Voltage influence on the incandescent light bulb efficiency

Filip Šklebar

Gymnasium Bjelovar, Croatia, fsklebar@gmail.com

Introduction

A light bulb converts electrical energy into light and heat. Light energy is the useful part, unlike heat, which is energy loss. This paper, on the basis of the measurements, describes how the voltage change affects the efficiency of an incandescent light bulb and the spectrum of its radiation.

Method of the research

The base of the measuring device is a three-layer glass calorimeter filled with a known mass of water. The calorimeter was made of glass to minimise the absorption of light energy. Light bulb efficiency can be determined by measuring the current and voltage drop accross the lamp and the time required to increase water temperature by 1 Kelvin. The temperature change was measured with a Pt100 resistance thermometer in a four-wire Kelvin connection. This method of measurement avoids errors caused by wire resistance. All measurements were performed on a small 1.5 W, 24 V lamp. Light bulbs smaller than 25 W require no fill gas, just a partial vacuum free of oxygen and water vapour [1].

The light bulb spectrum was studied using simple spectrometer which uses a compact disc as a diffraction grating. The spectrum was photographed with a digital SLR camera with a fixed aperture, shutter speed and sensitivity to light so that images of the spectrum at different voltages were comparable to each other. Photographs of the spectrum were analyzed using ImageJ [2]. The spectrometer was calibrated using a high-pressure sodium lamp which contains additional elements such as mercury. Since sodium and mercury have peaks in their emission spectrum for which wavelengths are well known calibration was performed between two peaks: 589 nm for sodium and 435 nm for mercury.

1 Results of the experiment

The efficiency of the light bulb increases with increasing voltage up to the declared voltage for certain type of the light bulb (Fig. 1). Even at that point the efficacy of the light bulb remains still low (under 16 %). This fact can be explained by the theory according to which a higher voltage increases the temperature of the filament and the peak of radiation curve moves to higher frequencies, thus increasing the amount of radiated light energy in the visible part of the spectrum. The analysis of the lamp spectrum at different voltages confirmed the described theoretical assumption. All measurements were carried out ten times. The errors in measurements were calculated using standard deviation. The trend in light bulb efficiency can be well approximated with the second order polynomial.

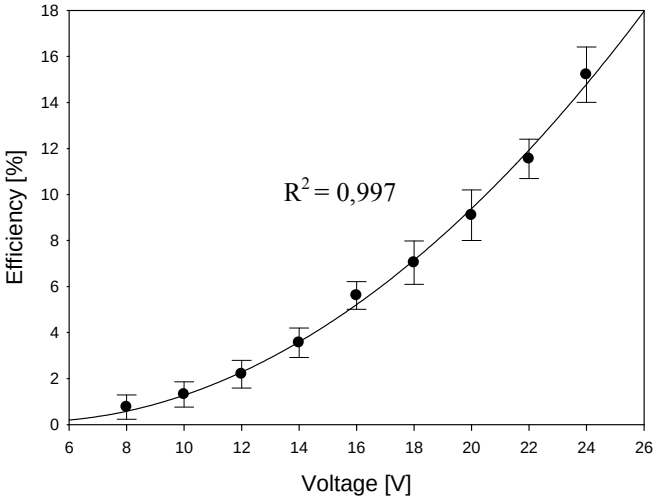

Fig. 1 Light bulb efficiency as a function of voltage

4 Conclusion

The aim of this research was to investigate how the voltage change affects the efficiency of the incandescent light bulb and the spectrum of its radiation. Precise measurements in temperature change were performed with an independently constructed three-layer glass calorimeter and the circuitry with a Pt100 resistance thermometer. A simple spectrometer with a compact disc was constructed and calibrated. Measurements indicate that incandescent light bulb efficiency increases with increasing voltage.

Based on the evidence of low efficacy of the incandescent light bulb some countries have passed measures to phase out such light bulbs introducing an energy sparing compact fluorescent lamp or light-emitting diode for general lightening.

References

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