Lecture 13

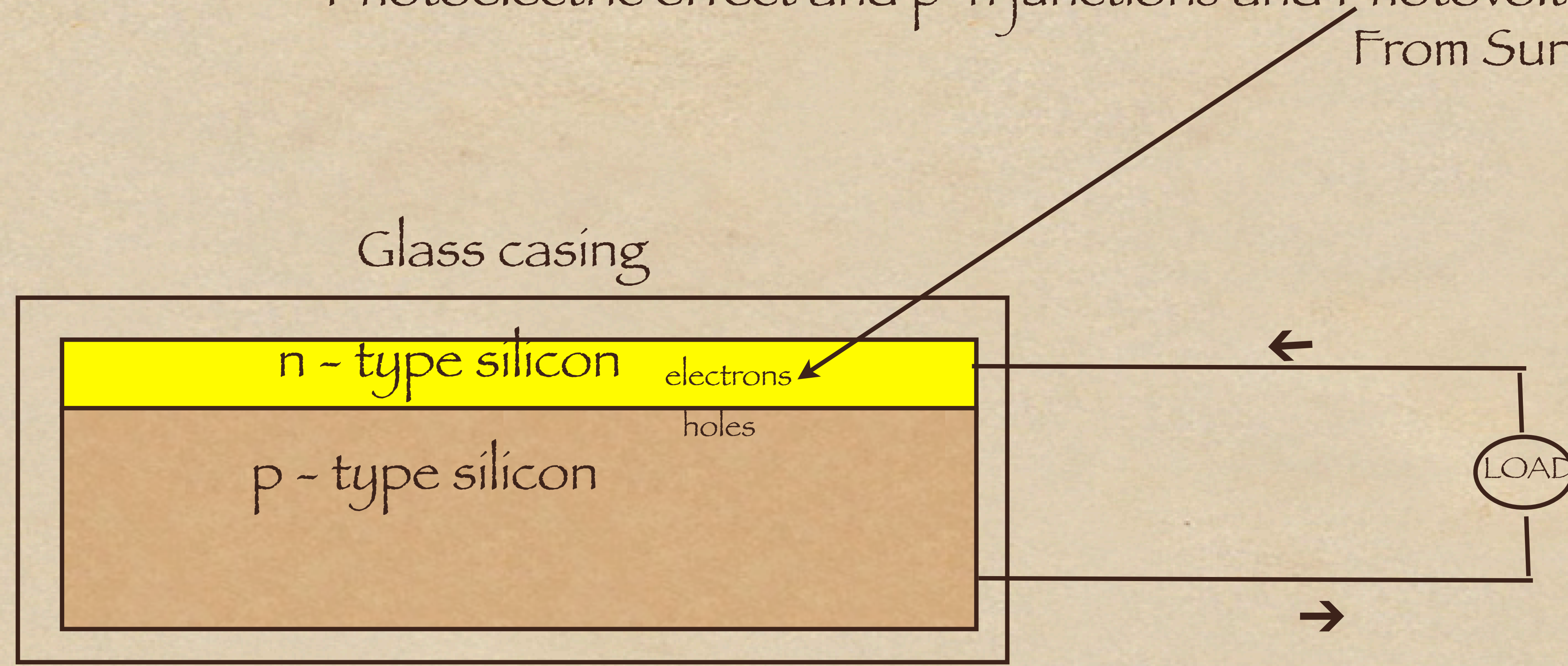
May 12, 2011

Metals Insulators and Semiconductors

Basic ideas from Quantum theory

From atoms to solids

Photoelectric effect and p-n junctions and Photovoltaics



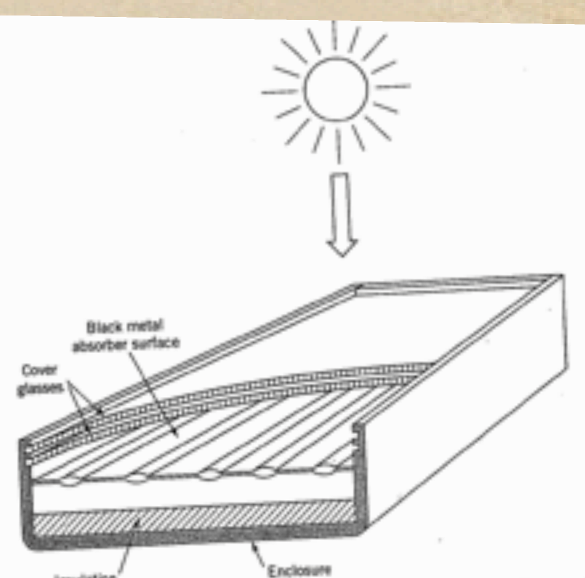
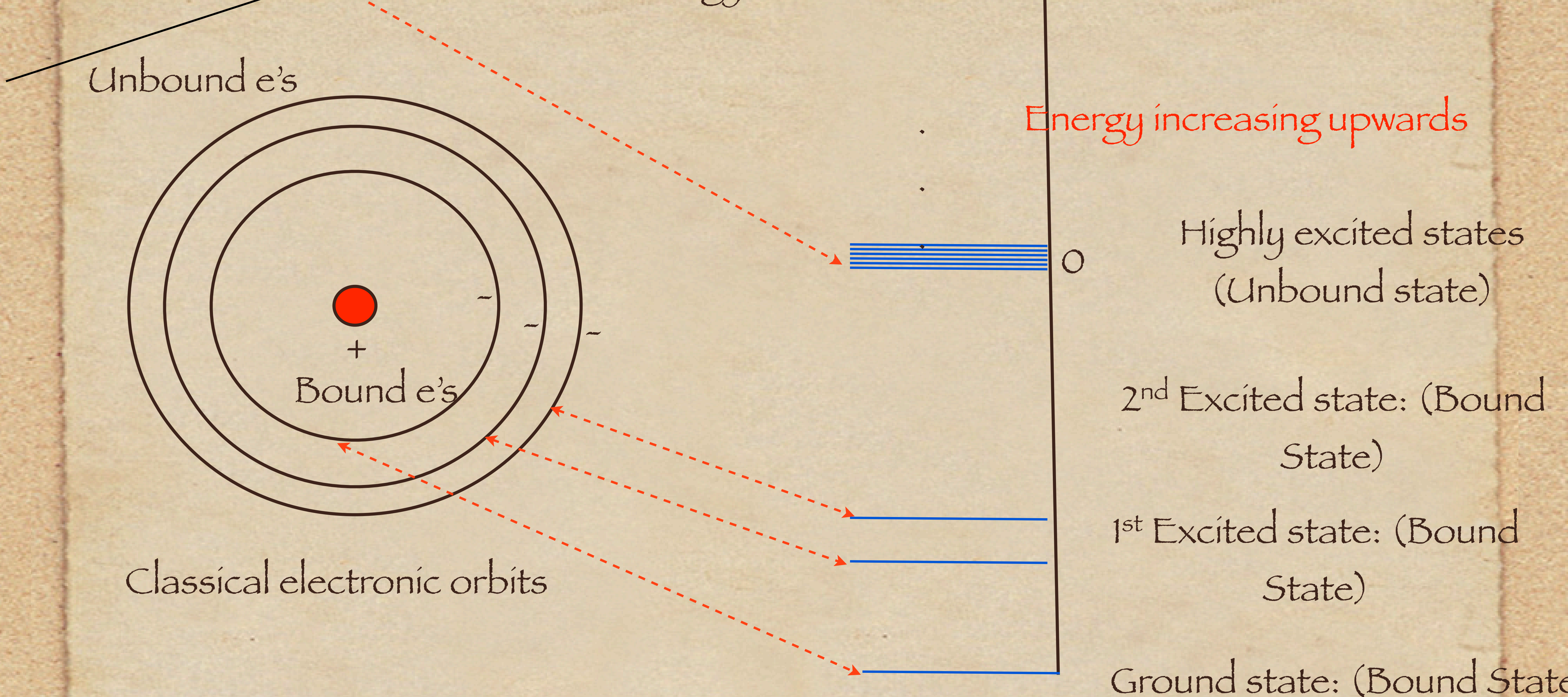


Figure 4.5 A cutaway view of a flat-plate solar collector with two cover glasses. A heat-transfer fluid is circulated through the tubular passages integrally formed into the metal absorber surface. (Not drawn to scale.)

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.

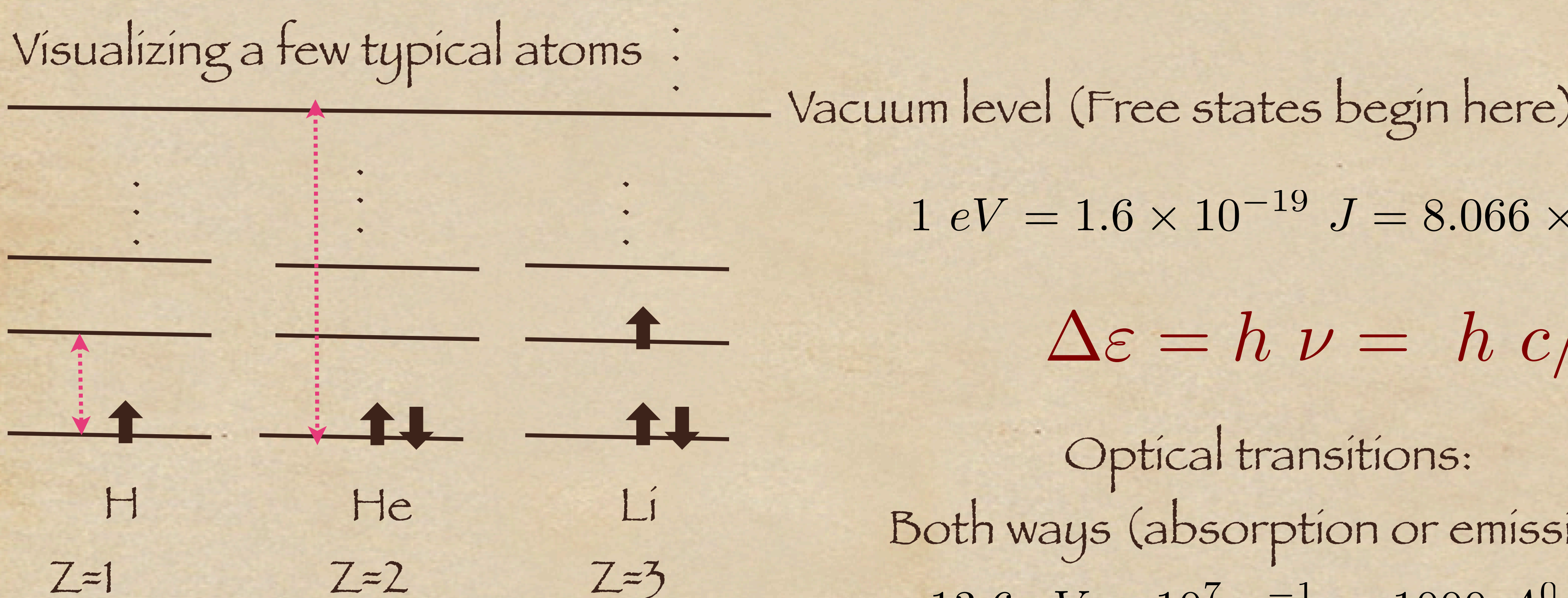
Excitation energies at resonance : $e_1 - e_2 = h\upsilon$

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



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

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

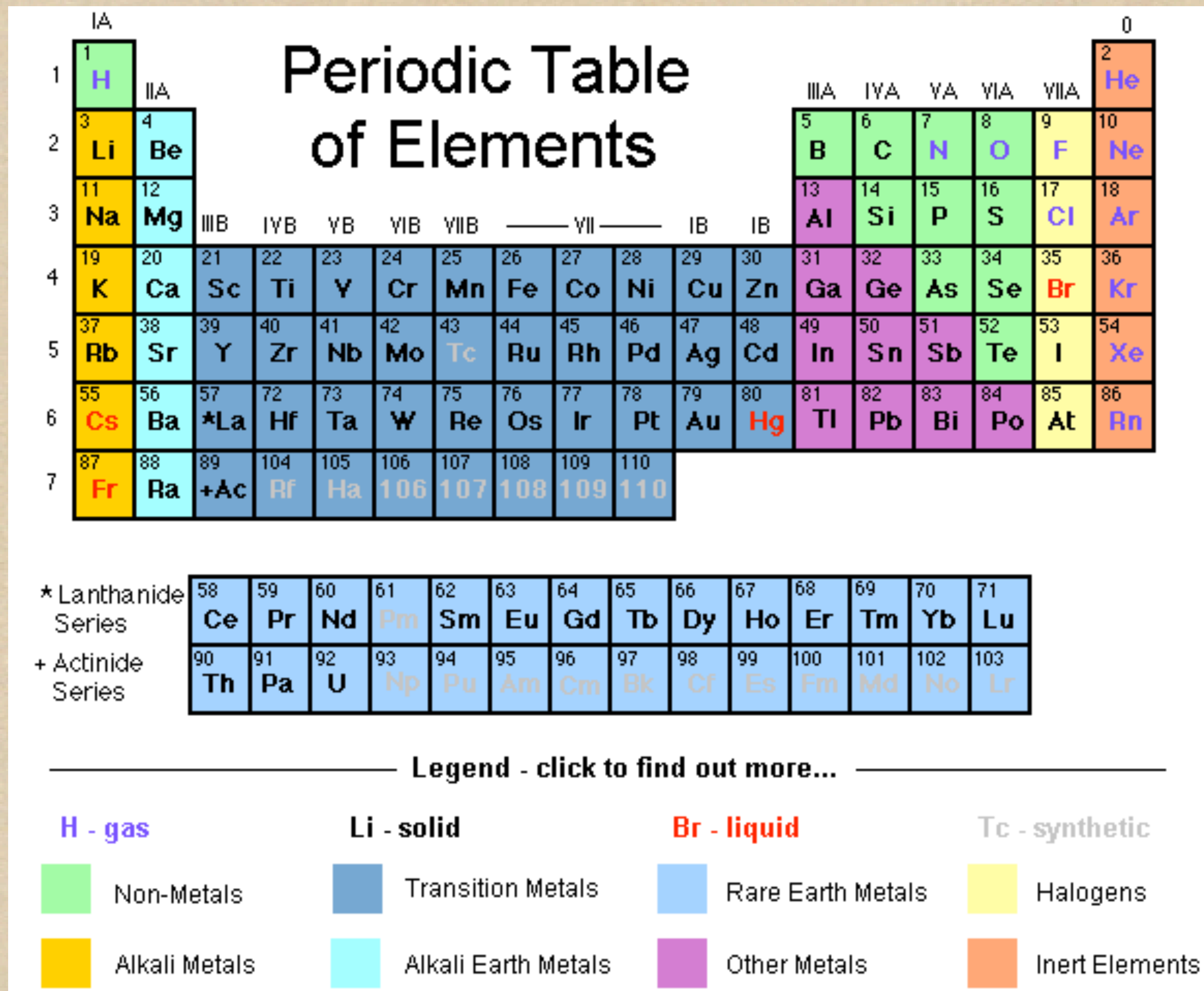
Optical transitions:

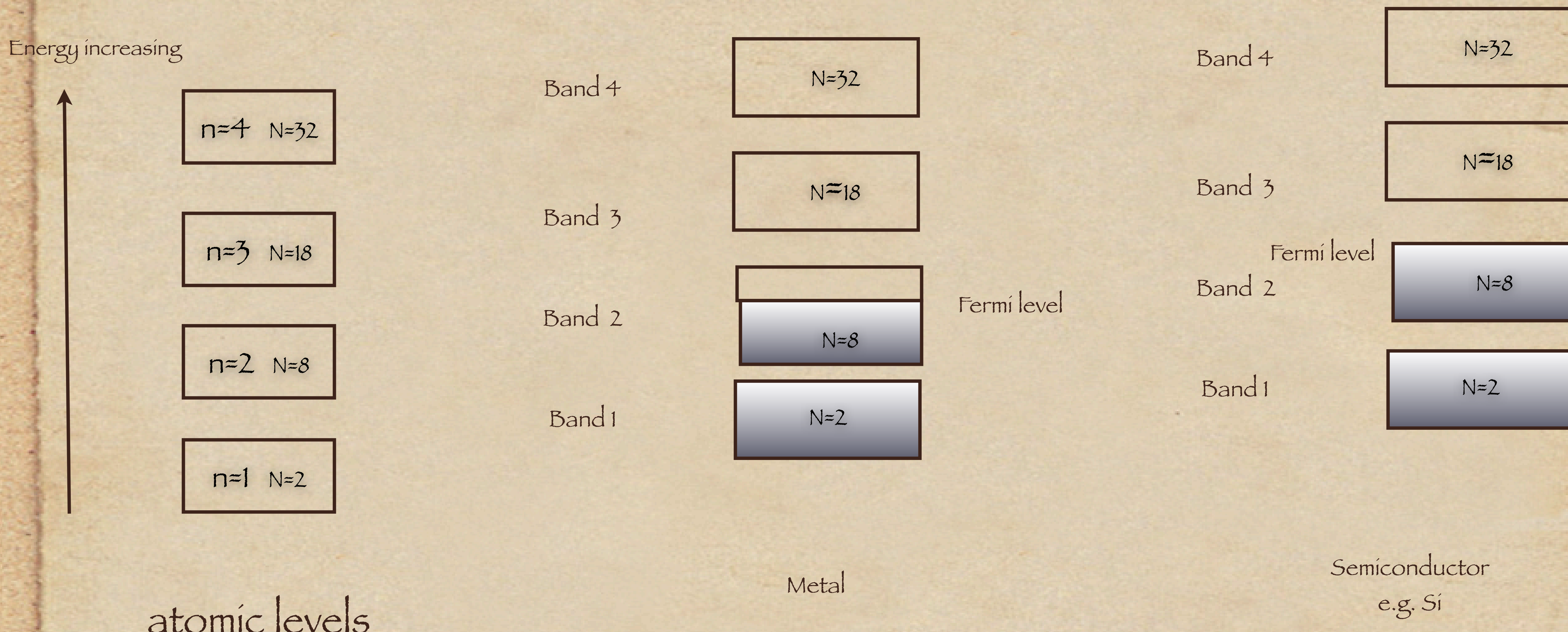
Both ways (absorption or emission)

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

Pauli's principle: Each "quantum state" can contain a fixed number of electrons. The value of the fixed number (i.e. the capacity) is determined by symmetry, it is at least 2 in the absence of magnetic fields. If we have more, electrons, we need to go search for vacancies.

Basic concept of metal and nonmetal-> semiconductor

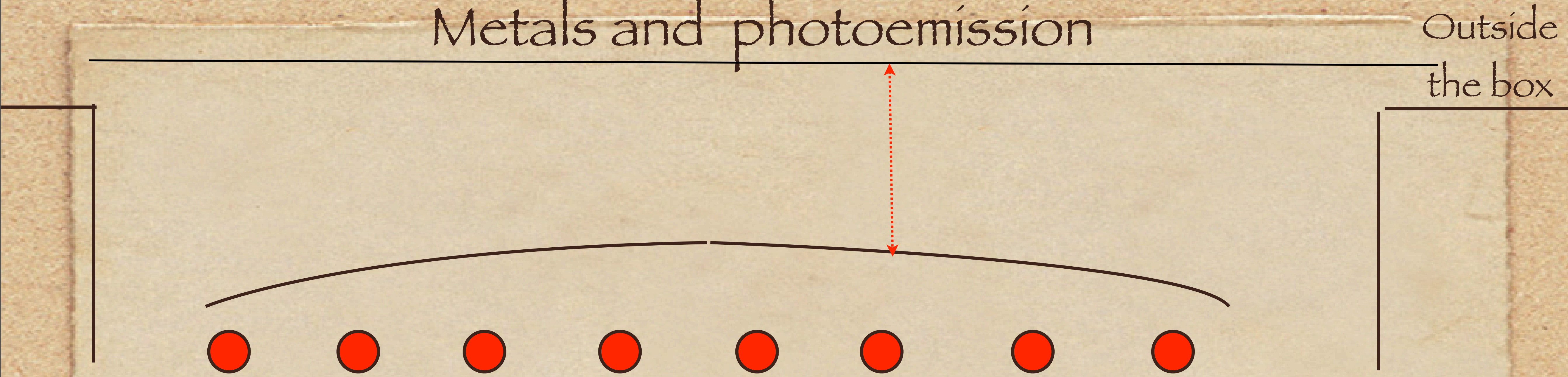




n= Principal Q N
N= number or e's accomodated

Solid= array of atoms

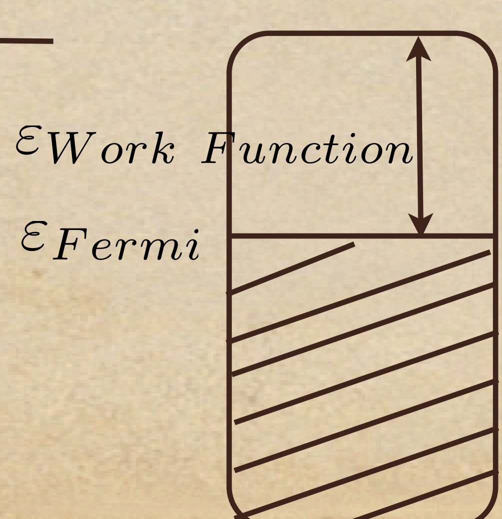
Metals and photoemission



Electron in the metal is shared by many ions. It is "unbound" from any one ion and is delocalized.

But the electron is confined to the box where the ions are located.

Optical transition corresponds to the photoelectric effect.



Filled Fermi sea of electrons corresponds to occupied unbound states within the box.

Silicon

⋮

↑↓ $3p^2$

↑↓ $3s^2$

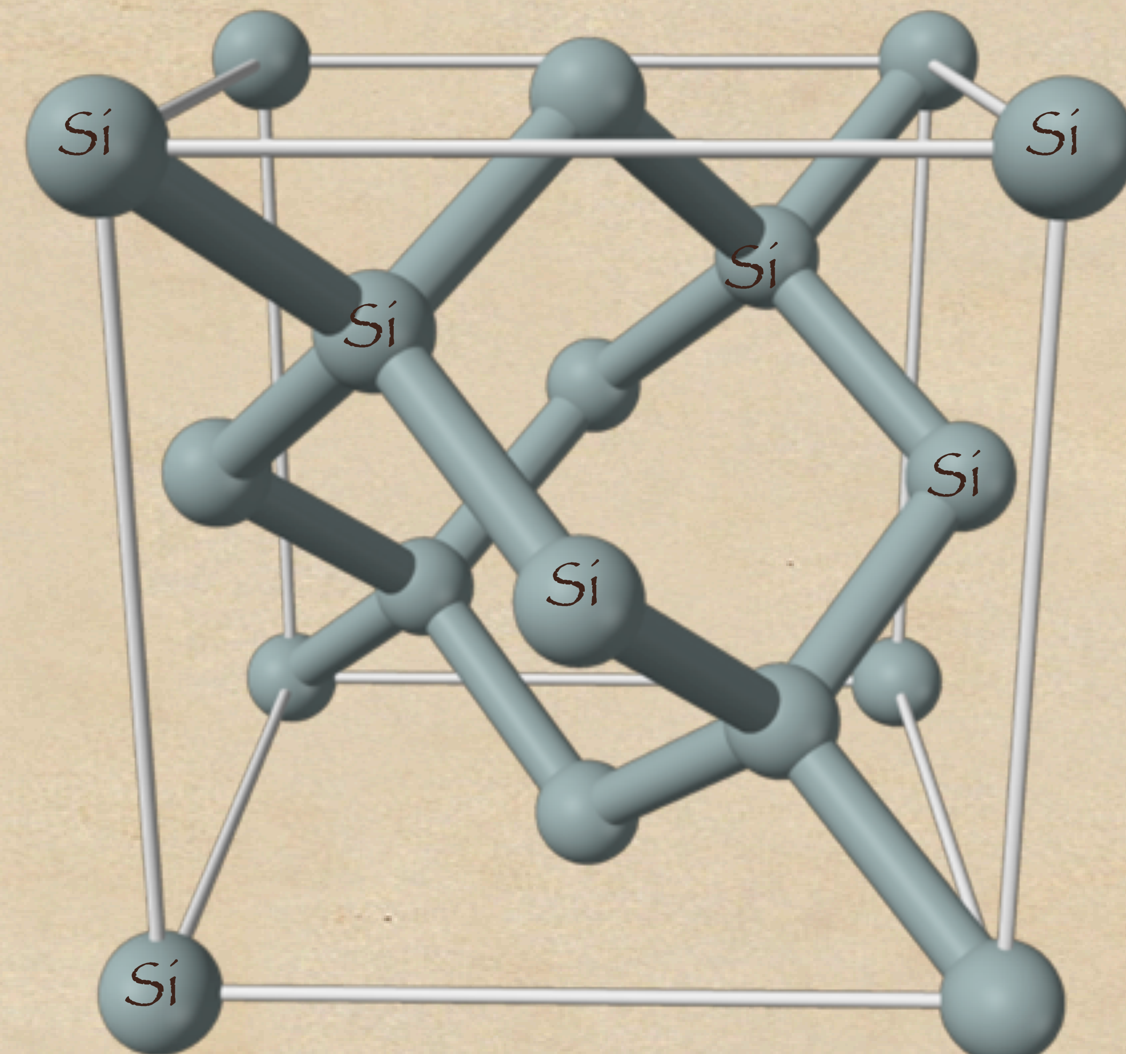
↑↑↑↓↓↓ $2p^6$

↑↓ $2s^2$

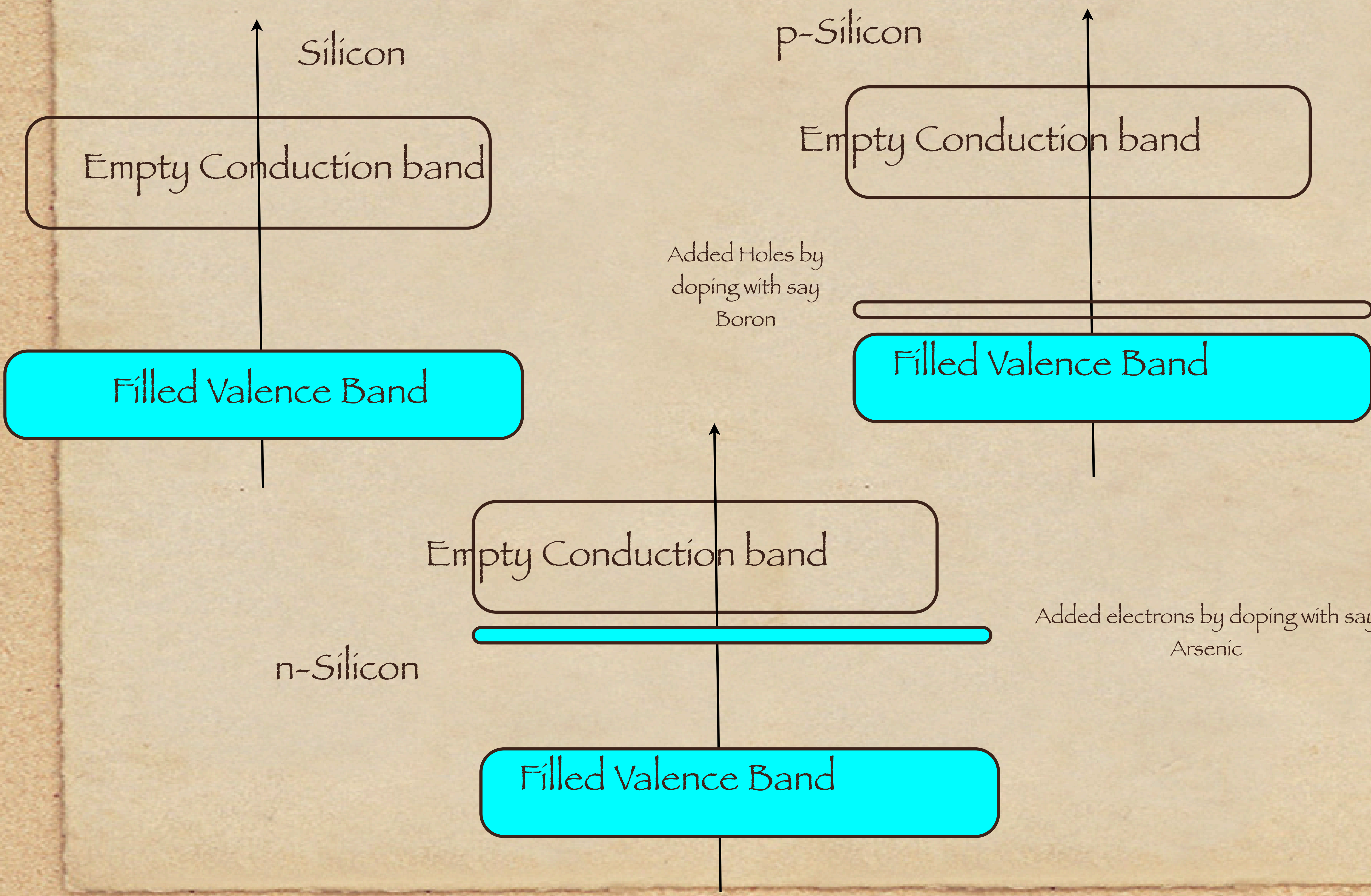
↑↓ $1s^2$

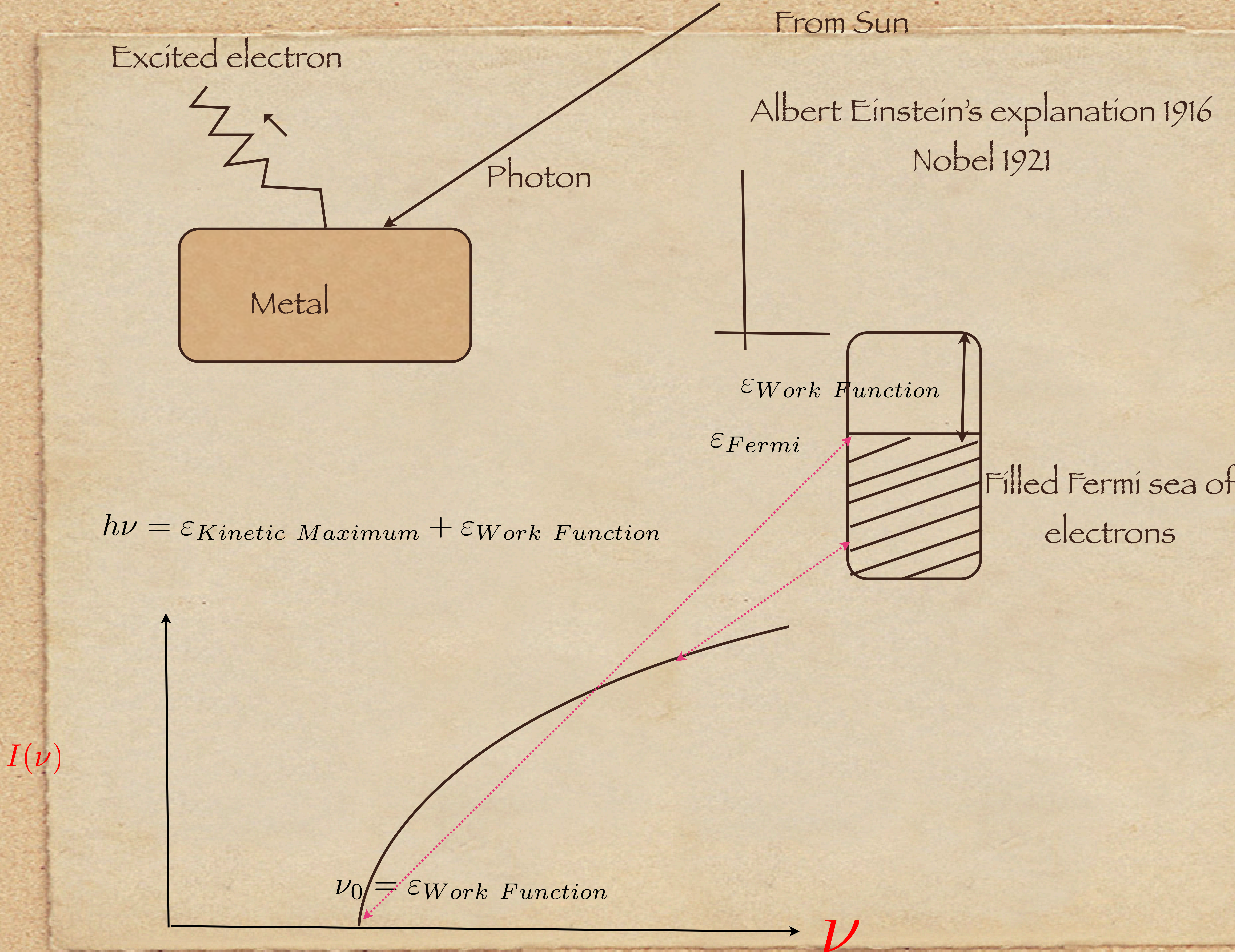
Si

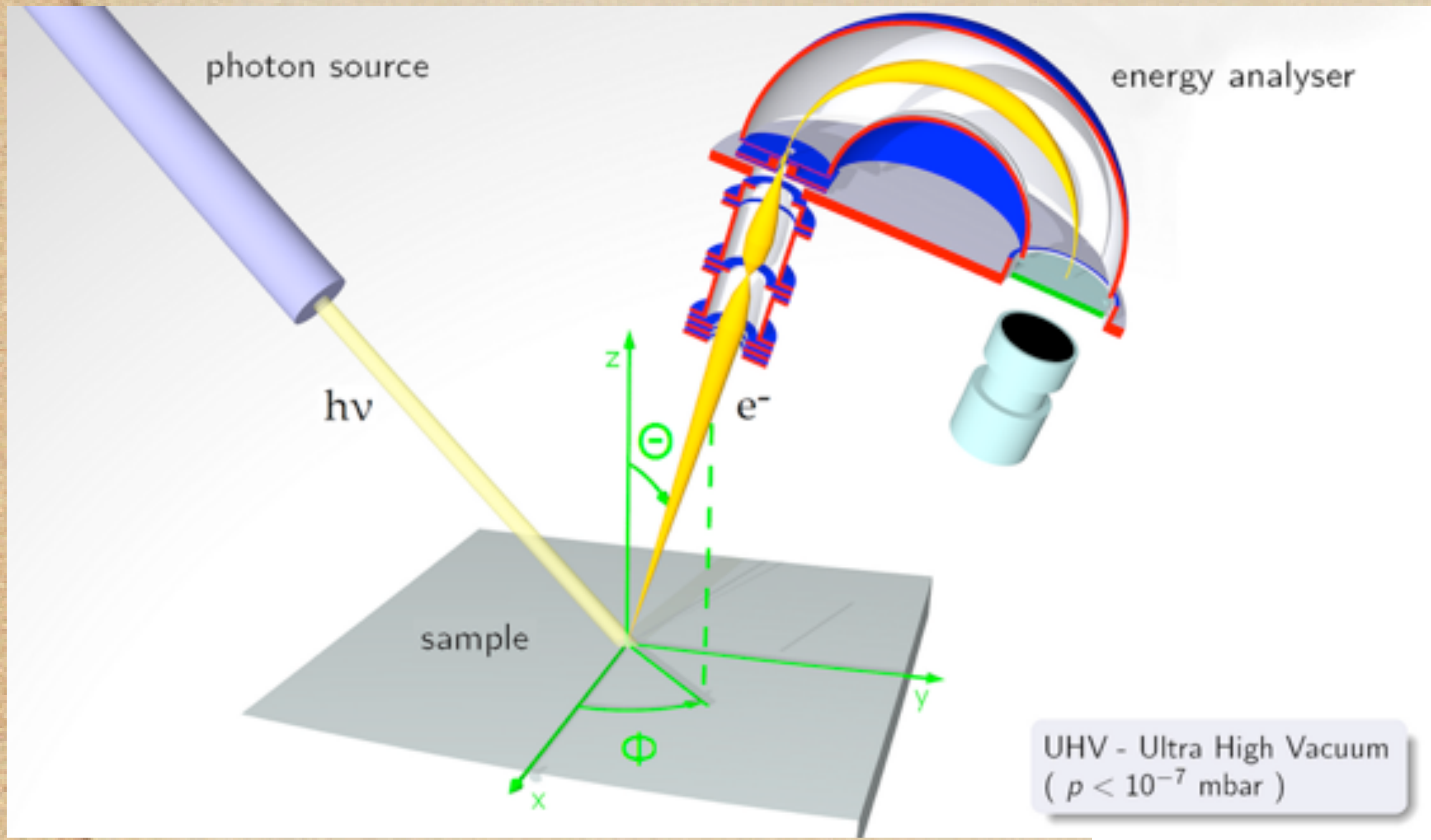
Z=14



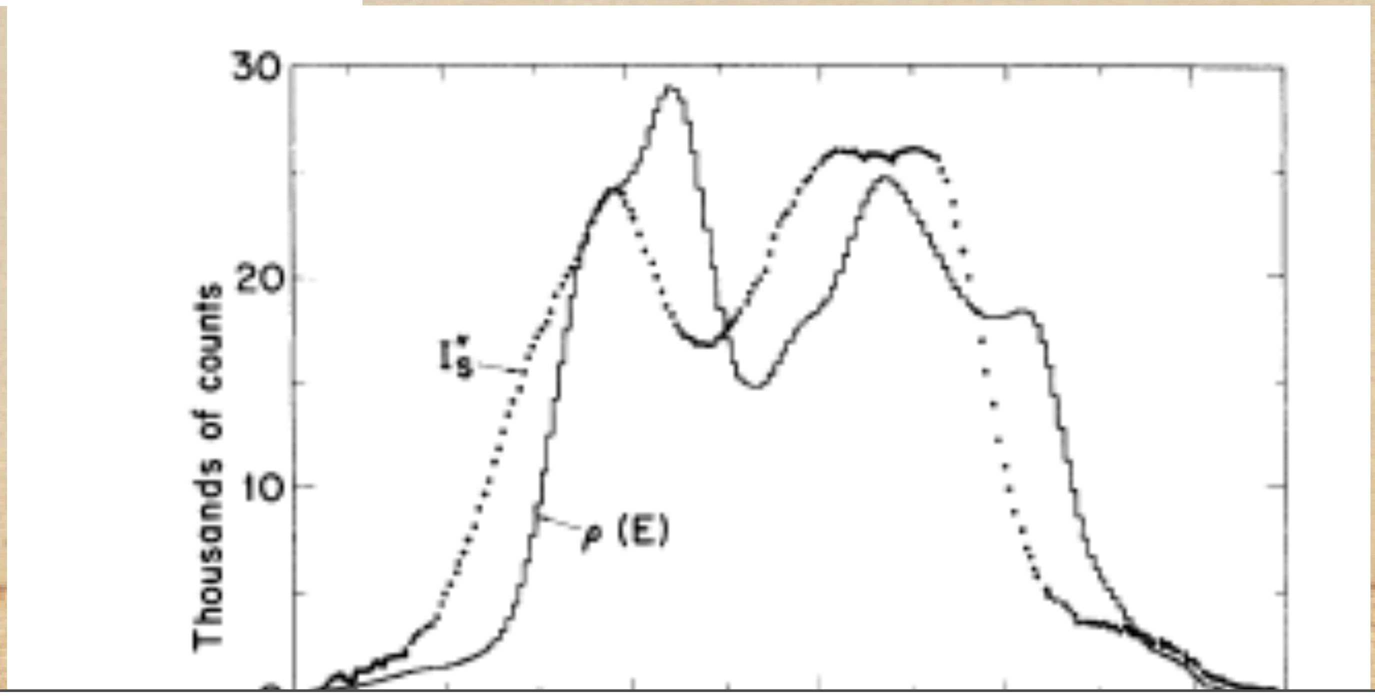
Optical transitions only between opposite parity states
(s to p) is allowed, but not (s to d)


Silicon
Empty Conduction band
Filled Valence Band
p-Silicon
Empty Conduction band
Added Holes by doping with say Boron
Filled Valence Band
Empty Conduction band
n-Silicon
Added electrons by doping with say Arsenic
Filled Valence Band


From Sun
Excited electron
Albert Einstein's explanation 1916
Nobel 1921
Photon
Metal
$\varepsilon_{Work\ Function}$
ε_{Fermi}
Filled Fermi sea of electrons
$h\nu = \varepsilon_{Kinetic\ Maximum} + \varepsilon_{Work\ Function}$
$I(\nu)$
$\nu_0 = \varepsilon_{Work\ Function}$
ν

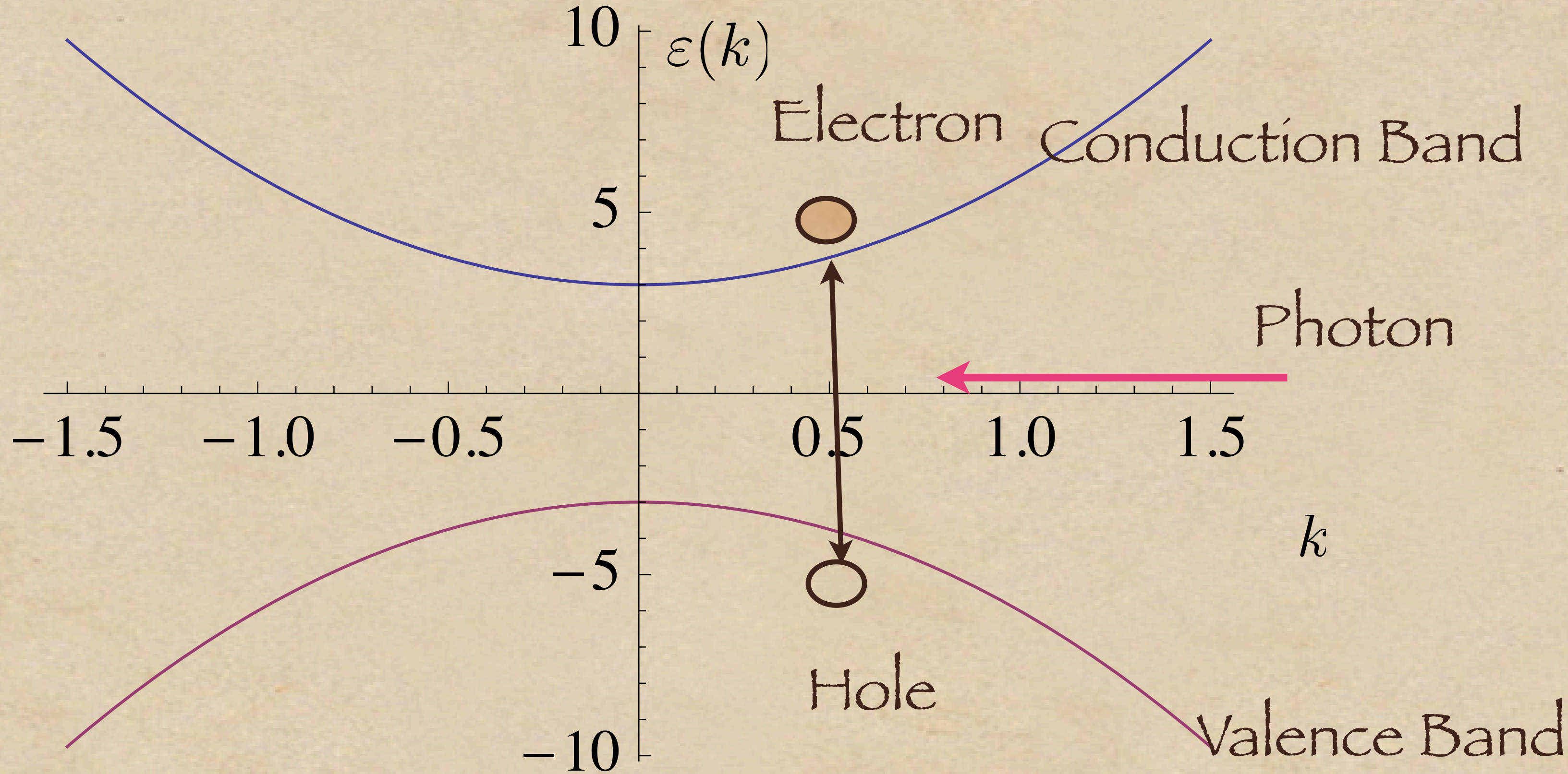


Contact Professor G. H Gweon
UCSC Physics to see this in action



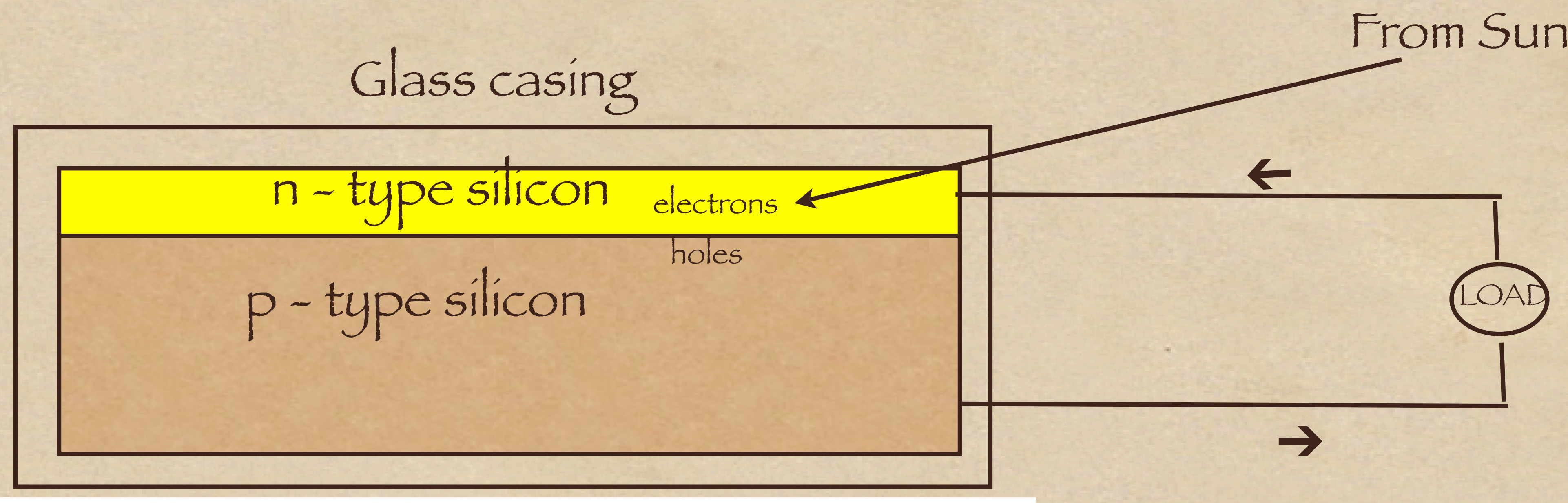
Semiconductor

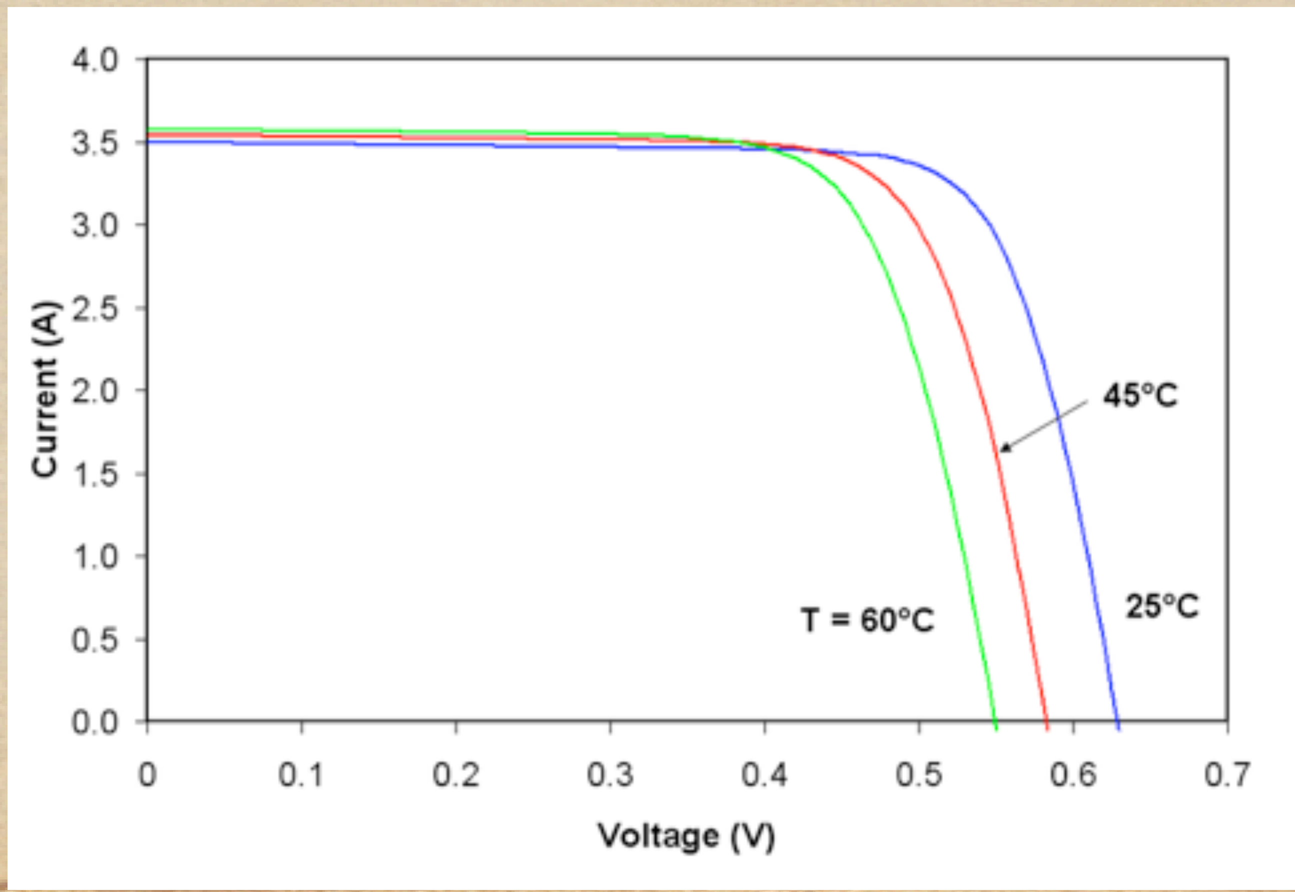
Picture of optical excitations



Photoelectric effect and p-n junctions and Photovoltaics

Each cell ~ 2" dia and 1/16" thick- stack up some 50 of them to get a voltage of 20/25 volts





Efficiency of solar cells:

Ratings:

Peak power W_p, the electrical power output when we have $1000 W/m^2$ incident at 25^oC

	Efficiency	Manufacturing cost $/Wp
Si single crystal	14-17%	2.9-4.0
Si amorphous	5-8%	2.00-3.00