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P1_8 Bright Nosed and Bushy Tailed

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Abstract

Rudolph the Red-Nosed Reindeer has a very shiny nose and if you ever saw it, you might even say it glowed. The purpose of this paper is to find out how much energy, in the form of carrots, Rudolph would need to help guide Santa's sleigh through thick clouds and fog with his nose. By comparing his nose to a 40W incandescent light bulb, we conclude that approximately 151 carrots would be required to provide power for the 12-hour night shift.

Introduction

The perfect Christmas scene is often depicted as a cosy house with a roaring fire while snow peacefully falls outside creating a serene backdrop. Santa slowly plods his way across the roof, drops off presents, snaffles a mince pie or three and takes carrots back for the reindeer. How lovely.

What is not often considered is the 12-hour journey through the thick snow clouds where no light from the ground helps guide the way and visibility is down to a minimum of 10m. Modelling Rudolph's nose on an incandescent lamp, we can estimate how many carrots poor Rudolph would need to consume during the night just to keep his nose bright enough to light the way.

Method and Results

Visibility is measured objectively as the transparency of the atmosphere and is represented by the distance at which the luminous flux of a collimated beam is reduced to 5%. This is referred to as the Meteorological Optical Range (MOR). The beam is from an incandescent lamp treated as a black body with a colour temperature, T_c, of 2700K[1]. Using Wien's displacement law, the peak wavelength corresponding to the maximum spectral irradiance of the black body, λ_{peak}, can be calculated[2]:

$$T_c \times \lambda_{peak} = b \tag{1}$$

Where $b = 2.898 \times 10^{-3}$mK therefore, $\lambda_{peak} =$ 1073nm. As seen in figure 1, the peak wavelength for $T_c = 2700$K is beyond the visible spectrum, outlined by the purple (ultra-violet, UV) and red (infra-red, IR) boundaries. This means that the lamp has a yellow-orange glow because the majority of the spectral irradiance within the visible range is nearer the IR boundary.

Rudolph is famous for having a red nose; thus, still modelling it on an incandescent light, we can adjust the colour temperature to that of a black body which peaks in the red part of the visible spectrum. λ_{peak} for red is 685nm[3] so equation 1 gives a colour temperature of 4230K. Figure 1 compares the two black bodies corresponding to the colour temperature and is plotted using Planck's law[2]:

$$E_\lambda = \frac{8\pi hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k T_c}} - 1} \tag{2}$$

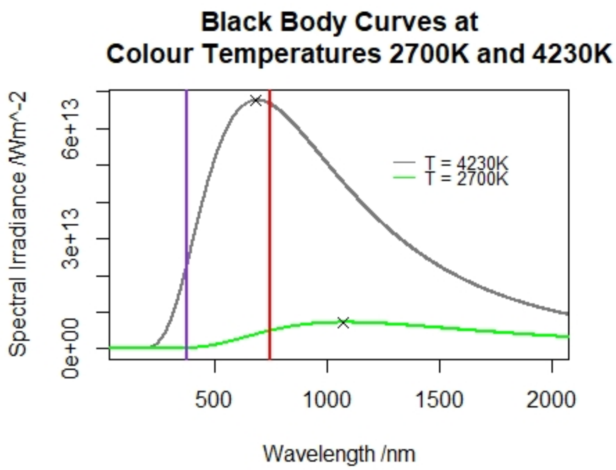

Figure 1: Spectral irradiance of the two black bodies over a wavelength range of 2000nm, $\times$ marks the peak wavelength. Source: J.Tranter

Assuming there is zero energy loss from initial powering of the nose to radiation of light, the luminosity, L is equal to the input power, P. The luminosity of the nose is based on the inverse square law and is derived from the Stefan-Boltzmann law[4]:

$$\frac{dP}{dA} = \sigma T_c^4 \tag{3}$$

$$P = L \ \rightarrow \ L = A\sigma T_c^4 \tag{4}$$

Where A is the surface area of the tungsten coil in a standard incandescent light bulb and the Stefan-Boltzmann constant is $\sigma = 5.67 \times 10^{-8}$ $\mathrm{Wm^{-2}K^{-4}}$. Using a typical 40W lamp, the surface area was found to be $A = 1.33 \times 10^{-5}\mathrm{m}^2$. This is a very small surface area, especially for a nose, thus we have assumed that within Rudolph's nose there is a small source of the light with this same surface area. Adopting this value for A and substituting $T_c = 4230\mathrm{K}$ into equation 4, the luminosity of Rudolph's nose is approximately $L = 241\mathrm{W}$. To find the energy required to run the nose during a 12-hour shift we utilise the relation between power and luminosity:

$$L = \frac{dE}{dt} \tag{5}$$

Hence,

$$\begin{aligned} dE &= L \times dt = 241 \times (24 \times 3600) \\ &= 20,822,400\mathrm{J} \end{aligned}$$

A typical carrot contains around 33kcal[5] which translates to 138kJ. So to power his nose for an entire night, Rudolph must consume 151 carrots.

Conclusion

The energy required to keep Rudolph's nose bright red and able to guide Santa's sleigh on a foggy Christmas Eve is approximately 20.8MJ equating to 151 carrots. However, significant inaccuracy arises from treating the nose like a black body because the amount of IR radiation produced would have probably set the rest of Rudolph and his friends on fire. Unless of course, his nose is as good an insulator as the glass surrounding an incandescent light bulb and that the cold winter wind helps cools it down.

References

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