Blackbody Radiation-Section3

Dr. Jayanta Das

Department of Physics, Maharaja College, Ara, Bihar-802301

1 Wien's distribution law of blackbody radiation

From thermodynamical calculations Wien found that the spectral emittance u_λ between wavelength range λ and $\lambda + d\lambda$ is given by:

$$\delta u_\lambda = \frac{A}{\lambda^5} f(\lambda T)\delta\lambda$$

Wien took help of Maxwell's energy distribution to find out the form of $f(\lambda$ T).

$$f(\lambda T) = e^{\frac{-b}{\lambda T}}$$

Therefore, the expression for spectral emittance becomes :

$$\frac{\partial u_\lambda}{\partial \lambda} = A\lambda^{-5} exp(-\frac{b}{\lambda T}) \tag{1}$$

Here, A and b are some constants. Equation (1) is Wien's distribution law of blackbody radiation.

At small λ values, the exponential factor in eqn (1) dominates over the λ^{-5} term. On the other hand, for larger λ, the effect of the exponential factor is negligible. In this region, the distribution curve is dominated by the λ^{-5} term. Therefore, the energy density, in this region, decreases with increasing λ.

2 Failure of classical theories

Both the Rayleigh-Jean's law and the Wien's distribution law are based upon the concept of classical physics. The Rayleigh Jean's law satisfies the experimental blackbody radiation curve poorly at infrared wavelength region and fails completely at ultraviolet wavelength limit. On the other hand, Wien's distribution law is good at short wavelength, but inadequate at longer wavelengths. In figure 2, the experimental blackbody radiation curve, Rayleigh Jean's and Wien's distribution laws are appended together. The black curve corresponds to the experimental blackbody radiation spectrum. The Rayleigh Jean's distribution curve is indicated by blue color. This curve matches the experimental data towards the higher value of λ. As λ decreases, this curve shows a sharp uprise and tends towards infinite value. The Wien distribution law, depicted in red, matches the experimental curve quite well at lower λ region. However, at higher λ it shows the energy density varies as λ^{-5}, which is quite inadequate for explaining the experimental curve. This shows that none of the classical theories can explain the experimental blackbody radiation curve completely.

References

[1] Thermodynamics, Author: S C Gupta, Publisher: Pearson Education, India.

[2] Heat and Thermodynamics, Author: Zeemansky and Dittman, Publisher: Mc Graw Hill.

[3] Heat Thermodynamics and Statistical Physics, Author: Brij Lal,Subrahmanyam, Hemne. Publisher: S Chand.

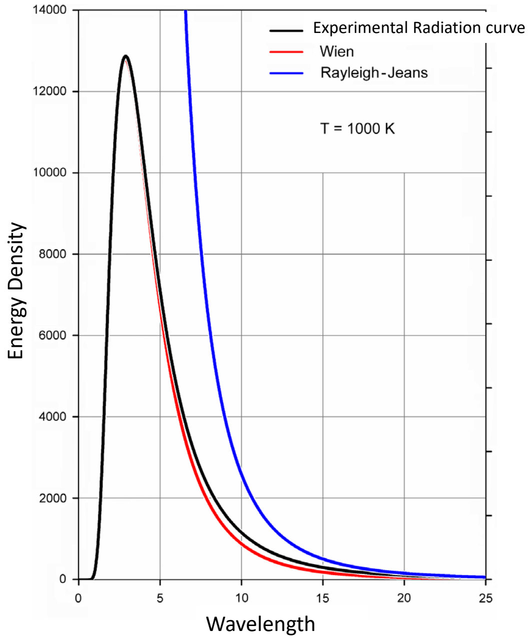

Figure 1: The experimental blackbody radiation curve is shown along with the Rayleigh Jean's distribution law and Wien's distribution law.

[4] Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, Authors: R. Eisberg, R. Resnick, Publisher: Wiley

[5] Quantum Physics, Author: Stephen Gasiorowicz, Publisher: John Wiley and Sons.

[1]

[1] Figures are collected from online resources.