Name:

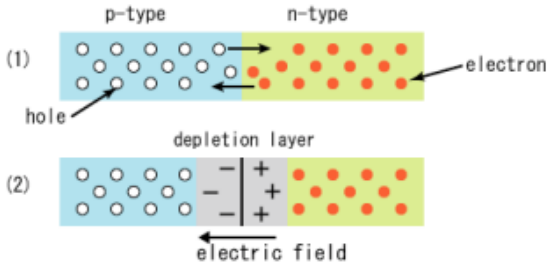
Student Number:

Quiz 3 ELEC 4705

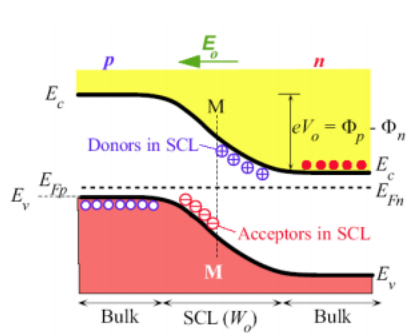
Tuesday, Nov. 12, 2019

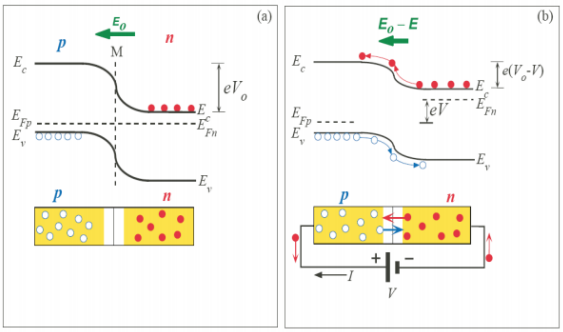
1. (10 marks) Diodes
   (a) Show the physical structure of the PN junction, including the depletion region and exposed dopants.
   (b) Draw the band structure of the diode under the following conditions clearly showing the applied voltage V (bias) and Fermi levels:
      i. In equilibrium (no bias)
      ii. Under forward bias
      iii. Under reverse bias
   (c) Explain the physical reason for the non-linear I-V relationship in a diode?

a)



b)





Equ. **Rev and Fwd**

c) The device works by thermonic emission (injection of minority carriers across the junction) which is a non-linear exponential relationship ($I \approx e^{qV/kT}$).

2. (8 marks) Transistors

Using an NPN transistor and an n-channel MOSFET, contrast the BJT and MOSFET. Specifically:

(a) Sketch physical devices labelling the terminals and semiconductor type.

(b) Are the BJT junctions forward or reverse biased?

(c) For the BJT during normal operation what is the carrier transport mechanism across:

i. The EB junction?

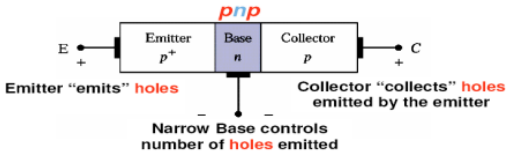
ii. The CB junction?

(d) For the MOSFET are the source/substrate and drain/substrate junctions forward or reverse biased in normal operation?

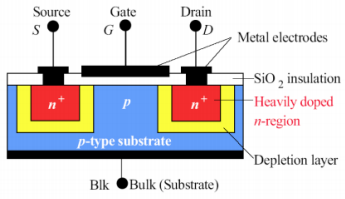
(e) For the MOSFET what is the carrier transport mechanism between the source and drain during normal operation?

(f) Explain pinch-off. Which device is this relevant for?

a)



BJT (PNP)



MOSFET

b) EB forward biased. CB reverse biased.

c)

- **The forward biased EB jct current is due to minority carrier injection (thermionic emission) and diffusion.**
- **The Reverse biased CB jct current is due to drift (falling down the large potential "cliff").**

d) Reverse biased or unbiased

e) Drift due to an electric field

f) Pinch off is when the drain voltage is raised sufficiently that the voltage from the gate to the channel at the drain end is below V_{th} and the channel is "pinched off" and the inversion layer is not created near the drain. This saturates the drain/source current and is useful for amplifiers as it makes the current independent of the drain/source voltage.

3. (7 marks) Optics

   (a) Give two advantages of optical transmission with respect to electrical transmission.

   (b) Give one disadvantage of optical transmission with respect to electrical transmission.

   (c) For a waveguide, what are modes? Why do they exist? What are their implications?

   (d) What is a ridge waveguide? What systems use them?

a) Faster (more bandwidth), lower loss (attenuation), less electromagnetic interference (EMI), etc.
b) Fragile, more expensive due to need for source and detectors, more complicated systems.
c) Modes are quantized wave solutions that exist for bound waves. The waves (light) in a fiber or light waveguide are bound in the cross-sectional dimensions leading to only specific field configurations propagating down the guide. One primary implication is that the modes travel at different speeds leading to pulse dispersion.
d) A ridge waveguide is a ridge of material (line) of higher index then the surrounding (possibly not the substrate) that acts as an electromagnetic dielectric waveguide. Typically used to route light in planar optical systems (integrated optics).