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S2_4 Stumbling Stormtroopers

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Abstract

Laser rifles are a common choice of weaponry in 'Star Wars'. In the opening scene of 'A New Hope', a stormtrooper is hit by a laser and forced backwards. Multiple scenes similar to this imply that lasers have significant momentum in 'Star Wars'. This provided the inspiration to calculate the momentum and energy contained in a single laser blast, then subsequently analyse the properties of the armour in 'Star Wars'. The energy was calculated to be 1.2×10^{11} J and the properties of armour were assessed regarding the material's heat capacity, as shown in Figure (2). From this, it was concluded that either the materials in 'Star Wars' are vastly different from Earth materials or that 'Star Wars' laser rifles do not fire actual lasers.

Introduction

Multiple scenes in the 'Star Wars' franchise depict laser rifle blasts as having momentum [1]. As the 'cannon' science behind 'Star Wars' weaponry is somewhat ambiguous, this paper aims to assess the possibility of these weapons being literal lasers. This was done by calculating the amount of photons required to impart a given amount of momentum onto a stormtrooper and subsequently the energy stored in one laser blast. We then calculated the specific heat capacity of 'Star Wars' armour that would be required to protect a stormtrooper from such a blast. This was then compared to Earth material properties to determine whether the laser rifles are actual lasers.

Method

In order to calculate the energy of a single laser blast, the total momentum of the blast was calculated. The total momentum ($\boldsymbol{p_{ph}}$) of a group of photons is

$$\boldsymbol{p_{ph}} = N\frac{h}{\lambda}, \tag{1}$$

where N is the total number of photons, h is plank's constant and λ is the wavelength. Given the red appearance of many of the lasers in 'Star wars', the wavelength was estimated to be 700 nm [2]. Equation (1) was then compared to the change in momentum of a stormtrooper when hit with a blast ($\Delta\boldsymbol{p_{st}}$) as illustrated in Figure (1);

$$\Delta\boldsymbol{p_{st}} = m_s\boldsymbol{v} = \boldsymbol{p_{ph}} = N\frac{h}{\lambda}. \tag{2}$$

$\boldsymbol{v}$ is the velocity of the stormtrooper after being hit and m_s is the mass of the stormtrooper. We estimated the mass to be 80 kg and the velocity immediately after impact to be 5 ms^{-1}.

Assuming a total transfer of momentum from the photons to the stormtrooper, Equation (2) can be rearranged to find the number of photons (N) required to achieve the change in momentum $\Delta\boldsymbol{p_{st}}$.

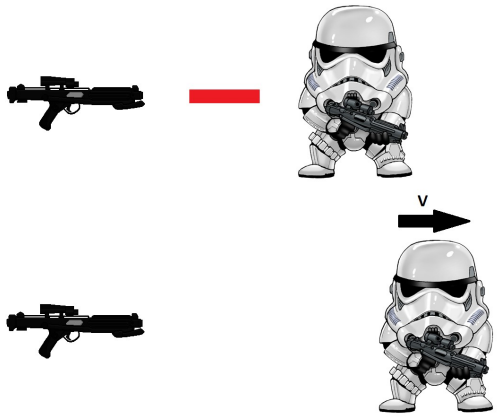

Figure 1: Diagram illustrates the stormtrooper being knocked backwards by a laser blast. '$\boldsymbol{v}$' represents the velocity of the stormtrooper after being hit.

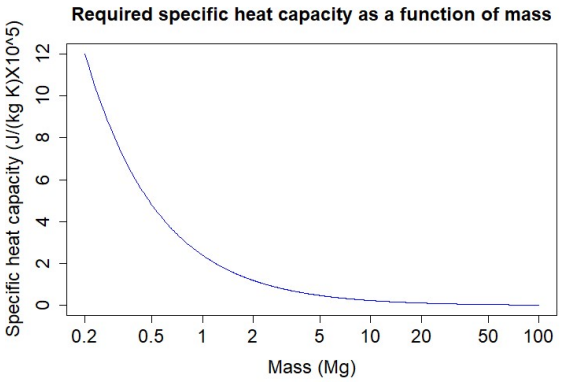

Figure 2: A graph showing the required specific heat capacity of an object to increase in temperature by 50 K from 1.2×10^{11} joules of energy as a function of mass. Note that the x axis is logarithmic

$$N = \frac{m_s v \lambda}{h}. \tag{3}$$

The total energy of a single blast (Q) is therefore;

$$Q = N\frac{hc}{\lambda} = \frac{m_s \boldsymbol{v} \lambda}{h}\frac{hc}{\lambda} = m_s \boldsymbol{v} c, \tag{4}$$

We then assessed whether a stormtrooper could survive such a blast using the following equation;

$$C_H = \frac{Q}{m\Delta T}, \tag{5}$$

where C_H is specific heat capacity and m is mass. Equation (5) shows the relation between the energy put into a system and the change in temperature. In this case, the energy was calculated from Equation (4) and the change in temperature (ΔT) is the limit of what a human could survive; estimated to be 50 K. Therefore, the survival of the stormtrooper depends on the mass and specific heat capacity of their armour. Figure (2) shows the specific heat capacity required to protect a stormtrooper as a function of mass. As there is a large variety of armament in 'Star Wars', such as large vehicles, a large range of masses was assessed.

Results

It was calculated from Equation (3) that 4.23×10^{29} photons would be required to produce enough momentum to achieve the scenes depicted in 'Star Wars'. This corresponded to 1.2×10^{11} J being stored within each laser blast. The required specific heat of armour to protect a stormtrooper was then calculated as a function of mass and demonstrated in Figure (2).

Conclusion

It was calculated that 1.2×10^{11} joules of energy is stored in each laser blast of a rifle from 'Star Wars'. The specific heat required to protect a stormtrooper from that amount of energy was then calculated as a function of mass and illustrated in Figure (2). By comparing this graph to real materials, it seems that the specific heat capacities required for a human to survive a laser blast, even if protected by a large and heavy vehicle, would be much higher than any known materials. Therefore, either 'Star Wars' laser rifles are not actually lasers, or materials have very different properties in galaxies far, far away.

References

[1] https://www.youtube.com/watch?v=j4N6tRgbGQU Accessed: [18/11/2017]

[2] http://www.livephysics.com/physical-constants/optics-pc/wavelength-colors/ Accessed: [18/11/2017]