Journal of Physics Special Topics

An undergraduate physics journal

A2_1 Zeus' Lightning Bolt

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November 5, 2019

Abstract

This paper outlines the calculated heat capacity that would be required for the mythological Greek god Zeus to be able to comfortably hold a, hypothetical, 'stationary lightning bolt'. Known properties of lightning and the human pain threshold were used to model the specific heat capacity required to elevate Zeus' hand temperature, from ambient to the upper limit of pain. In order for Zeus to be able to hold the lightning bolt, the calculated specific heat capacity that his hand must have was 6.38×10^{13} J kg^{-1} K^{-1}

Introduction

In stories from ancient Greek mythology, Zeus is considered to be the mighty ruler of the gods. In many depictions, he is known to hurl bolts of lightning at his enemies and any human who may have displeased him. While a physical bolt of lightning may seem like a proficient way to correct misdemeanours amongst the gods, lightning is actually a spectacular weather phenomenon, caused by opposing charges between cloud layers or between the cloud and ground. When the opposing charges build, eventually the insulating effect of air breaks down and an electrical discharge equalises the charge differences [1]. While 'true' lightning is an event, as opposed to a physical object that can be held (or thrown), the electrical and energetic properties of true lightning will be considered and applied to the hypothetical 'lightning bolt' for these calculations. When considering the physical properties Zeus must possess in order to successfully endure the energy produced by the lightning, the initial point to make would be the damage the electrical discharge would impart to himself. For the purpose of this paper, Zeus is considered to be a near perfect electrical insulator, with the dielectric strength of his skin being such that the electrical effects of the lightning bolt may be discounted and the heat energy can be considered as the only threat to life. In addition to this, since the size and shape of Zeus can be considered variable (as described in many myths) we will be taking Zeus' form to be that of an average man.

Theory

In nature, lightning strikes can have a voltage (V) of approximately 100 MV [2] and a current (I) as great as 300 kA [3]. With these values, equation (1) gives the power (P) of the hypothetical lightning bolt as 3×10^{13} W.

$$P = IV \tag{1}$$

With the power of the lightning bolt calculated, we can consider the power as thermal energy. Since the power is given as a rate, the time (t) required for Zeus to hold the lightning bolt is taken to be 10 seconds, as this is the time over which a human can endure the lower pain threshold temperature [4].

$$P = Q/t \qquad (2)$$

From equation (2), the heat energy (Q) from the lightning bolt is calculated to be 3×10^{14} J. The pain threshold temperature is given as 317 K [4]. Given an ambient skin temperature of 307 K [5], the change in temperature that would be tolerable would be 10 K. For Zeus' hand to increase by just 10 K from the thermal energy calculated, the specific heat for his hand would have to be extremely high. This is calculated using equation (3) using a value of 0.47 kg [6] for the mass of the hand.

$$Q = mc\Delta T \qquad (3)$$

This gives a specific heat capacity of 6.38×10^{13} J kg^{-1} K^{-1} .

Conclusion

The energy of the hypothetical lightning bolt would require Zeus' hand to have an incredibly high heat capacity to ensure he could endure the high thermal energy. The calculated figure of 6.38×10^{13} J kg^{-1} K^{-1} is orders of magnitude greater than any recorded heat capacity known today. It has also been assumed that the energy from the lightning bold is purely thermal, however the energy would also be light and electrical. Despite this, the thermal energy produced would still require a heat capacity higher than any known substance [7]. The values given for current and voltage for a lightning bolt do vary and the values used, for this calculation, are from the upper limit of the range stated in [2] and [3]. If the lower limit of both of these values were used, the calculated heat capacity would be 4.26×10^{12} J kg^{-1} K^{-1}. Despite being much lower than that calculated for the upper limit, it is still orders of magnitude over that of any known substance.

References

[1] https://www.nssl.noaa.gov/education/svrwx101/lightning/ [Accessed 2 October 2019]

[2] https://hypertextbook.com/facts/1998/MathieuLo.shtml/ [Accessed 2 October 2019]

[3] https://www.sciencedirect.com/science/article/pii/S0074614208602776 [Accessed 2 October 2019]

[4] https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100020960.pdf [Accessed 2 October 2019]

[5] Eus J.W. Van Someren, Handbook of the Biology of Aging (Seventh Edition), 2011

[6] https://exrx.net/Kinesiology/Segments [Accessed 2 October 2019]

[7] http://www2.ucdsb.on.ca/tiss/stretton/database/Specific_Heat_Capacity_Table.html [Accessed 2 October 2019]