Introduction to Blackbody radiation

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Introduction

Heat is a form of energy and can be transferred from one point to another by means of three methods namely, conduction, convection, and radiation. **Radiation** is a process of transference of heat from onr point to another without the aid of any intervening medium or without affecting the intervening medium if any. All bodies at all temperatures are capable of emitting heat. The heat emitted by radiation from abody due to its temperature is called **thermal radiation**.
In this document we are going to discuss some key concepts related to blackbody radiation. The key topics that we will be discussing are:

1. Properties of thermal radiation
2. Important definitions needed to understand radiation
3. Laws of radiation
    (a) Kirchhoff's law
    (b) Stefan's law
4. Fery's blackbody
5. Energy distribution in blackbody radiation
6. Wien's law
7. Rayleigh-Jean's law
8. Planck's hypothesis and quantum theory
9. To deduce Wien's law from Planck's law
10. To deduce Rayleigh-Jean's law from Planck's law

1 Properties of thermal radiation

Thermal radiation exhibits the following properties:

1. They travel in straight lines.
2. They do not require any materialmedium for their propagation.
3. They travel equally in all directions, in a homogeneous medium.
4. They travel with speed of light.
5. They obey inverse square law.
6. They exhibit the phenomenon of reflection and refraction.
7. The exhibit the phenomenon of interference diffraction and polarization.
8. When they fall on matter, heat is developed.
9. They are electromagnetic waves having wavelength greater than that of visible region.

2 Important definitions

1. **Monochromatic emissive power**: Monochromatic emissive power (e_λ) of a body at a temperature (T) for wavelength (λ) is defined as the energy radiated, in vaccum, per unit time, per unit area and per unit range around wavelength i.e., lying between $\lambda - \frac{1}{2}$ to $\lambda + \frac{1}{2}$. For a body, e_λ will be different for different values of λ and for different values of T.

2. **Emissive power**: Emissive power (E) of a body at a temperature T is defined as the total amount of energy for all wavelenghts, radiated per unit time, per unit area of the body.
   If dE is the amount of energy radiated per second per unit area for wavelength $d\lambda$, then

   $$dE = e_\lambda d\lambda \tag{1}$$

   The emissive power E, is given by

   $$E = \int_0^\infty e_\lambda d\lambda, \tag{2}$$

   measured in the units of $Jm^{-2}s^{-1}$.

3. **Spectral energy density**: Spectral energy density u_λ at any point, is defined as the radiant energy per unit volume, around the point, for wavelengths lying in a unit range around λ i.e., in between $\lambda - \frac{1}{2}$ to $\lambda + \frac{1}{2}$.

4. **Total energy density**: Total enegy density u at any point is defined as teh radiant energy per unit volume, around the point for all wavelengths taken together

   $$u = \int_0^\infty u_\lambda d\lambda \tag{3}$$

5. **Monochromatic absorptive power**: Monochromatic absorptive power a_λ of a body at temperature T for a wavelength λ is defined as the ratio of amount of radiation absorbed by the surface in a given interval of time to the total amount of ratiation falling upon the surface in that same time for wavelenght lying in a unit range around λ i.e., in between $\lambda - \frac{1}{2}$ to $\lambda + \frac{1}{2}$.

6. **Absorptive power**: Absorptive power a of a body at temperature T is defined as the ratio of the amount of radiation absorbed on the surface in a given interval of time to the total amount of the radiation falling on the surface in the same time, for all wavelengths,

$$a = \int_0^\infty a_\lambda d\lambda \tag{4}$$

3 Laws of radiation

1. **Kirchhoff's law**: *"The ratio of the emissive power to the absorptive power is the same for all surfaces at the same temperature and is equal to the emissive power of a perfect blackbody at that temperature"*.
   If e_λ and a_λ represent the emissive power and absorptive power of a given surface, E_λ and A_λ the corresponding values for perfect black surface at the same temperature, then according to the law, $\frac{e_\lambda}{a_\lambda} = \frac{E_\lambda}{A_\lambda}$.
   But A_λ for a perfectly blackbody is unity. Hence, $\frac{e_\lambda}{a_\lambda} = E_\lambda$ where, E_λ is some function of λ annd T.