Practical 1 – Topic 7

Boltzmann's radiation law

This lab is a modified version of lab 4F in *Physics by Experiment*, by J. R. L. Hartley and D. L. Misell, published by Stanley Thornes, 1987.

Criteria assessed

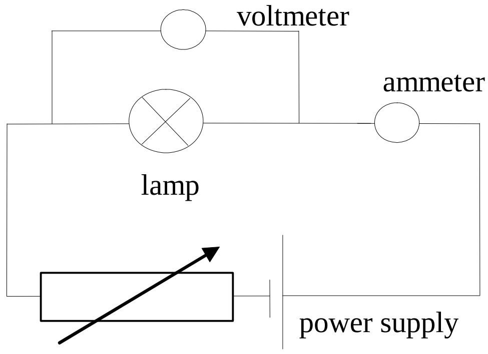
- DCP
- CE

Materials needed

- Lamp (with tungsten filament rated at approximately 12 V, 24 W)
- Power supply (0–12 V)
- Variable resistor (0–100 Ω)
- Ammeter and voltmeter

What to do

- Set up the circuit below:



- Measure the resistance of the lamp, making sure that the current through it is so small that the lamp does not glow.
- The resistance is given by the ratio of voltage to current. The resistance should now be larger than the cold resistance (why?).
- To calculate the temperature, assume that $R = R_0(1 + \alpha\theta)$, where R_0 is the resistance at 0 °C. For tungsten filaments found in most lamps $R_0 = 0.50$ Ω. Take the temperature coefficient of resistance of tungsten, α, to be = 0.005 K^{-1}. θ is the temperature of the filament in °C.
- Calculate the temperature θ and convert this temperature into kelvin.

The power dissipated in the lamp is $P = VI$.

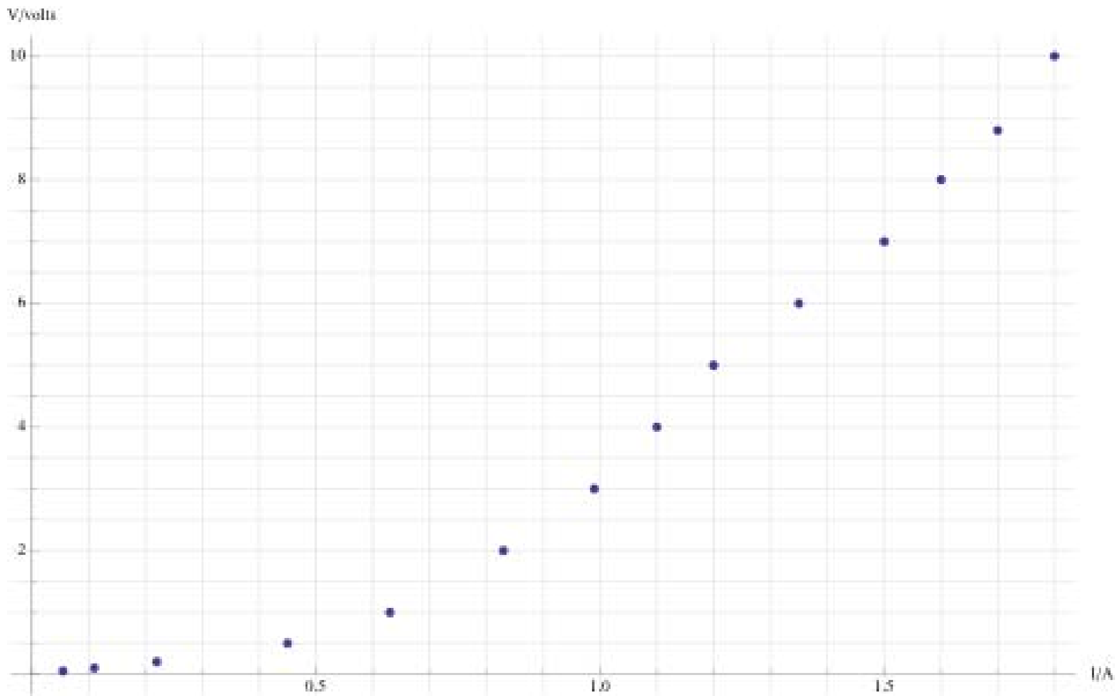
- Calculate the power dissipated in the lamp at different temperatures.
- If $P = kT^n$, what should be plotted to give a straight line?
- How is n determined?
- What should n be if the Boltzmann law is satisfied?

A graph of power P versus temperature T (in kelvin) should show two behaviours:

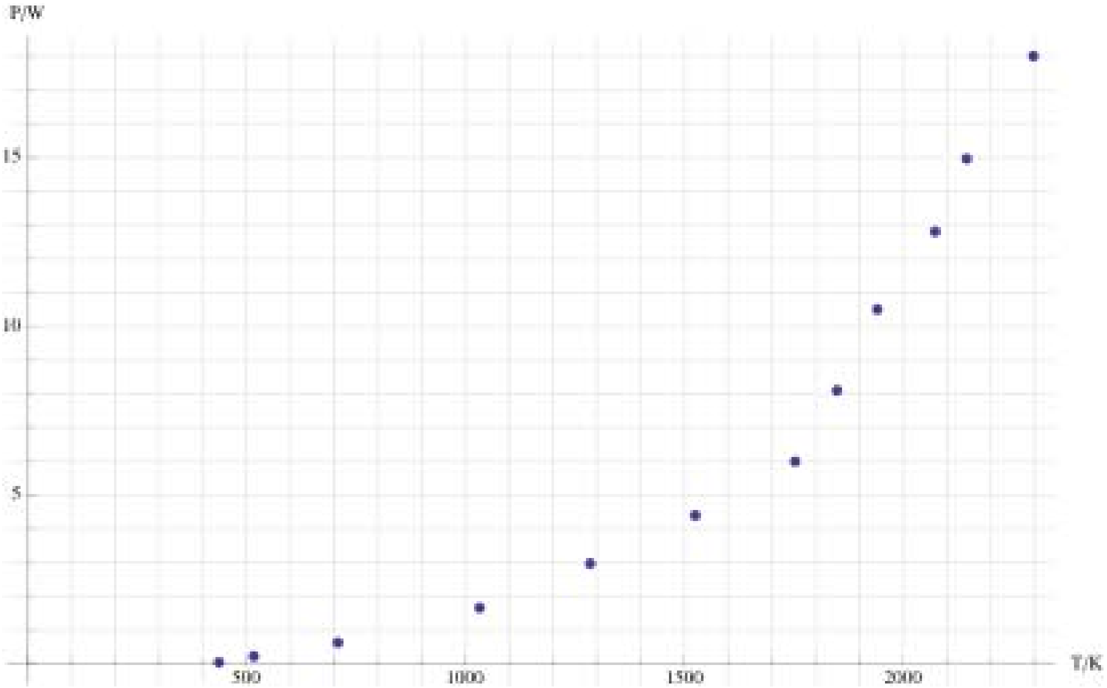
- an initial linear behaviour
- then a non-linear behaviour. A sample graph is shown as Graph 3.

The value for n that you got is probably smaller than what you expected.

- How is this explained?
- How can you use your version of sample graph 2 to improve the calculation of n?
- What is the improved value of n?



Graph 1 Typical voltage versus current graph for a tungsten filament lamp.



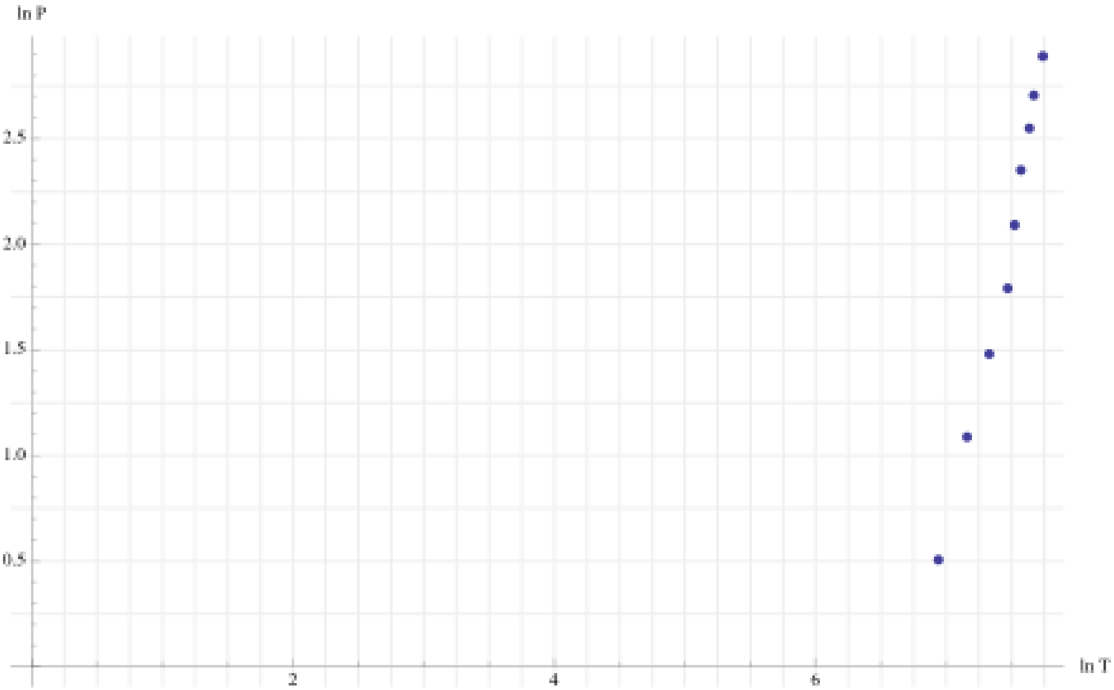
Graph 2 Power versus temperature graph for the tungsten filament lamp. Notice the changed behaviour at above 1000 K.

The change in behaviour is due to the fact that at about 1000 K the dominant mechanism of heat loss by the filament changes from convection to radiation.

- The rate of heat loss by convection is proportional to the difference in temperature between the filament and the room, T_R, i.e. $\frac{dQ}{dt} \propto T - T_R$,
- If radiation is the dominant mechanism then $\frac{dQ}{dt} \propto T^4 - T_R{}^4$.
- In both cases $T >> T_R$ and so to a very good approximation $\frac{dQ}{dt} \propto T$ for convection and $\frac{dQ}{dt} \propto T^4$ for radiation.

Note: even above 1000 K where radiation is dominant, convection is still present!

The information provided here should give lots of clues for the Conclusion and Evaluation sections of your report.



Graph 3 ln *P* versus ln *T*. The slope of this graph is 3.0.

