Stefan's Index

- **What is an ideal/perfect black body?**

  A body that allows all incident radiation and internally absorbs all of it.
  Implication: Zero reflectance, zero transmittance.
  True for: All wavelength, all incident directions.
  Consequently, a perfect black body emits maximum amount of radiation at a given temperature.

- Explanation (Only for student's reference):
  When light radiation falls on a body, three things can happen- incident radiation can be reflected by the body, the body can transmit the incident radiation falling on it and the body can absorb the incident radiation. A perfect black body is one which does not reflect light nor it transmits light but only absorbs it. In other words, reflectance $(R) = 0$, transmittance $(T) = 0$ and absorptance $(A) = 1$. Remember, for all bodies, $R + T + A = 1$.

  When a black body is in thermal equilibrium with the incident radiation, it must also emit radiation. Because a black body absorbs maximum amount of radiation, it must also emit maximum amount of radiation to continue its state of equilibrium.

- **Examples of a black body**

  There is no ideal black body in the universe. Objects painted with lamp black, platinum black, gold black, etc can be approximated as a black body.
  Radiation emitted by stars is approximated as radiation emitted by a black body.
  When tungsten filament is heated, it emits radiation like a black body.

- **State Stefan-Boltzmann law**

  The total energy radiated per unit surface area of a perfect black body across all wavelengths per unit time E is directly proportional to the fourth power of the black body's temperature T.

  $$E = \sigma T^4.$$

  Stefan-Boltzmann constant $\sigma = 5.670 \times 10^{-8}\,\mathrm{Wm^{-2}K^{-4}}$.

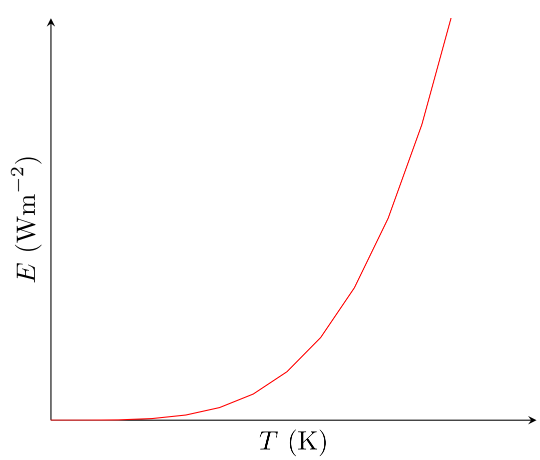

Figure 1: Variation of Radiant emittance E with temperature T for a black body.

Note:

- Any body at temperature $T > 0\,\mathrm{K}$ will emit radiation.
- No body can absorb more radiation than a black body at a given temperature (Perfect absorber).
- No body can emit more radiation than a black body at a given temperature (Perfect emitter).
- Higher the temperature of the body, more is the radiation emitted.

- **What is the aim of the experiment?**

  To verify the Stefan's fourth power law of radiation by electrical method or to determine Stefan's index.

- **What is Stefan's index?**

  In the equation, $E = \sigma T^4$, the power of temperature is called Stefan's index. Stefan's index is 4.

- **What is black body radiation?**

  When a black body is in thermal equilibrium with the incident radiation, the radiation emitted by the black body is called black body radiation.

- **What is the black body used in the experiment?**

  A heated tungsten filament inside the bulb can be approximated as a black body.

- **How is tungsten filament a black body?**

  Tungsten filament lights have a continuous black body spectrum. They emit radiation in visible and infrared region. Radiation emitted by heated tungsten is approximated as black body radiation.

- **What is tabulated in the experiment?**

  We set the voltage across the bulb and the current through it is measured. By knowing voltage V and current I, we can calculate power $P = VI$ and resistance $R = V/I$. Further, $\log P$ and $\log R$ is calculated for different voltages to determine Stefan's index.

- **How is the Stefan's index determined using electrical method?**

  We know that

  $$E = \epsilon\sigma T^4.$$

  For perfect black body, $\epsilon = 1$ otherwise $\epsilon < 1$. Applying logarithm to base 10, we have

  $$\log E = (\log \epsilon + \log \sigma) + 4 \log T$$

  E is rate of radiation emitted which is power P. Also for a conductor, resistance $R \propto T$. Therefore, our modified equation after rearranging is

  $$\log P = 4 \log R + X,$$

  which is of the form $y = mx + c$.
  X is all the constant terms.
  So if we plot $\log P$ along Y-axis and $\log R$ along X-axis, we must get a straight line with positive slope=4, if Stefan's law is correct.

- **What is the physical meaning of Stefan's constant σ?**

  When a perfect black body is kept at a temperature of $1\,\mathrm{K}$ then the energy of radiation emitted by the body per unit surface area per unit time is $5.670 \times 10^{-8}\,\mathrm{J}$.