Stefan Boltzmann Radiation Rule

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

In this experiment Stefan-Boltzmann Radiation Law is going to be studied by using a tungsten lamp and a radiation sensor. Video presentation on Moodle must be watched before answering the questions.

Q1. Write down the Radiation Rule. Define the elements in it and explain what it tells us.

Q2. Take the logarithm of it. Match it with the most general line equation: $y = mx + n$. **Show your calculations below explicitly or no credits!**

(3rd Question is on the next page!)

Q3. You know that radiation is proportional to the 4th power of temperature. Thus, we need to determine the temperature of the tungsten filament. How are we going to determine the temperature? By a thermometer? **Justify your answers, or no credits!**

Q4. Show dimension **analysis** for Stefan-Boltzmann constant σ **explicitly. Show your calculations below <u>explicitly or no credits</u>!**

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***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : The aim of this experiment is to determine the rate of temperature dependency in the Stefan-Boltzman Radiation Law.

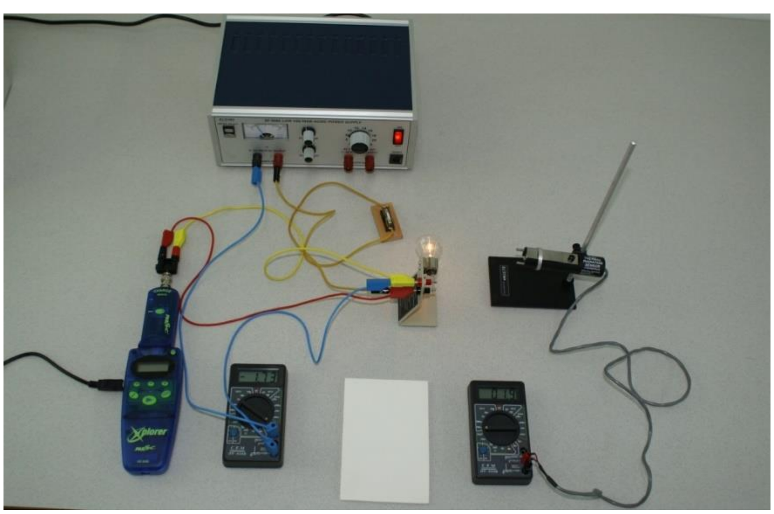
THEORY : Radiation from an object is observed to be dependent on its temperature. The distribution of photon frequencies can be understood in terms of quantum physics where the radiation occurs in the form of energy packets or photons. It has been observed that the wavelength at which the maximum intensity occurs (Wien's displacement law) or the total radiated power integrated over all wavelengths per unit area depends only on the temperature of the object. The latter is the subject of our experiment and is called the Stefan-Boltzman Radiation Law. It states that the total integrated radiated power per unit area from an object depends on the fourth power of its temperature:

$$R = \sigma T^4,$$

where σ is the Stefan-Boltzman constant ($\sigma = 5.6703\times10^{-8}$ W/m^{2}K^4).

The object that produces the radiation in this experiment is an incandescent tungsten bulb. The actual part that radiates is the tungsten filament. Since the resistance of metals increases as a function of temperature ($R = R_0(1+\alpha(T-T_0))$ where temperature coefficient of resistivity for tungsten is $\alpha = 4.5\times10^{-3}$ K^{-1}), we can determine its temperature by measuring its electrical resistance through Ohm's law: $R = \dfrac{V}{I}$.

We will use an infrared detector that is sensitive over a wavelength region between 0.5 to 40 µm. We will be measuring the total power radiated over this range only, but this should give us a value proportional to the total power radiated. Its output is in millivolts.



APPARATUS:

Stefan-Boltzman Lamp (a 12 V bulb), fuse and switch set, radiation sensor, reflecting heat shield, multimeter set to 200-millivolt range, multimeter set to 10-A range, Data Logger and the charge sensor, Pasco 24-V power supply, various leads and stand for the radiation sensor.

PROCEDURE :

1. Multimeters and the power supply are placed on the workbench at their proper settings. If you notice something is not set right, please inform your instructor, otherwise DO NOT MAKE ANY CHANGES IN THE SETTINGS. Make sure that the heat shield is placed between the bulb and the sensor, reflective side facing the sensor.
2. You will determine the resistance of the tungsten filament at room temperature first. For this purpose adjust the power supply current to its minimum value, 0.2 A. You will be reading the current value from the multimeter set to 10-A range and the potential across the filament from the data logger set as a voltmeter.
3. Calculate the resistance using the Ohm's law. This will be your R0. Your instructor will give you the value of the room temperature. Make sure that all your temperature values are in Kelvin.
4. Make sure that the metal ring on the detector has been pushed all the way to the front, otherwise the detector readings might be faulty.
5. While increasing the current very slowly, record the current, the potential drop across the lamp, and the sensor output at each current setting. **DO NOT EXCEED 2.6 AMPERES!**
6. Calculate the resistance of the tungsten filament at each current setting using the Ohm's law and divide these values by the value at room temperature that you have determined in step 2.
7. Using the temperature coefficient of resistivity for tungsten, $\alpha = 4.5 \times 10^{-3}$ K^{-1}, and $R/R_0 = (1+\alpha(T-T_0))$, determine the temperature of the tungsten filament at each current setting.
8. Plot your radiation sensor output versus temperature data on a log-log paper. Draw a straight line that passes through all the data points symmetrically, that is, either all the points fall on the straight line or equal number of points fall each side of the line.
9. A power law expression produces a linear plot when plotted on a log-log graph paper. Determine the slope of this straight line by picking two points far apart from each other. Slope is the ratio of the actual vertical distance to the actual horizontal distance on the graph. Since plotting on a log-log graph paper is equivalent to taking the base-10 logarithm of the values and then plotting them on a regular paper, slope is calculated through:

$$m = \frac{\log y_2 - \log y_1}{\log x_2 - \log x_1} = \frac{\log\left(\frac{y_2}{y_1}\right)}{\log\left(\frac{x_2}{x_1}\right)}$$

   where x and y values are direct readings from the graph.
10. Compare your result with the actual value of *n* = 4. What is your percentage error?

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Draw the circuit diagram:

Write down the formula to calculate the temperature from the resistance (see step 7):

....

.... T = ...

T_o = ...

I_o = 0.2 Amp. V_o = ...

R_o = ... α = ...

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Current *I* ( )	Potential Across the lamp *V* ( )	Radiation Sensor output V_{Rad} ( )	Resistance of the filament *R=V/I* ( )	R / R_o	Temperature of the filament T ( )

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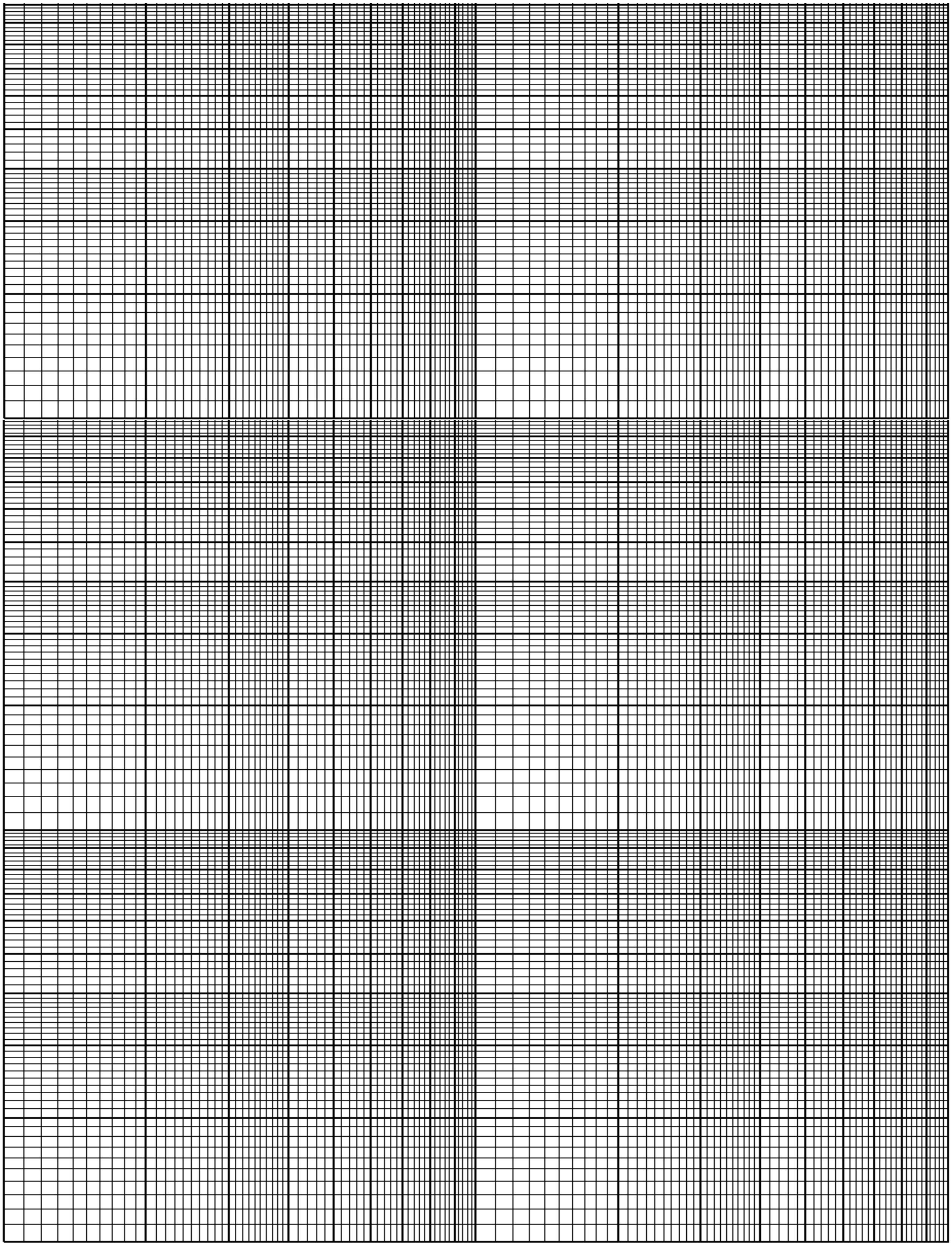

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A) From the graph, choose two SLOPE POINTS other than data points,

SP_1 : (;)

SP_2 : (;)

B) Calculate,

Description / Formula	Calculations (show each step)	Result
n = SLOPE =	....	....
	....	
% error =	....	....

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #8

PHYL202 Lab Book