Name:

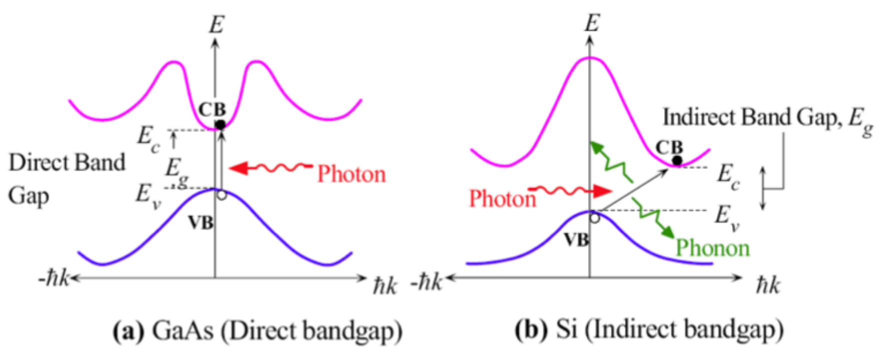
Student Number:

Quiz 3 ELEC 4705

Wed Nov 12, 2014

1. (8 marks) Optical

   (a) Draw $E-k$ diagrams for direct/indirect semiconductors.



   (b) For absorption of a single photon, describe an indirect and direct transition showing how momentum and energy are conserved. Which type of transition is more likely?

      i. **The diagrams show the transitions. Since photons have lots of E and not very much p the indirect transition must also involve a phonon.**

      ii. **Direct because it only involves two particles.**

   (c) Explain the difference between absorption, spontaneous emission and stimulated emission.

      i. **Photon absorbed, raising an electron into the conduction band (electron/hole generation)**

      ii. **Electron, with no stimulus, drops an energy level (electron/hole recombination), emitting a photon**

      iii. **Incoming photon causes electron in an excited state to drop to a lower energy, emitting a photon. Incoming photon not absorbed so have two photons out. They are in phase and coherent.**

2. (10 marks) Diodes

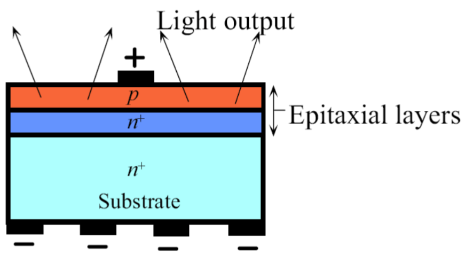
Use the simple PN diode to create an LED.

(a) Would you use a direct or indirect semiconductor? Explain why.

i. **Direct semiconductor**

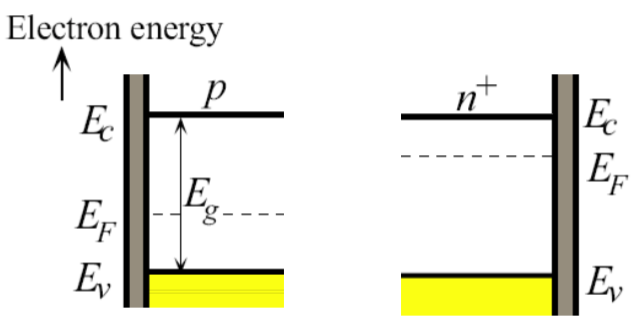
ii. **Better efficiency**

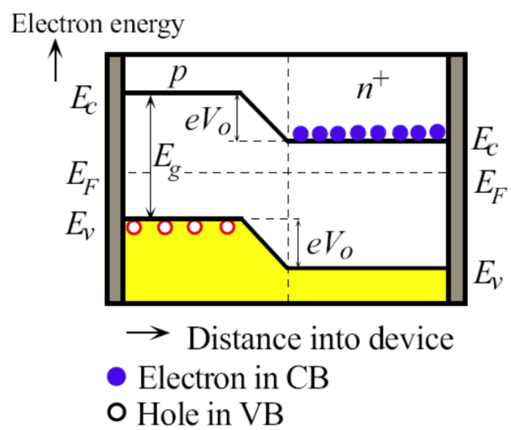
(b) Draw the basic physical structure of the device, making sure to include the depletion region and where the light will be emitted.



Depletion region is at the PN interface

(c) Draw the band structure of the PN Junction before and after contact. Make sure to identify the depletion region and Fermi levels.





Note: The depletion region is where bands bend.

(d) How will the band structure change when a forward bias is applied?

The applied bias reduces V_0 allowing electrons to diffuse over the barrier.

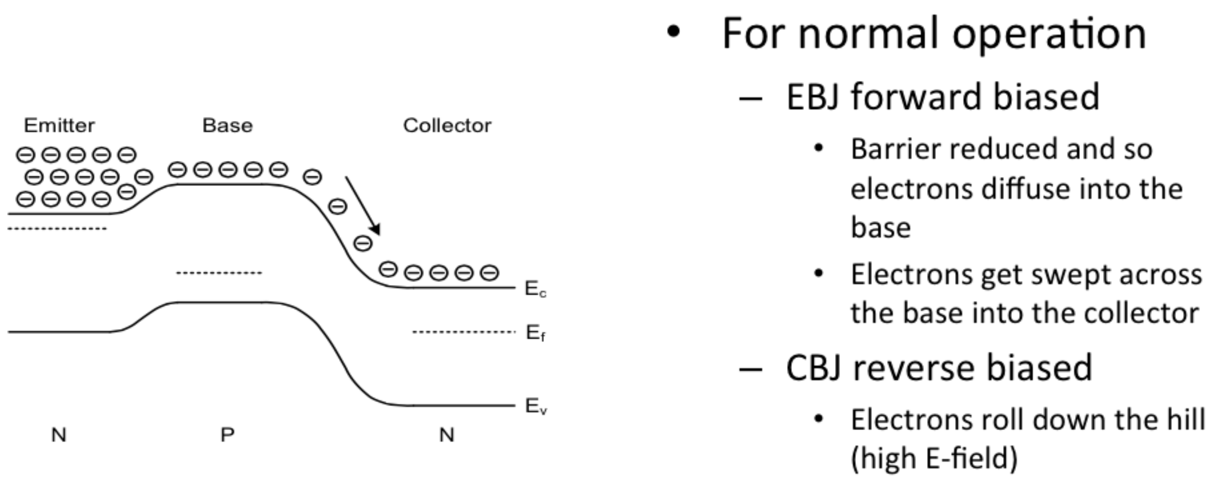
(e) How does a hetero-junction device differ from homo-junction. Why is it used?

i. **Hetero-junctions are the interface between two semiconductors with different band gaps, while homo-junctions are the interface between two layers of the same semiconductor (usually doped differently).**

ii. **Hetero-junctions use band gap engineering for many purposes. Can optimize performance by confining and 'holding' the carriers in the active region for better efficiency.**

3. (7 marks) BJT

(a) Draw the band structure of a BJT (npn) transistor in normal operation. Make sure to note whether each junction is forward or reverse biased. Show the Fermi energy on the diagram.



(b) What is the majority carrier in the base of this device?

Holes

(c) Describe the flow of the electrons through the device from the emittor to the collector for normal operation. Make sure to discuss the mechanism of flow across each junction and the base; as well as how the electron flow is affected by each junction's bias.

Refer to notes in Figure above.