Quantum Mechanics: Learning Objectives

Photo with an IR camera

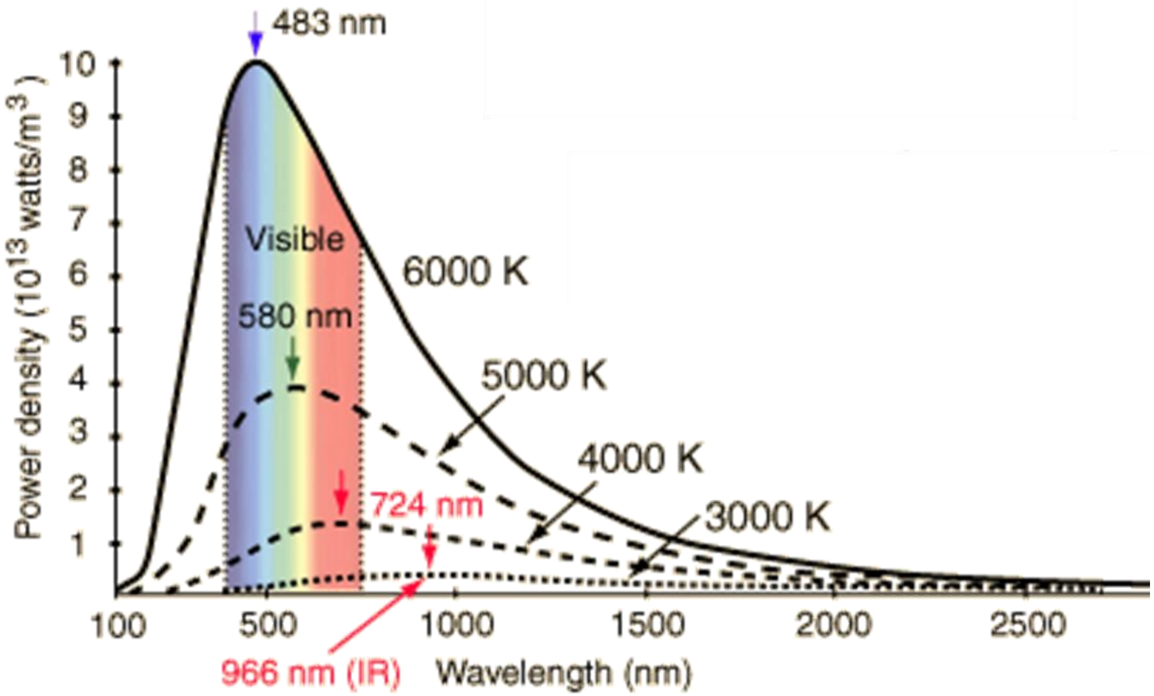
Ref. Thermal Physics by Garg, Bansal and Ghosh, Chapter 11.

Quantum Mechanics: Blackbody radiation

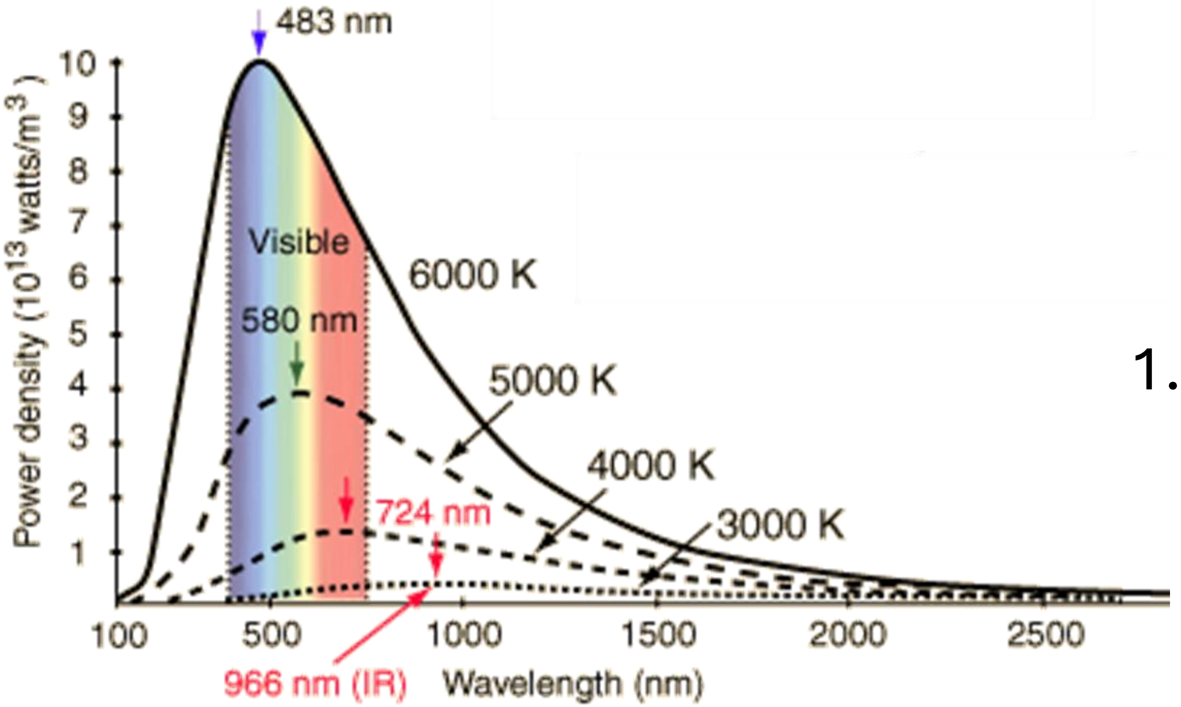
- Light radiated by an object characteristic of its temperature.
- Spectrum of radiation changes with temperature.

What is blackbody?

that absorbs all energy (irrespective of their wavelength) falling on it



Quantum Mechanics: Blackbody radiation



Explanation #1

1. Wein's displacement law

$$\lambda_{peak} = \frac{2.9 \times 10^{-3}\ \text{Km}}{\text{T(Kelvin)}}$$

- Explain only peak positions with temperature
- Insufficient to explain the shape of curve

Quantum Mechanics: Blackbody radiation

1. Find wavelength for body temperature which is 310K.

2. Sun's surface with 5800 K surface temperature.

310K (body temp) $= \dfrac{2.9 \times 10^{-3}\ \text{m}}{310} = 9\times10^{-6}\ \text{m}$

infrared light

---

visible light

5800K (Sun's surface) $= \dfrac{2.9 \times 10^{-3}\ \text{m}}{5800} = 0.5\times10^{-6}\ \text{m}$

Photo with an IR camera

Example of continuous and discrete distribution of a quantity

Suppose two litre of milk need to be distributed between two persons

1. Milk is an indivisible quantity,
No. of ways, you can divide it???

2. Milk is divisible

2.1 divide it 1 litre, no. of ways??
2.2 divide it in 0.5 litre, no. of ways??

2.1. Set a discreteness variable (quantum) say 1litre then 0,1,2 litre are possible ways of distribution.

2.2. Set a discreteness variable (quantum) say 0.5litre then 0,0.5,1,1.5,2 litre are possible ways of distribution.

https://youtu.be/7BXvc9W97iU?si=qIz7yaE7BrmSDaOP

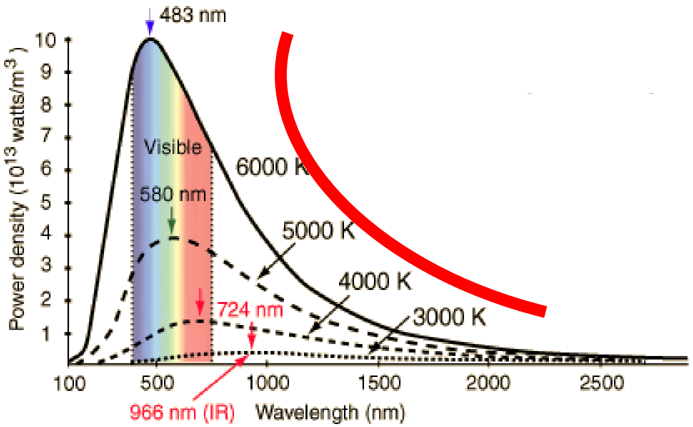
Quantum Mechanics: Blackbody radiation

Explanation for this observed curve

Explanation #2

2. Rayleigh jeans law

Distribution of energy in blackbody radiation is based on the principle of equipartition of energy for all possible modes of electromagnetic radiation. Each mode of vibration, on the basis of equipartition of energy, is assigned energy $\boldsymbol{K_b T}$.



$$\textbf{Energy density(u)} = \frac{8\pi\nu^2\, d\nu}{c^3} K_b T$$

Total number of modes of vibration of EM radiation in a frequency range

$$\textbf{Energy density(u)} = \frac{8\pi d\lambda}{\lambda^4} K_b T$$

- At short wavelength as $\lambda \to 0$ or $\nu \to \infty$ then u-> ∞, not possible and physically not acceptable.
- Implication of this failure were so serious that the behaviour of theory at low wavelength (high frequency) was termed as ***ultraviolet catastrophe***.

on the basis of equipartition of energy and it favors continuous energy exchange

Quantum Mechanics: Blackbody radiation

Explanation #3

Explanation for this observed curve

3. Planck's law

He concluded energy is not continuous variable.

Energy is discrete and integral multiple of ***h,*** which is hv.

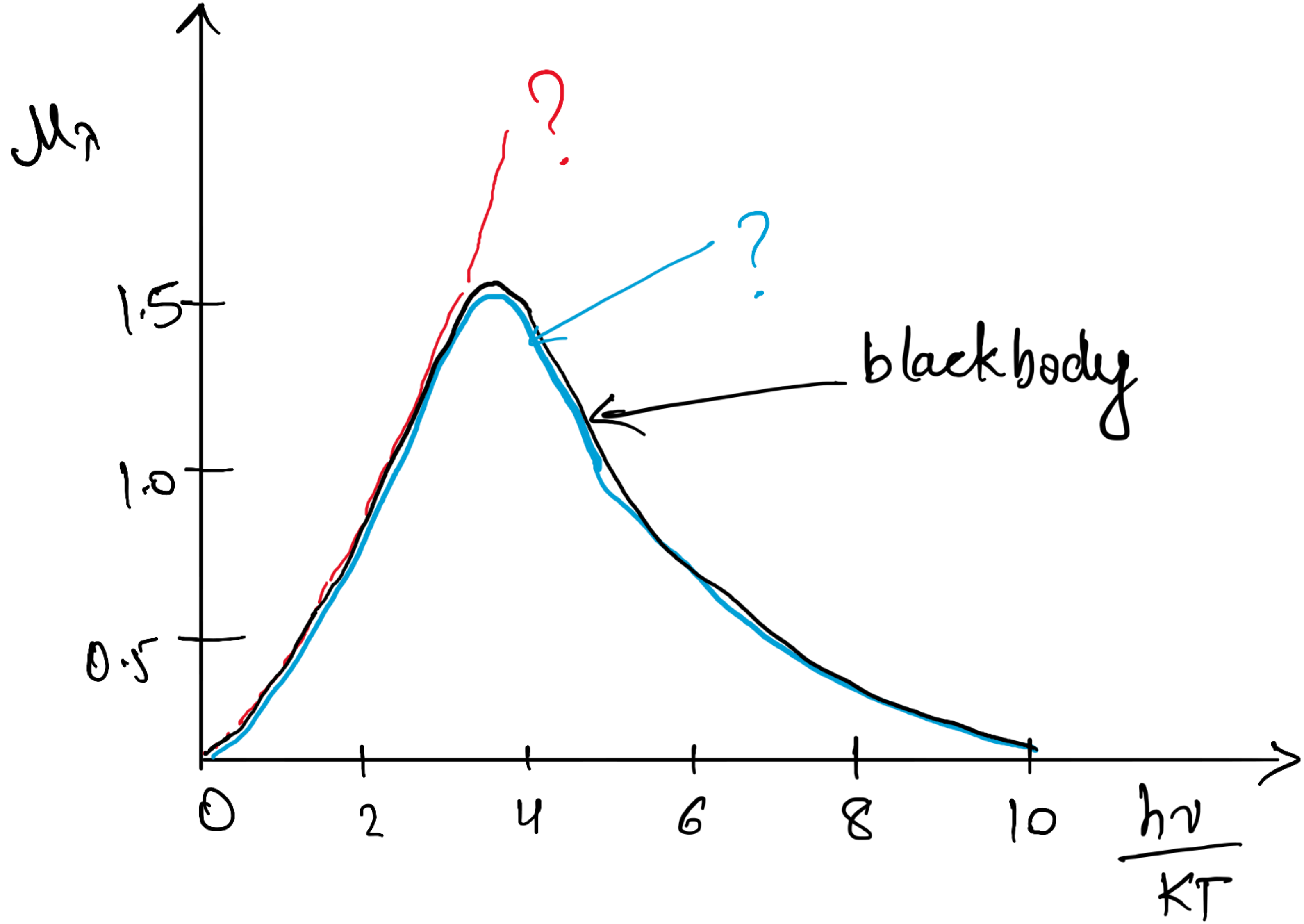
$$u(\nu)d\nu \; \textbf{\textit{Energy density(u)=}} \; \frac{8\pi\nu^2\, d\nu}{c^3}\left[\frac{h\nu}{e^{h\nu/kT}-1}\right]$$

$$\nu = \frac{c}{\lambda} \qquad |d\nu| = \frac{c}{\lambda^2}\,d\lambda$$

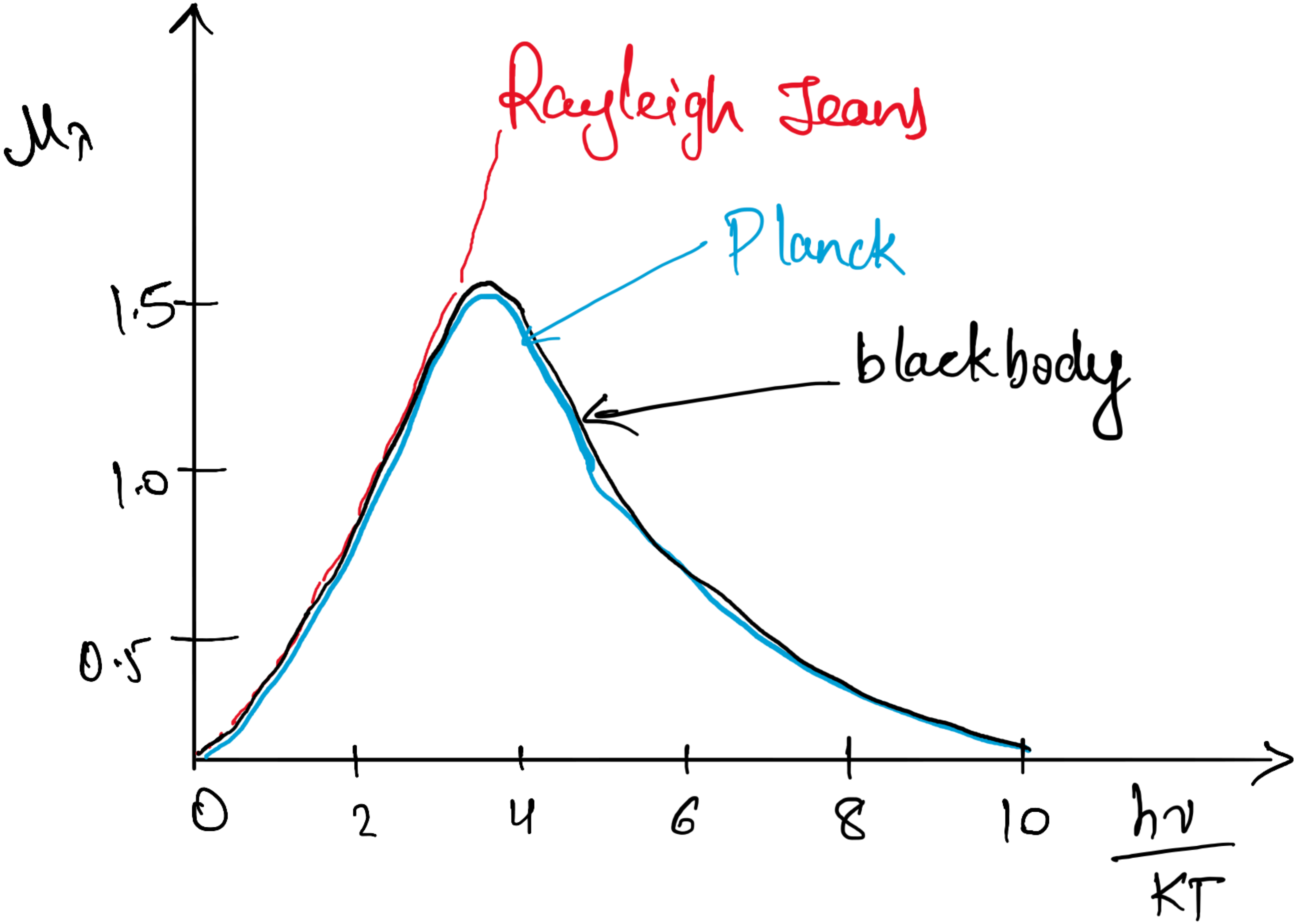
$$u(\lambda)\,d\lambda = \frac{8\pi hc}{\lambda^5}\left[\frac{1}{e^{\frac{hc}{\lambda kT}}-1}\right]d\lambda$$

Planck's law for energy density of blackbody.

A constant named in his honour, 1918- Nobel prize in Physics



M_λ
1.5
1.0
0.5
?
?
blackbody
0
2
4
6
8
10
$\frac{h\nu}{KT}$


Rayleigh Jeans
Planck
blackbody
M_λ
1.5
1.0
0.5
0
2
4
6
8
10
$\frac{h\nu}{KT}$

Quantum Mechanics: Blackbody radiation

Deductions from Planck's law

1. Rayleigh-Jeans law : low frequency or High wavelength

$$u_\lambda d\lambda = \frac{8\pi hc}{\lambda^5}\left[\frac{1}{e^{\frac{hc}{\lambda kT}}-1}\right]d\lambda \quad \text{Planck's law}$$