Tutorial 4: Blackbody Radiation

- Blackbody radiation and Planck's radiation law,
- Stefan- Boltzmann law, Wien's displacement law and Rayleigh-Jeans' law.

Q1:

In a tungsten filament lamp, thermionic emission takes place at $1{\cdot}2 \times 10^3$ K. Calculate the ratio of spontaneous emission to stimulated emission for non-degenerate energy levels. Interpret your result physically.

Take $\lambda = 550$ nm, $k_B = 1{\cdot}38 \times 10^{-23}$ JK^{-1}, $h = 6{\cdot}67 \times 10^{-34}$ Js and $c = 3 \times 10^8$ ms^{-1}. *10*

2013

Q2:

In deriving radiation laws, we consider a cubical container of volume V containing a photon gas in equilibrium. Calculate the differential number of allowed normal modes of frequency ω. *10*

2014

Q3:

State and explain Stefan-Boltzmann Law. Show that $\log P = \log K + 4 \log R$, where P is the power emitted by black body and R is the resistance of the black body, K is a constant. *10*

2014

Q4:

Using Planck's radiation law, deduce Wien's displacement law. How does this law enable one to estimate the surface temperature of the Sun or a star ? *15*

2015

Q5:

What are the characteristic features of Rayleigh scattering ? A very thin monochromatic beam of light is incident on a particle. Suggest a simple experimental method to ascertain whether the scattering by the particle is of Rayleigh type. *20*

2015

Q6:

The spectral energy curve of the moon shows maxima at 470 nm and 14 μm. What inference can you draw from this data? Also calculate the energy density and radiation pressure in both cases. Given, Wien's constant $b = 2\cdot892 \times 10^{-3}$ m K, Stefan's constant $\sigma = 5\cdot67 \times 10^{-8}$ J m^{-2}s^{-1}K^{-4} and speed of light $c = 3 \times 10^{8}$ m s^{-1}. 10

2016

Q7:

Briefly explain Planck's law of blackbody radiation. Show that Planck's law reduces to Wien's law and Rayleigh-Jeans law at lower and higher wavelength limits respectively. 20

2016

Q8:

Write down Stefan-Boltzmann law of radiation and derive it from Planck's law of radiation.

2017

Q9:

An aluminium foil of relative emittance 0·1 is placed between two concentric spheres (assumed perfectly black) at temperatures 300 K and 200 K respectively. Find the temperature of the foil once the steady state is reached. 15

2017

Q10:

A star is receding with a speed of 3000 km/s and emitting spectral line of hydrogen, H_α of wavelength 656·1 nm. What would be the wavelength observed by an observer on the Earth ? *10*

2018

Q11:

What are the limitations of Rayleigh-Jeans law in explaining the spectrum of radiations from a blackbody ? Explain how these limitations were overcome in Planck's radiation law.

प्लांक के विकिरण नियम से वीन के विस्थापन नियम की उत्पत्ति कीजिए ।

Deduce Wien's displacement law from Planck's radiation law. *20*

2018

Q12:

Discuss in brief the ultraviolet catastrophe. How did Planck solve this problem ? *10*

2019

Q13:

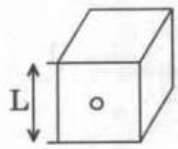
Briefly outline the theory of scattering of electromagnetic radiation by a bound electron and hence derive the conditions for Rayleigh scattering. How can you explain the blue of the sky ? *20*

2019

Q14:

A historic failure of Classical Physics is its inability to describe the electromagnetic radiation emitted from a black body. Consider a simple model for an ideal black body consisting of a cubic cavity of side L with a small hole on one side.

(i) Assuming the classical equipartition of energy, derive an expression for the average energy per unit volume and unit frequency range. In what way does this result deviate from actual observation ? What is this law called ?



(ii) Repeat the calculations now using quantum idea to obtain an expression that properly accounts for the observed spectral distribution.
Find the temperature dependence of the total power emitted from the hole. *20*

2020

Q15:

The spectral composition of solar radiation is similar to that of a black body radiator whose maximum emission corresponds to the wavelength $0{\cdot}48\ \mu m$. Find the mass lost by the Sun every second due to radiation. Evaluate the time interval during which the mass of the Sun reduces by 1 per cent.

Given : Stefan Boltzmann constant = $5{\cdot}669 \times 10^{-8}$ W m^{-2} K^{-4}, radius of the Sun = $6{\cdot}957 \times 10^{8}$ m, surface temperature of the Sun = 5772 K and mass of the Sun is $1{\cdot}9885 \times 10^{30}$ kg. *20*

2021

Q16.

How does Planck's law resolve the ultraviolet catastrophe predicted by classical physics? Calculate the average energy $\bar{\varepsilon}$ of an oscillator of frequency $0{\cdot}60 \times 10^{14}\ s^{-1}$ at $T = 1800$ K, treating it as *(i)* classical oscillator and *(ii)* Planck's oscillator. 15

2024

Q17.

Derive the Planck's radiation law for blackbody radiation using the Bose-Einstein distribution function. Explain how results from quantum statistics differ from classical results derived from the Rayleigh-Jeans law. *20*

2025