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A3_1 LED Refrigerator

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Abstract

This paper investigates the practicality of using light emitting diodes with an efficiency of 230% as a way of cooling air inside a refrigerator. Using the standard dimensions of a household refrigerator and surrounding the entire surface area with the LEDs, how long would it take to reduce the temperature from 20°C room temperature to 5°C. We found that it would take 14.7 hours.

Introduction

The Noble Prize for physics 2014 was awarded to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for the invention of the first blue LEDs in the 1990s. In more recent times the possibility of LEDs with efficiency of over 100% has become a reality, they use energy from its surroundings. The LEDs used by MIT physicists have a power output of 69pW of light where the electrical power supply is only 30pW, hence an efficiency of 230% [1]. They take 39pW of power from its surroundings. This paper attempts to calculate the time for the LEDs to remove heat energy from a refrigerator of standard size if the LEDs where placed on the entire surface area.

Theory

The change of temperature of the air inside the refrigerator depends on the specific heat of the air, c, the mass of the air, m and the amount of energy taken out, Q. The specific heat equation is given by

$$Q = cm\Delta T. \qquad (1)$$

Using the relationship between energy, Q and total power, P_T, Eq. (1) can be rewritten to give the time it takes for a certain power to change the temperature. Then substituting the mass, m for ρV, where V is the volume of the refrigerator and ρ is the density of air gives,

$$t = \frac{c\Delta T \rho V}{P_T}. \qquad (2)$$

The total power, P_T, depends on the number of LEDs used around the refrigerator. This then depends on the dimensions of the refrigerator, a, b, c, assuming it is a cuboid. Volume, $V = abc$ and surface area, $S = 2(ab + ac + bc)$. The total power can be written in terms of the dimensions,

$$P_T = PN = 2 \times 10^6 P(ab + ac + bc). \qquad (3)$$

Where P is the power absorbed by one LED and N is the number of LEDs that fit around the surface area of the refrigerator. Hence $N = \frac{S}{S_{LED}}$ where $S_{LED} = 10^{-6}\text{m}^2$, is the surface area of one LED. Substitute Eq. (3) into Eq. (2) and rearrange to get time dependent only on the dimensions such that,

$$t = \frac{c\Delta T \rho}{2\times 10^6 P}\left(\frac{1}{a} + \frac{1}{b} + \frac{1}{c}\right)^{-1} \qquad (4)$$

Discussion and Conclusion

Using Eq. (4) and substituting in the typical dimensions of a household refrigerator, $0.85\text{m} \times 0.58\text{m} \times 0.55\text{m}$ [3], the time taken to reduce the temperature from room temperature $20°$ to $5°$ is approximately 14.7 hours.

From Eq. (4) it is obvious that the smaller the area in which is being cooled the less time it would take to produce appropriate conditions for a refrigerator. This investigation only takes into account the possibility of using LEDs around the edge. For larger cooling devices the LEDs could not be placed inside the refrigerator because the heat absorbed would then just be emitted as light, therefore adding to the heat energy inside.

The approximation from Eq. (4) is the very minimum time needed, i.e. we assumed that the refrigerator is perfectly insulating. Further investigation is needed to test the capability of current refrigerators to keep out external heat and whether this would be sufficient enough to still allow for cooling down to low temperatures. This suggests that industrial size refrigerators cooled this way are unlikely with the current 230% efficient LEDs.

We have also made the assumption that the refrigerator in empty and if an object is to be cooled inside, this would add to the time taken due to the increased density.

References

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