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P6_6 Beginner Magic

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Abstract

In many forms of media that include magic one of the earliest spells learnt creates water, be it as a flow or floating ball. This paper will calculate how much energy is required to perform this spell as well as discuss the environment required to produce this energy by using special relativity and the Stefan-Boltzmann law for radiative transfer over a small circular face that connects the magic source to the world of the user. The energy to create an orb of water with a radius of 5cm is $\approx 4.7 \times 10^{16}$J this requires an temperature of the radiator to be between $\approx 2.3 \times 10^{7}$K and $\approx 3.2 \times 10^{6}$K depending on the area of the radiation source. The rate of energy transfer was found to be independent of the temperature around the magic caster.

Introduction

In many sources of media involving magic one of the beginner spells involves the creation of water. Aguamenti for example from the Harry Potter books and films or the numerous synonyms of 'water ball' used in anime [1] and [2]. The summoning of water from nothing defies conservation laws in this world, such as conservation of mass/energy. However, if magic is assumed to take energy from elsewhere to produce its spells, another dimension for example, then conservation laws need not be violated.

This paper will assume the casting of spells channels the energy from another dimension (dimension b) by creating a portal between them, this portal will be referred to as a 'magic circle'. The environment around the caster will be referred to as 'dimension a'. The energy required for the spells will be considered to transfer radiatively through the 'magic circle' which will be evaluated as a circle with a radius of between 1mm and 5cm. This is to approximate a circle size that varies between the tip of a wand and the size of the palm of ones hand, to generalise over the media portrayals [1] and [2]. The radiative transfer of energy will be assumed to occur within 1s in this paper, creating a sphere of pure water with a radius of 5cm.

Method

To start, the mass of water in the sphere needs to be calculated.

$$\rho_{water} \frac{4}{3} \pi R^3 = M_{water} \tag{1}$$

Using a radius of 5cm and a density of water of 1000kg/m^3[3], this gives a mass of the orb to be 0.524kg. This mass is then converted to energy using Einstein's equation for special relativity at non-relativistic speeds.

$$E = Mc^2 \tag{2}$$

$$E \approx 0.5(3 \times 10^8)^2 \tag{3}$$

This equation gave the energy of the orb to be 4.712×10^{16}J. This is the amount of energy that needs to be transferred through the 'magic circle' over a second to cast the spell. The assumption of radiative transfer allows for the conditions of 'dimension b' to be calculated. By rearranging the Stefan-Boltzmann equation we can calculate the temperature of 'dimension b'.

$$Q = \epsilon \sigma A T^4 \tag{4}$$

As the energy is assumed to be transferred over 1s, Q can be substituted as $Q = E$. Before computing the energy of 'dimension b' an adjustment needs to be made as the energy is being transferred to 'dimension a' where the magic caster is, which has a temperature of its own. 'Dimension a' will be assumed to have a temperature range between -40°C and 60°C to approximate an Earth like temperature range.

$$Q = \epsilon \sigma A (T_b^4 - T_a^4) \tag{5}$$

This equation will be used to approximate a black-body radiator so $\epsilon = 1$, σ is the Stefan-Boltzmann constant.

$$\frac{Q}{\sigma A} + T_a^4 = T_b^4 \tag{6}$$

The graph shows a plot of 'dimension b' temperature against area of the 'magic circle'. The black points assume that the temperature of 'dimension a' $T_a = 293$K with coloured red and blue lines at $T_a = 333$K and 233K respectively. These lines are indistinguishable on the graph. Using this graph the temperature of 'dimension b' was calculated based on various areas.For a 'magic circle' radius of 1mm (smallest reasonable wand tip) the temperature was found to be, $T_b \approx 2.3 \times 10^7$K. For a radius of 1cm (largest reasonable wand tip) the temperature was , $T_b \approx 7.2 \times 10^6$K. Finally, for a radius of 5cm (palm size) the temperature was, $T_b \approx 3.2 \times 10^6$K.

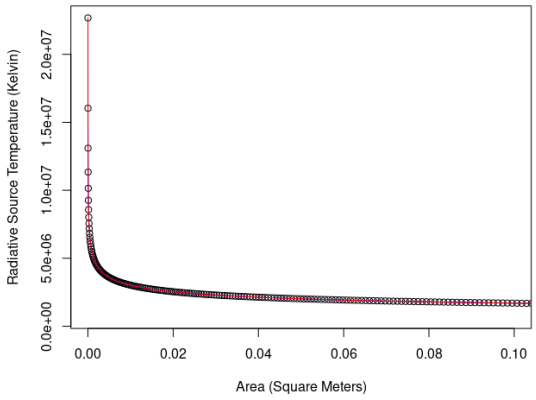

Figure 1: Graph of T_b against area of the 'magic circle'- showing an exponential decay of required temperature as the radiating surface increases

Conclusion

Even for beginner magic such as producing a small amount of water requires an enormous amount of energy. If the energy used during the process of spell casting is siphoned from another dimension then that source would have to be incredibly hot, having temperatures around the order of 1×10^7K. In calculating the energy required to summon water we demonstrate why magic is not possible on Earth as portrayed in fantasy media [1] and [2].

We also found that the magic power required to cast spells is independent of the temperature environment around the caster. The data calculation showed the temperature of 'dimension a' to be negligible in the radiative transfer equation.

References

[1] Harry Potter Wiki, `https://harrypotter.fandom.com/wiki/Water-Making_Spell`

[2] Mushoku Tensei Wiki, `https://mushokutensei.fandom.com/wiki/Magic_Spells#Water`

[3] USGS-water density, `https://www.usgs.gov/special-topics/water-science-school/science/water-density`