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P4_3 The Last Son Of Krypton

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Abstract

The physics behind Superman's solar radiation absorption and heat vision are explored. His absorption is treated as a photosynthesis process and his heat vision is modelled ad a CO_2 laser and the energies and efficiencies of both systems are investigated.

Superman

Superman is a fictional DC superhero created in 1938. He is the last survivor of the alien planet of Krypton, having been sent to Earth as a child by his parents moments before their planet exploded [1]. On Earth he realised that radiation from our sun interacted with his physiology in such a way that he obtained superhuman powers; one of which, heat vision, will be the subject of discussion in this paper.

CO_2 Vision

We will model his heat vision as a type of carbon dioxide laser. A CO_2 laser works by using the vibration and rotations of a CO_2 molecule to produce the laser light in the 10.6μm range [2]. This infrared beam is mainly used in industry for cutting, welding and engraving. Superman uses his heat vision for similar purposes and when you combine this with the fact that that this type of laser uses molecules readily found in the body it seems to be good choice for a modelling his heat vision. Although in the comics and films Superman's heat vision is primarily displayed as bright red beams this is probably more for visual effect. Add to this the fact that he is able to produce invisible beams it does not seem unreasonable to model his vision this way.

Photosynthesis

As stated, Superman's main source of energy is through the absorption of solar radiation, a process which will be assumed to work in a similar manner to photosynthesis. Photosynthesis is a chemical process in plants that uses the energy from sunlight to convert CO_2 into sugar and we can imagine that Superman's biology stores the solar energy in a similar way. We will assume that he only absorbs sunlight through uncovered skin i.e. his hands and face, which was estimated to be an area of about 0.09 m^2 by assuming a 20cm diameter face and taking the front and back of hands measuring 8cm by 20cm. The process of photosynthesis in plants has a maximum efficiency of 11%, however on a molecular level the theoretical limit in efficiency is 25% which is the value we will assume Superman's unique physiology possesses [3]. The amount of solar radiation incident on the Earth is on average 1367 Wm^{-2} [4] which means that at Earth the total amount of useful energy he absorbs is 29.76 Js^{-1}

Steel

Frequently Superman is shown using his heat vision to melt or cut through steel. The melting point of stainless steel is around 1713 K [5] and it has a specific heat and latent heat of fusion of 620 $Jkg^{-1}K^{-1}$ and 247,000 Jkg^{-1} respectively. The total energy needed to melt room temperature steel is given by

$$Cm(T_{melt} - T_{room}) + Lm, \qquad (1)$$

where m is the mass and C and L are the specific and latent heats. The density of stainless steel is 7900 kgm^{-3} and so assuming his heat vision is focused on one pupil sized

hole (3mm radius) in a 5cm thick piece of steel the total mass he would have to melt to cut through would be 0.0112 kg. If room temperature is taken to be 293 K then the total energy needed to melt the steel would be 12535.81 J. If his body was able to transfer the stored solar energy to his heat vision completely efficiently then he would need to bask in sunlight for 7 minutes and 2 seconds, however CO_2 lasers are on average only about 20% efficient meaning he would need to be in sunlight for 35 minutes and 7 seconds.

Discussion

Absorbing sunlight and storing energy in a similar manner to photosynthesis gives Superman on average 29.76 joules of energy each second. In order to melt a single 3mm radius hole in a 5cm piece of steel he would have to spend just over 35 minutes absorbing solar radiation. If we assume all his powers run on solar radiation then it seems unlikely he would have enough energy to do all the amazing things he does on a regular basis. It is possible that his physiology is so unique and specially adapted that the efficiencies of absorbing and converting solar radiation are much higher than 25% and 20%. At the theoretical maximum of 100% he would be able to absorb and redirect 119 Js^{-1} which would mean he would only need 1 minute and 46 seconds worth of sunlight to melt the 3mm radius hole in steel.

Instead of increasing the efficiency of his biology we could also increase his surface area of absorption. If his height and weight are estimated to be 1.9 m and 102 kg then his surface area can be calculated using

$$Area\ (m^2) = \frac{[m(kg)]^{0.425} \times [h(cm)]^{0.725}}{139.2} \qquad (2)$$

as 2.31m^2 [6]. Using this value and the 25% and 20% efficiencies we find the time taken would be 1 minute 20 seconds. Combining both the total body surface area and the 100% efficiencies we get a time of just 4 seconds to absorb the energy required.

Conclusion

Assuming Superman's absorption and heat vision processes are based around similar mechanism to photosynthesis and CO_2 lasers, and assuming current maximum efficiencies for both these processes we find it would be possible to gain enough solar energy to melt steel, however, to do it frequently and in a manner similar to that depicted in the comics he would need to either surpass the quoted efficiencies or utilise more of his surface area in the process.

References

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