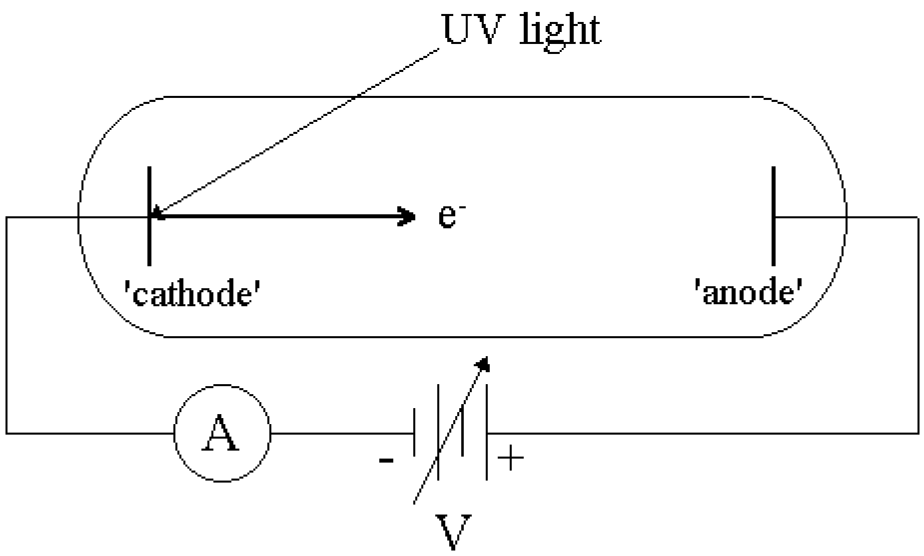
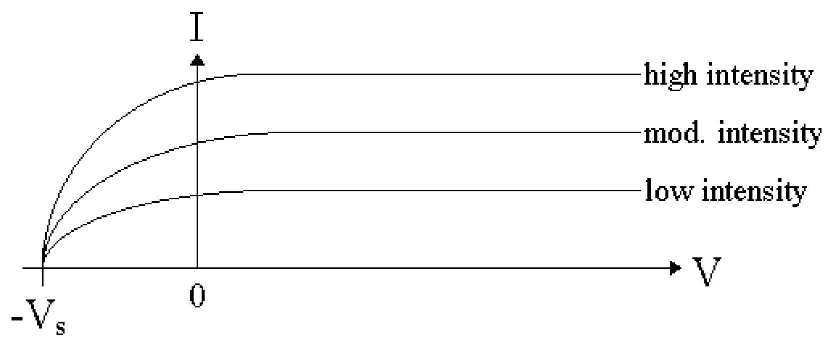
Lect. 15: Light as a Particle (Photon)

Wave properties for light: interference, diffraction, waveguide

But certain things cannot be explained by wave nature of light.

Photoelectron effects: electron emission when light shines on metal



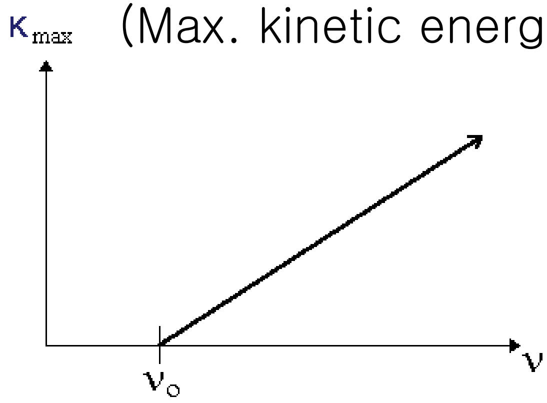


– Amount of emitted electrons depends on light intensity

– Same minimum voltage for current flow regardless of light intensity

➔ Same max. kinetic energy of emitted electrons regardless of light intensity

Lect. 15: Light as a Particle (Photon)



This results cannot be explained by wave nature of light.

Einstein's explanation: Light delivers energy in chunks (photon)

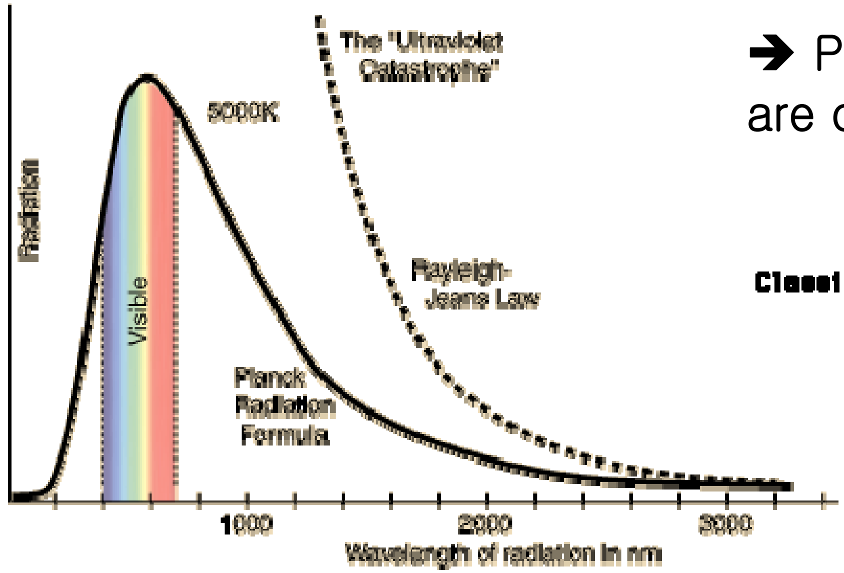
$$E_{photon} = h\nu \cong \frac{1.24}{\lambda[\mu m]} \text{ eV}$$

(h: Planck's constant =6.63x10^{-34} Joule-sec)

Lect. 15: Light as a Particle (Photon)

Consider the spectrum of light emission from an heated object (Thermal emission)
(heat ➔ oscillatrion of charges inside the object => EM emission)

Very detailed analysis is possible for "black body" radiation (Rayleigh-Jeans Law).
(black body: object that absorbs 100% of incoming EM radiation => 100% emission)
➔ Max. EM emission from a heated object at a given temperature)



Rayleigh-Jeans law did not make sense at high frequencies.

➔ Planck suggested that EM energies are quantized (photon) $E_{photon} = h\nu$.

Classical — Rayleigh-Jeans Law

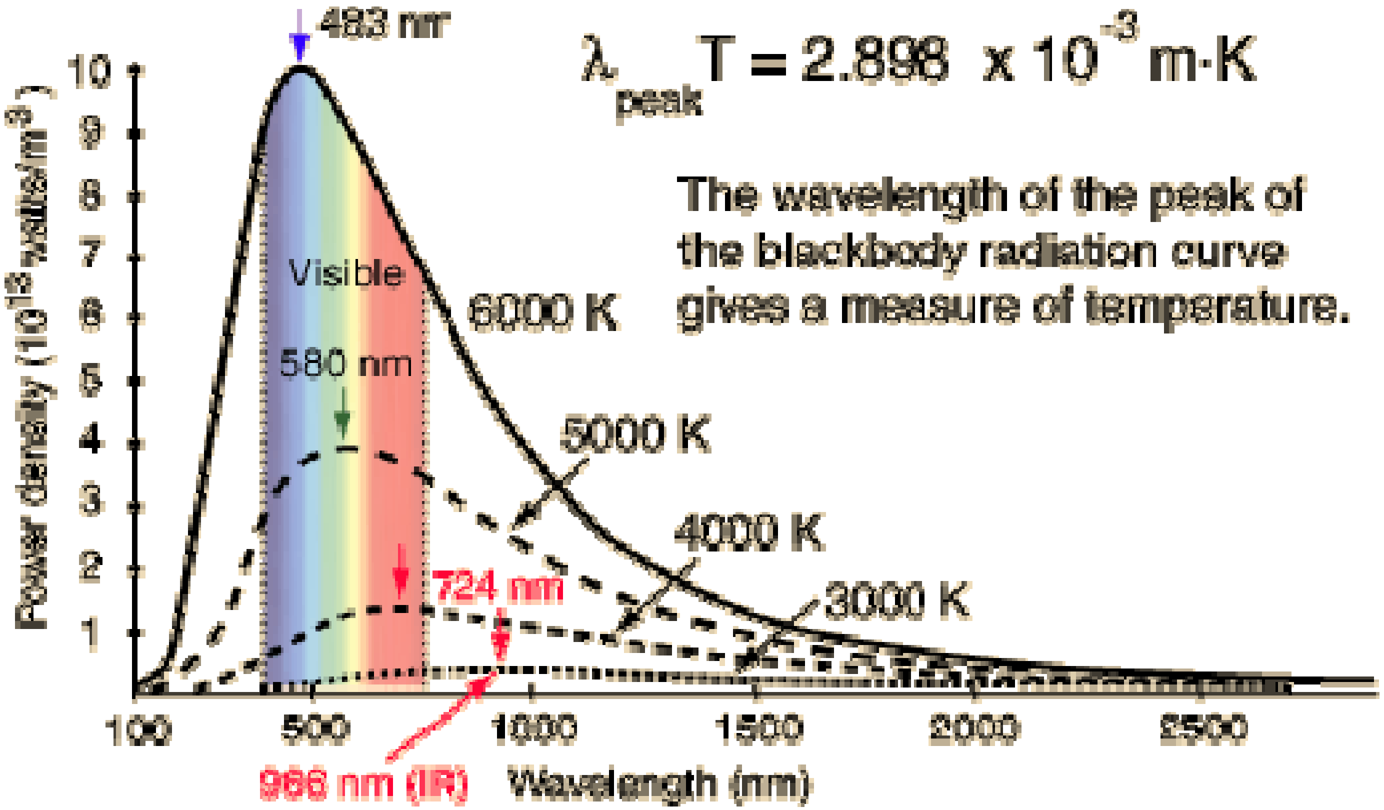
$$\frac{8\pi\nu^2}{c^3}kT$$

Planck Law — Quantum

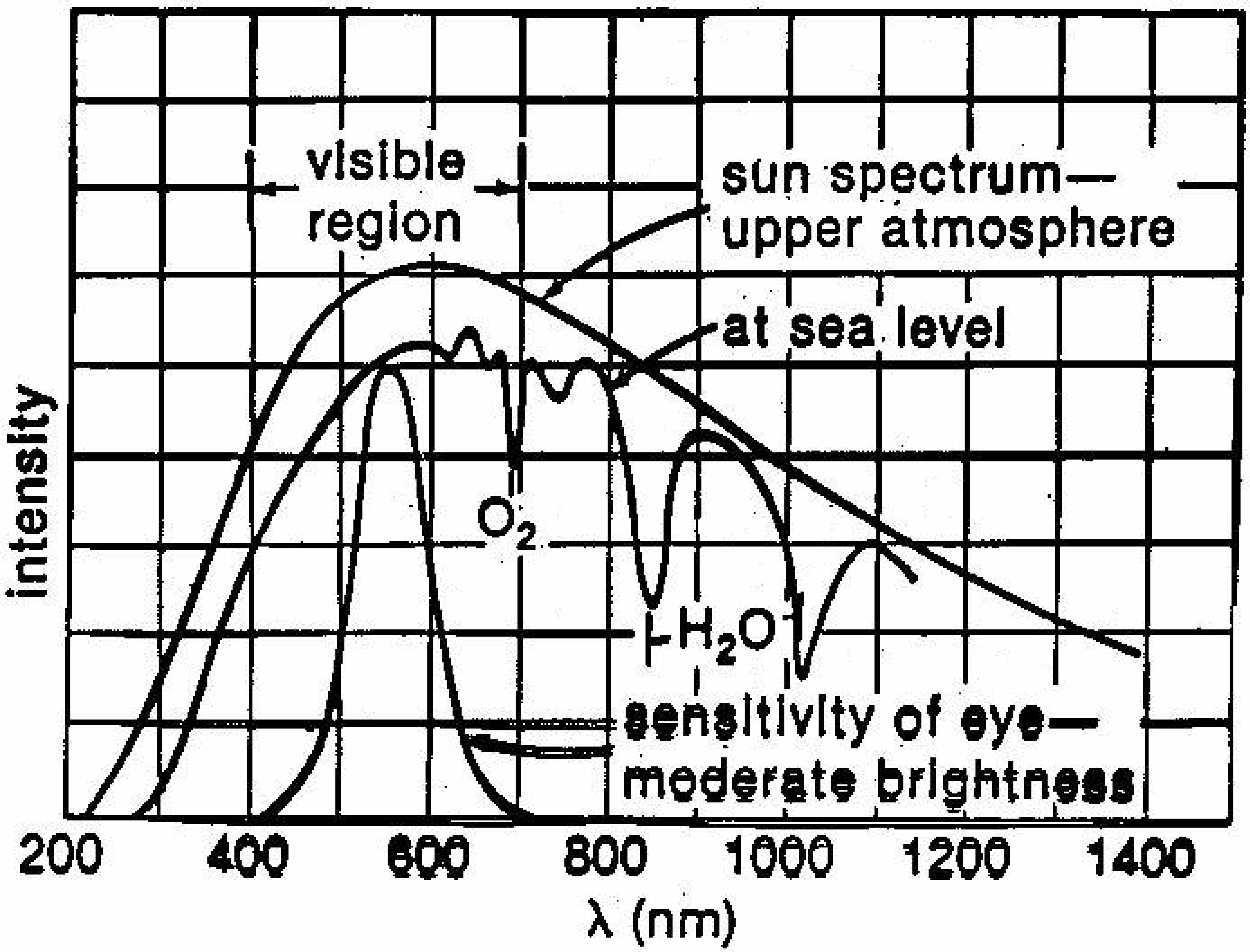
$$\frac{8\pi\nu^2}{c^3}\frac{h\nu}{e^{\frac{h\nu}{kT}}-1}$$

Planck Law approaches R-J Law when $h\nu \ll kT$.

Lect. 15: Light as a Particle (Photon)

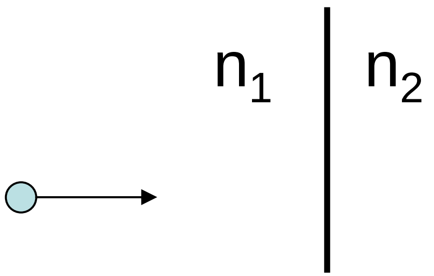


Lect. 15: Light as a Particle (Photon)

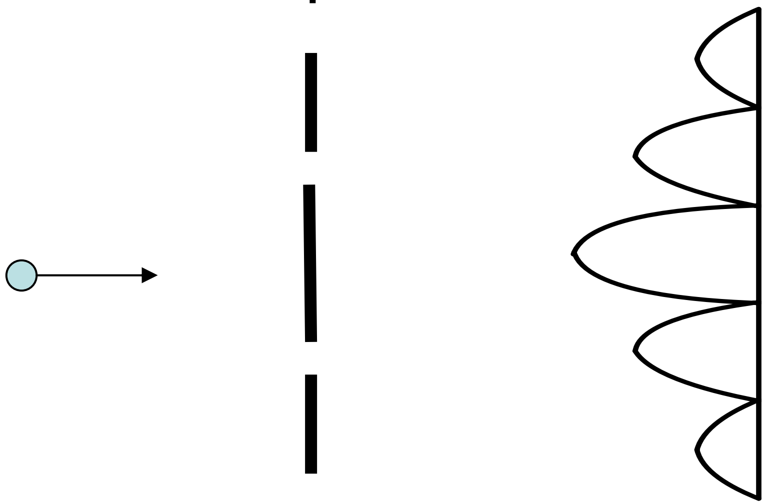


Lect. 15: Light as a Particle (Photon)

How can photons explain what we have learned:
Reflection, interference, waveguide, …



$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$



Probabilistic Interpretation:

light intensity ⇔ probability for detecting a photon

Choose whichever (wave or photon) is more convenient to use!

Duality can be applied to everything (Quantum Physics)