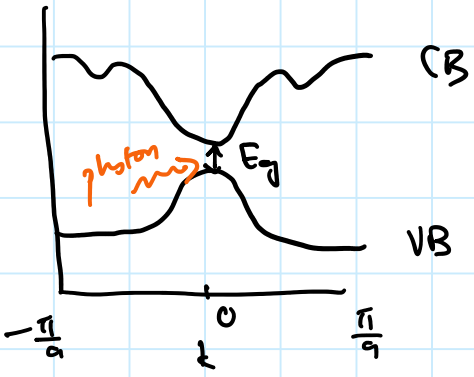
Section 6: Absorption (Worksheet)

Sunday, October 24, 2021 11:29 PM

(I.) Optical Absorption

a) Direct Bandgap



Direct gap: lowest minimum in conduction band lies directly above highest maximum in valence band.

Need to satisfy conservation of energy and conservation of momentum.

$$\Delta E = 0 \iff \Delta\omega = 0$$
$$\Delta p = 0 \iff \Delta k = 0$$

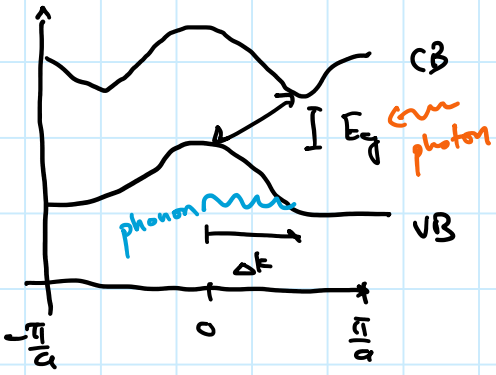
Note: photons — $p = \hbar k \approx 0$, $E = \hbar\omega > 0$

phonons (lattice vibrations) — $p = \hbar k > 0$, $E = \hbar\omega \approx 0$

Hence, direct bandgap semiconductors can directly absorb a photon with

can directly absorb a photon with energy $E_{ph} \simeq E_g$ since $\Delta k = 0$ already.

b) Indirect Bandgap



Indirect gap: Direct minimum in conduction band does not lie directly above highest maximum in valence band.

Hence, indirect bandgap semiconductors do not directly absorb a photon with energy $E_{ph} \simeq E_g$ since a phonon with appropriate k is needed as well (and phonons follow a statistical distribution of energies/momenta).

(II) Direct vs Indirect Bandgap Exercise

Consider two materials, Semiconductor A and Semiconductor B. A has a direct bandgap, while B has an indirect bandgap.

a) Which material has a larger absorption

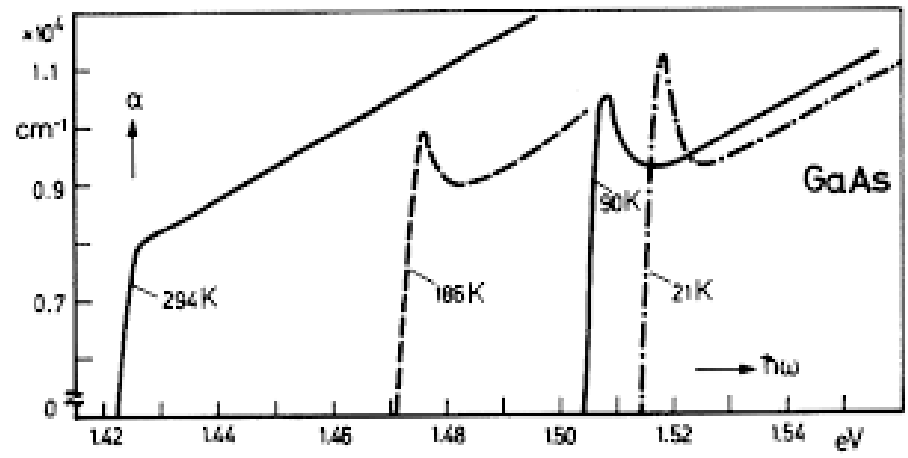
a) Which material has a larger absorption coefficient α? You can assume the incident light is above bandgap for both.

b) Suppose you want to make a solar cell. Both materials are available, but only in one thickness, $t = 525$ μm. Which would you use if you want to extract as much energy from the light as possible?

c) How would you improve the absorption of an indirect bandgap material in general?

d) It turns out that Silicon is an indirect bandgap material, while other options like GaAs are direct. Why is Si the main solar panel material then?

III. GaAs Absorption Spectrum



a) Let's look at the room T (294 K) absorption spectrum first. Again, GaAs is a direct gap semiconductor. How would you expect the plot to change if GaAs was indirect?

b) The spectrum clearly changes as the temperature changes. Do the changes make sense?

c) What do you think those peaks at low temperature are?