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A5_7 Popeye vs. The Sun

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Abstract

Popeye is a fictional character able to perform amazing feats after eating a can of spinach. One such feat involves him blowing out the Sun. This paper models the situation by using a density profile, and temperature ranges for different layers of the Sun to work out the energy needed to cool the Sun to 0 K. This was found to be 2.4×10^{38} J. When compared to the rest energy of the spinach, it has been found that Popeye's efficiency at converting the spinach to energy was 7.0×10^{23} %. Thus, Popeye must be able to perpetually create energy in order to perform this feat.

Introduction

Popeye is a fictional character that is able to perform fantastical feats by consuming a can of spinach. According to this website [1] in one episode Popeye blows out the Sun after consuming a can of spinach, so he can have some alone time with Olive Oyl. To calculate the energy needed to be gained from a can of spinach to perform such a task, some assumptions had to be made.

Assumptions

1. Popeye can hold enough air in his lungs.
2. The wind from the blow is homogeneous.
3. The geometry of the Sun is constant.
4. The gas in the Sun is an ideal gas.
5. Energy of the wind is the same as the heat lost via the cooling of the Sun, with no losses.
6. The Sun has no atmosphere and is made up of only a core, radiative zone and a convective layer.

Theory

The energy needed to cool the Sun as much as possible i.e to 0 K was found using equation (1) where ΔQ is the change in heat, m is the mass of the Sun, c is the specific heat capacity of a monatomic ideal gas (12.465 $Jkg^{-1}K^{-1}$), and ΔT is the change in temperature.

$$\Delta Q = mc\Delta T, \qquad (1)$$

However since the density of the Sun isn't constant, we modelled the Sun as layers of changing density and as such changing mass, so equation (1) becomes,

$$\Delta Q = c\Delta T \int \rho(r) 4\pi r^2 dr, \qquad (2)$$

$\rho(r)$ is the density profile, and $4\pi r dr$ is a small volume element where r is the width of the layer.

$$p(r) = 519r^4 - 1630r^3 + 1844r^2 - 889r + 155. \qquad (3)$$

Equation (3) is the density profile of the Sun in units of g/cm^3 [2]. It should be noted that it is a best fit model in which r ranges between

0 and 1 Solar radii. Performing the integral in equation (2) gives,

$$m_c(r) = \frac{519}{7}r^7 - \frac{1630}{6}r^6 + \frac{1844}{5}r^5 - \frac{889}{4}r^4 + \frac{155}{3}r^3, \quad (4)$$

where $m_c(r)$ is the cumulative mass of the Sun at radius r. As stated before since r is Solar radii, $m_c(r)$ needs to be multiplied by $(6.9 \times 10^{10})^3$ where 6.9×10^{10} is the radius of the Sun in cm to give the mass in g. Since the temperature of the Sun is not constant, equation (2) was split into three parts to represent each section of the Sun.

Section of the Sun	Radius (solar radii)	Temperature (K)
Core	$0 - 0.24$	15.7×10^6
Radiative Zone	$0.24 - 0.7$	4.5×10^6
Convective Zone	$0.7 - 1$	5700

Using these values [3] and equations (1) and (4) the energy needed to cool the Sun can be calculated. Then comparing this energy to the energy gained from a can of spinach [4] the efficiency of Popeye can be found.

Results and Discussion

Using the method outlined above we found the total solar heat to be 2.4×10^{38} J. The solar cumulative heat is displayed in Figure 1. As a can of spinach holds 181×10^3 J of nutritional energy, a person without Popeye's powers would need 1.3×10^{33} cans to produce enough energy to counteract the heat of the Sun.

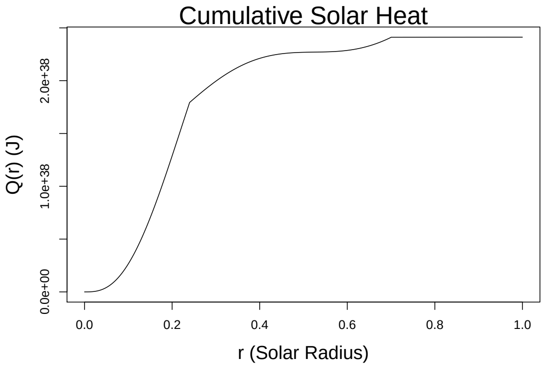

Figure 1: The plot depicts the cumulative solar heat as a function of solar radius.

To be able to harness the total energy from a single can Popeye would have to extract energy at a higher efficiency than human digestion. Assuming that the nutritional energy is equivalent to the energy absorbed during digestion, human digestion in this case only extracts 5.3×10^{-10} % of the spinach's rest energy. Popeye manages to obtain a whopping 7.0×10^{23} % efficiency, hence demonstrating that Popeye is a perpetual motion machine.

Popeye maybe 'super' strong but our model is not. The assumptions used to simplify the model limits its validity. Firstly, if the blow is not homogeneous the unbalanced force of the wind would shift the geometry of the Sun, perhaps instead blowing it out by scattering the Sun. Next, if the Sun's geometry does not stay constant the gravitational pull would overcome radiation pressure, collapsing the star thus causing it to reheat and ignite. We also assume that the Sun is made up of an ideal gas, however the pressure would be too high to use this approximation. Finally we do not detail the mechanism of cooling, realistically cooling efficiency would not be 100 %.

Conclusion

We started out by setting the scene, Popeye manages to blow out the Sun using the 'power' given to him by consuming a can of spinach. We calculated the total heat of the Sun using its properties, density profile and temperature ranges, and applied them to an equation of thermal dynamics (equation (1)). We found the total heat to be 2.4×10^{38} J. In order for Popeye to extract this large quantity of energy from one can of spinach he would have to process the spinach with 7.0×10^{23} % efficiency indicating he can perpetually create energy.

References

[1] `https://tinyurl.com/w2a37u2` [05/12/19]
[2] `https://tinyurl.com/r3ln8co` [05/12/19]
[3] `https://tinyurl.com/sojzu7o` [05/12/19]
[4] `https://tinyurl.com/w64hnnd` [05/12/19]