Planck's Constant

The "missing constant" essential to understanding size of atoms.

Size of atoms $\Leftrightarrow$ Avogadro's Number..

Car tire lasts $\simeq 10^5$ miles. $\equiv L$
$\simeq 2\cdot 10^5$ km $\simeq 2\cdot 10^8$ m $\simeq 2\cdot 10^{10}$ cm

Assume 1 layer of atoms peels off per revolution of the tire.

$r \simeq 30$ cm, $2\pi r \simeq 180$ cm $\simeq 2\cdot 10^2$ cm
$t \simeq 2$ cm (thickness of tread)
$a =$ atom size $\quad w \simeq 10$ cm (width of tire)
$m \simeq \ldots 1$ gm/cm3 $\cdot V$

$V \cong 2\pi r \cdot t \cdot w = 2\cdot 10^2 \cdot 2 \cdot 10^2 = 4\cdot 10^4$ cm^3

$m \simeq 4\cdot 10^4$ gm

then... $\underbrace{L a \cdot \cancel{w}}_{\text{volume of rubber deposited on road}} = \overbrace{2\pi r t \cdot \cancel{w}}^{\text{volume of tire}}$

$a \simeq \dfrac{2\pi r t}{L} = \dfrac{2\cdot 10^2 \cdot 2}{2\cdot 10^{10}} \simeq 2\cdot 10^{-8}$ cm

$\boxed{a \simeq 10^{-8} \text{ cm}}$ $\Leftarrow$ atomic size.

(not quiz)

Avogadro: how many "atoms" in a gram

How many atoms in the $4 \cdot 10^4$ gm in the tire?

$$N_{atom} = \frac{4 \cdot 10^4 \, cm^3}{10^{-24} \, \frac{cm^3}{atom}} \simeq 4 \cdot 10^{28}$$

$$N_{AV} \simeq \frac{N_{atom}}{m} \simeq \frac{4 \cdot 10^{28}}{4 \cdot 10^4} \simeq 10^{24}$$

$N_{AV} \simeq 10^{24}$, really $6 \cdot 10^{23}$

meaning: # of mass carrying constituents in matter

mass carrying constituents $\equiv$ neutrons or protons.

1 gram of stuff < Hydrogen / Uranium

has $\simeq 6 \cdot 10^{23}$ = # neutrons + # protons.

$6 \cdot 10^{23}$ ^{238}U weighs $\simeq 238$ gm

$\uparrow$

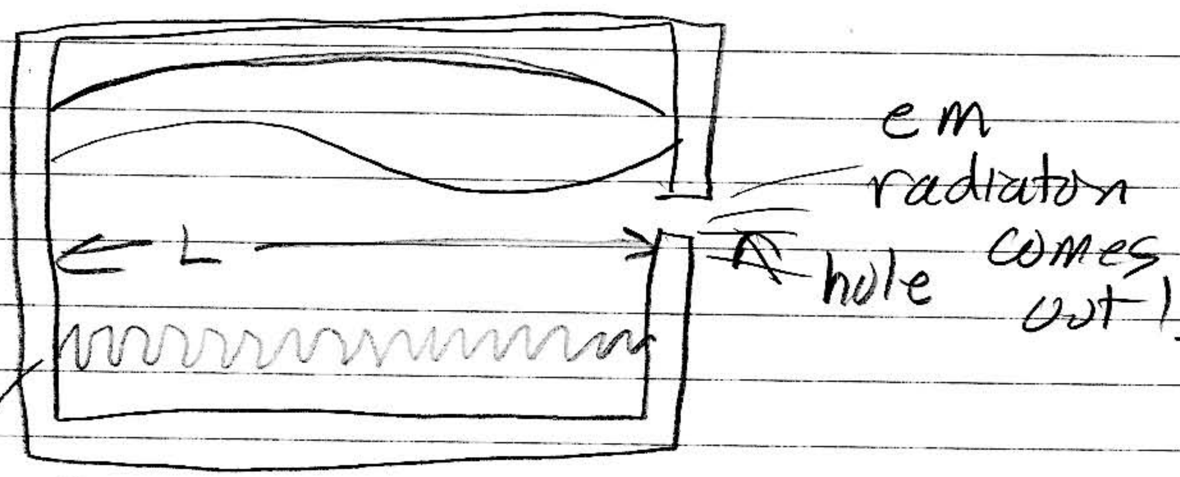
238 n+p

Explain $a \simeq 10^{-8}$ cm ?

⇒ Planck's Constant.

⇒ First appearance, black body radiation

Black Body box of conductor



walls at temperature T (think Kelvin).

→ the electromagnetic field is a "degree of freedom"

wavelength:

$$n \frac{\lambda_n}{2} = L$$

$$\lambda_n = \frac{L}{2n}$$

each n yields a degree of

freedom! Should be equal amount of energy in each "increment" of wavelength.

$$|\Delta\lambda| = |\lambda_{n+1} - \lambda_n| = \left|\frac{L}{2(n+1)} - \frac{L}{2n}\right|$$

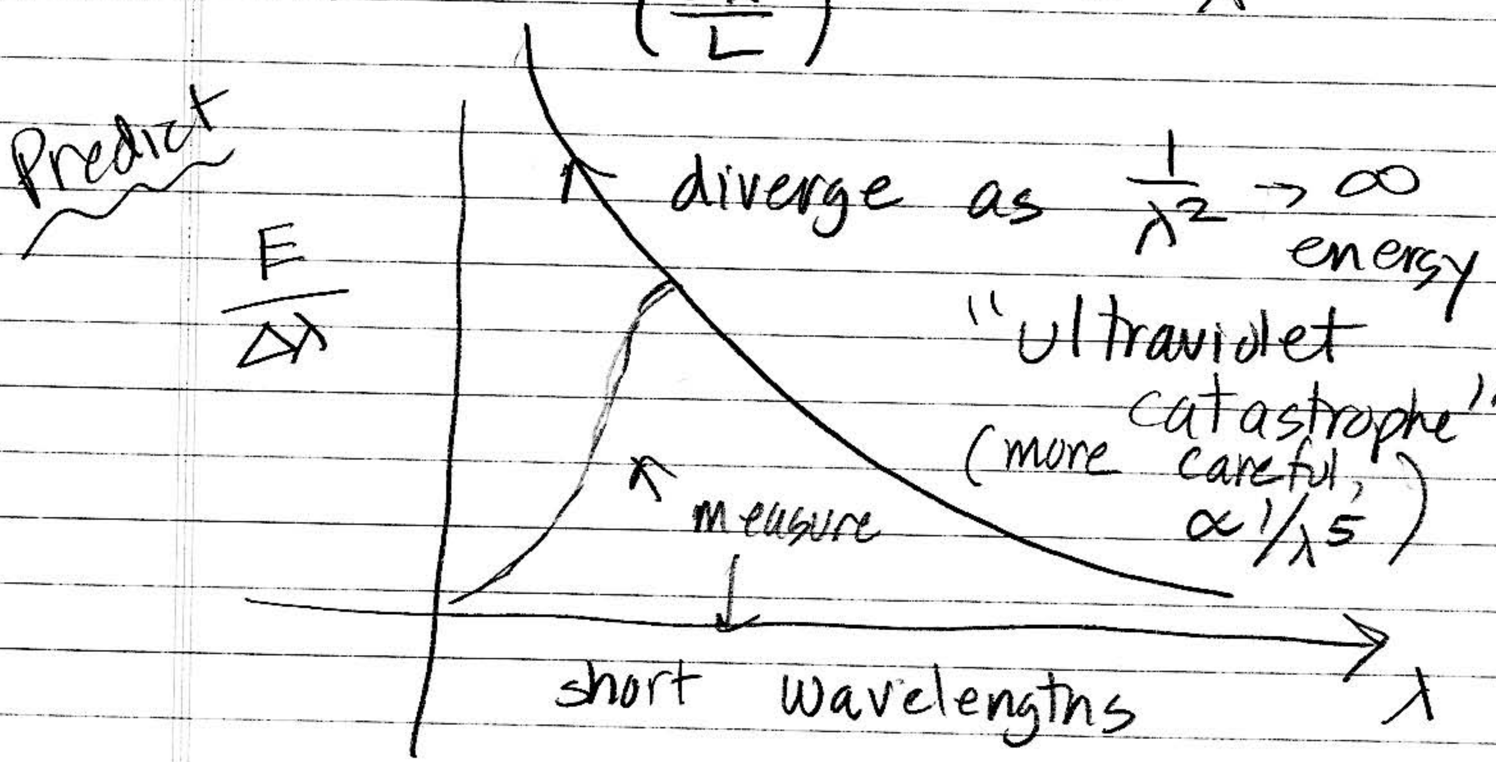
$$\simeq \left|\frac{L}{2}\left[\frac{1}{n(1+\frac{1}{n})} - \frac{1}{n}\right]\right|$$

$$= \left|\frac{L}{2}\frac{1}{n}\left[1 - \frac{1}{n} - 1\right]\right| \simeq \frac{L}{2n^2}$$

$$n = \frac{L}{2\lambda}$$

$$|\Delta\lambda| = \frac{L}{2\left(\frac{L}{2\lambda}\right)^2} = \frac{2\lambda^2}{L}$$

$$\frac{E}{\Delta\lambda} \sim \frac{kT}{\left(\frac{2\lambda^2}{L}\right)} \simeq \frac{1}{2}\frac{LkT}{\lambda^2}$$



"freeze out" ... killed by an exponential ~~factor~~

$$\propto e^{-\frac{\gamma}{\lambda}}$$

$\gamma \rightarrow$ involves planck's constant.
$\rightarrow$ temperature

$$\frac{\gamma}{\lambda} = \frac{hc}{\lambda} \cdot \frac{1}{kT} \qquad k: \text{Boltzmann}$$

will be the energy of a <u>quantum</u> of light.

new constant

In full form,

$$E(\lambda, T) = \left(\frac{8\pi hc}{\lambda^5}\right) \frac{1}{e^{(hc/\lambda kT)} - 1}$$

$$h = 6.626 \cdot 10^{-27} \text{ erg-s}$$

Photoelectric Effect

<u>Puzzle</u>: shine as strong a light as you want on a metal surface,