Lecture 12

May 10, 2011

Solar cells is thought to be **the** future.

Need some background of quantum theory

- Atomic levels: Bound and free levels
- Optical transitions between levels
- Metals
- Semiconductors

http://www.solarwarrior.com/

Adelmans' photovoltaic system. Santa Cruz CA!!! Our system has a 2,880 square foot array with a theoretical output of 30.5kW.

Clean Air Fair Santa Cruz.

Sun/Earth:

Solar energy reaching upper atmosphere in direct line of sight of Sun.
Averaging over seasons reduces this.

Solar Constant = 2 cal/min/ cm^2 (averaged over the 24 hr day)

Effective Solar Constant = 0.5 cal/min/ cm^2

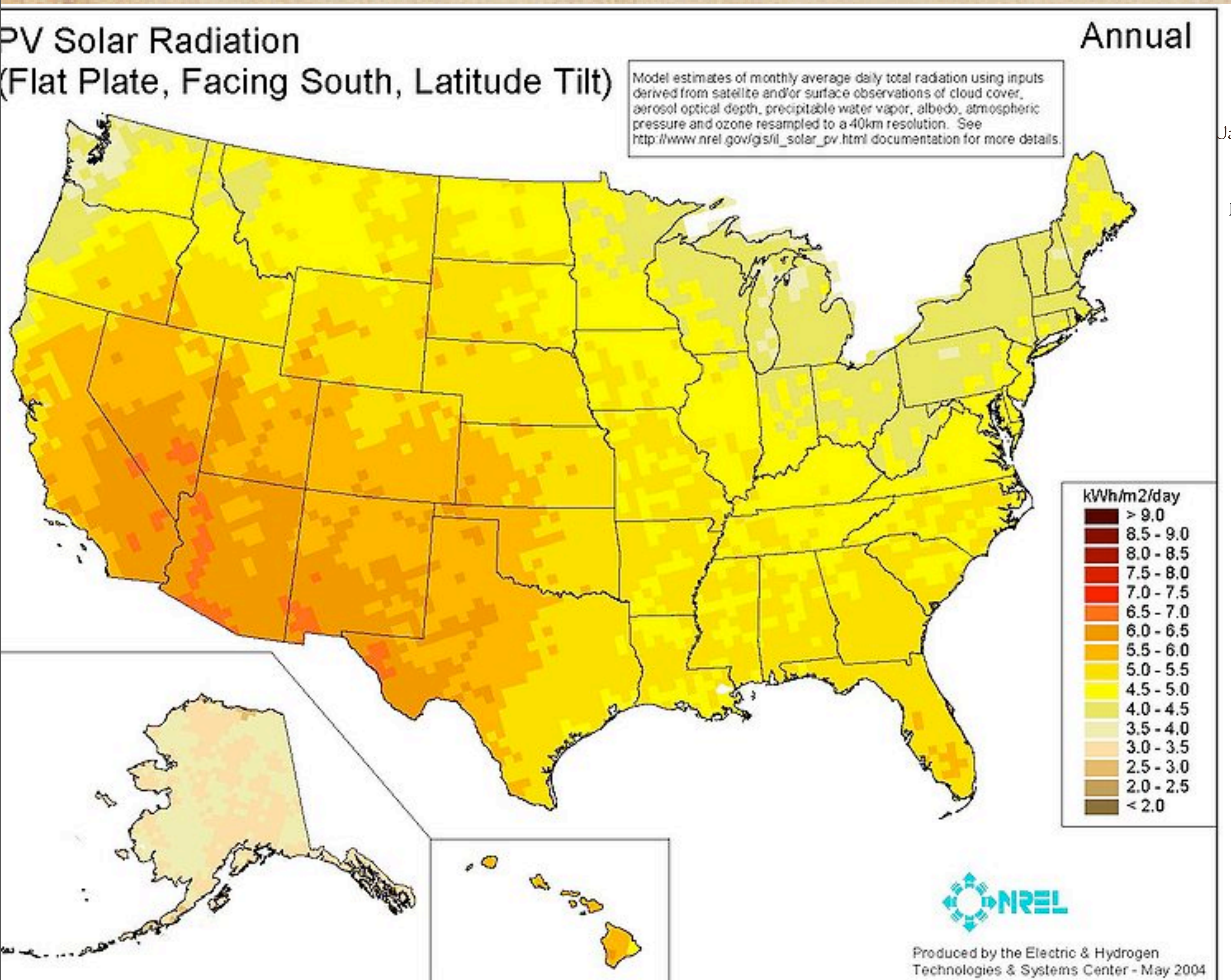
Losses in atmosphere due to absorption amount to 53% so we get about 47% of that

For an 8 hour day @ noon

$$600\ W/m^2 \ \sim 190 \frac{Btu}{ft^2\ hr}$$

Insolation is defined as energy in a 8 hour day
e.g. in place X it is ~ 1520 BTU/ft^2 or 4.5 kWH/m^2

Units of Insolation: Energy/Area= Powerxtime/Area
Often given as kWH/m^2



Insolation in units of KW/m²

Jan-Dec and annual average reading down

CA	CA	AZ
Los Angeles	San Francisco	Phoenix
34' N	38' 31" N	33 ' 26" N
118' W	121' 30" W	112' 1" W
3.09	2.35	3.25
4.25	3.33	4.41
5.09	4.42	5.17
6.58	5.95	6.76
7.29	6.84	7.42
7.62	7.39	7.7
7.45	7.55	6.99
6.72	6.51	6.11
6.11	5.75	6.02
4.42	3.92	4.44
3.43	2.65	3.52
2.72	2.06	2.75
5.4	4.89	5.38

Total energy supplied to USA per year by the Sun

Energy = Insolation x Days x Area

Insolation x number of days per year x total area

1520 Btu/ ft2 x 365 x 3.6

$\times 10^6$ miles^2 x $(5280)^2$

$$E_{total} = 5.6 \times 10^{19}\ Btu/year$$

$$E_{total-Used} = 98 \times 10^{15}\ Btu/year$$

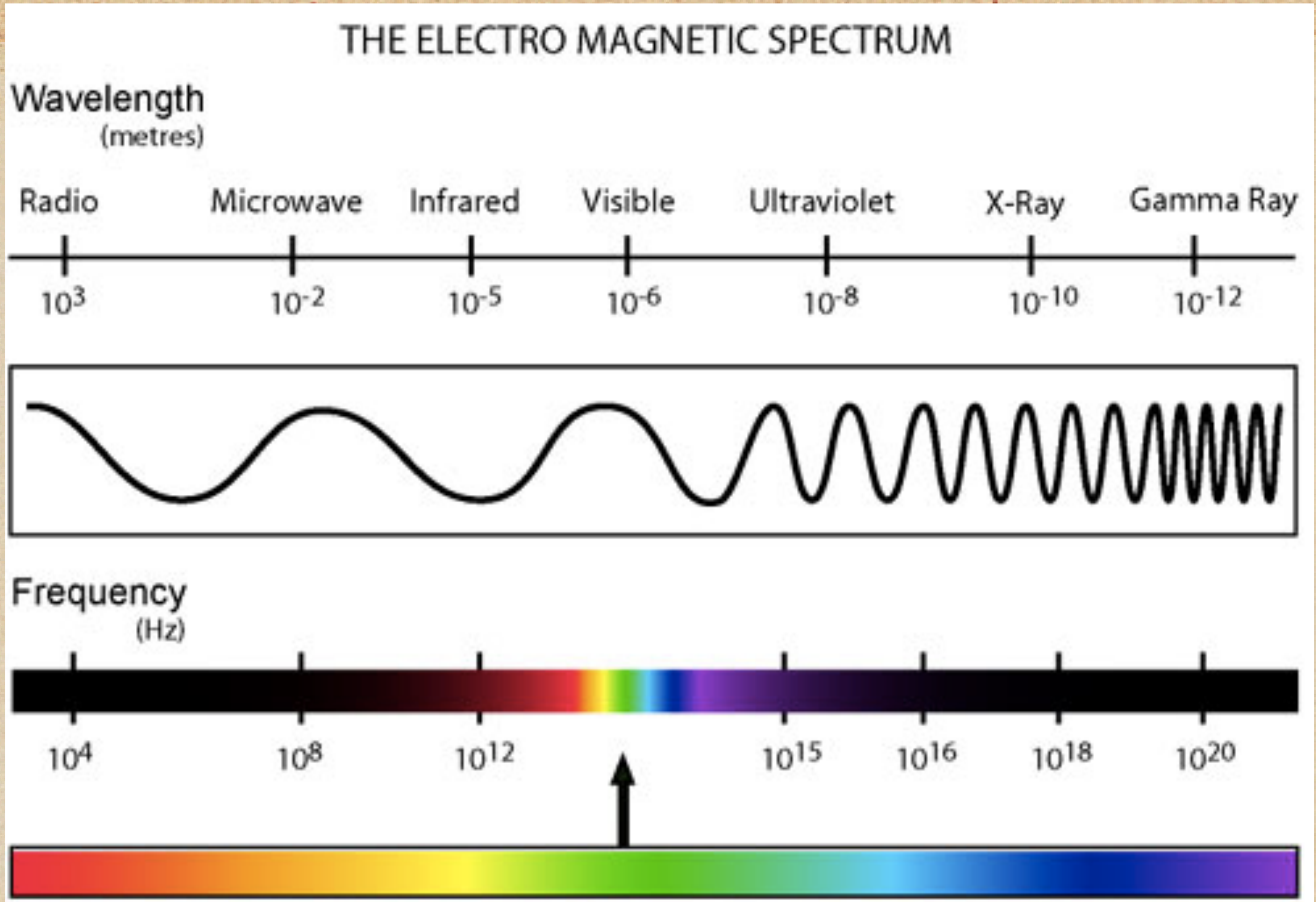
A mere 0.16% !!!!

Two questions arise regarding the sun:

Q1: Sun is at 5800^0 K. How do we know that?

Related also to Greenhouse effect.

Q2: Origin of solar energy? Thermonuclear processes.

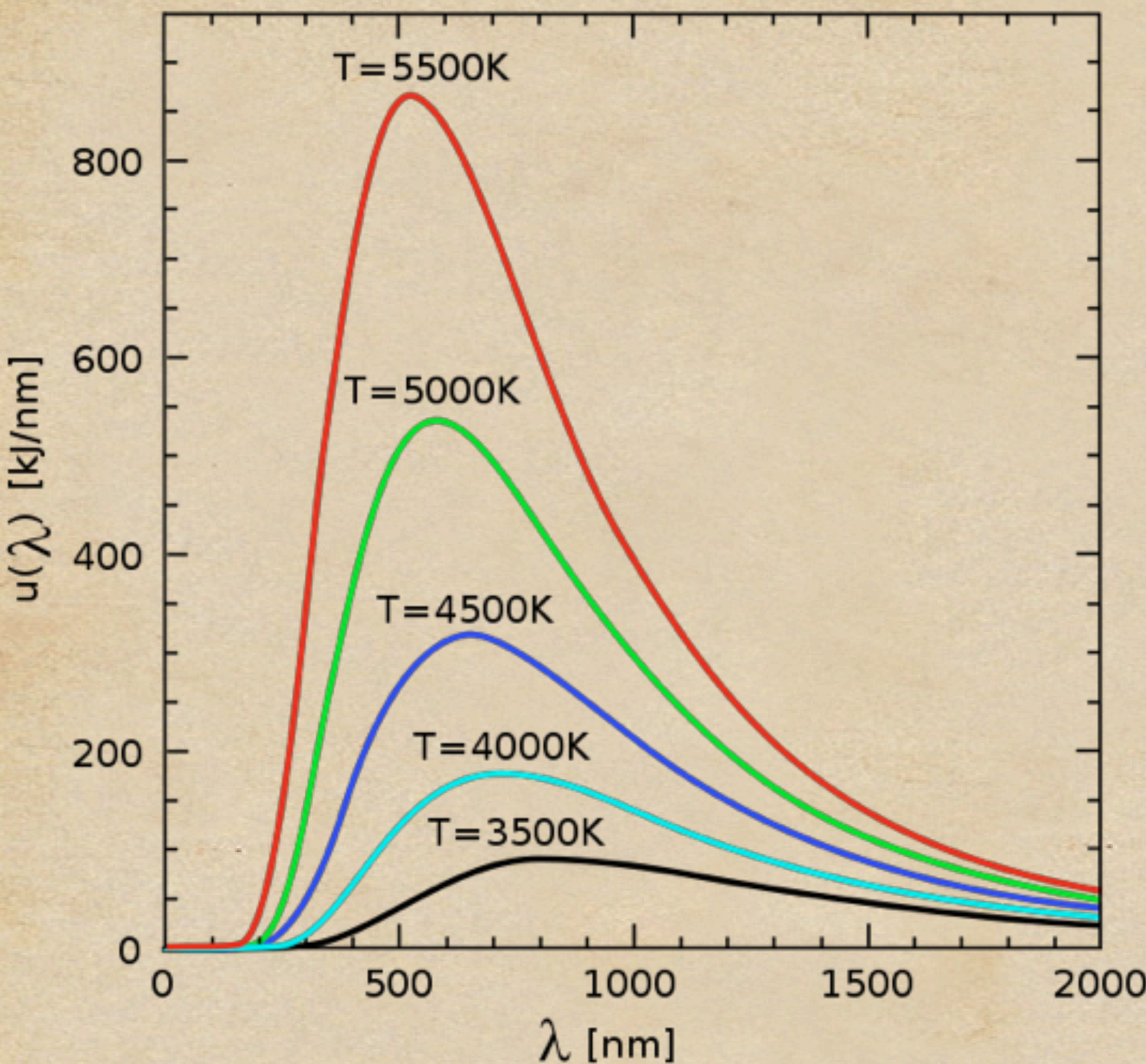


$$E = \frac{hc}{\lambda} \qquad or \qquad E = h\nu$$

E = energy of light (photons)
h = Planck's constant 6.63×10^{-34} J x sec
c= Velocity of light 3×10^{8} m/sec
λ = wavelength in meters
ν = frequency Hertz (=inverse sec)

Example: freq = 10^{13} Hertz energy = 6.63×10^{-23} J (!!small)

Wein's displacement law



u is the radiant
energy of a body at temperature T
as fn of wave length

$$\lambda_* = \frac{2898}{T(K)}$$

$$\mu\ m = \ 10^{-6}\ m$$

$$1\mu\ m = \ 10,000\ A^0$$

$$1\ A^0\ =\ 10^{-10}\ m$$

Nanometer = 10 Angstroms =10^{-9} m

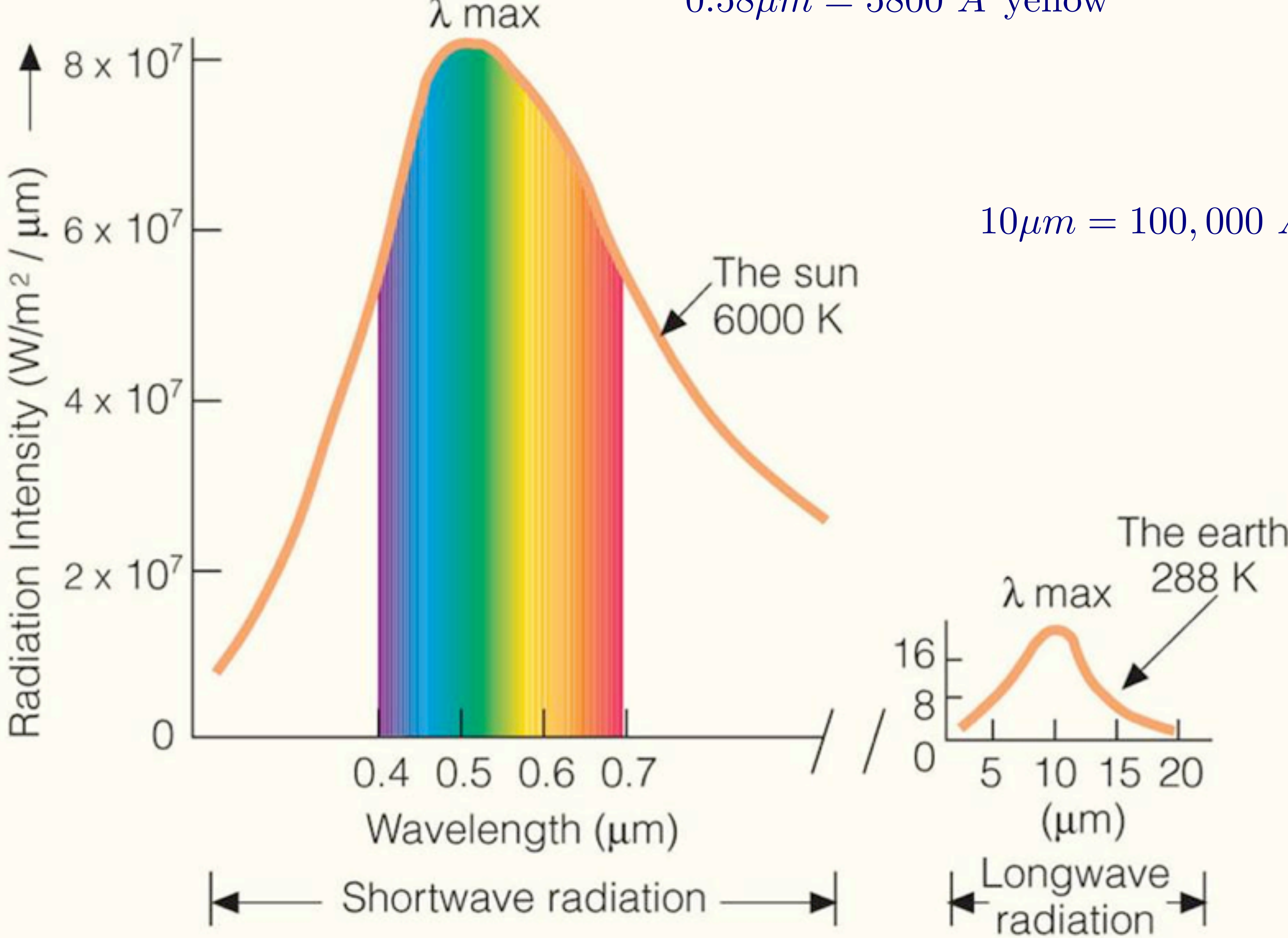
μ m

Every body radiates!!

Recall changes in color of a steel bar
as it is heated up in a furnace. "Red hot"

$$0.58\mu m = 5800\ A^0\text{yellow}$$

$$10\mu m = 100,000\ A^0$$



Stefan's law of radiation

P = Power radiated by the body

$$\frac{P}{A} = \frac{Watts}{sq.\ meter}$$

$$\frac{P}{A} = \epsilon\ \sigma\ T^4$$

ϵ = surface emittivity

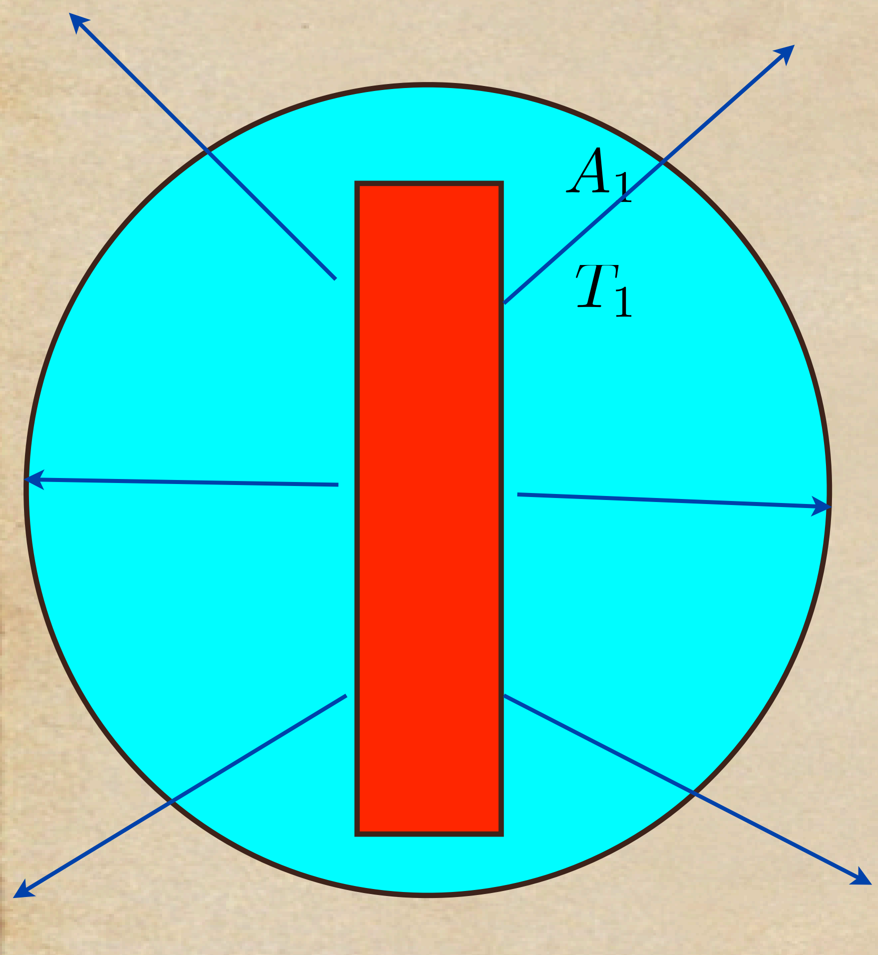
$\epsilon \sim .1$ shiny body

$\epsilon \sim .9$ dull body

SHINY BODIES EMIT LESS

$\therefore P \propto T^4$ Hot bodies radiate much more

$\therefore P \propto A$ Power is proportional to area of radiator.

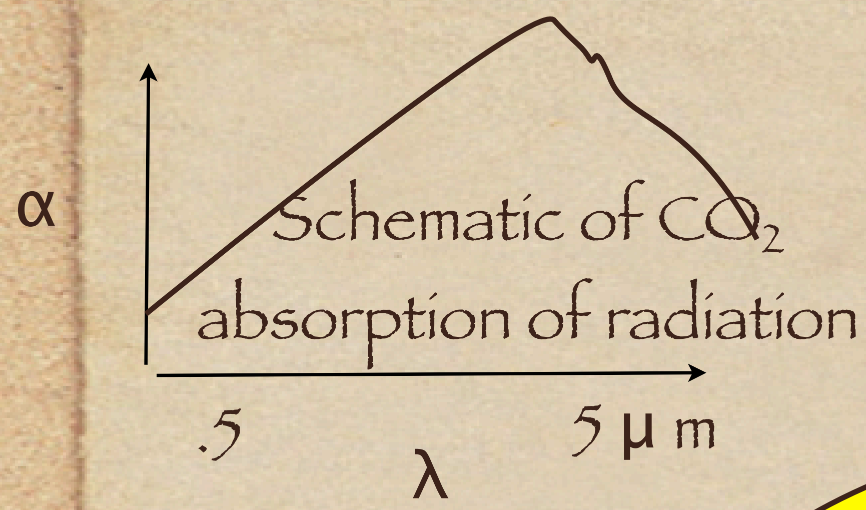


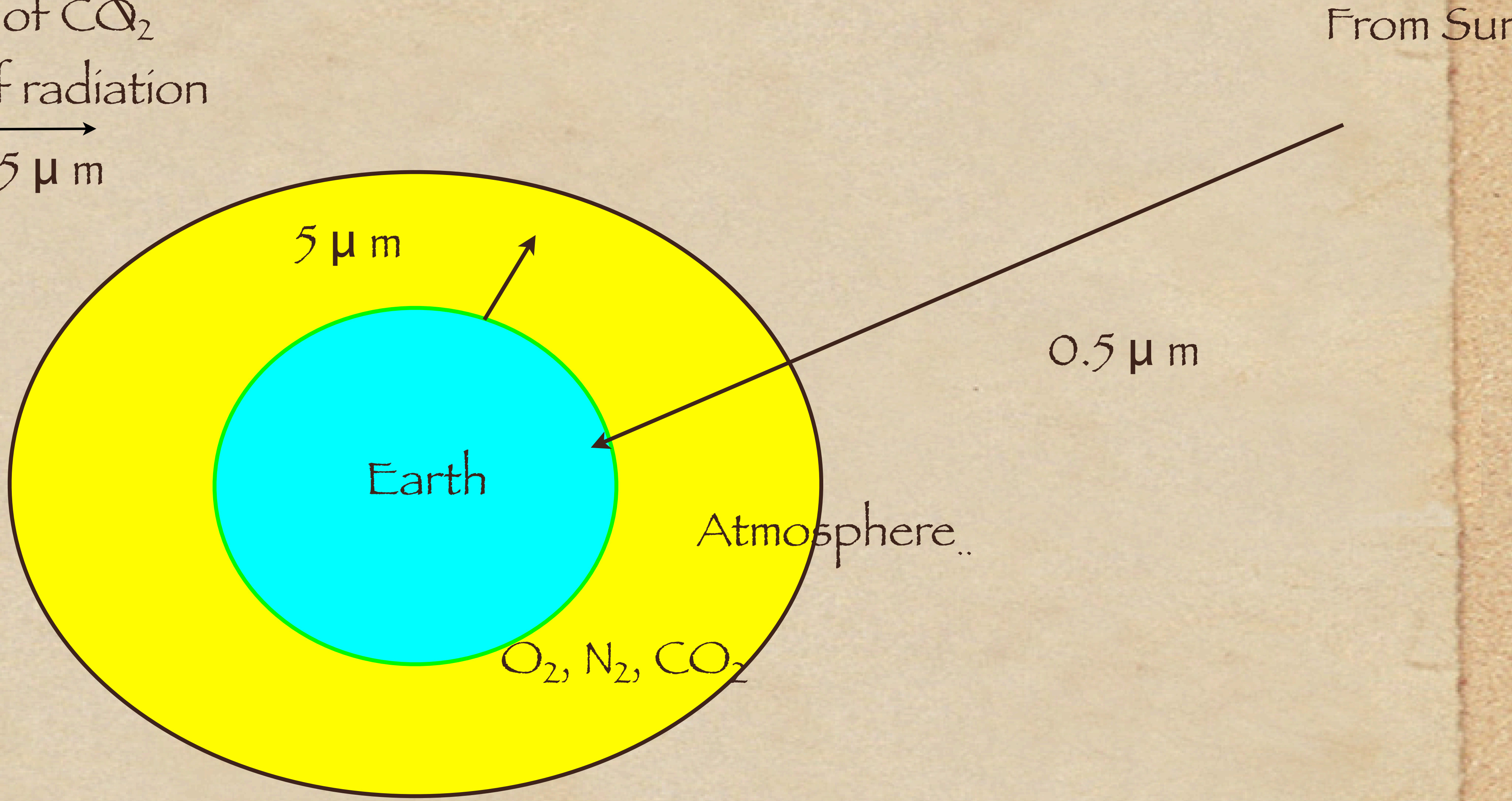
Each object is radiating isotropically by Stefan's law

Each object is also absorbing, and will in time reach "radiative equlibrium"

But that takes a lot more time than we are usually interested in!

However, "greenhouse effect" becomes possible due to different absorption at different wavelengths.

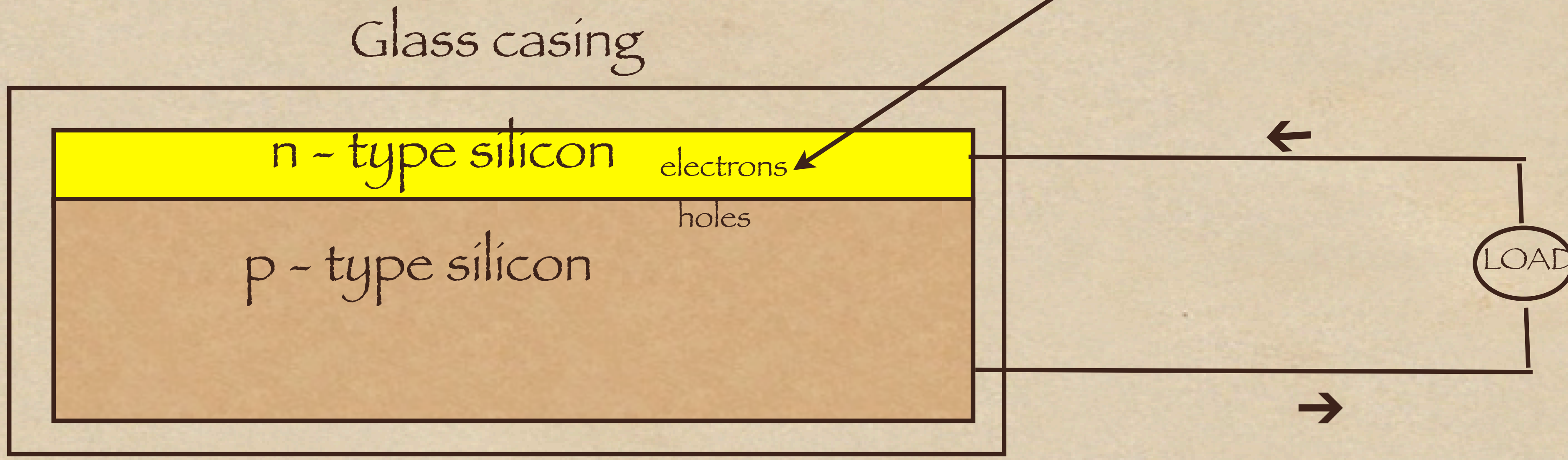




Thus CO_2 production impacts us very negatively: it absorbs in the range of 5 micrometers due to its quantum efficiency, and hence drives up the atmospheric temperature.

It did have a big role to play initially in getting us here, but human production of CO2 by industrial processes is changing the temperature worldwide.

Photoelectric effect and p-n junctions and Photovoltaics



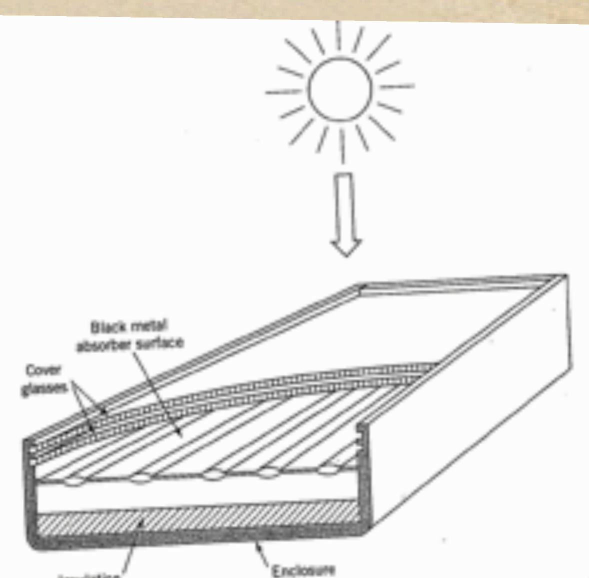
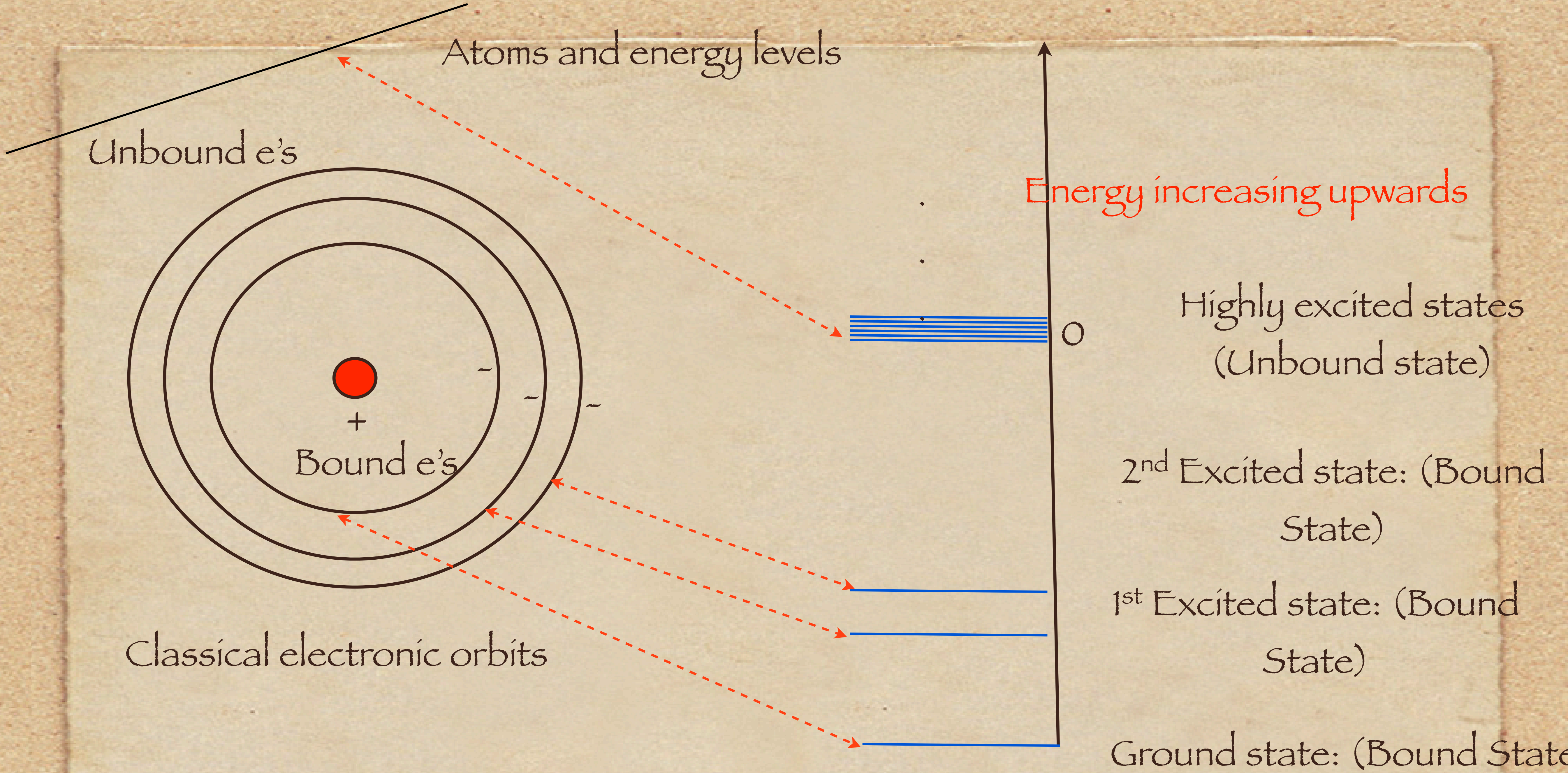


Figure 4.5 A cutaway view of a flat-plate solar collector with two cover glasses. A heat-transfer fluid is circulated through the tubular passages integrally formed into the metal absorber surface. (Not drawn to scale.)

Flat plate Collector system with circulating liquid

Atoms and energy levels



Modern picture of an atom.

Bohr's old quantum theory as described in many books.

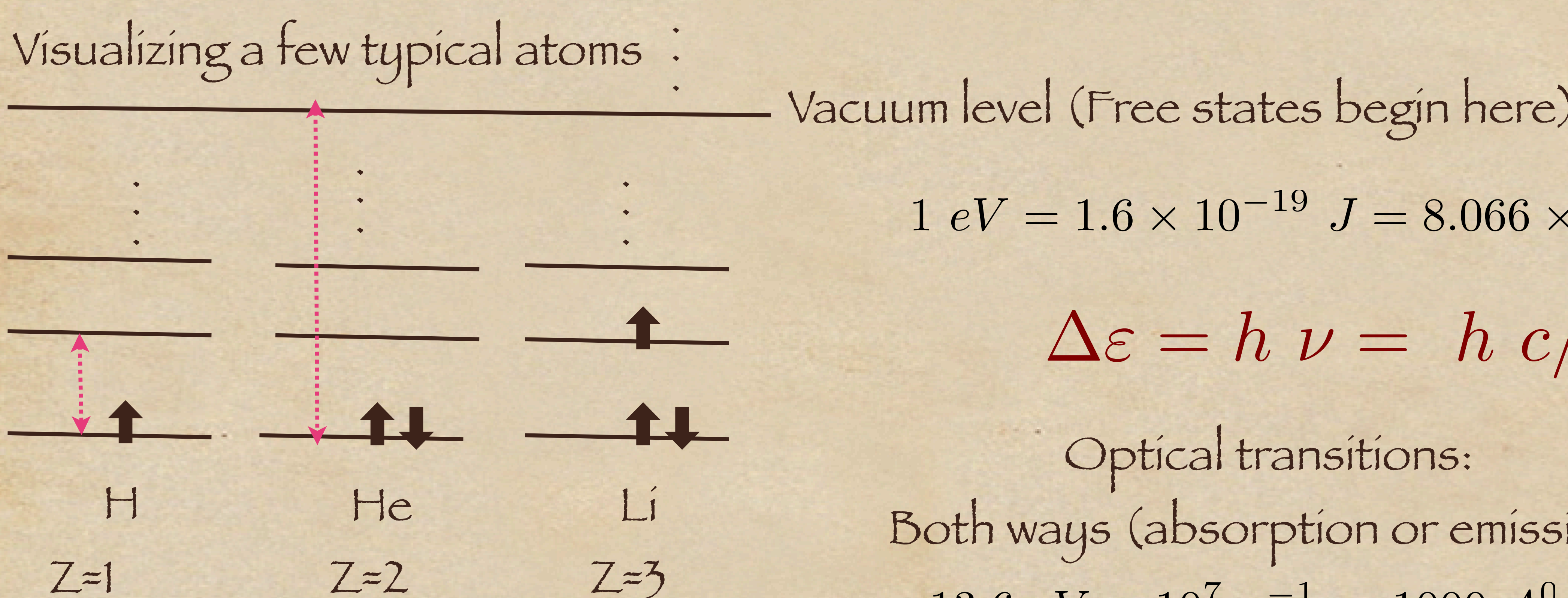
Excitation energies at resonance : $e_1 - e_2 = h\upsilon$

get related to specific wave lengths.

Atomic or molecular excitations dominate quantum efficiency of absorption (CO_2 problem)

- A bound state has an electron in "perpetual captivity" of an ion.
- Different bound states usually have different energies. However a given energy level can and does accomodate a fixed number of electrons. (2 for s, 6 for p, 10 for d etc).
- The number of bound states is usually infinity
- An unbound state corresponds to electrons that are free and not bound to an ion

Visualizing a few typical atoms



$$1\ eV = 1.6 \times 10^{-19}\ J = 8.066 \times 10^{5} m^{-1}$$

$$\Delta\varepsilon = h\ \nu = \ h\ c/\lambda$$

Optical transitions:

Both ways (absorption or emission)

$$13.6\ eV \sim 10^{7} m^{-1} \rightarrow 1000\ A^{0}$$