Roll No.:........................

National Institute of Technology, Delhi

Name of the Examination: End Semester Examination: Autumn 2022: B. Tech

Branch	: ECE	Semester	: III
Title of the Course	: Solid State Devices	Course Code	: ECB 201

Time: 3 Hours | Maximum Marks: 50

- Questions are printed on BOTH sides. Answers should be CLEAR AND TO THE POINT.
- All parts of a single question must be answered together. ELSE QUESTION SHALL NOT BE EVALUATED.

Use following data if not given in a problem: $\varepsilon_o = 8.85\times10^{-14}$F/cm, $\varepsilon_r(SiO_2) = 3.9$, $\varepsilon_r(Si) = 11.8$, At room temperature for Si [$\mu_n = 1350 cm^2/V\cdot S$, $\mu_p = 480\ cm^2/V\cdot S$, $n_i = 1.5\times10^{10}/cm^3$, $E_g = 1.12$ eV], k $= 8.62\times10^{-5}$ eV/K, $\tau_n = \tau_p = 1\mu s$, $E_g(Ge) = 0.7$ eV, $n_i(Ge) = 2.5\times10^{13}/cm^3$.

1. For the following circuit in figure 1, calculate the output voltage and voltage amplification. **[2M]** Assume $\alpha_{ac} \sim 1$

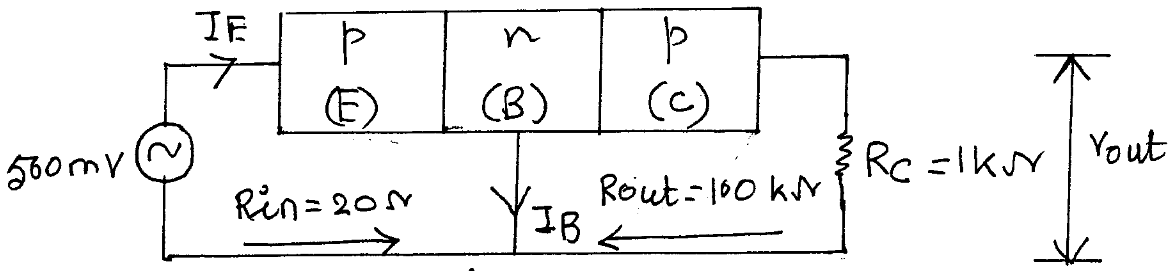

Figure ①

2. The following circuit, as shown in figure 2, is a CMOS logic circuit. Estimate the performance **[3M]** of the circuit and determine the following:

   (a) The Boolean function representing the circuit.
   (b) The truth table, representing the circuit.
   (c) Name the circuit.

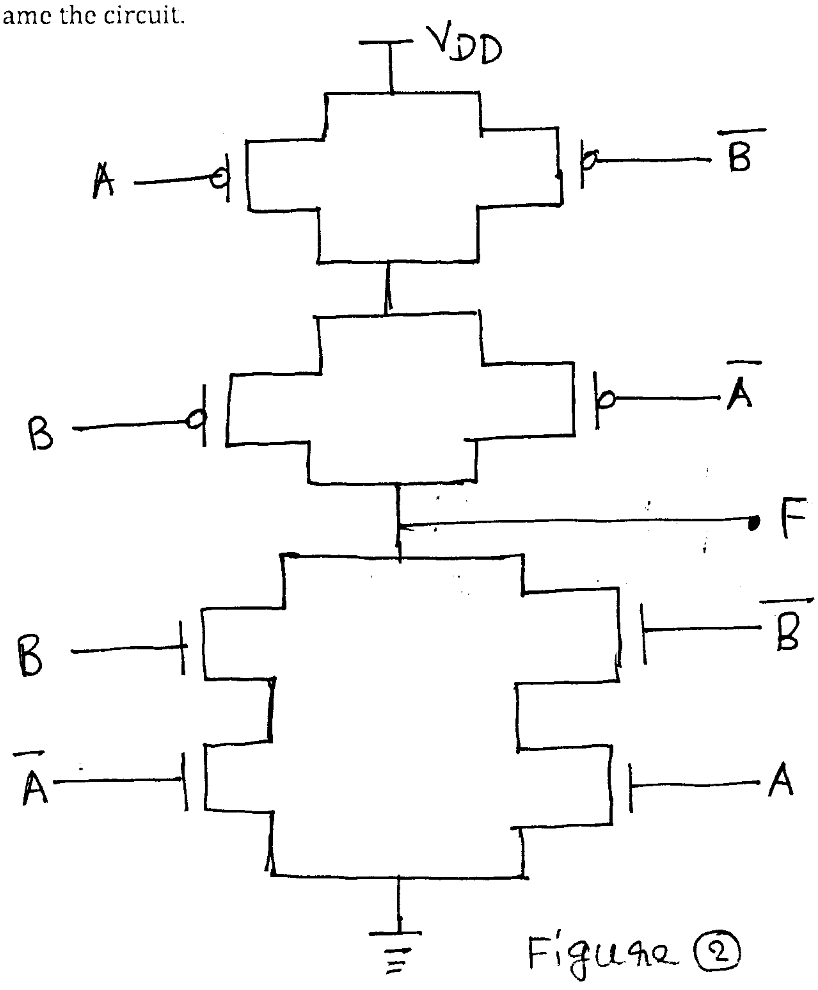

Figure ②

3. Consider a tunnel diode with $N_A = N_D = 4.41\times10^{19}$ /cm³. At room temperature, calculate the height of the potential energy barrier under open circuit conditions. [2M]

4. For the circuit, as shown in figure 3, V_{CC} = 10 V, V_{BB} = 5 V, V_{BE} = 0.7 V, R_b = 10K, R_C = 500 Ohm, R_e = 100 Ohm and h_{FE} = 100. Calculate I_B, I_C, and I_E for this circuit. [3M]

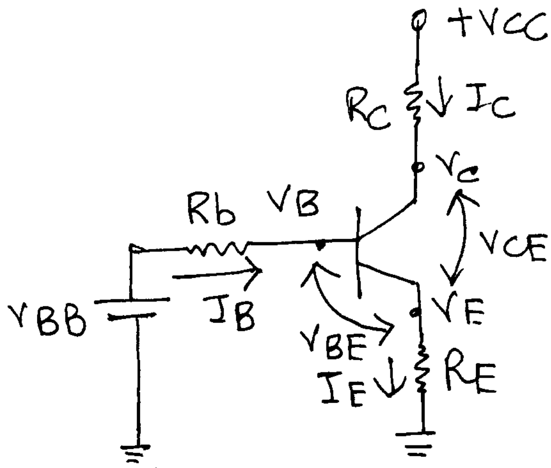

Figure ③

5. Write brief notes on each of the following: [3x2 = 6M]

   (a) Thermal Runway
   (b) Depletion Mode MOSFET.
   (c) Hall Effect.

6. **Choose the appropriate answer and write the correct answer only in the answer booklet against respective questions.** [5x1 = 5M]

(a) Common Base current gain can be increased by enhancing the **injection efficiency/ base transport factor/ both above** of a transistor.

(b) As reverse bias increases, collector current **increases/ decreases/ remains the same** in a Bipolar Junction Transistor.

(c) Higher base doping **increases/ decreases/ retains the same** base current.

(d) In a CRO, if the sweep rate frequency is 100 Hz with 2 full sinusoidal cycles observed, then the frequency of the input vertical voltage will be **100 Hz/200 Hz/ 1000 Hz.**

(e) At pinch-off situation in a JFET, pinch-off voltage refers to the corresponding **gate-to-source voltage/ drain-to-source voltage/ gate-to-drain voltage.**

7. Two *p-n* junction Ge diodes are connected in series, as shown in figure 4. A 5-volt battery is impressed upon this arrangement. Assuming that the magnitude of Zener voltage, V_Z, is greater than 5 volt. Find the voltage across each junction at room temperature. Let's assume the overall current flowing through the circuit is 2 Ampere, reverse saturation current can be neglected, and the operating temperature of the circuit is 300 K. [4M]

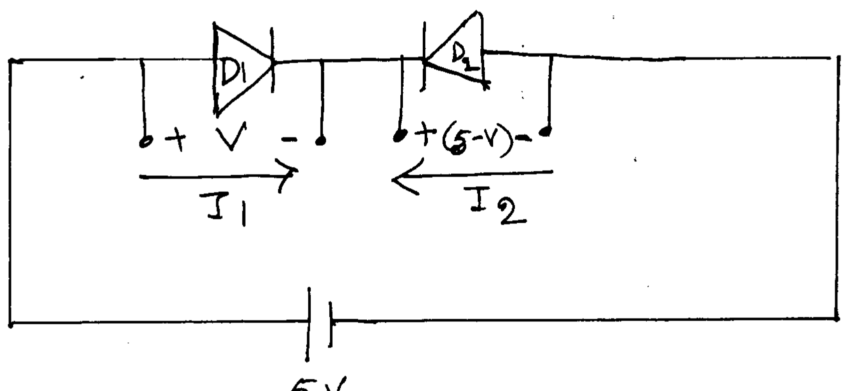

Figure ④

8. In an abrupt Si p-n junction diode with an area 10^{-4} cm^2 has $N_a = 10^{17}$/ cm^3 and $N_d = 10^{18}$ cm^3. The diode has a forward bias voltage of 1 volt. Mobility's for electrons and holes are 1350 cm^2/v-sec and 400 cm^2/v-sec, respectively. Carrier lifetimes for electrons and holes are 10 nano-sec each. [4M]

Find the excess carrier concentrations for electrons.

9. **(a)** Implement the following Boolean expression using minimum numbers of CMOS and construct a CMOS logic circuit. [5M]

(b) Write down the truth table.

(c) Use the K-Map solution as well to cross-verify it's answer.

$$F = \overline{\overline{(A.B)} + C}$$

10. A doped Si sample A of thickness 3 mm, shows a Hall voltage of $V_y = 5$ mV for current density $J_x = 500$ Amp/ m^2 under a magnetic field of B_Z=1 W/m^2. [4M]

(a) Find the toe of the semiconductor.
(b) Find the doping concentration of the semiconductor.
(c) Calculate the position of Fermi Level (E_F) w.r.t intrinsic Fermi Level (E_i).
(d) Sketch and label the energy band diagram indicating the value obtained in part (c).

11. **(a)** A p-n diode is reverse biased at V_r and the generated capacitance is 20 pF. If the doping of the p-side is doubled and the bias is changed to twice of the previous value, what will be the new value of capacitance from 20 pF value? [3M]

(b) If further the bias is changed to 10.V_r, what will be the revised value of capacitance?

12. The current equation for a p-n junction for $v > \frac{3.K.T}{q}$ is given as $I = I_0 . exp\left(\frac{q.V}{K.T}\right)$, where, $I_0 = A. exp.\left[\frac{-1.12eV}{K.T}\right]$. Calculate the suitable forward bias voltage required at 320 K temperature for this diode to maintain the same current as available in this diode at 300 K temperature for 0.5 V forward bias voltage. [4M]

13. For a particular semiconductor material $N_C = 1.5\times10^{18}$/ cm^3, $N_V = 1.3\text{X}10^{19}$/ cm^3 and E_g =1.43 eV at T= 300 K. [5M]

(a) Determine the position of the intrinsic Fermi level E_i w.r.t the centre of band gap.
(b) What will be the position of Fermi level (E_F) w.r.t the top of the valence band (E_V).
(c) Draw the above energy band diagram.

Useful Equations

$$n_0 = n_i e^{(E_F - E_i)/kT}$$
$$p_0 = n_i e^{(E_i - E_F)/kT}$$

$$n_0 p_0 = n_i^2$$

$$n = N_c e^{-(E_c - F_n)/kT} = n_i e^{(F_n - E_i)/kT}$$
$$p = N_v e^{-(F_p - E_v)/kT} = n_i e^{(E_i - F_p)/kT}$$

$$np = n_i^2 e^{(F_n - F_p)/kT}$$

$$\frac{I_x}{A} = J_x = q(n\mu_n + p\mu_p)\mathscr{E}_x = \sigma\mathscr{E}_x$$

$$\frac{p_p}{p_n} = \frac{n_n}{n_p} = e^{qV_0/kT}$$

$$W = \left[\frac{2\epsilon(V_0 - V)}{q}\left(\frac{N_a + N_d}{N_a N_d}\right)\right]^{1/2}$$

Diffusion length: $L \equiv \sqrt{D\tau}$ Einstein relation: $\frac{D}{\mu} = \frac{kT}{q}$

Continuity: $\frac{\partial p(x,t)}{\partial t} = \frac{\partial \delta p}{\partial t} = -\frac{1}{q}\frac{\partial J_p}{\partial x} - \frac{\delta p}{\tau_p}$ $\quad \frac{\partial \delta n}{\partial t} = \frac{1}{q}\frac{\partial J_n}{\partial x} - \frac{\delta n}{\tau_n}$

For steady state diffusion: $\frac{d^2\delta n}{dx^2} = \frac{\delta n}{D_n\tau_n} = \frac{\delta n}{L_n^2}$ $\quad \frac{d^2\delta p}{dx^2} = \frac{\delta p}{L_p^2}$

Equilibrium: $V_0 = \frac{kT}{q}\ln\frac{p_p}{p_n} = \frac{kT}{q}\ln\frac{N_a}{n_i^2/N_d} = \frac{kT}{q}\ln\frac{N_a N_d}{n_i^2}$

Equlibrium: $V_0 = K.T.ln\left(\frac{N_A.N_B}{n_i 2}\right)$

$$I = I_0.\left[exp.\left(\frac{V}{\eta K.T}\right) - 1\right]$$

$$I = q.A.\left[\frac{D_p}{L_p}.p_n + \frac{D_n}{L_n}.n_p\right].\left[exp\left(\frac{q.V}{K.T}\right) - 1\right]$$

$$V = \frac{J}{q.p_0}.B.t$$

Equilibrium: $V_0 = \frac{kT}{q}\ln\frac{p_p}{p_n} = \frac{kT}{q}\ln\frac{N_a}{n_i^2/N_d} = \frac{kT}{q}\ln\frac{N_a N_d}{n_i^2}$