Journal of Physics Special Topics
An undergraduate physics journal

A4_2 This Barbie is Radioactive

N. Savic, H. Birch, L. Tzabach

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

November 1, 2023

Abstract

In this paper, we investigate how many Barbies are required to absorb the energy of Oppenheimer's atomic bomb developed in the Manhattan Project. To do this, we calculate the latent heat of one Barbie to determine how much energy one is able to endure before melting. We find that, to fully absorb the energy from Oppenheimer's atomic bomb, we would need roughly 4.64 billion Barbies.

Introduction

Barbie has been a hugely popular children's toy since its creation in the 1950s. With there being a wide range of Barbies, Dream Houses, and accessories to choose from, it is no surprise that children all across the world still love to play with these dolls. Had they been around in the 1940s, how many Barbies would it have taken to fully absorb the energy released from Oppenheimer's famous atomic bomb?

Barbie's Melting Point

Barbie's main body is made of a plastic known as Acrylonitrile Butadiene Styrene (ABS). ABS has no true melting point, however it goes through a glass transition state in which the material goes from a brittle state to a viscous one. The glass transition state of ABS is $105\,^{\circ}\mathrm{C} = 378\,\mathrm{K}$ [1]. We assumed that Barbie is entirely made out of ABS and that its glass transition state is its melting point.

To calculate the total absorption energy of a Barbie, we used the equation:

$$Q = mc\Delta T \tag{1}$$

where Q is the heat energy, m is the mass of the object, c is the specific heat capacity, and ΔT is the temperature difference.

The average specific heat capacity of ABS is $1.99\,\mathrm{J/g/^{\circ}C}$ [1], which, in SI units, is $1990\,\mathrm{J\,kg^{-1}\,K^{-1}}$. Assuming room temperature is $300\,\mathrm{K}$, the temperature difference between this and the glass transition state of ABS is $378 - 300 = 78\,\mathrm{K}$. We have taken the mass of a Barbie doll to be $122\,\mathrm{g}$ ($0.122\,\mathrm{kg}$) [2].

We substituted all these values into Equation 1, obtaining a value of $18,900\,\mathrm{J}$

Oppeneheimer's Atomic Bomb

In this paper, we assumed that all the energy released from Oppenheimer's atomic bomb, Trinity, is thermal energy, and that it is all absorbed by the Barbies. The total force exerted by Trinity is equivalent to 21 kilotonnes of TNT [3], or $87.86\,\mathrm{TJ}$.

Taking our calculated absorption energy of a Barbie, we determined the number of Barbies required to fully absorb the impact. We did this by dividing the total energy by the Barbie energy:

$$n_{\mathrm{Barbie}} = \frac{87.86 \times 10^{12}}{18,900} \approx 4,640,000,000$$

Therefore, we require approximately 4.64 billion Barbies to fully absorb the energy of Trinity.

Since their initial release in the 1950s, over 1 billion Barbies have been sold worldwide [4]. This is nowhere near the required number of Barbies to fully absorb the explosion.

Assuming we obtained every Barbie ever made, we can calculate the estimated impact radius of Trinity. Therefore, we took the estimated value of its impact radius, 160 mi [5] (257,000 m). This would be the point at which there are 0 Barbie dolls to absorb the impact.

Taking the ratio of Barbies produced worldwide to the total Barbies required for a full absorption of energy, we get:

$$\frac{1,000,000,000}{4,640,000,000} \approx 0.2155$$

If we multiply the ratio with the impact radius with 0 Barbies, the distance value we get is the difference between the two impact radii. Therefore we need to subtract this distance from the 0 Barbie impact radius. Therefore:

$$257,000 - (257,000 \times 0.2155) \approx 202,000\,\text{m}$$

Hence, all the Barbies ever produced would only reduce the impact radius by $\sim 50,000$ m.

Discussion

Our calculations find that, even using every single Barbie ever created, the impact radius of an atomic bomb the same size as Trinity would still be large at 202 km. To reduce the impact radius, the Barbies would need to be made of a plastic with a higher melting point. Polytetrafluoroethylene (PTFE) would be a slightly better candidate due to its high melting point of 327 °C [6], but even with a melting point this high the number of Barbies required to fully absorb the energy of an atomic bomb would still be a similar order of magnitude to the value calculated in this paper.

Conclusion

Overall, we have found that to absorb the energy of the Trinity nuclear bomb test, we would need approximately 4.64 billion Barbie dolls - over 4 times the number of dolls produced since the inception of the brand.

References

[1] *The Online Materials Information Resource* (2011) MatWeb. Available at: https://www.matweb.com/search/DataSheet.aspx?MatGUID=eb7a78f5948d481c9493a67f0d089646&ckck=1 [Accessed: 10 October 2023]

[2] Saccone, E.J. and Chouinard, P.A. (2019) *'Barbie-Cueing Weight Perception'*, i-Perception, 10(3), p. 204166951985059. doi:10.1177/2041669519850590.

[3] Mackelden, A. (2023) *Oppenheimer Tells the True Story of the Invention of the Atomic Bomb*, Harper's Bazaar. Available at: https://www.harpersbazaar.com/culture/film-tv/a44604873/oppenheimer-movie-true-story/ [Accessed: 10 October 2023]

[4] Chappet, M.-C. (2023) *The real history of Barbie*, Harper's Bazaar. Available at: https://www.harpersbazaar.com/uk/culture/entertainment/a44129282/barbie-real-history/ [Accessed: 10 October 2023]

[5] *Trinity Site* (2016) National Parks Service. Available at: https://www.nps.gov/whsa/learn/historyculture/trinity-site.htm#:~:text=The%20explosion%20point%20was%20named,of%20at%20least%20160%20miles. [Accessed: 11 October 2023]

[6] (2020) *Top 5 Heat-Resistant Plastics*, SyBridge Technologies. Available at: https://sybridge.com/top-5-heat-resistant-plastics/#:~:text=Polytetrafluoroethylene%20(PTFE)&text=PTFE%20has%20one%20of%20the,C%20and%20%2B260%C2%B0C. [Accessed: 11 October 2023]