Boğaziçi University

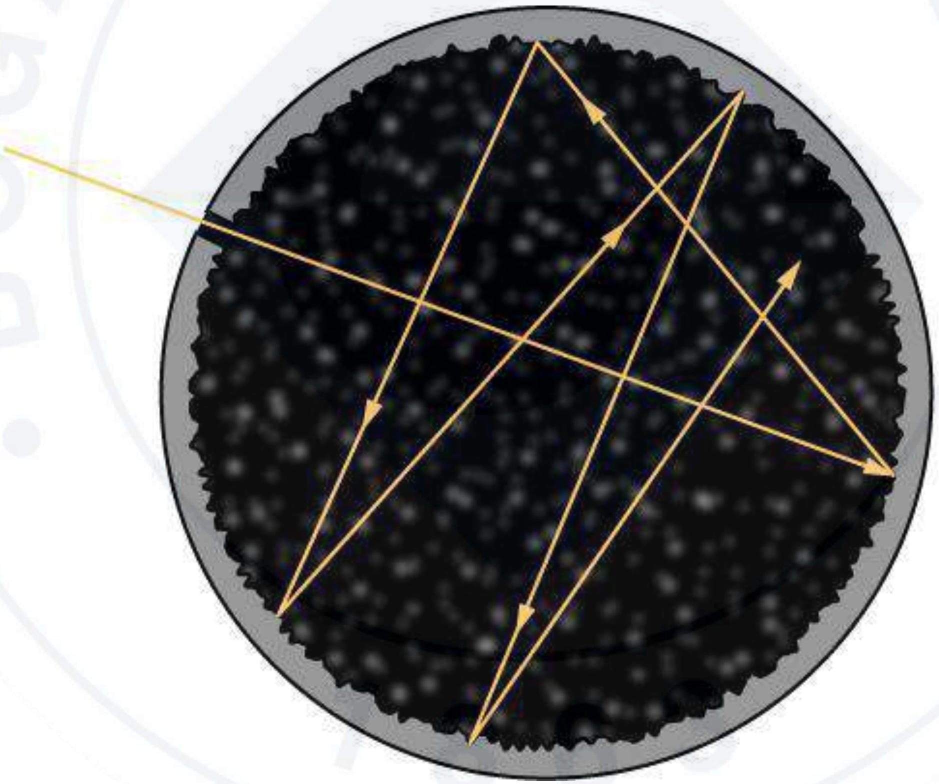
Introductory Phys Labs

STEFAN-BOLTZMANN RADIATION LAW

PHYL 202

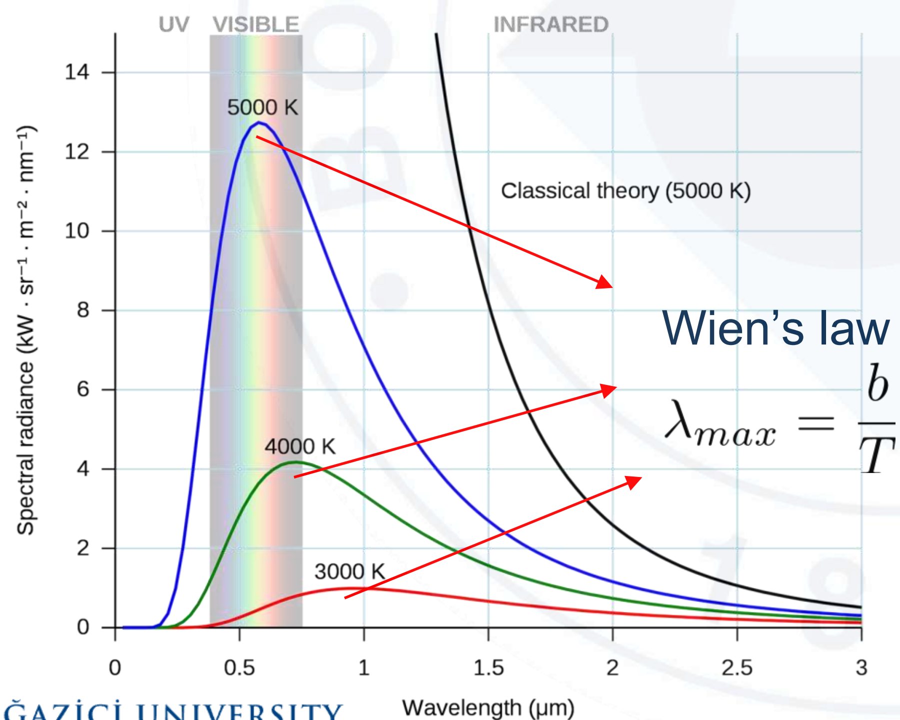
THEORY

Definition of a black body: An idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence



Classical theory formed by Rayleigh and Jeans predicted at shorter wavelengths energy emitted by black-body tends to go infinity, hence the **ultraviolet catastrophe** and it is contradicted with experimental data.

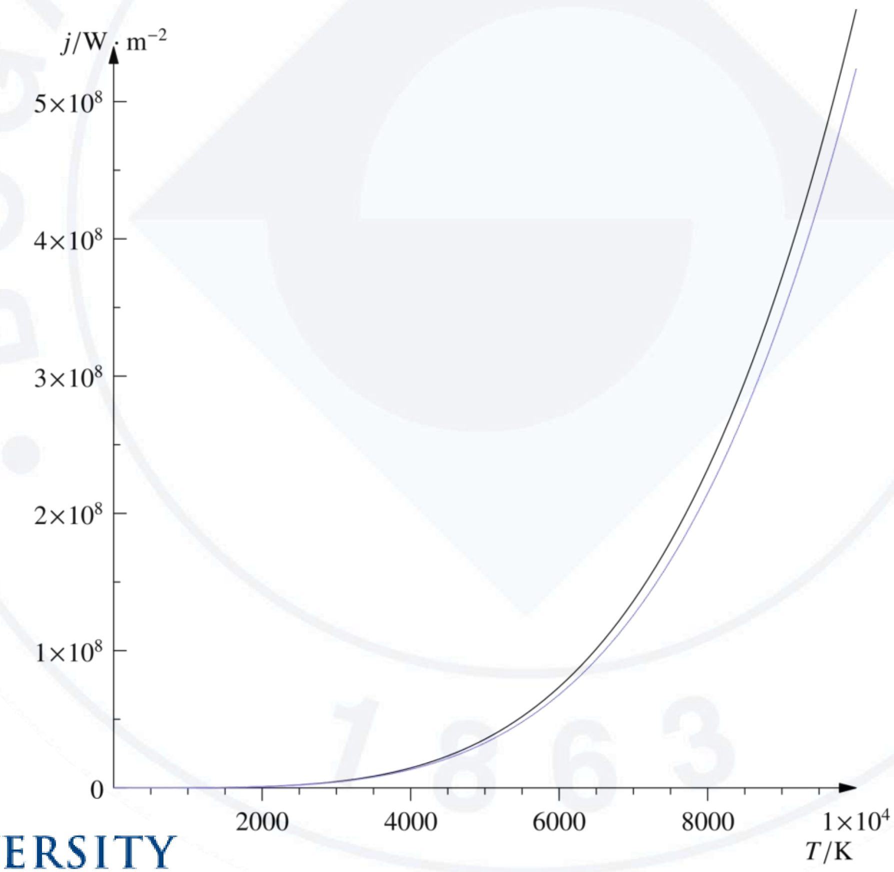
Planck transformed this idea by **quantizing** the energy inside of the cavity.



STEFAN-BOLTZMANN RADIATION LAW

Stefan-Boltzmann Law states that the total energy radiated per unit surface area of a black body at all wavelengths per unit time depends only on the temperature of the object

$$R = \sigma T^4$$



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STEFAN-BOLTZMANN RADIATION LAW

- The proportionality constant is called as Stefan-Boltzmann constant and it is derived from other physical constants:

$$\sigma = \frac{2\pi^5 k_B^4}{15c^2h^3} = 5.670373 \times 10^{-8} W m^{-2} K^{-4}$$

where:

- k_B is Boltzmann constant
- h is Planck constant
- c is the speed of light.

If an object is not blackbody (it doesn't absorb all the incoming radiation at all wavelengths), the emitted energy is less than of black-body

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

where ε < 1.

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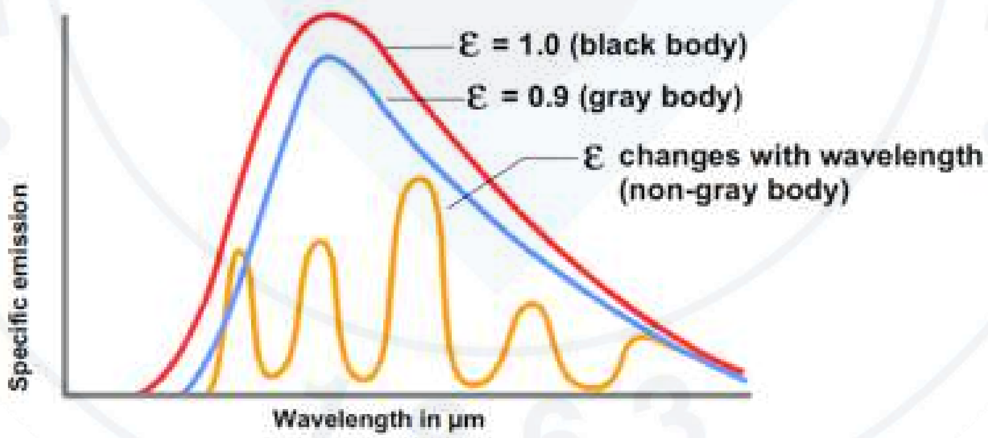
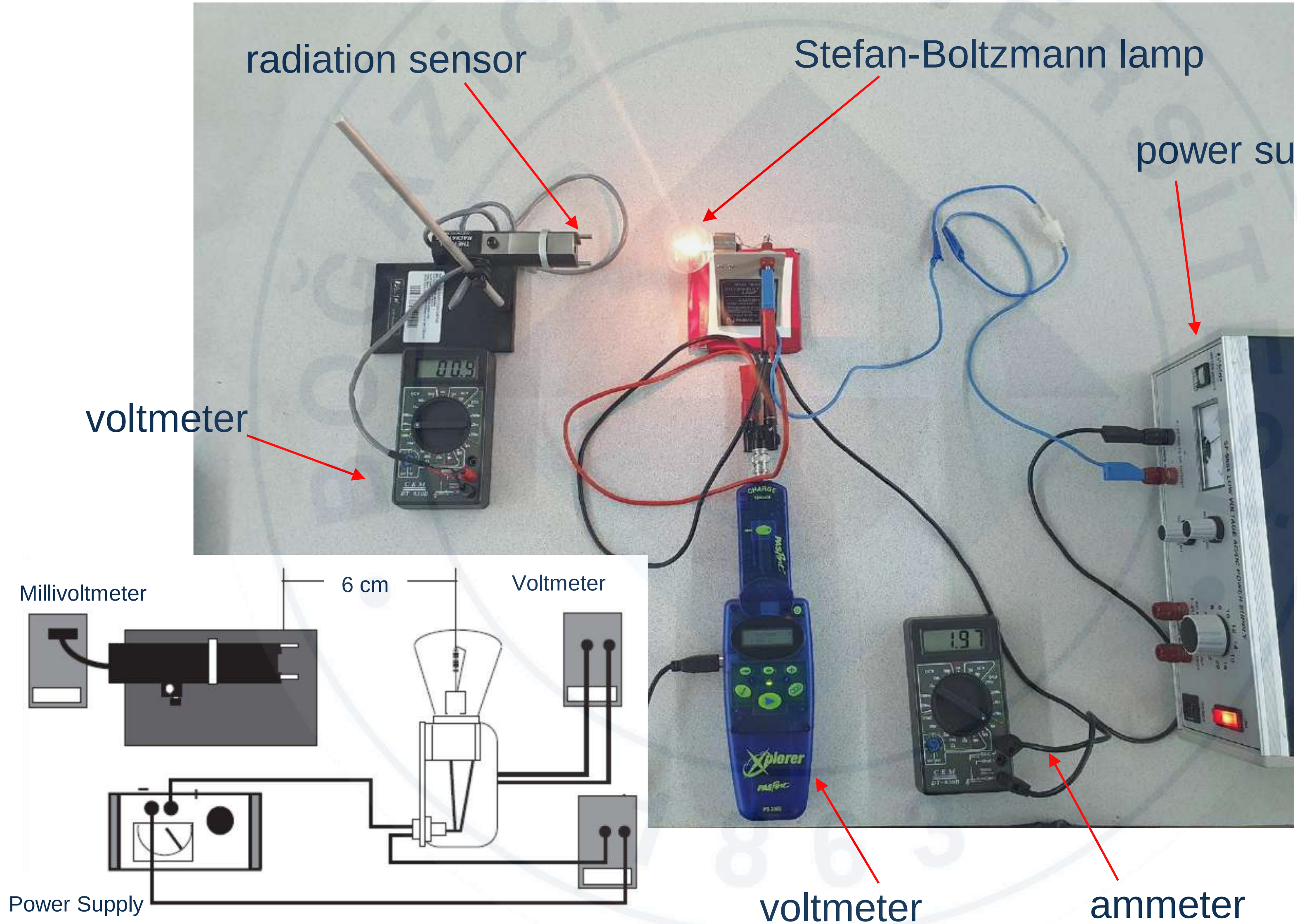


APPARATUS

STEFAN-BOLTZMANN RADIATION LAW



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EXPERIMENT

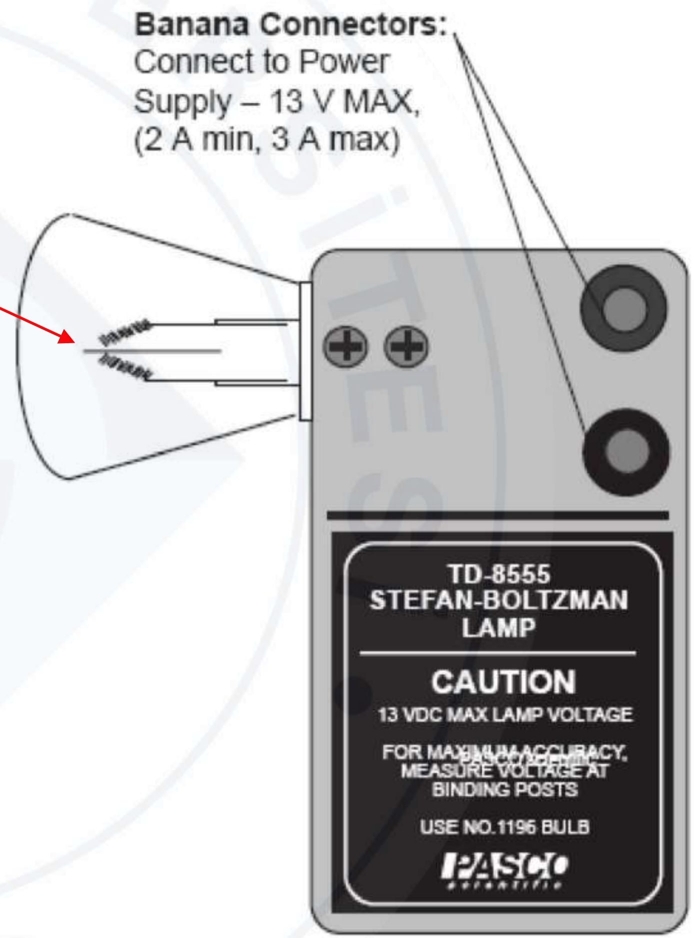
STEFAN-BOLTZMANN RADIATION LAW

- The **objective** of our experiment is to determine rate of temperature dependency $R = \sigma T^{n}$ where $n_{TV} = 4$.

- In our experiment, the radiation sensor is only sensitive to infrared region of electromagnetic spectrum which turns Stefan-Boltzmann equation into a proportionality. $R \propto \epsilon \sigma T^4$

STEFAN-BOLTZMANN RADIATION LAW

Measuring high temperatures inside a light bulb can be tricky! So instead of measuring a temperature of a **tungsten filament** of the lamp, we will measure voltage and corresponding current across the lamp at constant temperature, and calculate resistance by using Ohm’s law.



From calculated resistance from the Ohm's law (R=V/I), we will calculate temperature with following formula

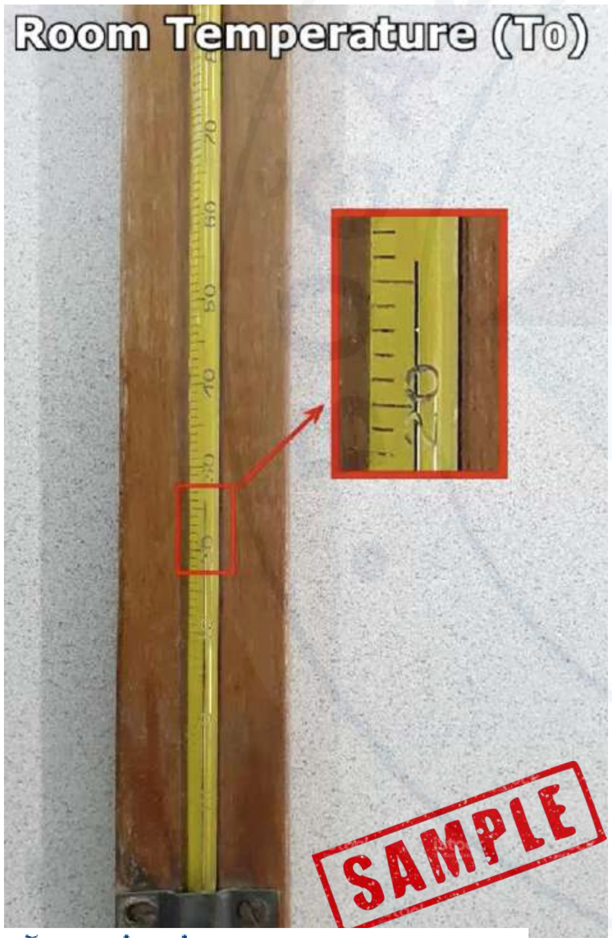
$$\frac{R}{R_0} = (1 + \alpha(T - T_0))$$

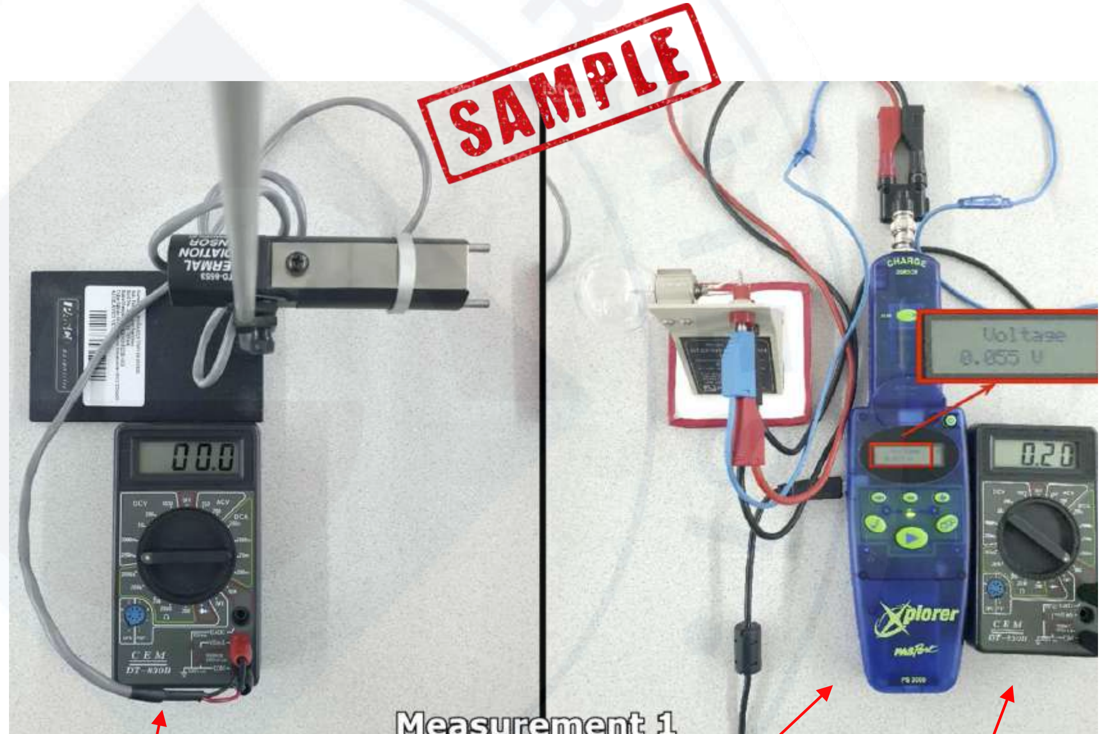
- R is the resistance at temperature T
- T_0 is the room temperature
- R_0 is the resistance of tungsten filament at room temperature
- α for tungsten is $4.5 \times 10^{-3} K^{-1}$

STEFAN-BOLTZMANN RADIATION LAW

Measuring R_0 and T_0

- Set applied current to 0.20 A and measure V_0 and calculate R_0





radiation sensor output in terms of mV

voltage across lamp (V)

current across lamp (A)

PhysLabs

Draw the circuit diagram:

Write down the formula to calculate the temperature from the resistance
$R / R_0 = (1 + \alpha(T - T_0))$ **Solve for T:**

$$\frac{R}{R_0} = (1 + \alpha(T - T_0))$$

T = Solve for T

T_o = Room temperature

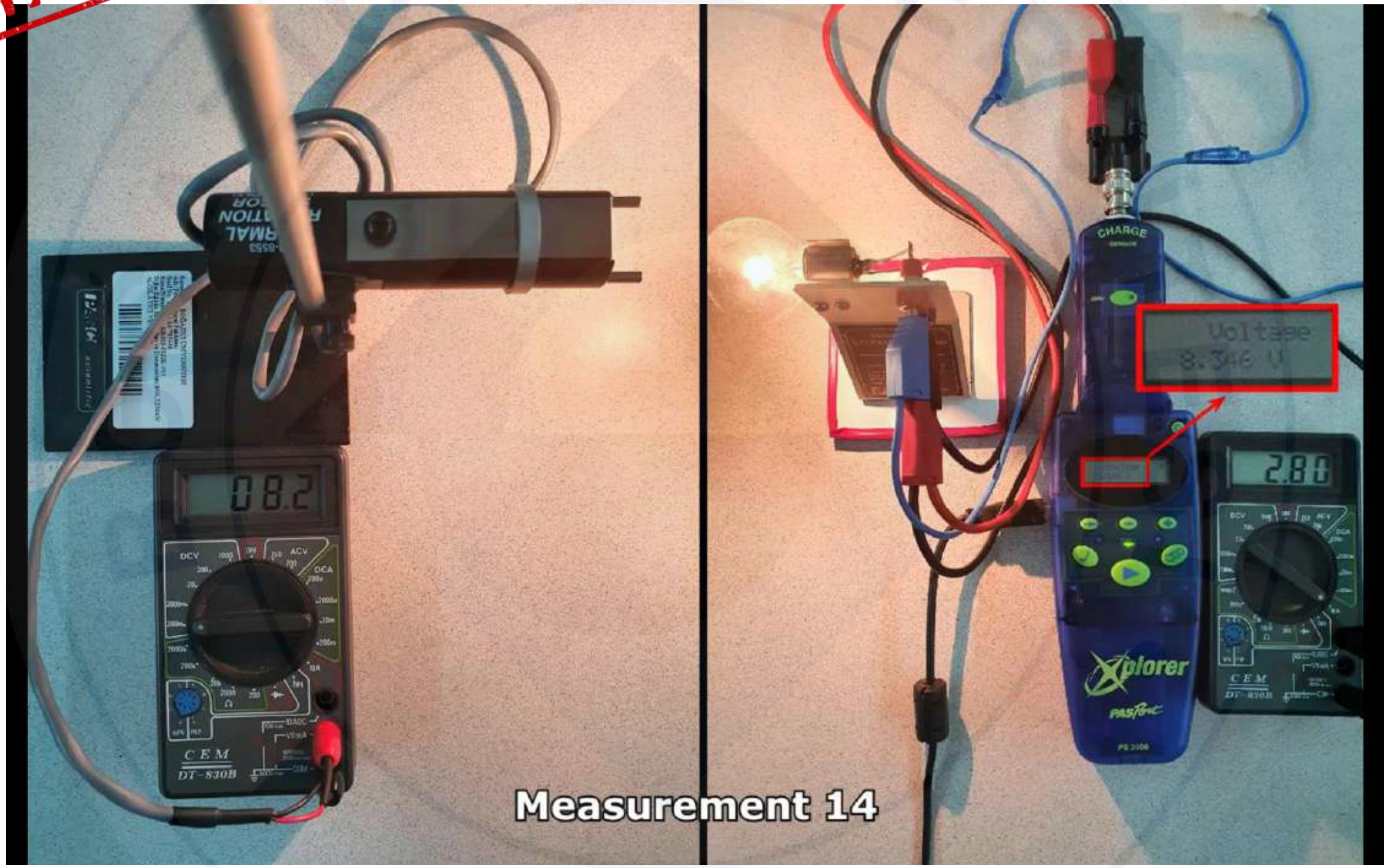
I_o = 0.20 Amp.

V_o = Measure!

R_o = Calculate!

α = 4.403 x 10^{-3} K^{-1}

STEFAN-BOLTZMANN RADIATION LAW



- Measure radiation sensor output, voltage & current across the lamp by the increment of 0.20 A.

STEFAN-BOLTZMANN RADIATION LAW

Ohm's Law

$$\frac{R}{R_0} = (1 + \alpha(T - T_0))$$

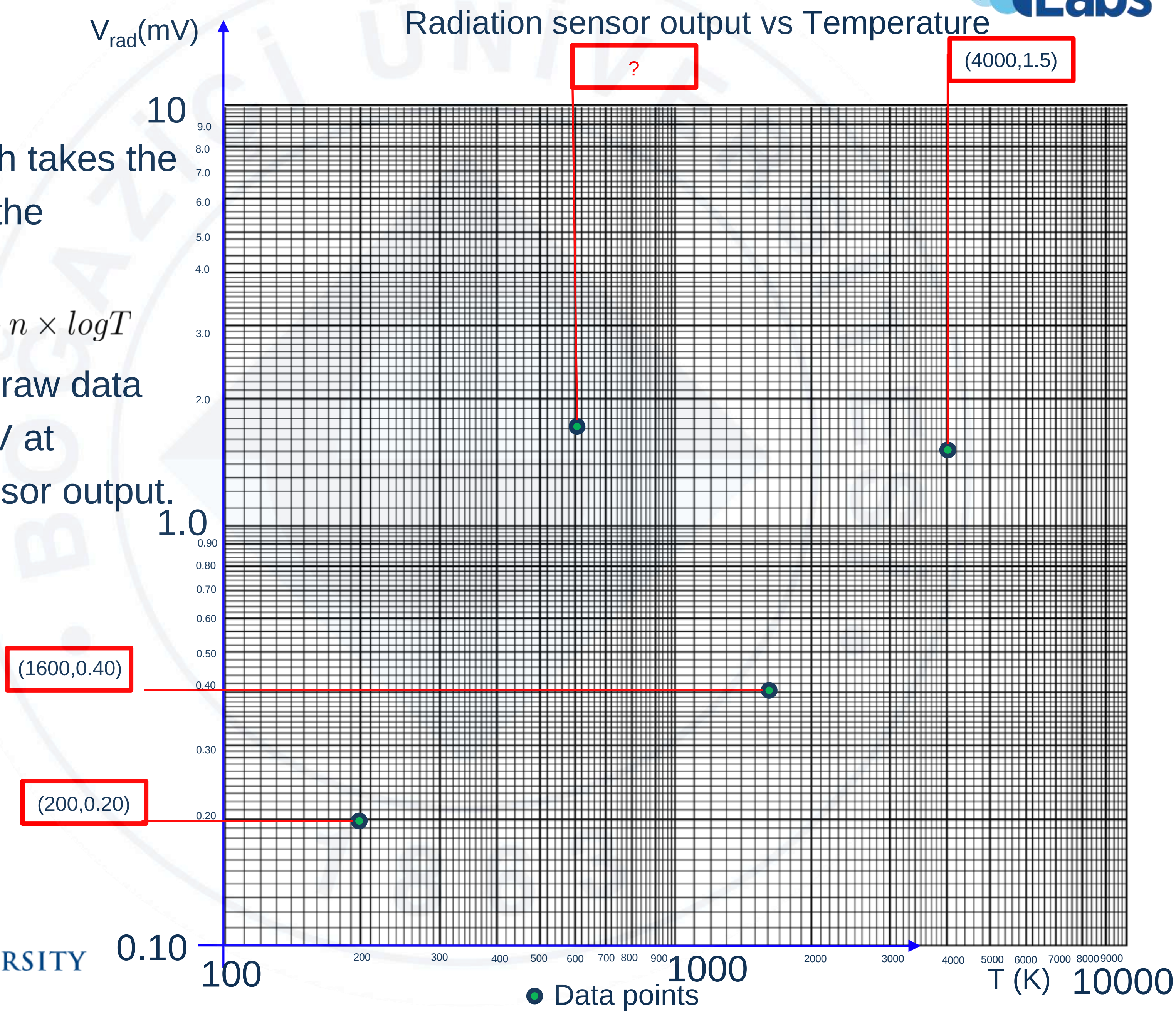
Current I ( )	Potential Across the lamp V ( )	Radiation Sensor output, V_{Rad} ( )	Resistance of the filament, $R=V/I$ ( )	R/R_0	Temperature of the filament, T ( )

STEFAN-BOLTZMANN RADIATION LAW

- Log-log graph takes the logarithm of the equation

$$logR = \log\sigma + n \times logT$$

- No need to draw data below 0.1 mV at radiation sensor output.



Don't forget to take the logarithm of the selected points!

n = SLOPE = $m = \frac{log y_2 - log y_1}{log x_2 - log x_1} = \frac{log(\frac{y_2}{y_1})}{log(\frac{x_2}{x_1})}$ ....

....

% error = ...