BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE – PILANI, K K BIRLA GOA CAMPUS
FIRST SEMESTER 2019-2020

PHY F426 & PHY G541 Comprehensive Exam (Closed book) Time: 3 hrs
Physics of Semiconductor Devices Date: 13/12/2019 Time: 9 AM – 12 noon
Max. Marks: 80

Part A (5 marks each)

1) What is the difference between density of states and effective density of states? Why is the latter such a useful concept?

2) An unknown semiconductor has E_g = 1.1 eV and $N_c = N_v$. It is doped with 10^{15} cm^{-3} donors, where the donor level is 0.2 eV below E_c. Given that E_f is 0.25 eV below E_c, calculate n_i and the concentration of electrons and holes in the semiconductor at 300 K.

3) What are the two material parameters that determine the carrier transport in semiconductors? Discuss the carrier transport in semiconductors quantitatively with necessary equations.

4) Briefly describe pn junction capacitance.

5) Draw a laser p-n junction at equilibrium and at forward bias. Mark the bands. Explain briefly how it works.

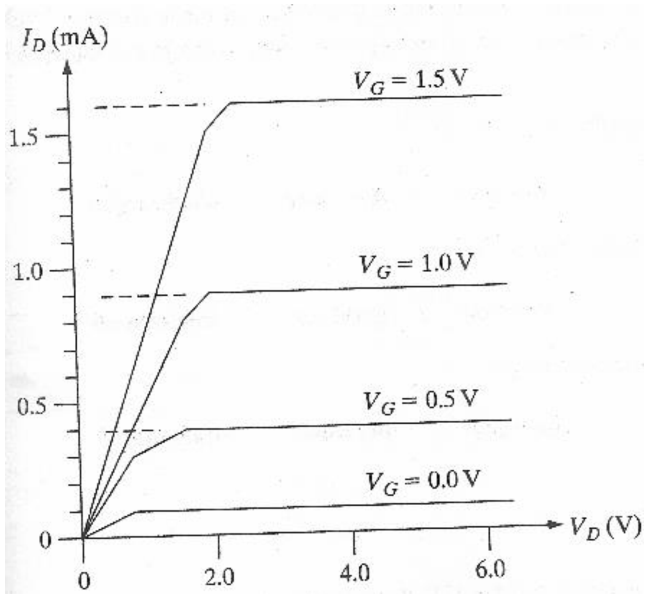
6) Consider a silicon pn junction diode at 300 K with an applied forward bias voltage V= 0.65 V. $N_a = N_d = 10^{16}$ cm^{-3}. Given that the total current far from the junction in the n-region will be majority carrier electron drift current, calculate the electric field required to produce this drift current.

Part B

7) We deposit a metal with a work function of 4.6 eV on silicon (electron affinity of 4 eV) and acceptor doping level of 10^{18} cm^{-3}. Draw the equilibrium band diagram and mark off the Fermi level, the band edges and the vacuum level. Is this a Shottky or ohmic contact? Why? By how much should the metal work function be altered to change the type of contact? Explain with reference to the band diagram. **[8]**

8) (a) Derive an expression for the density of states of a one dimensional crystal. Take L as the length of the crystal, b as the width and c as the thickness.
   (b) Find out the permitted energy levels for the electrons in the crystal given that it is confined in both y and z directions.
   (c) Draw the density of states as a function of energy and explain. **[3+6+5]**

9) Consider the following MOSFET characteristics. Answer the questions below. <u>Justify every answer.</u>



(a) Is this an n-channel or p- channel device?
(b) Does this appear to be long channel or short channel device?
(c) What is the apparent threshold voltage V_T?
(d) Is this a depletion-mode or enhancement-mode MOSFET? **[4x2]**

10) (a) What are quantum dots? What is the role of quantum dot in single electron transistors?
(b) What is Coulomb blockade? What are the criteria to achieve Coulomb blockade?
[2x4]

11) (a) What are Chiral vectors? How is it important in determining the electrical properties of carbon nanotubes?
(b) Describe Raman scattering? Why is it known as 'molecular finger print' of materials?
(c) What is spin Hall effect? How is it different from normal Hall effect? **[3x4]**

Useful parameters and equations: The symbols have the usual meaning

$n_i = 1.5\text{x}10^{10}$ cm^{-3}, D_n= 25 cm^2/s, D_p= 10 cm^2/s, $\tau_{p0} = \tau_{n0} = 5\text{x}10^{-7}$ s, μ_n = 1350 cm^2/V-s for silicon

Intrinsic electron concentration,

$$n = 2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2} exp\left(\frac{E_F - E_C}{k_B T}\right)$$

Intrinsic hole concentration,

$$p = 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{3/2} exp\left(\frac{E_V - E_F}{k_B T}\right)$$

The ideal reverse saturation current density   is given by

$$\frac{eD_n n_{po}}{L_n} + \frac{eD_p p_{no}}{L_p}$$