Assignment - 1

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Question - 1 ans b) Wien's law: "In the black body spectrum, the wavelength (λ_m), for which emissive power is maximum, is inversely proportional to the absolute temperature T of the body."

$$\boxed{E\lambda_m \propto \frac{1}{T}} \quad \text{or} \quad \boxed{\lambda_m \times T = \text{constant}}$$

Rayleigh - Jeans law: "According to electromagnetic theory, a black body radiator emits radiation of continuously variable wavelengths from zero to infinity. This radiation is assumed as broken up into independent mode of vibrations."

The energy carried by each mode of Vibration

$$\boxed{E_\lambda = \frac{8\pi kT}{\lambda^4}}$$

where, K = Boltzmann's constant.

ans a) Inadequacies of classical mechanics are:

i) Energy distribution curves of Black - Body radiation: It is found that at any one temperature the energy is not uniformly distributed, the intensity of radiation initially increases with wavelength, reaches a maximum value and finally decreases with the further increase of wavelength.

Wien's formula for energy distribution is in good agreement with experimental curves for short wavelengths only, on the other hand Rayleigh - Jeans formula could be made to fit the curves in the region of long wavelengths only. none of these theoretical formulae could therefore account for the shape of the radiation curve over its entire wavelength range.

2) Compton effect: The phenomenon of scattering with change in frequency.
The classical theory (which predicts that when electromagnetic radiation is scattered from a charged particle, the scattered radiation will have the same frequency as the incident radiation in all directions) failed to explain this change of frequency.

Question: 2) ans a) Stefan's law: "The total energy of radiation at a given temperature is represented by the area under the curve and is directly proportional to the fourth power of the absolute temperature of the black body".

$$\boxed{E \propto T^4}$$

Wien's displacement law: "wavelength corresponding to the maximum energy (λ_m), shifts to shorter wavelength side as the temperature of the body increases. Hence, the wavelength (λ_m) for maximum radiation intensity, decreases as the temperature increases."

$$\boxed{\lambda_m \propto T = \text{constant} = 0.003\,mK}$$

ans b) Planck's Radiation formula for black body.

$$\boxed{U(\nu)\,d\nu = \frac{8\pi \nu^2}{c^3} \times \frac{h\nu}{e^{h\nu/kT}-1}\,d\nu}$$

ans c) Basic postulates of Planck's law of radiation are:-

1) The cavity of an experimental black body also contains electrical linear oscillators of molecular dimensions which can vibrate with all possible frequencies. The frequency of radiation emitted by an oscillator is the same as the frequency of its vibration

2) The linear oscillator cannot emit energy in a continuous manner, but in the multiple of a small unit called quanta (photon).

$$\boxed{E_n = nh\nu}$$

Question: 3 ans a) De-Broglie's hypothesis of matter waves:
"A moving particle always has a wave associated with it and the motion of the particle is guided by that wave in similar manner as photon is controlled by a wave."

The wavelength of matter wave or de-broglie wave is given by

$$\boxed{\lambda = \frac{h}{mv} = \frac{h}{P}}$$

ans b) Two properties of matter waves.

1) The matter waves are generated by moving ~~particle~~ charged particles as well as by moving neutral particles.

2) The wave and particle aspects of matter never appear simultaneously in the same experiment.

Question-4) ans a) The objective of conducting Davisson and Germer experiment was to find out the physical reality of de-Broglie's concept of matter waves i.e material particles have wave like character.

Davisson and Germer in 1927 during his diffraction experiment with slow electrons. They not only confirmed the existence of waves associated with electrons by detecting de-Broglie's waves but also succeded in measuring their wavelengths.

ans b)

Matter Waves	Electromagnetic waves.
* Matter waves are associated with moving particles irrespective of whether the particles are charged or not.	* Electromagnetic waves are produced only by accelerated charged particles.

* Matter waves obtained by charged particles are associated with electric and magnetic fields.

* The velocity of matter waves is generally less than the velocity of light.

* The velocity of matter waves depends upon the velocity of the material particles.

* Matter waves obtained ~~by char~~ are neither emitted by the particles nor radiated into space. These are simply associated with the particles.

* Electromagnetic waves are associated with electric and magnetic fields perpendicular to each other as well as to the direction of propagation of wave.

* The velocity of electromagnetic waves is equal to the velocity of light.

* The velocity of E.M waves is constant in a given medium.

* Electromagnetic waves can be radiated into space.

Question-5:) ans a) (ψ) is the variable quantity associated with the moving particle and is a complex function of space co-ordinates of the particle and the time. (ψ) is called the wave function.

"The physical significance of the (ψ) wave functions is that the square of its absolute value, $|\psi|^2$, at a point is proportional to the probability of experimentally finding the particle described by the wave function in a small element of volume $d\tau = (dx\, dy\, dz)$ at that point".

ans b) Wave function (ψ) must fulfill the following conditions:

1) Normalised wave function must be single-valued:
 - if state function (ψ) has more than one value at any point it would mean that there are more than one probability of finding the particle at the point. which is obviously inaccessible.

2) It must be finite everywhere: for instance if it is infinite for a particular point, it would mean ~~that there are more than one~~ an infinitely large probability of finding the particle at the point. This would violate Heisenberg's uncertainty principle.

3) (ψ) must be continuous throughout the entire space of the system and have a continuous first derivative.

Question-6) ans a) "The phenomenon of scattering with change in frequency is called the Compton effect."

- The scattered radiation unchanged in frequency are called unmodified scattered radiation or coherent scattering.
- The scattered radiation with changed frequency are called modified scattered radiation or incoherent scattering.

ans b) As, $(\Delta\lambda)$ (compton shift $= \frac{h}{m_0 c}(1-\cos\theta)$

$\therefore$ The maximum change in wavelength $\Delta\lambda$, is when $\theta = 180°$

$$\Rightarrow (\Delta\lambda)_{max} = \frac{h}{m_0 C}(1+1) \approx 0.05\,Å$$

thus, the maximum wavelength possible is about $0.05Å$ for visible light, whose wavelength is about (λ_{mean}) $5000\,Å$, $(\Delta\lambda)_{max}$ is only about $0.001\,\%$ of the incident wavelength which is undetectable. Hence, compton effect cannot be detected for visible light rays.

Question-7) ans a) "when a monochromatic wave that is a wave of single frequency and wavelength, travel through a medium It's velocity of advancement in the medium is called a wave velocity or phase velocity."

or

"The rate at which the phase of matter wave propagates"

- "The velocity with which the wave packets obtained by ~~sg~~ super position of wave travelling in group is called group velocity. Therefore, the group velocity is the velocity with which wavepackets is transmitted."

ans b) Schrödinger steady state equation or Schrödinger time independent wave equation, i.e

$$\boxed{\nabla^2\psi + \frac{2m}{\hbar^2}(E-V)\psi = 0}$$

can be solved only for certain values of energy." The value of energy for which steady-state equation (time-independent) can be solved are called eigen values."

and "The corresponding wave functions are called eigen functions."