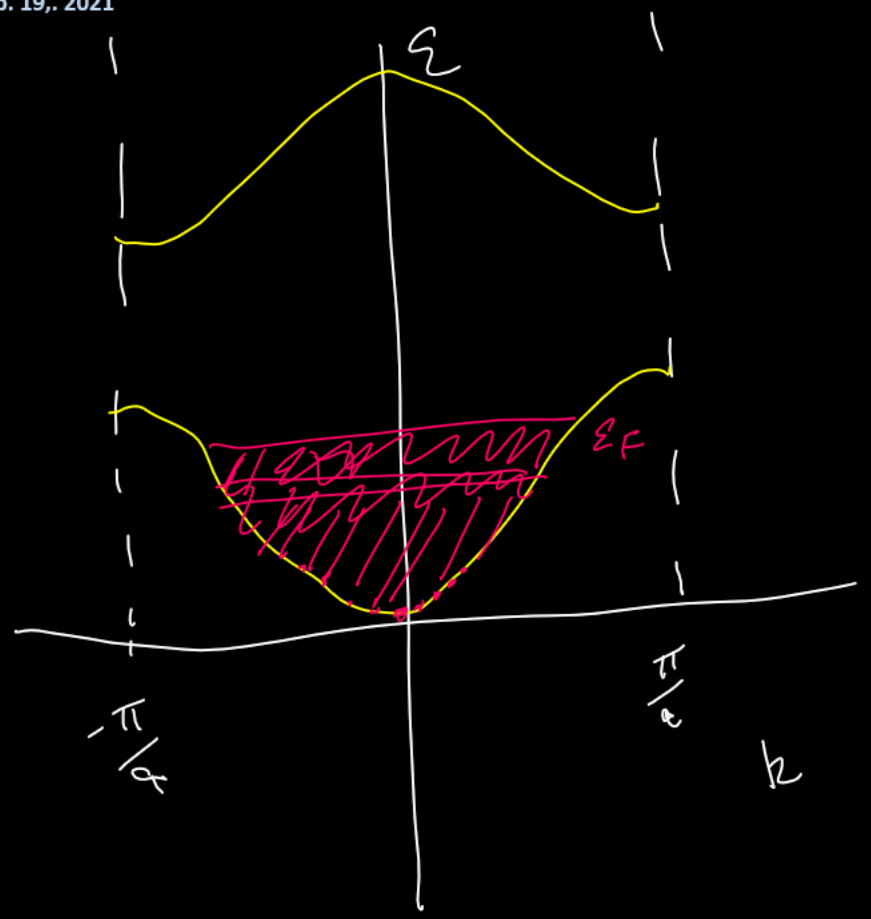
Lecture 16

Friday, Feb. 19,. 2021



SINGLE PARTICLE LEVELS

FERMIONS $\Rightarrow$ 1 ELECTRON PER STATE

WHAT MAKES A SEMICONDUCTOR?

EMPTY CONDUCTION BAND

E_g

FILLED VALENCE

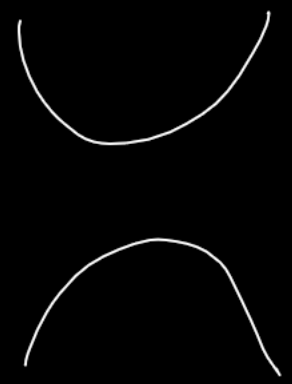
CONDUCTION

VALENCE (FULL)

@ T = 0 (UNDOPED)

RESISTIVITY $\rho = \frac{1}{\sigma}$	METALS	INSULATORS	SEMICONDUCTORS
	$10^{-6}\ \Omega$-cm	$10^{22}\ \Omega$-cm	$10^{-3} - 10^{9}\ \Omega$-cm

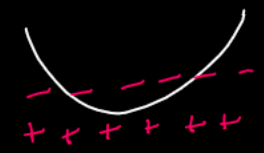
INTRINSIC (NO DOPING)



@ $T=0$ $\sigma \to 0$

NO EXTRA CARRIERS

DOPED



$\sigma \to$ FINITE @ $T=0$

TYPICAL SEMICONDUCTOR CARRIER CONCENTRATIONS

$10^{13} \rightarrow 10^{18} / cm^3$ @ ROOM T

INTRINSIC $\longleftrightarrow$ DOPED

INTRINSIC - CARRIERS EXCITED ACROSS GAP

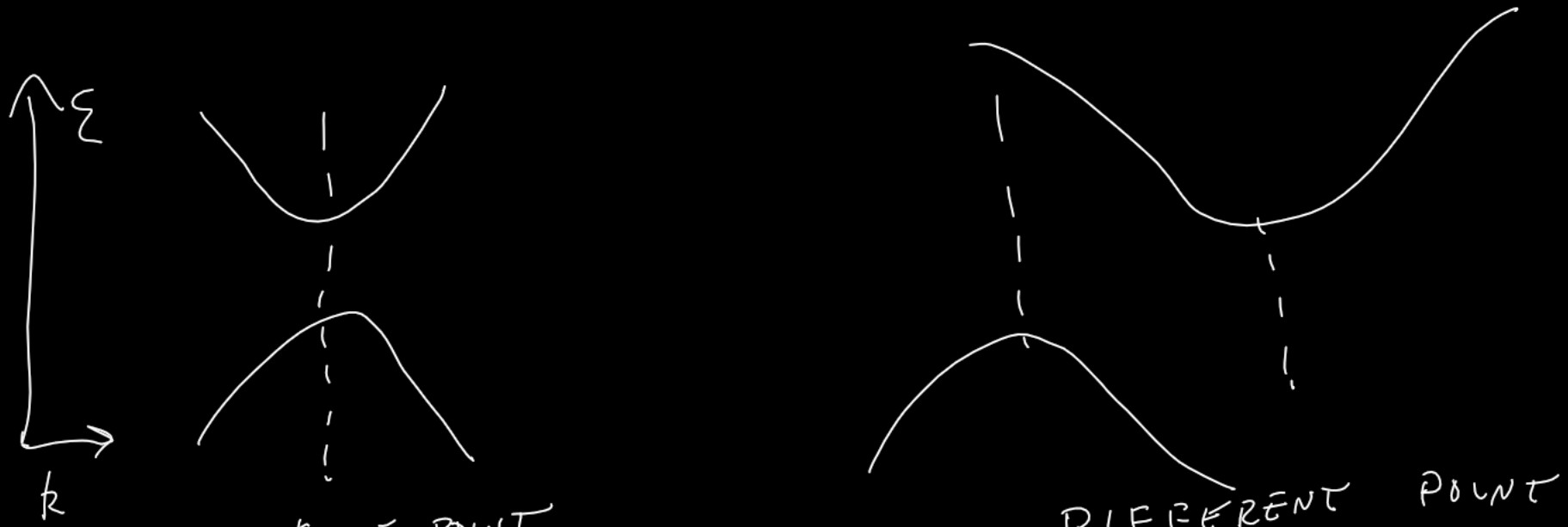
$$n \sim \frac{1}{e^{B(\varepsilon - \mu)} + 1}$$

@ $T = 0$ $\mu = \mu_{MID\ GAP} = E_G/2$

$T \approx 0$

$$n \sim e^{-B E_G/2}$$

DIRECT GAP VS INDIRECT GAP



SAME POINT

DIRECT

DIFFERENT POINT

INDIRECT GAP

GAP CAN CHANGE WITH TEMPERATURE.

① THERMAL EXPANSION ⇒ "a" CHANGES

② "LATTICE VIBRATIONS" INCREASE WITH T

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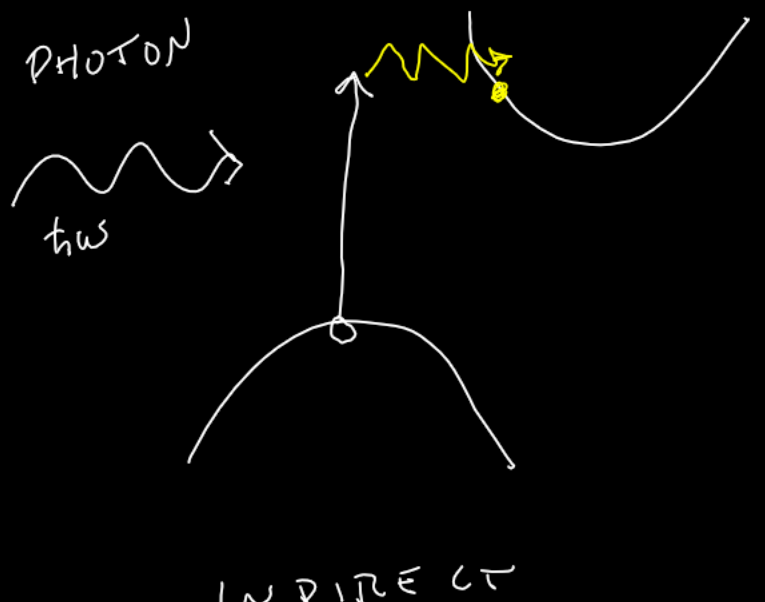
(PHONONS)

TYPICALLY $E_g \sim T^2$ @ LOW T

$\sim T$ @ HIGH T



$0 \approx k(\text{PHOTON}) = k_c - k_h + k_{\text{PHONON}}$

"PHONON ASSISTED OPTICAL TRANSITION"

$\Rightarrow$ GaAs OPTICAL DEVICES (DIRECT GAP) LEDs – LASORS

		T = 0	T = 300 K
GaAs			
INDIRECT GAP	Si	1.17 eV	1.12 eV
	Ge	0.75 eV	0.67 eV
DIRECT GAP	GaAs	1.52 eV	1.4 eV