

Object: To verify the Stefan's law of radiation by using an incandescent lamp.

Features:

- ❖ The board consists of the following built-in parts
- 1. 0-6V D.C. at 2A, I.C. regulated continuously variable and short circuit protected power Supply with coarse and fine voltage control.
- 2. Digital panel meter $3\frac{1}{2}$ digit 19.99 volt D.C.
- 3. Digital panel meter $3\frac{1}{2}$ digit 1.999 Amp. D.C.
- 4. Incandescent lamp.
- 5. Mains ON/OFF Switch and fuse.

❖ The unit is operative on $230V \pm 10\%$ at $50Hz$ A.C. Mains.

Good Quality, reliable terminal/sockets are provided at appropriate places on panel for connections/observation of waveforms.

Theory

The electrical current passes through a meter filament of an incandescent lamp and the emission results into continuous spectrum, a characteristic of filament temperature. Stefan-Boltzmann relation (1) relates such a radiant energy of radiator by following relation.

$$E = \sigma A \varepsilon T^4 \quad (1)$$

A = Surface area of filament

ε = Emissivity

$\varepsilon = 1$ (for black body)

$\varepsilon < 1$ (for other bodies)

For a black body the radiant energy per unit area per second is given by

$$E = \sigma T^4$$

However the power P (watt) in electrical filament circuit is the product of voltage drop V_t and current I_t gives loss of electrical energy per second. Hence on presumption that whole of P is converted to E , we can write modified form of relation (1) in term of P in the following order:

$$P = \sigma' T^4 \quad (2)$$

where σ' is a constant related to σ through the area of cross-section of the filament and radiation losses also note that the filament is not a black body.

In order to verify Stefan's law in term of equation (2), we take logarithm of this equation and write

$$\log_{10} P = \log_{10} \sigma' + 4 \log_{10} T \quad (3)$$

Now this relation is subjected to test by plotting a linear relation by taking $\log_{10} P$ on y-axis and $\log_{10} T$ on x-axis. The slop of the relation should come out to be close to 4 and the intercept on y-axis should yield σ' of the order of σ .

Temperature T can be obtained by using Langmuir's Formula [eqⁿ 4]. Here we calculate temperature for Tungsten filament. There are two eqⁿ i.e.

For particular temperature i.e.

$$\left(\frac{R_T}{R_0}\right) = \left(\frac{T}{T_0}\right)^{1.2} \quad \dots \dots \dots \quad (4)$$

where

R_T = Resistance of bulb filament at particular temperature (T)

R_0 = Resistance of bulb filament at 0°C temperature (T_0)

At room temperature (T_R)

$$\frac{R_R}{R_0} = \left(\frac{T_R}{T_0}\right)^{1.2} \quad \dots \dots \dots \quad (5)$$

where, R_R = Resistance of bulb filament at room temperature (T_R)

At draper point (T_D)

$$\frac{R_D}{R_0} = \left(\frac{T_D}{T_0}\right)^{1.2} \quad \dots \dots \dots \quad (6)$$

R_D = Resistance of bulb filament at draper point

$T_D = 527^\circ\text{C} = 800^\circ\text{K}$

The Draper point is the temperature at which the filament of bulb just glows with dull red colour.

The difficulty arises when we have to find the resistance of the filament at room temperature which requires that the filament SHOULD NOT GLOW and must remain cold (at the room temperature). Since this is a difficult work to realize in practice, we are modifying the method slightly.

In practice we find the resistance of the tungsten filament at the DRAPER POINT ($\approx 527^\circ\text{C} = 800^\circ\text{K}$) and utilize this resistance (R_D in the text) for all subsequent calculations.

Dividing eqⁿ(5) by eqⁿ(6)

$$\frac{R_R}{R_D} = \left(\frac{T_R}{T_D}\right)^{1.2} \quad \dots \dots \dots \quad (7)$$

$$R_R = R_D \left(\frac{T_R}{800}\right)^{1.2} \quad \dots \dots \dots \quad (8)$$

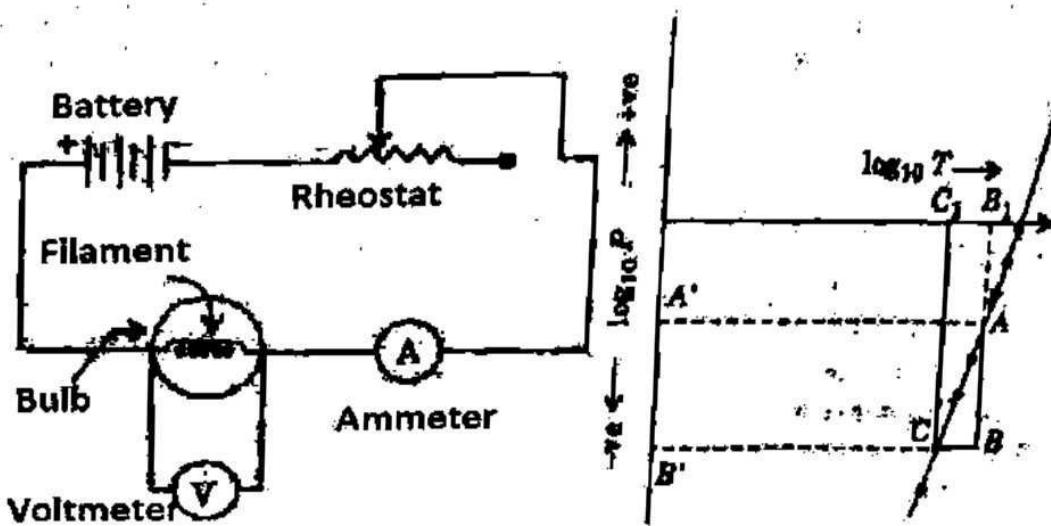
Dividing eqⁿ(4) by eqⁿ(5)

$$\frac{R_T}{R_R} = \left(\frac{T}{T_R} \right)^{1.2}$$

$$\frac{T}{T_R} = \left(\frac{R_T}{R_R} \right)^{1/1.2}$$

$$T = T_R \left(\frac{R_T}{R_R} \right)^{0.833}$$

(9)



Procedure:

1. Connect the lamp 6V, 10W to D.C. power supply (0-6V, 2Amp.).
2. Connect main to A.C. main socket having $230V \pm 10\%$ at 50Hz.
3. Starting with a low current raise it till filament just shown glow (keeping the bulb in a covered enclosure help judging the state).
4. Note down V_D and I_D at draper point (when bulb shows just glow) and calculate R_D

$$R_D = \frac{V_D}{I_D}$$

where

V_D = Voltage at draper point

I_D = Current at draper point

R_D = Resistance of bulb filament at draper point

5. We can find out room temperature by thermometer

$$\text{Room temperature } T_R = t^\circ\text{C} = (273 + t^\circ\text{C})^\circ\text{K}$$

6. Now we calculate R_R by following eq.

$$R_R = R_D \left(\frac{T_R}{800} \right)^{1.2}$$

7. Increase the voltage in steps and note down value of V_T and I_T and calculate R_T at different temperature

$$R_T = \frac{V_T}{I_T}$$

8. We can calculate T by following eq.

$$T = T_R \left(\frac{R_T}{R_R} \right)^{0.833}$$

9. Now at each setting of voltage V_T and current I_T to the lamp calculate different temperature (T) of the filament and power supply ($P = V_T \times I_T$).

10. Take $\log_{10} P$ and $\log_{10} T$

11. Plot a graph by taking $\log_{10} T$ on X-axis and $\log_{10} P$ on Y-axis as a straight line.

12. Determine the slop of line and note that it is about 4. Also determine intercept on Y-axis as $\log_{10} \sigma'$ and take its antilogarithm to find the value of σ in M.K.S. units. You will see that the value of σ differ than the value of σ (5.76×10^{-8} watt m $^{-2}$ k $^{-4}$). It is due to the surface area of filament, emissivity (ϵ) and radiation losses.

Observation:

Bulb : 6V, 10W

Room Temp: _____ °C, $T_R = 273 +$ _____ °C = _____ K

Bulb resistance at Draper point $R_D = \frac{V_D}{I_D}$

Observation table

S. No.	V_T (volt)	I_T (Amp.)	$R_T = \frac{V_T}{I_T}$	$P = V_T I_T$	$\log_{10} P$	$T = T_R \left(\frac{R_T}{R_R} \right)^{0.833}$	$\log_{10} T$

$$\text{Slope} = \frac{\Delta \log_{10} P}{\Delta \log_{10} T} = \dots \equiv \dots$$

$$\text{Intercept on Y-axis} = \log_{10} \sigma' = \dots$$

$$\sigma' = \text{antilog } \dots \equiv \dots$$

Precautions

1. Special care is needed during V_D measurement. The V leads must be soldered to the bulb base directly. So that the resistance of the contacts of bulb terminals & socket does not occur in R_D . Also the lead wires must be thick.
2. Resistance at particular temperature R_T to be found by each setting of voltage and current of D.C. Power supply but the value of R_R and T_R Should be same.