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A1_11 The Littlest League

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Abstract

In this paper, we investigated quantum tunnelling by replacing the batter with a potential barrier in a baseball game. We found that the width of a potential barrier that represents a batter needs to be between 1.57×10^{-36} m and 1.41×10^{-36} m in order for the transmission probability of a baseball through the potential barrier to equal the strike rate of Major League Baseball (MLB) pitchers of 62% to 65%. Considering these values are smaller than the Planck length, it is therefore physically impossible to replicate the observed MLB strike rates with the potential barrier we used.

Introduction

Quantum effects such as quantum tunnelling do not translate well when considering macroscopic quantities, such as the incredibly small chance of a tennis ball quantum tunnelling through a tennis racket found by Morris et al. (2013) [1]. Quantum tunnelling has a corresponding transmission probability which represents the probability of a particle tunnelling through a potential barrier. In this paper, we compare the transmission rate of a baseball through a potential barrier representing a batter to the rate of which a Major League Baseball (MLB) pitcher throws strikes to see if it is possible to recreate this observed strike rate with quantum tunnelling transmission rates.

Theory

For this analysis, we treat the baseball as a single particle approaching a potential barrier that represents a batter. The tunnelling probability of a particle through a potential barrier is obtained from,

$$T = e^{-2a\sqrt{\frac{2m_p(U-E_p)}{\hbar^2}}} \quad [2], \tag{1}$$

where T is the transmission probability, a is the barrier width, m_p is the particle mass, U is the barrier potential energy, E_p is the particle energy, and $\hbar$ is the reduced Planck constant. We assume the potential energy and particle energy to be the kinetic energy of the bat and ball respectively, found from,

$$E = \frac{1}{2}mv^2, \tag{2}$$

where v is bat or ball velocity and m is the bat or ball mass. We then rearrange equation (1) for the width of the potential barrier,

$$a = \frac{-\ln T}{2\sqrt{\frac{2m_p(U-E_p)}{\hbar^2}}}. \tag{3}$$

Results

The mass of a baseball and baseball bat were taken as 0.145 kg [3] and 0.94 kg [4] respectively. We took the velocity of the baseball to be the fastest recorded pitch of 105.1 miles h^{-1} (roughly 47.0 m s^{-1}) [5] and the velocity of the bat to be 106 miles h^{-1} (roughly 47.4 m s^{-1}) [6]. Using equation (2), this leads to a particle energy of $E_p \approx 160$ J and a potential barrier energy of $U \approx 1056$ J. We then substituted these values into equation (3) using R code for a range of transmission probabilities from 0.001 to 1, generating Figure 1, with green and red dotted lines representing the upper MLB strike rate of 65% and the average strike rate of 62% respectively [7]. From Figure 1, we found that, in order for the transmission probability of a baseball through the potential barrier we established to match the MLB strike rate range of 62% to 65%, the width of the potential barrier must be within the range of 1.57×10^{-36} m to 1.41×10^{-36} m.

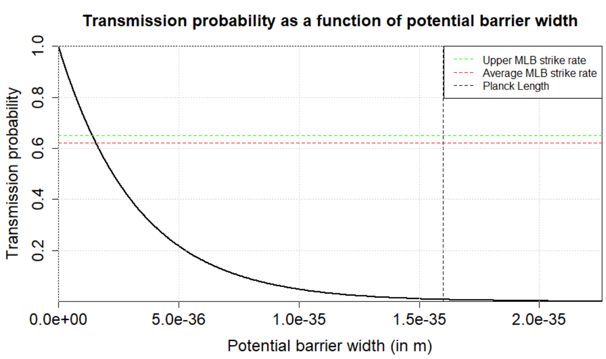

Figure 1: R plot showing the transmission probability of the baseball through the potential barrier (the strike rate) against the barrier width

Discussion and Conclusions

Added onto Figure 1 is the Planck length of approximately 1.6×10^{-35} m [8], represented by the black dotted line. This shows that the required values of the potential barrier width are almost a magnitude smaller than the Planck length, and thus it is physically impossible for a potential barrier that could reproduce the MLB strike rate to be created using the current energy values. The largest physically possible transmission probability for this set up was found when the width of the potential barrier is equal to the Planck length, giving a transmission probability of approximately 0.01, 62 times smaller than the lower strike rate value.

Although attaining the needed strike rate is currently impossible, it could be made possible by modifying the initial conditions. Lowering the bat velocity would lower the barrier potential energy in this scenario, which increases the transmission probability of the baseball through the barrier, effectively shifting Figure 1 to the right. This could lead to further investigation, as it is therefore possible to find a maximum bat speed that allows the transmission probability to fall within the MLB strike rate range while having a physically possible potential barrier width.

In conclusion, we find that in order for a potential barrier with an energy of roughly 1056 J to recreate the strike rate of MLB pitchers, the barrier width must be between 1.57×10^{-36} m and 1.41×10^{-36} m, which would be physically impossible to recreate due to this length being smaller than the Planck length.

References

[1] T. Morris et al. *P2_3 Tennis Ball Tunnelling*, PST 12, (2013).

[2] Paul Allen Tipler and Mosca, G. (2008)., Physics: for scientists and engineers: with modern physics., pp. 1214, New York: W.H. Freeman And Company.

[3] `https://bit.ly/2Dl9i3R` [Accessed 27th November 2019]

[4] `https://bit.ly/2QU7dDY` [Accessed 27th November 2019]

[5] `https://bit.ly/2rC2T1i` [Accessed 27th November 2019]

[6] `https://bit.ly/2qJf9xi` [Accessed 27th November 2019]

[7] `https://bit.ly/34tTbge` [Accessed 27th November 2019]

[8] `https://bit.ly/2Or2Eze` [Accessed 27th November 2019]