INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Autumn Semester Examination 2024-25

EC 21201 (Basic Electronics)

Date of Examination – 18/09/2024, AN, Full Marks: 60 Time: 2 hours

PART A: (Question for 1st year Students only)

Answer All Questions.

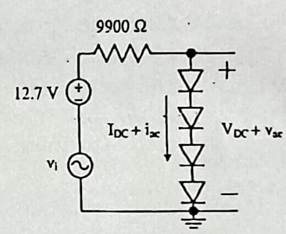
PART A

Q1. (a) A n-type Silicon bar is 2 cm long and has a cross-section of 2mm × 2mm. When a 1 V battery is connected across it, a current of 8 mA flows. Find (i) doping concentration and (ii) drift velocity. Assume mobility of electron is $1300\text{cm}^2/\text{V} - \text{sec}$. [5]

(b) The electron concentration in Silicon is given by $n(x) = 10^2 + 10^{18}\exp(-x/L_n)$ for $(x \geq 0)$ in which L_n = 20 μm. If electron diffusion coefficient is D_n = 30 cm²/s, determine the electron diffusion current density J_n in A/cm² at (i) x = 0, (ii) x = 20 μm and (iii) x = 30 μm. Draw an approximate plot of electron concentration versus distance, showing the direction of electron diffusion and electron diffusion current density. [5]

Q2. (a) Assume a piecewise linear model of pn junction diode in which the cut-in voltage V_γ = 0.6 V and forward diode resistance r_f = 20 Ω. Consider a pn junction diode in series with an 8 KΩ resistor and 5 V power supply. Draw the circuit first. Next, calculate diode voltage V_D (in Volt), diode current I_D (in mA) and power dissipated in diode P_D (in mW). Draw the diode piecewise equivalent circuits when $V_D \geq V_\gamma$ and when $V_D < V_\gamma$. [5]

(b) In the circuit shown below, assume that the voltage drop across a forward biased diode is 0.7 V. The thermal voltage $V_T = \frac{kT}{q}$ = 25mV at T=300K. The small signal input $v_i = 100\cos(wt)$ mV . Find the (i) bias current I_{DC} through the diodes and (ii) ac output voltage v_{ac}. Consider emission coefficient or ideality factor = 1 and diode forward resistance = 0. [5]



Q3. Design an energy efficient diode bridge rectifier based power supply with filter capacitor for the following specifications:

Input ac voltage: 230 V (rms), 50 Hz
Output voltage: 9 V (peak)
Load current variation: 0 to 120 mA
Output ripple voltage: 10% of peak output voltage
Use silicon diode (cut-in voltage = 0.7 V), transformer and necessary filter circuit.

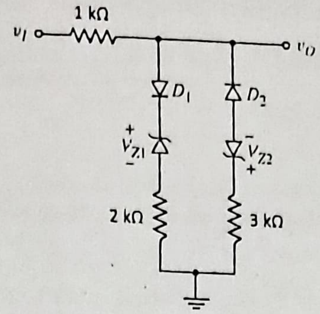
(a) Draw the necessary circuit diagram. [3]
(b) Calculate the turns ratio of the transformer, PIV of diode, and the value of filter capacitor. [7]

Q4. Consider the circuit as shown in Figure below where the cut-in voltage of the silicon diode is 0.7V. The voltages of two Zener diodes (V_{Z1} and V_{Z2}) are 3V and 6V, respectively. The resistances of two Zener diodes are assumed to be zero.

(a) Find three expressions of output voltages (v_O) for three different operating ranges only in terms of input voltage (v_I) when the input voltage varies from −15V to +15V. [8]

(b) Draw the plot of output voltage versus input voltage when the input voltage varies from −15V to +15V. [2]

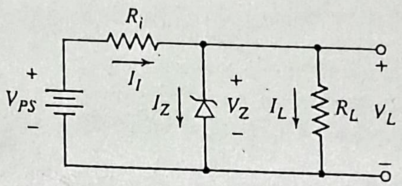
PART A continuation...



Q5. Consider the circuit shown in Figure below where the input voltage (V_{PS}) varies from 8 V to 10V and the Zener diode voltage (V_z) is 6 V. The load resistance (R_L) can vary from 200 Ω to 100 Ω. The minimum value of Zener current (I_z) can be considered as one-tenth of the maximum value of I_z.

(a) Calculate the maximum value of R_i so that the load voltage (V_L) remains constant at 6V for all possible values of R_L and V_{PS} within the specified range and find the maximum power dissipated by the Zener diode. [6]

(b) Calculate the minimum value of R_i so that the power dissipated by Zener diode never exceeds 0.5 W for all possible values of R_L and V_{PS} within the specified range. [4]

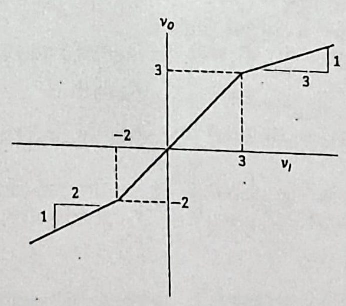


Q6. Design a circuit using diodes (with cut-in voltage $V_\gamma = 0.7$ V) and Zener diodes with appropriate breakdown voltages to provide the voltage transfer characteristic shown below.

(a) Draw the complete circuit diagram. [3]

(b) Find the breakdown voltages of the Zener diodes. [3]

(c) Find the relations of the required resistances in the circuit. [4]



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PART B: (Question for 2nd year Students only)

PART B

Instructions:

- **Answer All Questions. All waveform sketches / diagrams must be neatly drawn and clearly labeled.**
- The final answers (numerical values with unit) should be underlined or enclosed within box with unit.
- Avoid writing answers of the various parts of a single question at different locations in your answer-script.
- **If not explicitly mentioned in the question, (please assume) Thermal voltage (at room temperature) – 26 mV**
- Any value related to any device/ circuit parameter, which you may find not given, assume suitable value for such parameters.

1. (A) Two semiconductor materials have exactly the same properties except that material A0 has a bandgap of 1 eV and material A1 has a bandgap energy of 1.2 eV. What is the ratio of intrinsic concentration of material A0 to material A1 at 27° Celsius? (T=300K and Boltzmann's constant: 86×10^{-6}eV/K) [5]

   (B) Assume electronic charge $q = 1.6\times10^{-19}$ C, KT/q = 25 mV and electron mobility, $\mu_n = 1250\ cm^2/V-s$. If the concentration gradient of electrons injected into a p-type silicon sample is $-1\times10^{21}/cm^4$, What is the magnitude of electron diffusion current density (in A/cm²) ? [5]

2. (A)

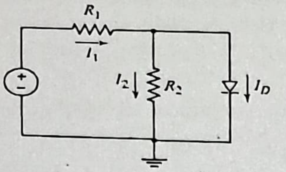

Fig 2(A)

A circuit contains a diode with cut-in voltage V_D= 0.7V. The diode is to remain biased "on" for a power supply voltage in the range $6 \le V_{PS} \le 12$V. The minimum diode current is to be $I_D(min)$ = 3 mA. The maximum power dissipated in the diode is to be no more than 15 mWatt. Determine appropriate values of R1 and R2. [5]

(B)

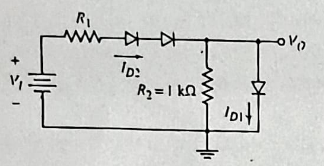

Fig 2(B)

Assume each diode in the circuit shown has a cut-in voltage of V_D=0.65V. Resistor R_2 is 1kΩ. Determine the appropriate values of R_1 and the currents I_{D1} and I_{D2} . Let input voltage be V_I = 5V . What is the value of R_1 required such that I_{D1} is one-half the value of I_{D2}? Also, determine the values of I_{D1} and I_{D2}. [5]

3. (A) The common-emitter current gain β for a bipolar junction transistor is given by

   a. I_C/I_B b. I_B/I_C c. I_E/I_B. d. I_B/I_E [1]

   (B) In a bipolar transistor biased in the forward-active region, the base current is i_B = 2.8μA, and the emitter current is i_E = 325μA. The common-emitter current gain β and collector current i_C are given by [1]

   a. β =115, i_C=322.2μA b. β =100, i_C=2.8μA c. β =50, i_C=325μA d. β =120, i_C=3.5μA

   (C) The range of common-emitter current gain β for a particular type of transistor is $110 \le \beta \le 180$. Determine the corresponding range of common-base current gain α. [1]

   a. 0.8801≤ α ≤ 0.8899 b. 0.9909≤ α ≤ 0.9944 c. 0.7722≤ α ≤ 0.7753 d. 0.6654≤ α ≤ 0.6696

   (D) A bipolar transistor is biased in the forward-active mode. The emitter current i_E = 1.25 mA and common-emitter current gain β = 150. Determine the base current i_B.. [1]

   a. 8.28 μA b. 4.56 μA c. 3.98 μA d. 9.87 μA

   (E)

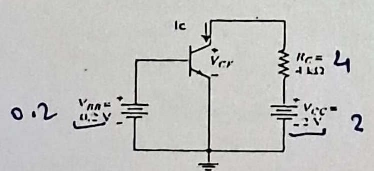

Fig 3(E)

For the transistor in the circuit Fig 3(E), β = 120, $V_{BE(on)}$ = 0.7 V. Determine I_C and V_{CE}. [2]

a. I_C = 0, V_{CE}=0.2V

b. I_C=0.2 mA, V_{CE}=2V

c. I_C=0.5 mA, V_{CE}=3V

d. I_C=-0.5 mA, V_{CE}=-1V

(F) A npn transistor has a common emitter current gain of β = 125. The transistor is biased at base-emitter voltage v_{BE} = 0.615 V. Determine the base current i_B, and emitter current i_E by assuming $I_s = 5\times10^{-15}$A (where $I_s = i_C e^{\frac{-v_{BE}}{V_T}}$). [2]

a. i_B=0.6889μA, i_E=78.95μA b. i_B=0.7495μA, i_E=94.44μA c. i_B=0.678μA, i_E=87.94μA d. i_B=0.967μA, i_E=56.98μA

PART B continuation...

(G)

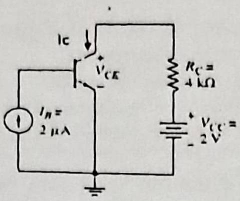

Fig 3(G)

For the transistor in Fig 3(G), $\beta = 120$. Determine I_C and V_{CE}. [2]

a. $I_C = 0$, $V_{CE} = 0.2$
b. $I_C = 0.24$ mA, $V_{CE} = 1.04$ V
c. $I_C = 0.3$ mA, $V_{CE} = 2.5$ V
d. $I_C = 0.5$ mA, $V_{CE} = -2$ V

4. (A)

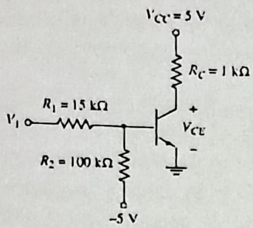

Fig 4(A)

Consider the circuit in Fig 4(A):

let $\beta = 25$ and $V_{BE(on)} = 0.7$ V for the transistor. Determine the range of V_I such that $1.0\text{V} \le V_{CE} \le 4.5\text{V}$. Sketch the load line and show the range of the Q-point values. [5]

(B) Consider the *npn* transistor circuit as shown in Fig 4(B):

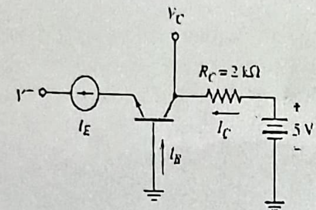

Fig 4(B)

(i) Let the common-emitter current gain of the transistor be $\beta = 80$. The emitter is driven by a constant-current source with $I_E = 1.2$ mA. Determine I_B, I_C, V_C, and the common-base current gain α. [2.5]

(ii) For the transistor, $\alpha = 0.9910$, and the emitter current in the circuit is I_E=0.80 mA. Determine base-emitter voltage V_{BE}, base current I_B, and collector current I_C by assuming the reverse saturation current for the base-emitter junction as $I_{EO} = 5\times10^{-14}$A. [2.5]

5. (A)

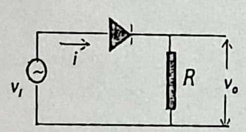

Fig 5(A)

For the circuit in Fig 5(A), vi=10 sinωt V, R=1 kΩ, $V\gamma$= 0.6V and forward diode resistance r_f = 20 Ω. (i) Find the average value of v_o (ii) Determine the peak diode current (iii) What is the PIV of the diode? [3+1+1]

(B)

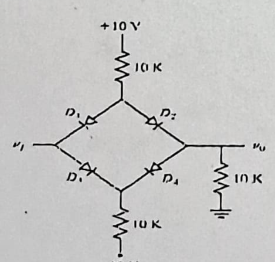

Fig 5(B)

In the circuit Fig 5(B), assume V=0.7V for each diode in the circuit below. Plot v_o vs v_I for $-10\text{V} \le v_I \le +10\text{V}$. [5]

6. (A) A DC power supply (bridge rectifier & capacitor filter) to deliver an average power of 2 Watt to a cell phone with a voltage of 3.6V and a ripple of 0.2 V. Find the capacitor value of the filter and PIV of each diode (Assume, f= 50 Hz, $V_{D,on}$ = 0.8 V). [3+2]

(B)

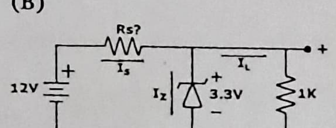

Fig 6(B)

In the circuit Fig 6(B), the Zener diode can handle up to 2 Watt power. Find the minimum value of Rs? Find maximum current flow through Zener. [3+2]