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MAIN EXAMINATION

JANUARY - APRIL 2015 TRIMESTER

FACULTY OF SCIENCE

DEPARTMENT OF NATURAL SCIENCES (PHYSICS)

PHY 307: PHYSICAL ELECTRONICS

Date: April 2015	**Duration: 2 Hours**
Instructions: Answer Question ONE and any other TWO Questions.	

Si Material Parameters
Intrinsic carrier density for Germanium, $n_i = 2.5\times10^{19} m^{-3}$
Effective density of states: N_c=2.8 x 10^{19}cm^{-3}, N_v=1.04 x 10^{19}cm^{-3}
Effective Mass; $m_e^* = 1.08 m_o$, $m_h^* = 0.81 m_o$
Mobility: $\mu_n = 1400 cm^2/v.s$, $\mu p = 450 cm^2/v.s$
Diffusion coefficients: Dn = 34.6cm^2/s; Dp = 12.3cm^2/s.
Permittivity of Vacuum, $\varepsilon_o = 8.855x10^{-14} F/cm$
Planck's Constant, $h = 6.625\times10^{-34} JS$
Speed of light, C = 3.0 x 10^{10}cm/s
Electronic charge, $e = 1.6\times10^{-19} C$
Boltzmann's constant, $K_B = 1.38\times10^{-23} JK^{-1}$
Electron rest mass, $m_0 = 9.11\times10^{-31} kg$

Q1. a) What makes semiconductor so important to electronics? **(2 marks)**

b) Describe a semiconductor in terms of resistivity and resistance. **(2 marks)**

c) State the mass action law. **(1 mark)**

d) A conductor is transparent to light with a wavelength longer than 0.87 μm. Calculate its band gap energy in eV. **(3 marks)**

e) A silicon pn junction employs $N_a = 2x10^{14} cm^{-3}$ and N_d= 4 x 10^{16}cm^{-3}. Determine the built in potential at room temperature (27^0C).

(3 marks)

f) A silicon diode has an external bias voltage of 12V with an external resistance of 150Ω. Determine the total forward current given that the forward voltage drop for silicon drode is 0.7V.

(3 marks)

g) State the major difference between a Bipolar Junction Transistor FJT and Field effect transistor (FET).

(2 marks)

h) Calculate the drift velocity of free electrons in a copper conductor of cross-section area 10^{-4}m^2 and in which there is a current of 200A.

(2 marks)

i) Define the term; volt equivalent of temperature and determine its value at 300K.

(2 marks)

j) List the possible parameters governing the intrinsic carrier concentration in a semiconductor.

k) i) What is energy band diagram?

ii) Schematically sketch and show the main features of an energy band diagram.

(2 mark)

iii) Using the energy band model state why it is sufficient to focus only on the properties of the two bands.

(2 mark)

Q2. a) Define the following terms:

i) Diffusion length **(1 mark)**

ii) Negative temperature coefficient **(1 mark)**

iii) Density of state **(1 mark)**

iv) Doping **(1 mark)**

v) Covalent bonding **(1 mark)**

b) Show that the election conductivity can be expressed as

$$\sigma = \frac{ne^2\tau}{m}$$

Where n is the number density of electrons, and τ is the time between collisions.

(7 mark)

c) The Barrier potential is a function of the equilibrium densities of mobile charges at the junction faces. Using the Boltzmann equation, derive an expression of the barrier potential, V_B, in terms of Impurity densities that create it.

(8 mark)

Q3. The following information is given about a semiconductor sample:
Donor concentration $1.1 \times 10^{16} cm^{-3}$

- Accepts or concentration = $2 \times 10^{16} cm^{-3}$
- Effective density of states in the valence band = 2×10^{19} cm^{-3}
- Effective density of states in the conduction band = 1×10^{19} cm^{-3}
- Electron and hole mobility respectively $800 cm^2/vs$ and 200 cm^2/V^s
- Temperature = 27^0C
- Intrinsic carrier concentration = $1.0 \times 10^{16} cm^{-3}$

a) Assuming total ionization, calculate the election and hole concentrations. **(4 marks)**

b) Identify the type of semiconductor material. **(1 mark)**

c) Determine the distance between the Fermi level, E_F and the top of the valence band, E_v **(3 marks)**

d) The length of material needed to make a resistor with resistance $1k\Omega$. Using a cylinder with cross-sectional area $1.0 \times 10^{-4} cm^2$. **(6 marks)**

e) If 10v is placed across the resistor in part 3(d) above, calculate the total current density. **(6 marks)**

Q4. a) Derive an expression for the Hall Voltage, V_H, for a semiconductor placed in a magnetic field. B, which is perpendicular to the current direction. **(6 marks)**

b) i) Define the Fermi function, F(E) **(3 marks)**

ii) Show that, for an intrinsic semiconductor the location of the Fermi energy levels, E_F is given as

$$2E_F = E_C + E_V$$

Where E_c and E_v are the conduction and valence energy levels. **(6 marks)**

c) i) Calculate and show on an energy band diagram the location of the Fermi energy level, E_F in the energy band of silicon at 300k with

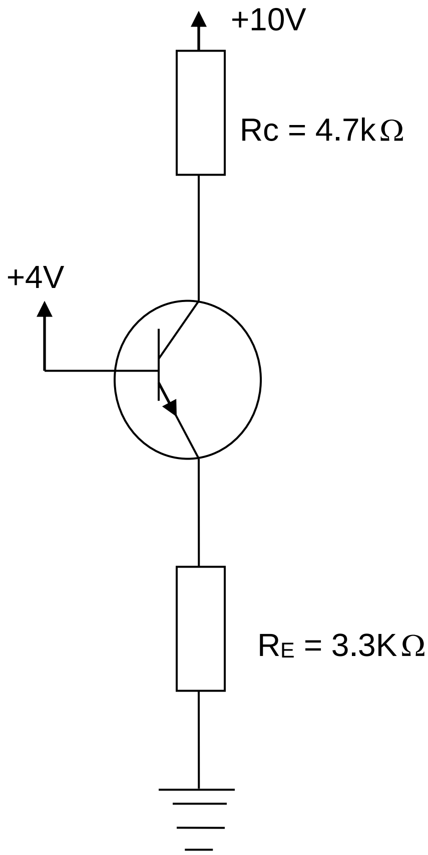
I) $n = 10^{17} cm^{-3}$ **(3 marks)**
II) $p = 10^{14} cm^{-3}$ **(3 marks)**

Q5. a) Measurement on an npn BJT in a particular circuit shows the collector current to be 1mA and the base current to be 10 μA, calculate;

i) α **(3 marks)**
ii) β **(2 marks)**

b) Show that $\beta = \frac{\alpha}{1-\alpha}$ and $\alpha = \frac{\beta}{1-\beta}$ **(5 marks)**

c) Consider Fig.1 below;



Given that β =100 and V_{BE} = 0.7V, calculate;

i) V_E **(2 marks)**

ii) I_E **(2 marks)**

iii) I_C **(2 marks)**

iv) V_C **(2 marks)**

v) I_B **(2 marks)**

END