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A4_8 The Power of Mjolnir

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Abstract

This paper calculates the maximum kinetic energy that Mjolnir can achieve when thrown by Thor and how much energy he can use from the redirection of lightning strikes during thunderstorms. The kinetic energy achieved from a throw was calculated to be 4.72 x 10^5 J and the energy redirected from a single lightning flash was 10^8 J. It was also calculated that Thor could use the total power output of a thunderstorm equivalent to 2 x 10^{12} W.

Introduction

Thor is the son of Odin and is the Norse God of Thunder who wields the mighty weapon Mjolnir [1]. Mjolnir is an enchanted hammer that was created from a mould based on the core of a dying star and also gives the wielder many abilities, such as the abilities of weather manipulation and energy redistribution, both of which will be discussed in this paper [2]. It is also noted that within comics and films that Mjolnir is depicted as being 'weightless' to Thor, possibly due to the worthiness enchantment [2], but gains mass once Thor releases it.

Kinetic energy of Mjolnir?

As mentioned previously Mjolnir is said to have been created using the core of a star as a mould. Unlike what other articles have mentioned the core is not a white dwarf or neutron star. These occur after a star has lost its outer atmosphere or gone supernova and is already 'dead'. We assume therefore that the core and mould are comprised of iron, as a dying star would be at the end of its lifetime and is in its red giant phase [3]. It is even stated on the Marvel Wikia that in the process of using the core as a mould 'the star exploded' reinforcing the assumption that the core was not already a white dwarf or neutron star [2].

It is also stated from some sources that if Mjolnir is made from the Asgardian metal Uru it would weigh 42.3 lbs [4]. However, for this investigation we are assuming that the hammer is made from iron as this is what we assumed the mould is made from. Assuming the density of iron, ρ, is 7870 kg m^{-3} [5] the mass of Mjolnir is found using the following expression.

$$m = \rho V \ . \tag{1}$$

Where m is the mass of Mjolnir and V is its volume. The mass was found to be 148 kg (326 lbs). Mjolnir's strap mass was considered negligible in comparison to the hammers head so dimensions of 0.25 x 0.25 x 0.3 m were approximated for Mjolnir's 'head' to calculate its volume. It can be seen that Uru is considerably less dense than iron. Using the dimensions above gives Uru a density of approximately 1013 kg m^{-3} similar to the density of water.

Thor is seen to spin Mjolnir to increase its angular speed. Assuming that Thor can spin Mjolnir with an angular velocity of 15 revs s^{-1} (94.2 rad s^{-1}) the linear velocity can be found using the following equation (15 revs s^{-1} is an estimation from watching Thor spin Mjolnir in the Marvel films):

$$v = \omega r. \tag{2}$$

Where v is linear velocity and r is the full length of Mjolnir (assumed to be 0.6m [2]). Using these values gives a linear velocity of 56.5 ms^{-1}. The kinetic energy can now be calculated from the following expression:

$$E_K = \frac{1}{2}mv^2. \quad (3)$$

Using the values calculated above gives a kinetic energy of 4.72 x 10^5 J. This is approximately the energy of a 1000kg car travelling at 21.7 ms^{-1} (48.5 mph). This mass is assumed to be an effective mass which only occurs when Mjolnir is not in contact with any person. Once someone tries to pick Mjolnir up the enchantment activates and, unless worthy, they cannot lift the hammer [2].

Redistributing the energy of Lightning

Thor has other powers that include weather manipulation and energy redistribution. If Thor creates a thunderstorm he can redistribute the energy of lightning strikes to use them as an offensive attack. A typical thunder storm creates a potential difference of approximately 10^8 Volts between the clouds and the ground and can produce currents up to 2 x 10^4 Amps [6]. A lightning flash contains 3 strokes, with each stroke lasting for approximately 50 μs [7]. The energy released during each stroke can be calculated using the expression:

$$E = Pt = VIt. \quad (4)$$

Using the values defined above the energy per stroke is calculated to be 10^8 J. The energy of each flash is therefore 3 x 10^8 J. If we assume that Mjolnir can redirect the energy per flash with 100% efficiency without any energy dissipated as heat then the value calculated above is the energy that can be used as a potential attack [2].

If Thor was to redirect a continuous flow of lightning strikes from the thunderstorm he could attack with a power output reaching 2 x 10^{12} W. The largest nuclear reactor currently operating is the Kashiwazaki-Kariwa nuclear plant in Japan [8]. It has a power output (when fully operational) of 7.965 x 10^9 W and could provide 3% of Japans energy [8]. Thor's output could reach over 100 times this value and so he could effectively supply the whole of Japan's energy requirements with plenty to spare.

Conclusion

Under the assumption that Mjolnir was created from iron, see justification for this assumption above, the kinetic energy of Mjolnir when thrown by Thor was calculated to be 4.72 x 10^5 J. Using some of Mjolnir's enchantments Thor could redirect individual lightning flashes each with an energy of 10^8 J or redirect a continuous flow of lightning flashes giving Thor an average electrical power output of up to 2 x 10^{12} W.

References

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[7] http://hyperphysics.phy-astr.gsu.edu/hbase/electric/lightning2.html; Last viewed 18/11/2014

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