

The DEMISE of CLASSICAL PHYSICS (cont'd)

(a) Blackbody radiation - When heated all objects emit light!

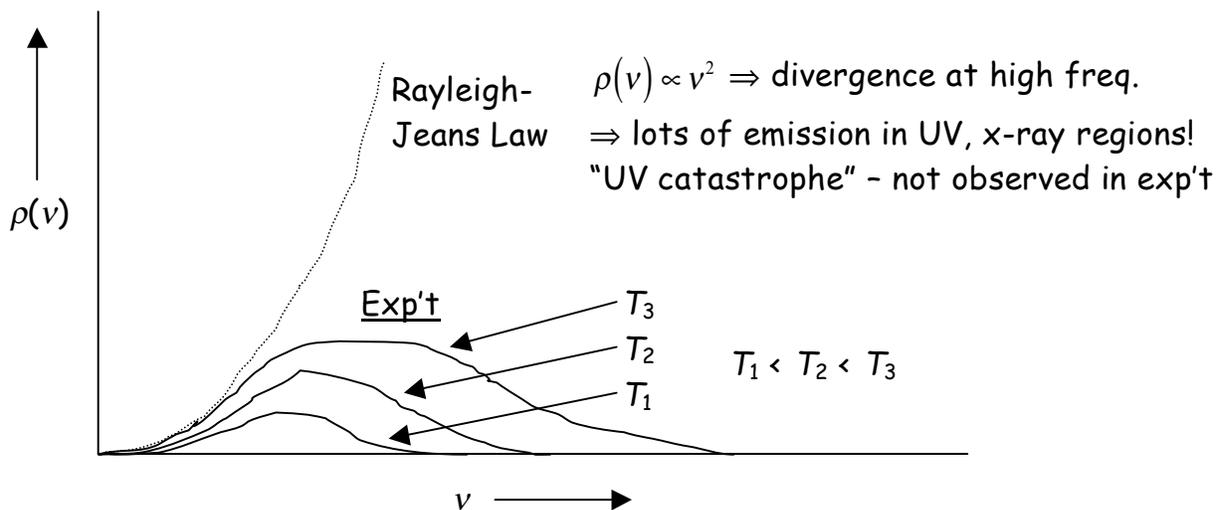
- Classically:
- (1) Radiation from a blackbody is the result of electrons oscillating with frequency ν
Oscillating charged particle \Leftrightarrow antennae
 - (2) The electrons can oscillate (& radiate) equally well at any frequency

\Rightarrow Rayleigh-Jeans Law for spectral density $\rho(\nu)$, where intensity of emitted light in frequency range from ν to $\nu+d\nu$ is $I(\nu) \sim \rho(\nu)d\nu$

$$d\rho = \rho(\nu, T) d\nu = \frac{8\pi kT}{c^3} \nu^2 d\nu \quad \boxed{\propto \nu^2}$$

where $d\rho(\nu, T)$ = density of radiative energy in frequency range from ν to $\nu+d\nu$ at temperature T

k = Boltzmann's constant [= R/N_A (gas constant per molecule)]
 c = speed of light



Planck (~1900) \Rightarrow First "quantum" ideas

- (1) The energy of the oscillator \propto frequency

$$E \propto \nu$$

- (2) The energy \propto an integral multiple of ν

\rightarrow (the # of oscillators n)

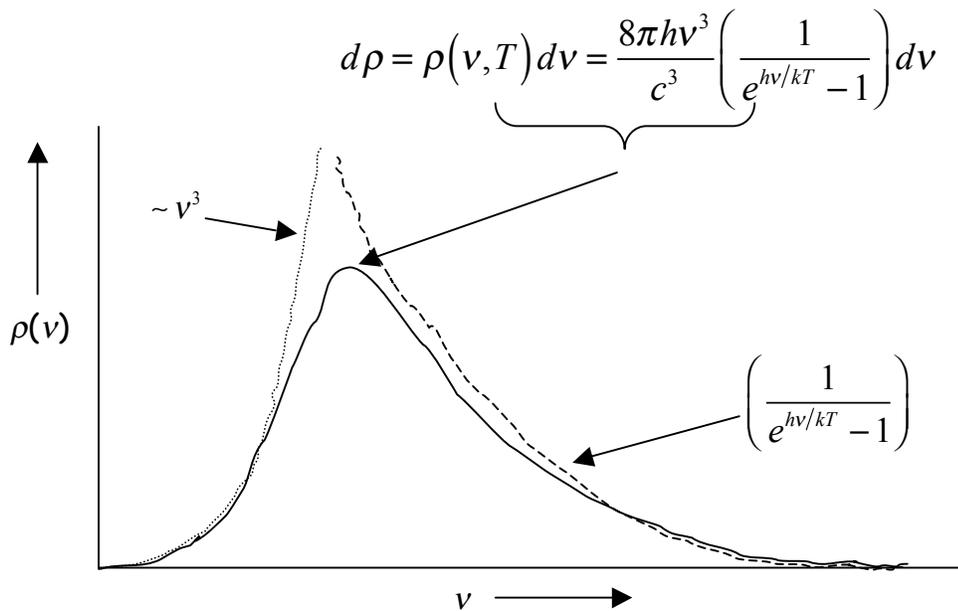
$$E \propto n\nu$$

or $E = nh\nu$

\downarrow
constant

$h\nu$ becomes a "quantum" of energy

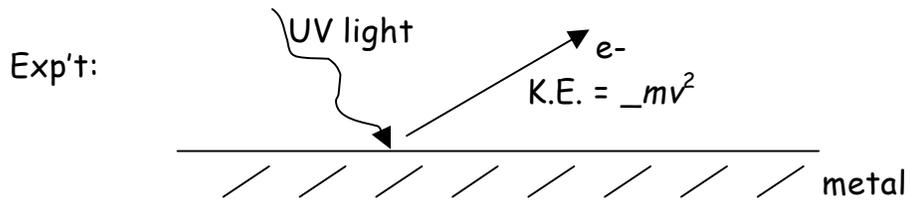
Planck used statistical mechanics (5.62) to derive the expression for black body radiation



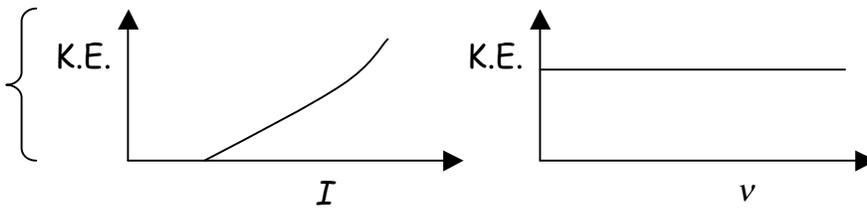
Fitting exp't to model \Rightarrow

$$h = 6.626 \times 10^{-34} \text{ J-sec}$$

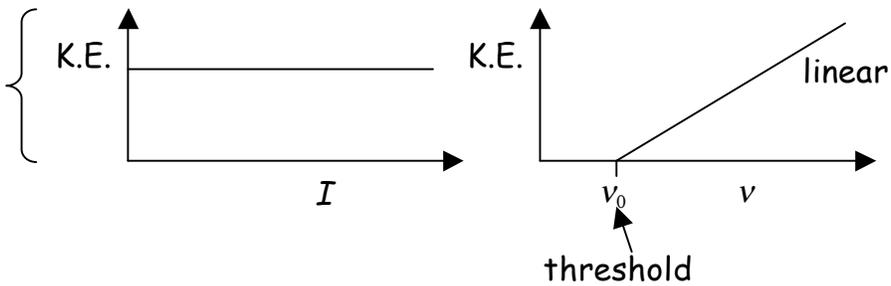
Planck's constant

(b) Photoelectric effect

Classically
expect:



Exp't:
Opposite!

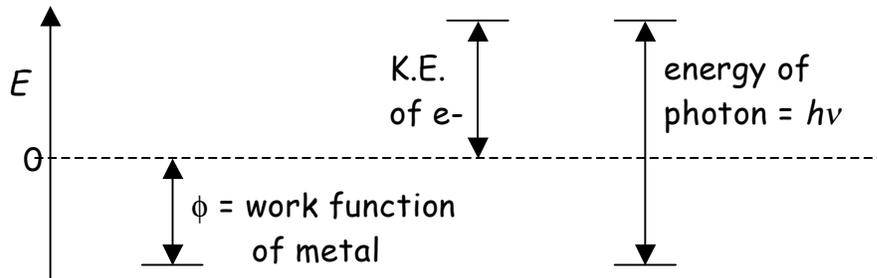


Einstein (1905) proposed:

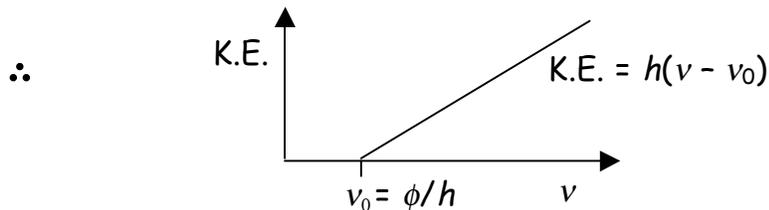
- (1) Light is made up of energy "packets": "photons"
- (2) The energy of a photon is proportional to the light frequency

$$E = h\nu \quad h \equiv \text{Planck's constant}$$

New model of photoelectric effect:



$$\therefore \text{K.E.} = h\nu - \phi = h\nu - h\nu_0 = h(\nu - \nu_0)$$



Comparing to exp't, value of "h" matches the one found by Planck!

This was an extraordinary result !

Summary:

- (1) Structure of atom can't be explained classically
- (2) Discrete atomic spectra and Rydberg's formula can't be explained
- (3) Blackbody radiation can be "explained" by quantifying energy of oscillators $E = h\nu$
- (4) Photoelectric effect can be "explained" by quantifying energy of light $E = h\nu$