→ de Broglie Postulate (1924):

If EM waves could display properties associated with particles, then particles could also display wave-like properties.

$$p = \frac{h}{\lambda}$$ (For massless objects or, according to de Broglie postulate, for particles with appreciate masses, too.)

$$\therefore \lambda = \frac{h}{p} = \frac{h}{mv}$$

where m is the mass of the particle
v is the velocity of the particle.

$\lambda = \frac{h}{mv}$ is called the de Broglie wavelength, and is very useful to predict the energy or frequencies of extremely tiny particles, such as electrons or protons.

Dual Nature of Light

Light has wave and particle nature

Light can be represented as discrete packets of energy called photons.

$$E_{photon} = h\nu = \frac{hc}{\lambda} = hc\bar{\nu}$$

(J) (J.s)(s⁻¹)

h : Plancks constant $= 6.626 \times 10^{-34}$ J.s

$$E_{photon} = \hbar\omega \qquad \hbar = \frac{h}{2\pi}$$

$$\omega = 2\pi\nu$$

Photons have also definite momentum (p)

Momentum is defined as the product of mass and velocity.

$$\vec{p} = m\vec{v} \qquad (kg \cdot m/sec)$$

For massless objects, such as photons, the formula is

$$p = \frac{h}{\lambda} = \frac{hc}{\lambda c} = \frac{E}{c}$$

→ The Electromagnetic Spectrum

Regions of EM radiations:

NMR

① Radio Frequency region: (3 MHz – 3 GHz)
It has enough energy to flip the spin of a proton with the presence of magnetic fields of a few teslas.

Microwave, ESR and Rotational spectroscopy

② Microwave region: (3 GHz – 300 GHz)
This region corresponds to the rotational transition and electron-spin flipping in molecules.

③ Infrared region: > 600 GHz ($\sim 20\ cm^{-1}$ – $13000\ cm^{-1}$)

Vibrational spectroscopy
Raman techniques.

(a) Far-infrared: ($\sim 20\ cm^{-1}$ – $350\ cm^{-1}$)
(b) Mid-infrared: ($400\ cm^{-1}$ – $4000\ cm^{-1}$)
(c) Near-infrared: ($4000\ cm^{-1}$ – $13{,}000\ cm^{-1}$)
The IR region corresponds to the vibrational transition in molecules.

④ Visible and ultravisible regions: ($13{,}000\ cm^{-1}$ – $50{,}000\ cm^{-1}$)

UV-vis and Raman source

ⓐ Visible region: 780 nm – 390 nm
red to violet

Electronic spectroscopy

ⓑ Near UV : 390 nm – 200 nm
$26{,}000\ cm^{-1}$ – $50{,}000\ cm^{-1}$

ⓒ Far UV : 200 nm – 10 nm
$50{,}000$ – $100{,}000\ cm^{-1}$

This region excites valence electrons in molecules.

X-ray diffraction

⑤ X-Ray region: $< 10\ nm$
$> 100{,}000\ cm^{-1}$

The wavelength of x-ray is associated with the spacings between atoms in normal lattice.

$$1\ nm = 10\ Å$$

This region corresponds to electron transition from inner most orbitals.

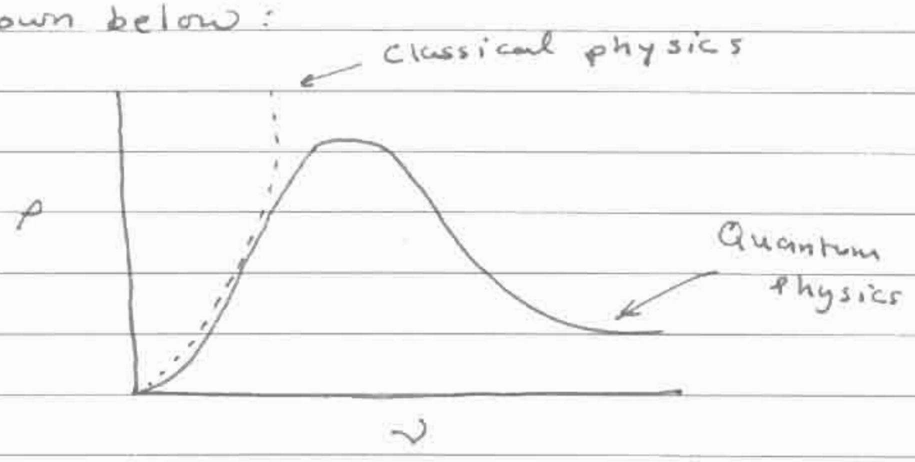
⑥ γ-Ray region: $< 0.01\ nm$ (or $< 0.1\ Å$)

This very-high energy region is associated with nuclear processes ($\simeq 1 \times 10^{6}\ eV$)

→ Blackbody Radiation

Blackbody is an ideal body that absorbs all the light that falls on it. EM radiation can't pass through it nor can be reflected by its surface, but is totally absorbed.
Blackbody basically absorbs all frequencies and also emits all frequencies.

Thus, the intensity of the radiation emitted can be defined as a radiation density (ρ). A plot of the ρ vs. frequency at temperature T is shown below:



$\rho \propto T\nu^2$

Classical physics failed to explain blackbody phenomenum, as it was based on the assumption that energy is continuum.

Planck in 1900 came up with a new look to the energy. He proposed that energy is discrete and has to be proportional to an integral multiple of the frequency ($E = nh\nu$; where $n = 1, 2, \ldots$).

Then he derived an equation that enables to understand the black body radiation at higher frequency regions such as UV region.

He proposed Planck distribution law for blackbody radiation:

$$\rho_\nu(T) = \frac{8\pi h}{c^3} \frac{\nu^3 d\nu}{e^{h\nu/k_B T} - 1}$$

k_B is the Boltzmann constant $= 1.380650 \times 10^{-23}$ J/K

c is the speed of light.

One can show that the energy density (ρ_ν) has the unit of J/m^3.

Temperature dependence was very nicely predicted by Planck equation.

h is planck constant $= 6.626 \times 10^{-34}$ J.s.