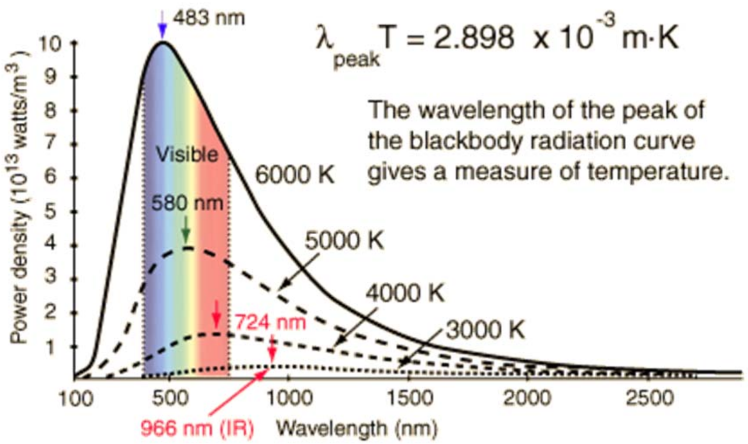
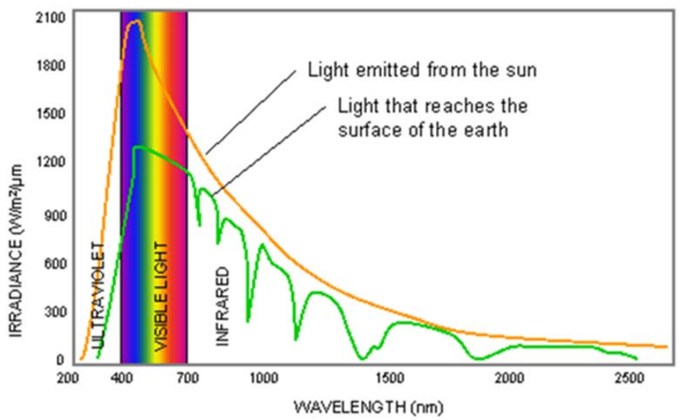
Lect. 17: Light as a Particle (Photon)

Blackbody Radiation: EM radiation from an heated object at equilibrium



Temperature
➔ oscillation of charges inside the object
➔ EM radiation



Temperature of sun at the surface: 5778K

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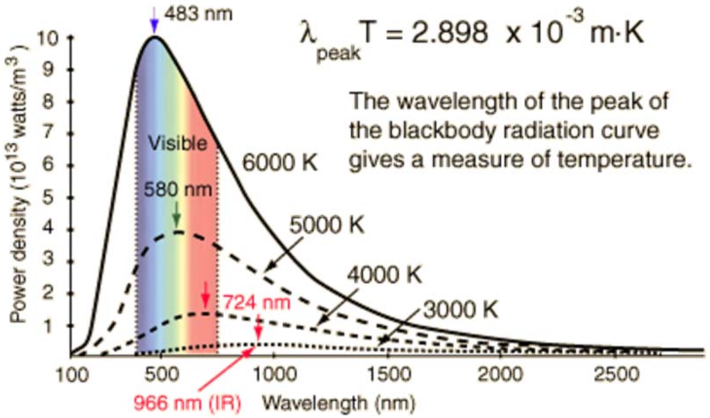
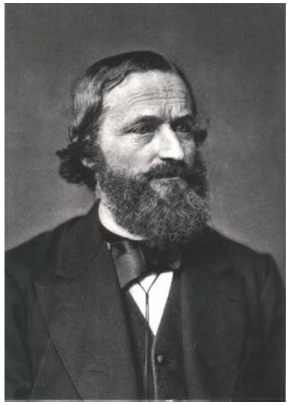
Blackbody Radiation: EM radiation from an heated object at equilibrium



Temperature
➔ oscillation of charges inside the object
➔ EM radiation

Scientists in 19th century knew much about EM waves and thermodynamics

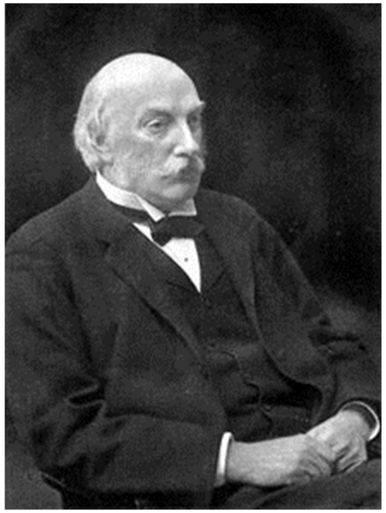
For example,

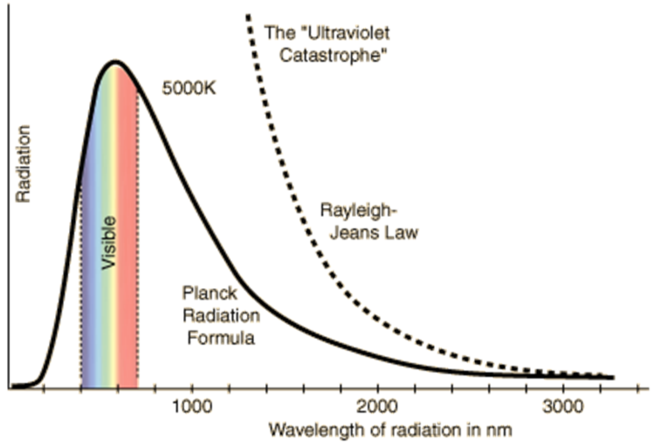


Gustav Kirchoff
(1824 ~ 1887)

Lect. 17: Light as a Particle (Photon)

Rayleigh-Jeans Law : $$\frac{8\pi\nu^2}{c^3}kT$$



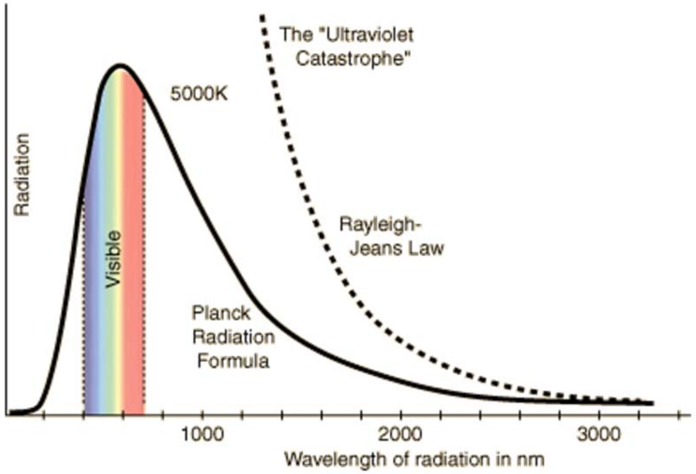


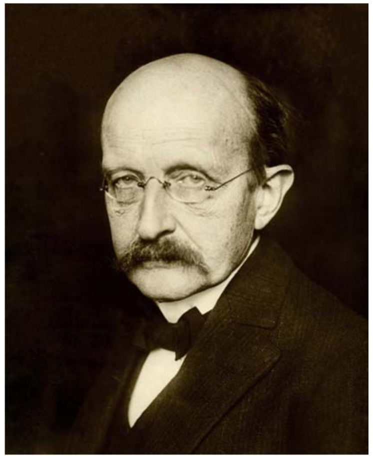
John Strutt (Lord Rayleigh)
(1842~1919)
Nobel Prize in Physics in 1904

(Sir) James Jean
(1877~1946)

Lect. 17: Light as a Particle (Photon)

Rayleigh-Jeans Law: $\frac{8\pi\nu^2}{c^3}kT$





Max Planck (1858~1947)
Nobel Prize in Physics in 1918

In 1900, Planck proposed EM energies are quantized (photon)

$E_{photon} = h\nu$

(h: Planck constant, 6.626×10^{-34} J-s, 4.136×10^{-15} eV-s)

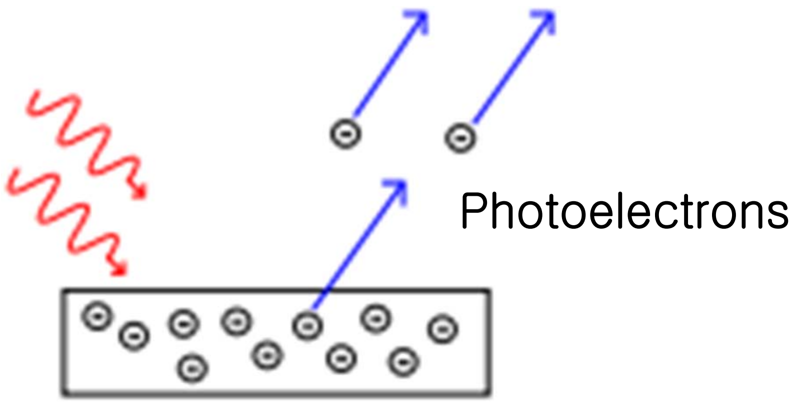
Classical	Rayleigh-Jeans Law $\frac{8\pi\nu^2}{c^3}kT$	Planck Law $\frac{8\pi\nu^2}{c^3}\frac{h\nu}{e^{\frac{h\nu}{kT}}-1}$	Quantum

(Spectral energy density: energy per bandwidth per volume)

Beginning of Quantum Mechanics

Lect. 17: Light as a Particle (Photon)

Photoelectric effects: Electron emission when light shines on a material

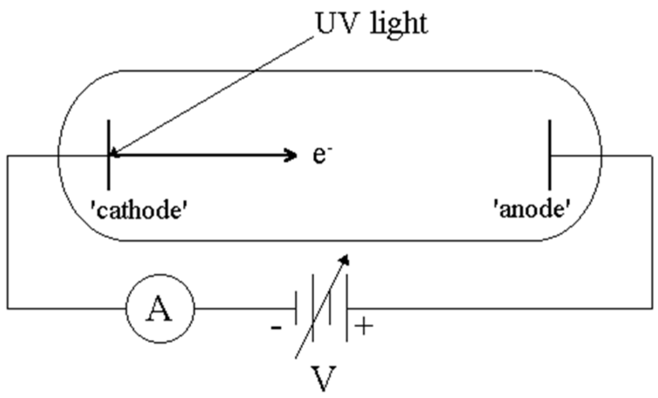


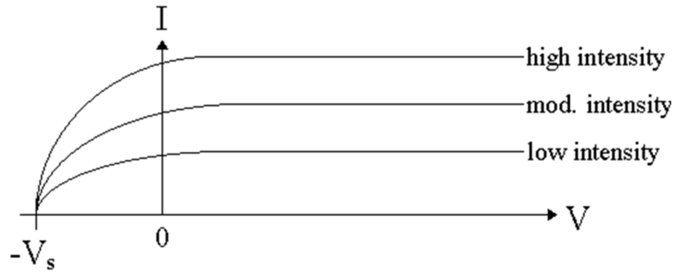
Discovered in 1887 by

Heinrich Hertz
(1857 - 1894)

Lect. 17: Light as a Particle (Photon)

Photoelectric effect





- Amount of photoelectrons depends on light intensity
- Same minimum voltage for current flow regardless of light intensity

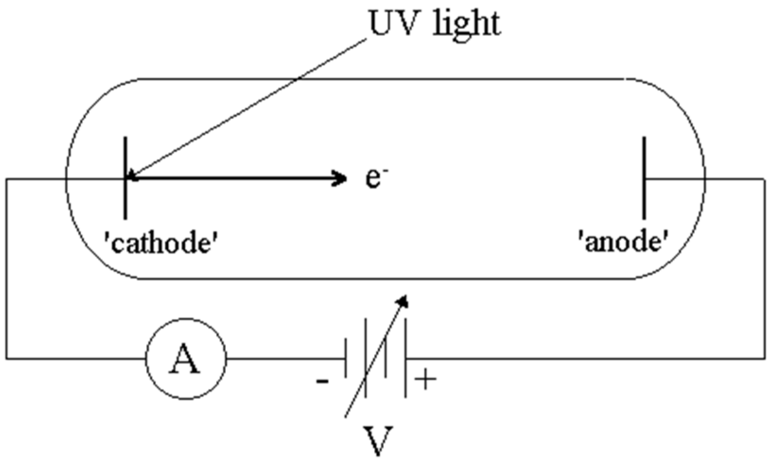
$$qV_s = \frac{1}{2}mv_{\max}^2 (= K_{\max})$$

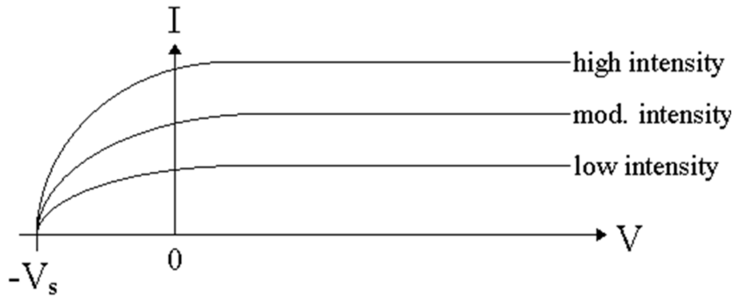
➔ Same max. kinetic energy for emitted electrons regardless of light intensity?

- What determines the max. kinetic energy of photoelectrons?

Lect. 17: Light as a Particle (Photon)

Photoelectron effects:





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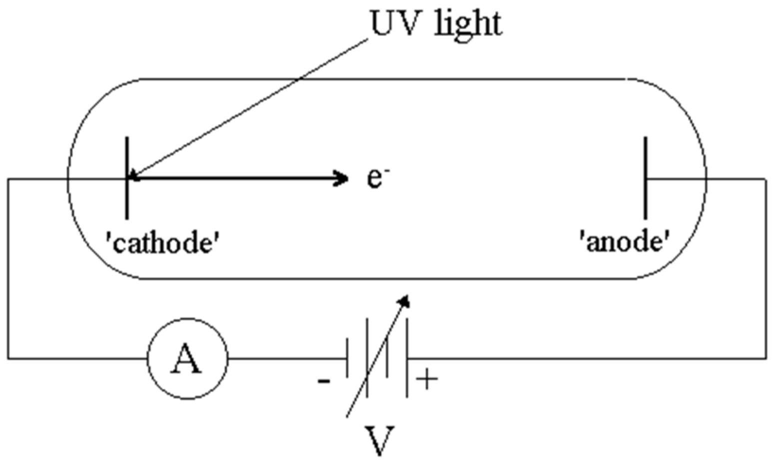
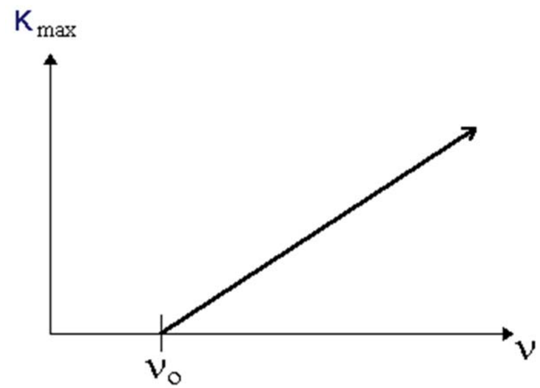
➔ What determines the max. kinetic energy of emitted electrons?

Lect. 17: Light as a Particle (Photon)





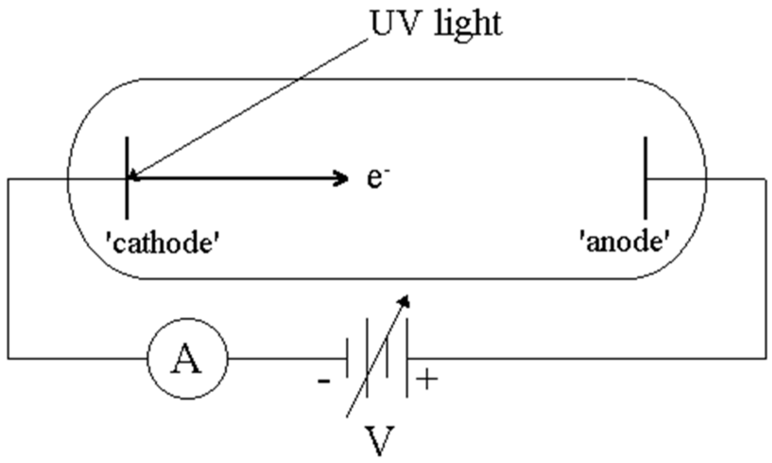
- K_{max} increases with ν
- No photoelectrons if ν is smaller than a certain value

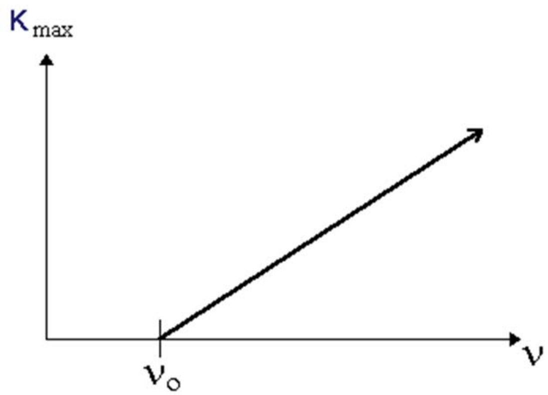
➔ These cannot be explained by EM waves

Larger intensity => larger E-field
But larger E-field inserts larger force (F=qE) and
therefore photoelectronics should have larger kinetic energy

EM waves with any frequency should produce photoelectrons
if its intensity is large enough

Lect. 17: Light as a Particle (Photon)





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

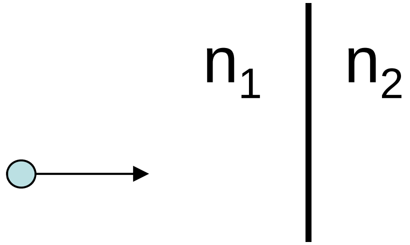
$$E_{photon} = h\nu$$

$$E_{photon} = h\nu \ = h\frac{c}{\lambda} \ \simeq 4.136\times10^{-15}(eV\cdot\text{sec})\frac{3\times10^{8}\,\text{m/sec}}{\lambda} \ \simeq \frac{1.24}{\lambda[\mu m]}eV$$

Lect. 17: Light as a Particle (Photon)

How can photons explain what we have learned about EM waves

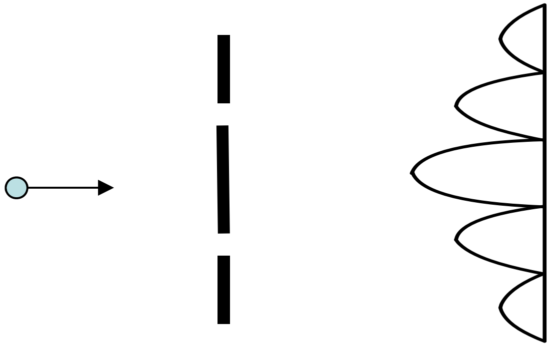
➔ reflection, interference, waveguide …

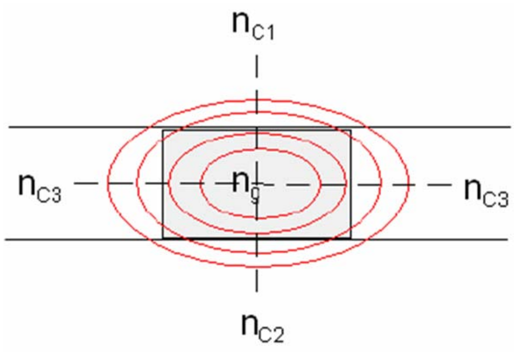


$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

Probabilistic Interpretation from QM

➔ R represents probability for detecting the reflected photon





- Use whichever (wave or photon) is more convenient for the given problem

- Wave/particle duality applies to everything (Quantum Physics)

Lect. 17: Light as a Particle (Photon)