Name(s)

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Project Number

J1809

Project Title

Heat Transfer in an Incandescent Lamp: An Investigation by Computer-Controlled Experiment

Abstract

Objectives/Goals

How much of an incandescent lamp's electric power input is wasted by thermal conduction from the filament? If these losses are substantial, their reduction could significantly improve the operating efficiency of incandescent lamps.

Methods/Materials

The subject of the investigation is a common 25-watt evacuated light bulb. I connected it to a programmable power supply and used two high-precision digital meters to measure the current flowing through the lamp and the EMF across it. The ambient temperature was measured by a precise digital thermometer. The four instruments were connected to a computer via a GPIB-to-USB interface. I wrote a program in Visual Basic for Applications to control the experiment and bring the data into Microsoft Excel for analysis. The program commands a timed sequence of approximate current values and obtains precise current and EMF measurements at each condition. From each pair of measurements, I calculate the lamp power (product) and resistance (quotient). I infer the filament temperature from the resistance using existing data on the temperature dependence of tungsten resistivity. Using the power, filament-temperature, and ambient-temperature data, the input power can be decomposed into thermal-conduction and thermal-radiation components. This is possible because the conduction is linearly proportional to the filament temperature (Fourier's Law), but the radiation is proportional to the fourth power of the filament temperature (Stefan-Boltzmann Law).

Results

I obtained data over seven decades of lamp input power (0.002mW to 22.7W) in which the lamp resistance increased nearly thirteen fold (45 to 567 ohms). Up to about 0.5mW (T=315K), the filament temperature appears to vary linearly with input power with a slope of 40 K/mW. Fourier's Law allows the thermal conduction to be thus extrapolated into higher power ranges where radiation is important. At about 10mW (T=485K) the contributions of conduction and radiation are approximately equal. Faint incandescence was first observed at 136mW (T=850K). At this point, thermal conduction accounts for 10% of the input power. At the highest power tested (22.7W, T=2395K), the conduction loss fraction is only 0.2%.

Conclusions/Discussion

These results imply that the prospects for improving the efficiency of incandescent lamps by reducing thermal conduction losses are dim. Existing lamp technology appears to be extremely good in this respect.

Summary Statement

This project is an experimental study of the thermal behavior of an incandescent lamp, looking for opportunities to improve lamp efficiency.

Help Received

Father coached me on the research plan, apparatus construction, experimental procedure, and data analysis. Mother helped me edit the report. Like in athletics, coaching helped me acquire the knowledge, develop the skills, and do the work.