to be made entirely of lead which has a relative atomic mass of 207. This leads to a value for m of 3.43×10^{-22} kg/atom. By using these values along with Eqn. 1 we attain a de Broglie wavelength of 5.52×10^{-15}m.

It is then possible to find the energy of each particle [2] by using

$$E = \frac{\hbar^2 k^2}{2m} = \frac{h^2}{2m\lambda^2}; \qquad (2)$$

where; E is the energy of the particle, $\hbar$ is the reduced Planck's constant and k is the wavenumber. Using the previously calculated wavelength along with Eqn. 2 we attain a value for the energy of 2.10×10^{-17}J.

Next we must calculate the height of the potential barrier, V_0, that the atoms must overcome. This was determined by assuming that the thickness of the body was roughly 0.35m and then finding the energy required to penetrate this distance. For the bullet used, this was found to be 658 J [3].

The probability of tunnelling [4] occurring by an atom is found using

$$P = \frac{16E(V_0 - E)}{V_0^2}\exp(-2\kappa b)\ ; \qquad (3)$$

where P is the probability of tunnelling, b is the thickness of the barrier (taken as the thickness of the body which is 0.35m) and κ [5] is

$$\kappa = \left[\frac{2m(V_0 - E)}{\hbar^2}\right]^{\frac{1}{2}}. \qquad (4)$$

Using Eqn. 4 along with the values of V_0 and E we attain a value of 6.40×10^{24} m^{-1} for κ.

From Eqn. 3 we can now deduce that the probability for one atom of lead to tunnel through a body is $(5.11 \times 10^{-19}) \exp(-4.48 \times 10^{24})$ which is effectively zero, as was logically expected.

In order to find the probability of all of the bullet's atoms tunnelling successfully this value must be raised to a power equal to the number of atoms in the bullet.

For the 11g bullet it was worked out that there were 3.21×10^{19} atoms present using the mass per lead atom found earlier of 3.43×10^{-22} kg/atom. Therefore the probability of all atoms tunnelling is $((5.11 \times 10^{-19}) \exp(-4.48 \times 10^{24}))^{3.21 \times 10^{19}}$, rendering the situation even more improbable.

Conclusion

This paper has shown that the likelihood of a bullet completely tunnelling through a person instead of hitting them is practically zero. This is to be expected when applying this type of quantum mechanics to a macroscopic scale.

References

[1]http://en.wikipedia.org/wiki/.40_S%26W accessed 21/10/2014
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[3]A.I.M. Rae, *Quantum Mechanics*, Fifth edition, p. 30
[4]http://www.hornadyle.com/assets/site/files/Hornady-LE-Military-Application-Guide.pdf accessed 21/10/2014
[5]A.I.M. Rae, *Quantum Mechanics*, Fifth edition, p. 25