NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

ACADEMIC YEAR 2021-2022

SEMESTER 2

EE2003 SEMICONDUCTOR FUNDAMENTALS

TUTORIAL 10

---

1. A bipolar transistor is biased in the forward-active region.

   (a) For a base current of I_B = 4.2 μA and a collector current of I_C = 0.625 mA, determine (i) β, (ii) α, and (iii) I_E.

   (b) For a collector current of I_C = 1.254 mA and an emitter current of I_E = 1.273 mA, determine β, α, and I_B.

   [148.8, 0.9933, 0.6292 mA]
   [66.0, 0.9851, 0.0190 mA]

2. For a uniformly doped ***n***$^{++}$***p***$^{+}$***n*** bipolar transistor in the forward-active region.

   (a) Sketch the energy band diagram across the emitter region, the base region, and the collector region. Mark the conduction band, the valance band and the Fermi level.

   (b) Sketch its minority carrier distribution across the emitter region, the base region, and the collector region. Indicate the electric field directions in the emitter-base and the base-collector space charge regions.

3. Consider a bipolar junction transistor made of ***p***$^{+}$***np*** junctions (emitter-base-collector), with the emitter region having the largest doping and collector the lowest. Hint: Answer the following questions considering two back-to-back junctions in reverse orientation and use your background in junction theory.

   (a) Sketch the energy band diagram across the emitter region, the base region, and the collector region. Make sure to mark the conduction band, the valance band and the Fermi level.

(b) Plot the electric field in the emitter-base and the base-collector space charge regions and show the levels of space charge densities in these regions. Be careful about the charge density levels, the peak electric fields and the extent of depletion regions.

4. The parameters of the base region in a silicon *npn* bipolar transistor are: D_n = 18 cm^2/s, x_B = 0.8 μm, cross-sectional area $A_{BE} = 5 \times 10^{-5}$ cm^2, and $n_{B0} = 4 \times 10^3$ cm^{-3}.

   (a) Calculate the collector current for V_{BE} = 0.58 V.

   (b) For a common-base current gain α = 0.9850, determine the common-emitter current gain β, and the emitter and base currents.

[3.827×10^{-5}A]
[65.7, 38.85μA, 0.5828μA]

NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

ACADEMIC YEAR 2021-2022

SEMESTER 2

EE2003 SEMICONDUCTOR FUNDAMENTALS

TUTORIAL 11

---

1. For a two-level energy system, is it possible to achieve population inversion under thermal equilibrium? Please state your reasons.

2. For a two-level energy system,

   (a) To achieve lasing action, what are the requirements?

   (b) What are the typical pumping mechanisms for a laser?

   (c) Explain the sources of optical losses in a laser.

3. For a laser system,

   (a) Derive the round trip gain in a laser cavity.

   (b) State the condition for the net amplification.

   (c) State the condition for the laser oscillations to die.

   (d) State the threshold condition and derive the threshold small signal gain coefficient.

   (e) Show the threshold point in the light output vs. current plot of a laser diode.

4. A 300 μm thick single crystal Si wafer is subjected to incident surface-normal light with a total power of 20 mW. The absorption coefficient of Si is 5×10^4 cm^{-1} and its refractive index is 3.5 at the light frequency.

   (a) Determine the power absorbed within the first 0.2 μm and then the next 0.2 μm by the Si crystal.

(b) Explain why it is unlikely that the energy absorbed in the Si wafer can be converted into optical energy output through photon emission.

[(a) 8.74 mW, 3.21 mW]

5. For a Fabry Perot laser cavity, the reflection coefficient of two mirrors both are 50%. The threshold gain coefficient is 5 cm^{-1}. When one of the two mirrors is coated with a layer of metal providing 100% reflection, the threshold gain coefficient becomes 3 cm^{-1}. Calculate the loss coefficient γ cm^{-1} of the laser system.

[1 cm^{-1}]

NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

ACADEMIC YEAR 2021-2022

SEMESTER 2

EE2003 SEMICONDUCTOR FUNDAMENTALS

TUTORIAL 12

---

1. For a laser diode, plot the emission spectra below and above the lasing threshold. Briefly explain the main features of each spectrum.

2. A semiconductor laser diode is typically comprised of a highly doped junction such that the Fermi level on the n-side lies in the conduction band and that on the p-side in the valence band. Sketch the energy band diagrams of this laser diode under the equilibrium condition (zero bias) and then under the forward bias. Mark the conduction band, the valence band, and the Fermi levels. Explain your answer.

3. Sketch the energy band diagram of a typical light-emitting diode (LED) under forward bias. Explain how LED works.

4. What are the differences between a laser diode (LD) and a light emitting diode (LED)?

NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

ACADEMIC YEAR 2021-2022

SEMESTER 2

EE2003 SEMICONDUCTOR FUNDAMENTALS

TUTORIAL 13

1. What are the difference and similarity between a solar cell and a photodiode?

2. A Si photodiode has an active light receiving area of diameter 0.4 mm. When radiation of wavelength 700 nm (red light) and intensity 0.1 mW /cm^2 is incident it generates a photocurrent of 56.6 nA. What is the responsivity and quantum efficiency (QE) of the photodiode at 700 nm?

   [0.45AW^{-1}, 80%]

3. A silicon photodiode has an external quantum efficiency of 70% at 830 nm. If the incident optical power is 10 nW, what is the photocurrent?

   [4.7 nA]

4. Briefly explain the role played by the internal electrical field in the space depletion region in a solar cell.