LECTURE #20

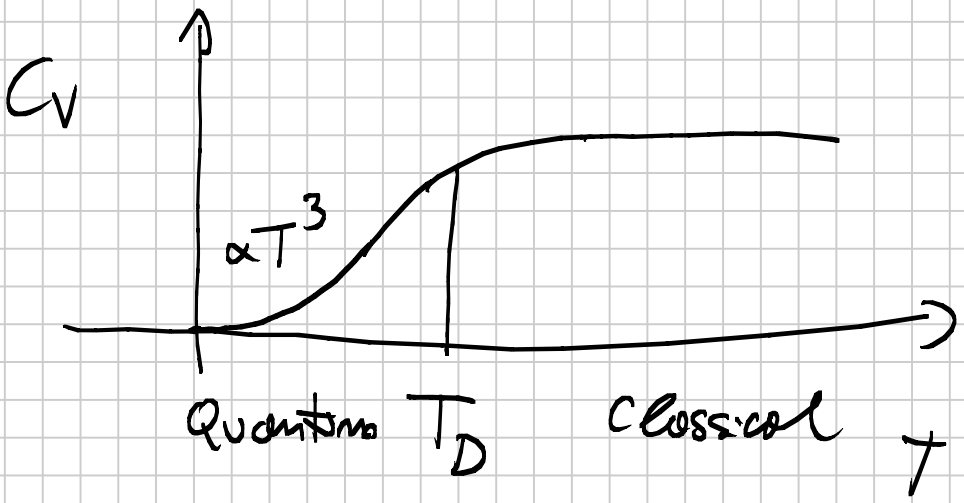
Note Title 11/19/2007

WED NOV 21

CLASS (HOMEWORK # 5 IN CLASS)

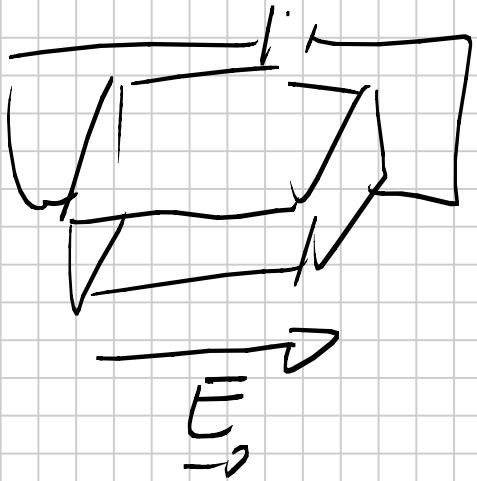
→ THERMAL PROPERTIES ←

$C_V(T)$



$K_B T_D$

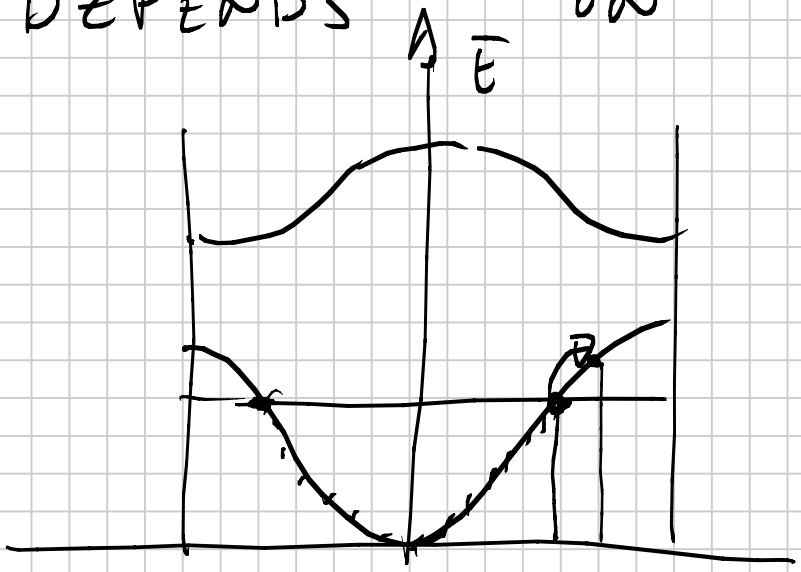
→ TRANSPORT PROPERTIES



APPLY ELECTRIC FIELD

MEASURE CURRENT

GOOD CONDUCTORS OR BAD CONDUCTORS IT DEPENDS ON BAND STRUCTURE



BAND NOT COMPLETELY FILLED

FERMI SURFACE

$\hbar k_F = p_F$ ELECTRON MOMENTUM

$\vec{F} = -e\vec{E}$

$$\frac{\Delta \vec{p}}{\Delta t} = -e\vec{E}$$

WE HAVE PHONONS IN THE SYSTEM $\Rightarrow$ ACCELERATION OCCURS ONLY BETWEEN 2 PHONON SCATTERING EVENTS.

$$\langle \Delta \vec{p} \rangle_{AVERAGE} = \vec{F} \cdot \tau$$

τ = RELAXATION TIME (AVERAGE DELAY BETWEEN TWO ELECTRON-PHONON SCATTERING)

$$m\langle v_f - v_i \rangle = m\langle \vec{v}_f \rangle = -e\vec{E}\tau$$

$$\vec{j} = -en\langle \vec{v}_f \rangle = \frac{ne^2\tau}{m}\vec{E}$$

σ CONDUCTIVITY

$$\vec{j} = \sigma \vec{E} \qquad \sigma = \frac{ne^2\tau}{m}$$

[DRUDE CONDUCTIVITY]

$$\frac{1}{\sigma} = \rho \rightarrow \text{RESISTIVITY (OHM-CM)}$$

BAND COMPLETELY FILLED

PAULI PRINCIPLE

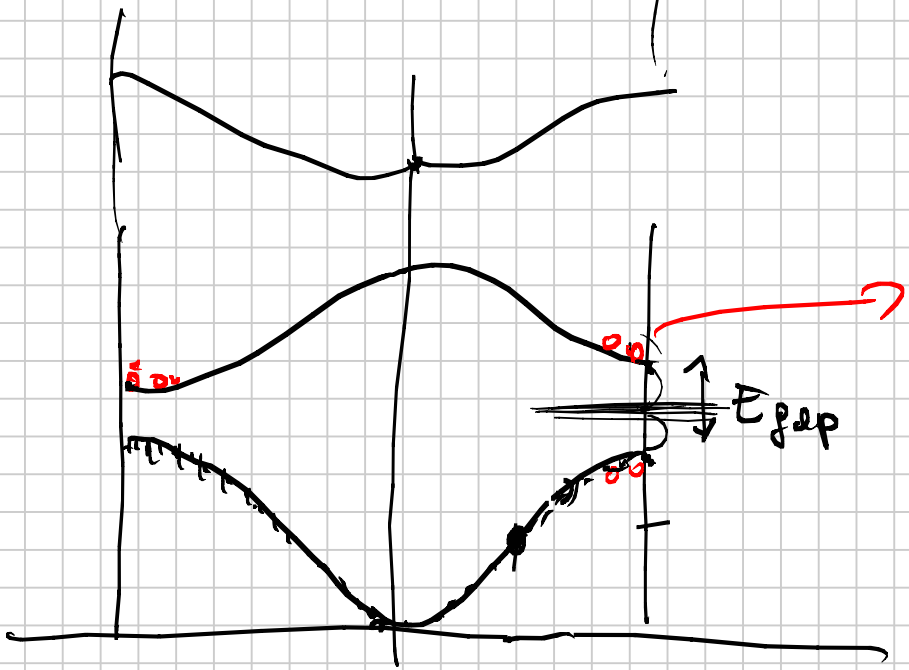
$\Downarrow$

NO $\langle \Delta \vec{p} \rangle$ POSSIBLE

$\Rightarrow \vec{F} = 0 \Rightarrow$ SYSTEM INSULATOR

CONSIDER SYSTEM WITH FILLED BAND

BUT FINITE TEMPERATURE



$k_B T \sim E_g$

→ THERMALLY EXCITED ELECTRONS

↓

THEY CAN GIVE CURRENT

CLASSIFY SOLIDS AS:

① METALS

FERMI SURFACE

UNFILLED BAND

$$\sigma \sim \frac{n e^2 \tau}{m}$$

$$\rho = \frac{1}{\sigma} \sim 10^{-6}\ \Omega\text{-cm}$$

② SEMICONDUCTORS

NO FERMI SURFACE

$$E_g \sim K_B T$$

$$\rho \sim 10^{-3} \sim 10^{9}\ \Omega\text{-cm}$$

T AT ROOM

③ INSULATOR

$$E_g > K_B T$$

$$\rho \text{ UP TO } 10^{22}\ \Omega\text{-cm}$$

$\rho(T)$?

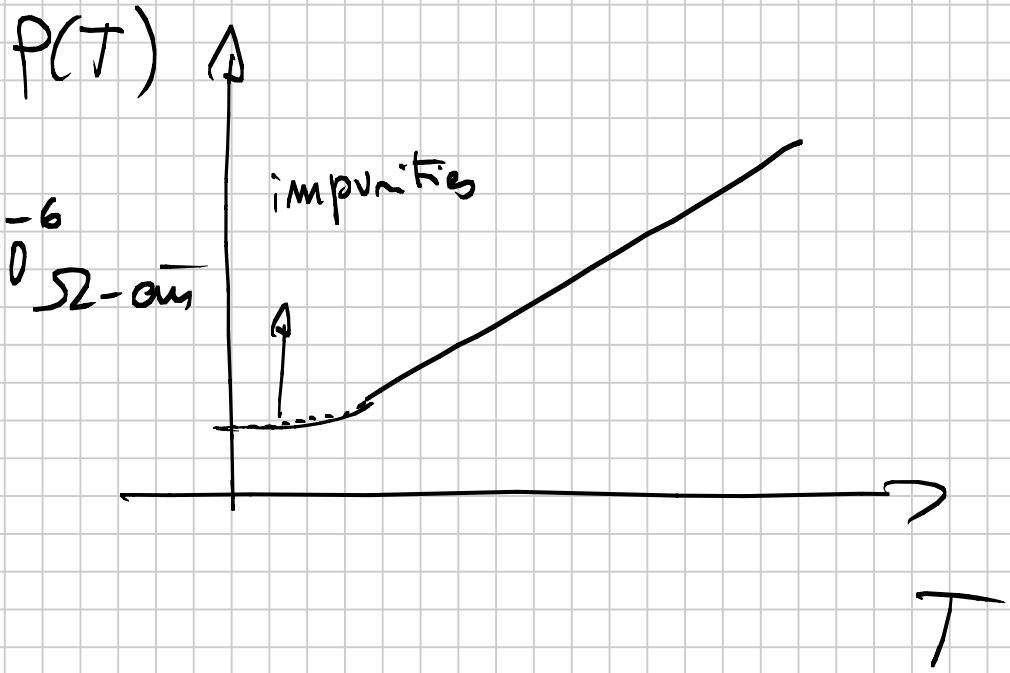
① METAL $\quad \rho = \dfrac{m}{n e^2} \cdot \boxed{\dfrac{1}{\tau}}$

PROBABILITY OF SCATTERING WITH PHONONS

$\Downarrow$

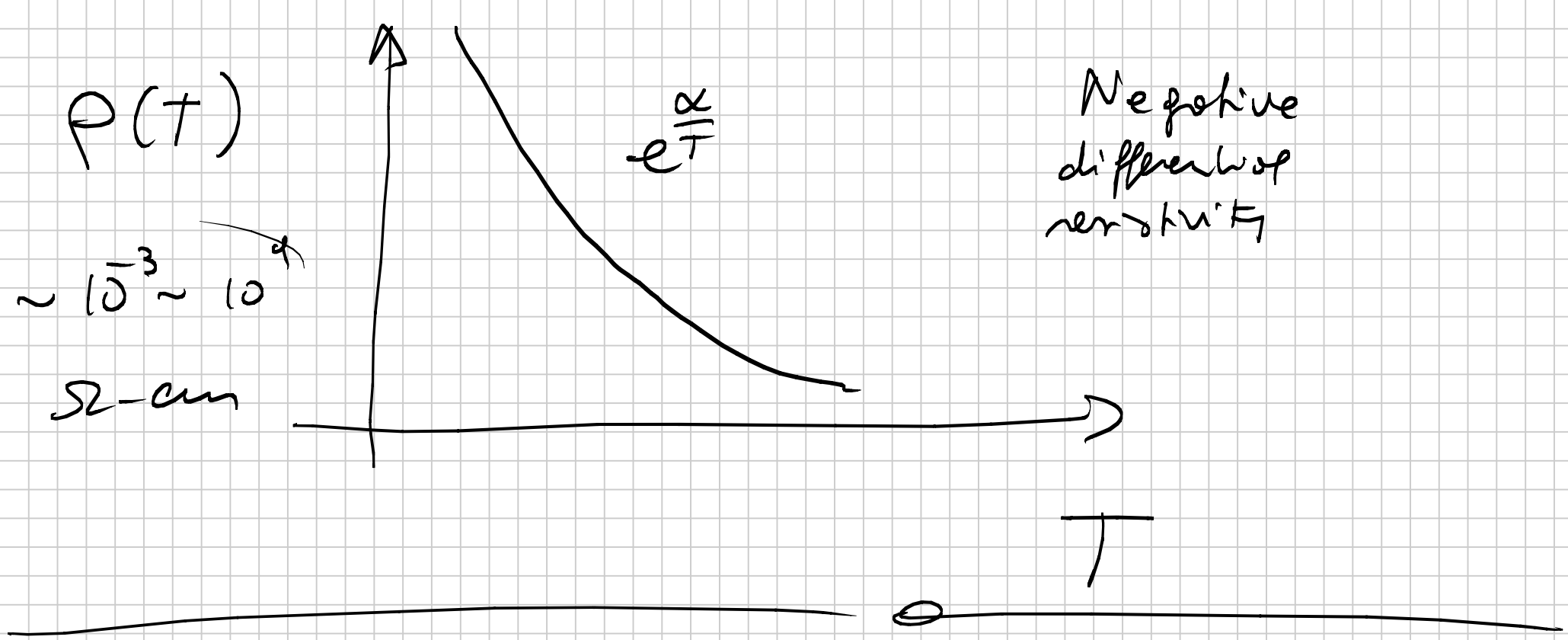
$\dfrac{1}{\tau} \propto$ DENSITY OF PHONONS

$\dfrac{1}{\tau} \propto T$



② SEMICONDUCTOR

$$\sigma \sim \frac{n(T)\, e^2 \tau}{m} \sim \frac{n_0 e^{-\frac{E_g}{2 k_B T}} e^2 \tau(T)}{m}$$



EXAMPLES OF SEMICONDUCTORS

GROUP IV SEMICONDUCTOR

FCC WITH BASIS $\frac{a}{4}(111)$

- C → DIAMOND $E_g \sim 4\ eV$
- Si → 1.1 eV
- Ge → .8 eV
- Sn → .2 eV
- Pb → METAL

III - V SEMICONDUCTORS

B	N
Al	P
Ga	As
In	Sb

FCC WITH BASIS

Ga AT (0,0,0)

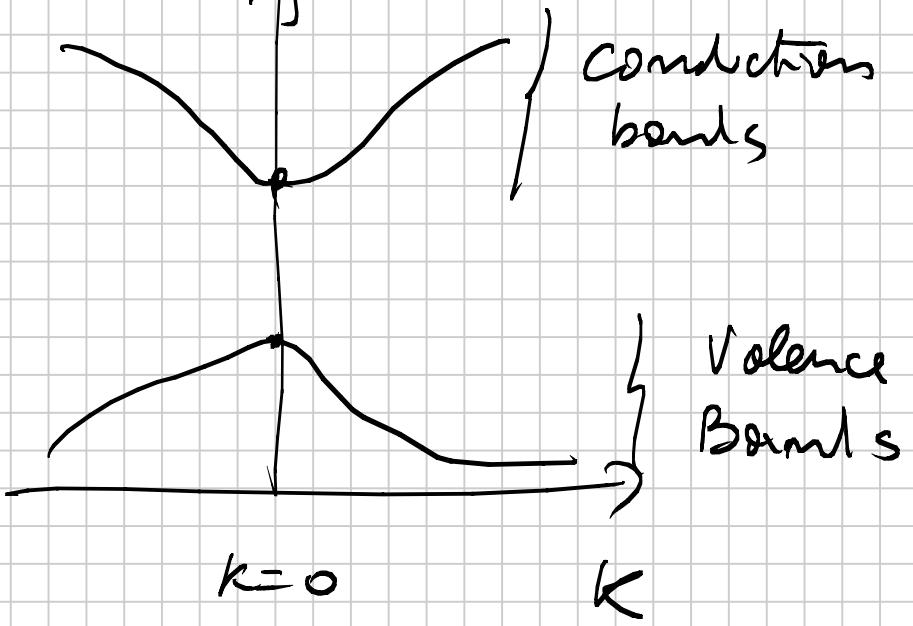
As AT $\frac{a}{4}(1,1,1)$

II - VI

Zn	Se
Cd	Te

FCC OR HCP

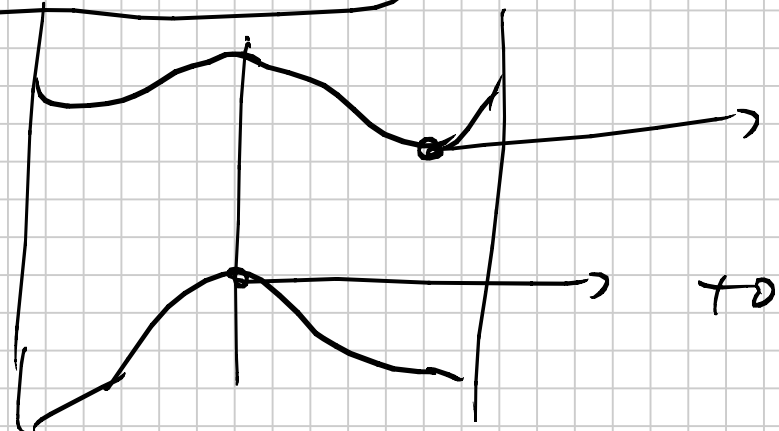
DIRECT vs INDIRECT GAP



Min Conduction bands

Max Valence band at the same k point in the BZ

INDIRECT

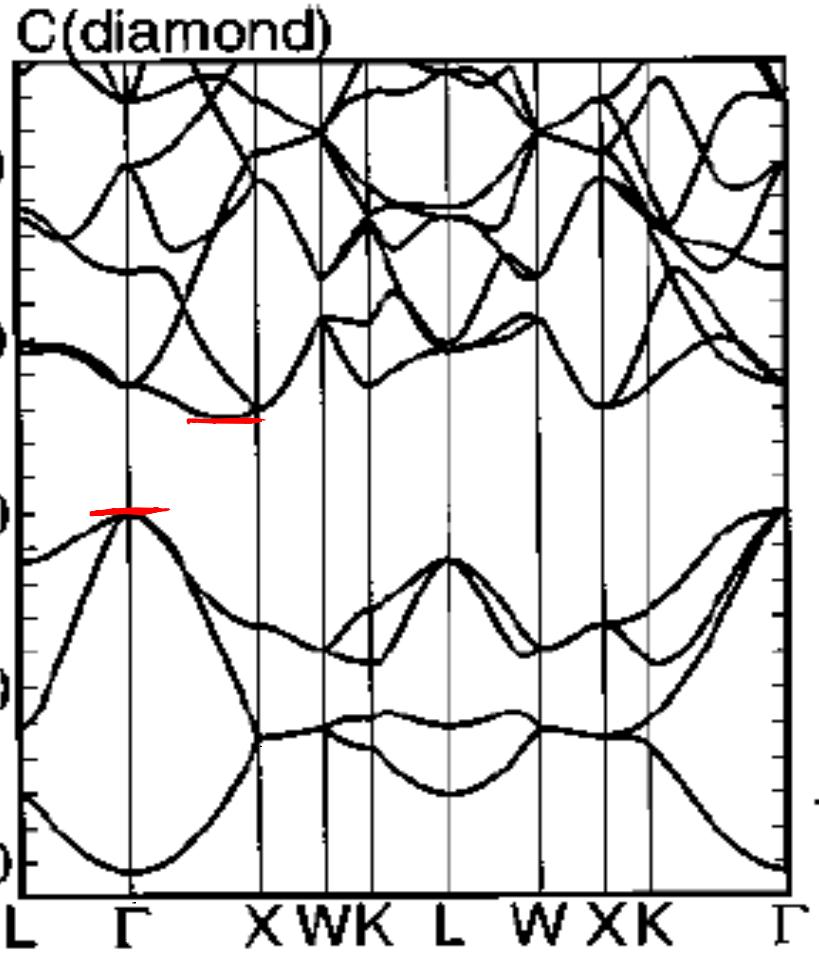


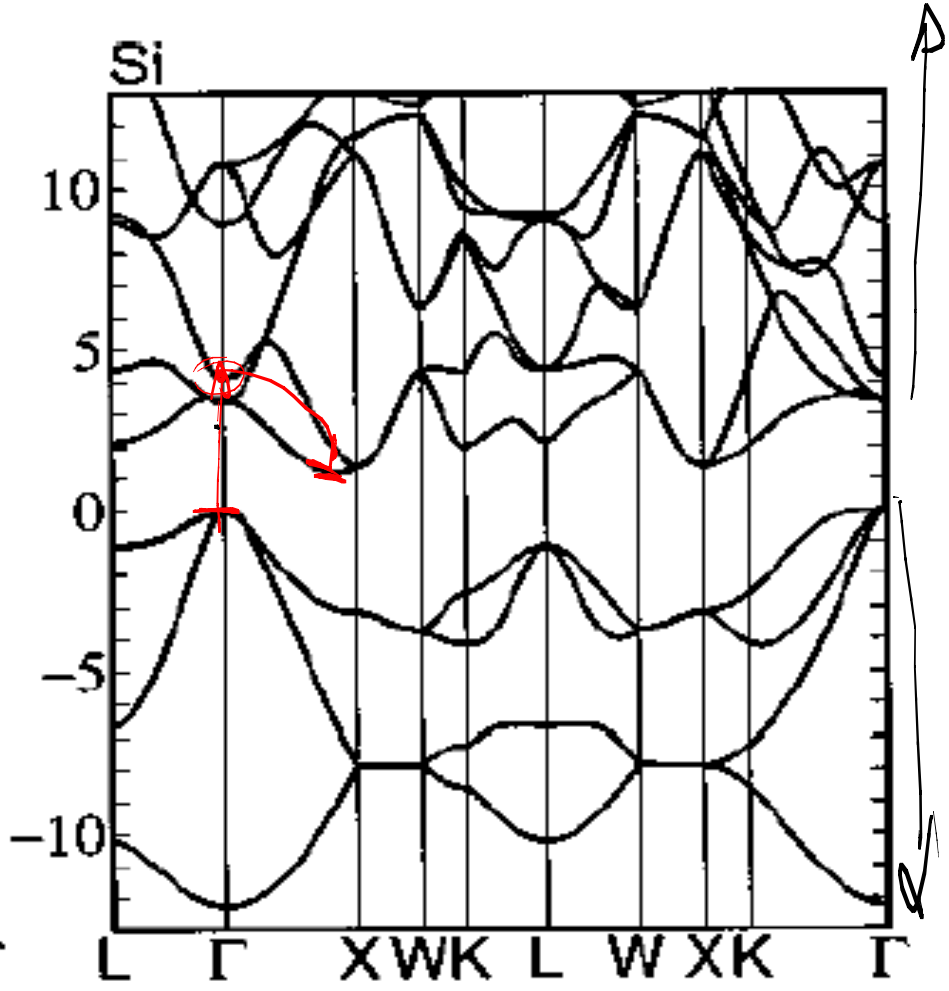
BOTTOM OF CONDUCTION AT K≠0

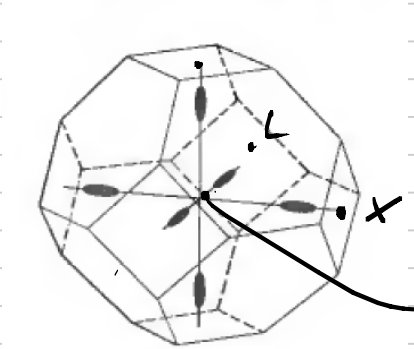
TOP VALENCE AT K=0

EMPTY BANDS

FILLED







→ Γ center

DIRECT GAP