UNAM

UNIVERSITY OF NAMIBIA

FACULTY	AGRICULTURE, ENGINEERING AND NATURAL SCIENCES
DEPARTMENT	ELECTRICAL AND COMPUTER ENGINEERING
SUBJECT	**ANALOGUE ELECTRONICS 1**
SUBJECT CODE	I3691CA
DATE	JUNE 2024
DURATION	3 HOURS **MARKS** 100

FIRST OPPORTUNITY EXAMINATION

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This Memo consists of 8 pages excluding this front page.

Instructions

1. Answer **ALL FOUR** questions.
2. The marks allocation for each question are shown
3. Marks for different sections are shown on the right-hand margin
4. Begin each question on a new page
5. Clearly show your reasoning and all calculations.
6. Clearly show your calculations and sketch good label diagrams where required.
7. Important Equations on the last page of this question.

Question 1: [25 Marks]

(a) (i) You recently secured an attachment with an engineering firm fabricating electronic components and you are lucky to be part of a project where character recognition plays a very important role using photodiodes as a major component. Beyond this application of photodiodes, list at least four (4) other areas of applications of this component. **[4 Marks]**

(ii) Discuss the concept of drift and diffusion currents with respect to analogue electronics and highlight key differences between Drift and Diffusion Currents in a tabular format? **[3 Marks]**

(iii) The LED in Figure Q1A requires 30 mA to emit a sufficient level of light. Therefore, the collector current should be approximately 30 mA. For the following circuit values, V_{CC} = 9V, $V_{CE\,(sat)}$= 0.3V, R_C = 220 Ω, RB = 3.3 kΩ, β_{DC} =50, and V_{LED} =1.6 V. Determine the collector current at saturation i.e. $I_{C(sat)}$ and the minimum base current to make sure that the transistor saturate i.e. $I_{B(min)}$. **[5 Marks]**

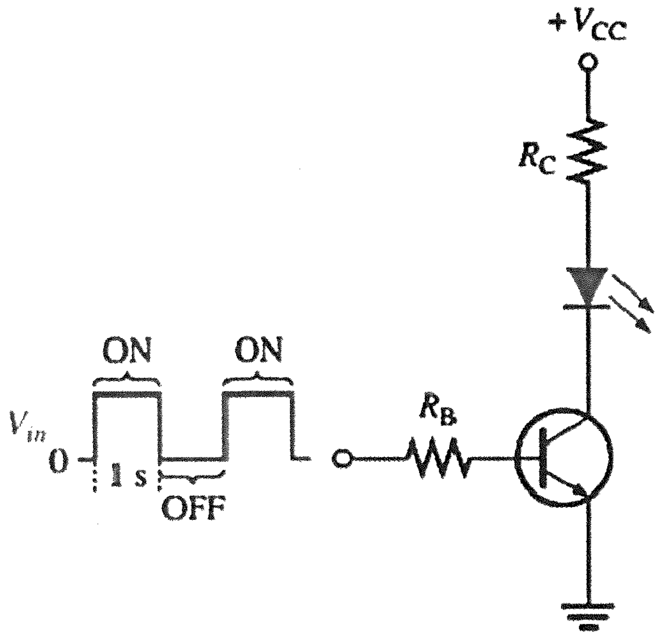

Figure Q1A

(bi) Calculate the majority and minority carrier concentrations in silicon at T = 300 K; $n_i = 1.5\text{x}10^{10}\,\text{cm}^{-3}$ for (i) $Nd = 2 \times 10^{16}$ cm^{-3} and (ii) $Na = 10^{15}$ cm^{-3}. **[3 Marks]** (bii) Determine the emitter current, base current and the voltages V_{CE} and V_{CB} for the circuit in figure Q1B below.

[10 Marks]

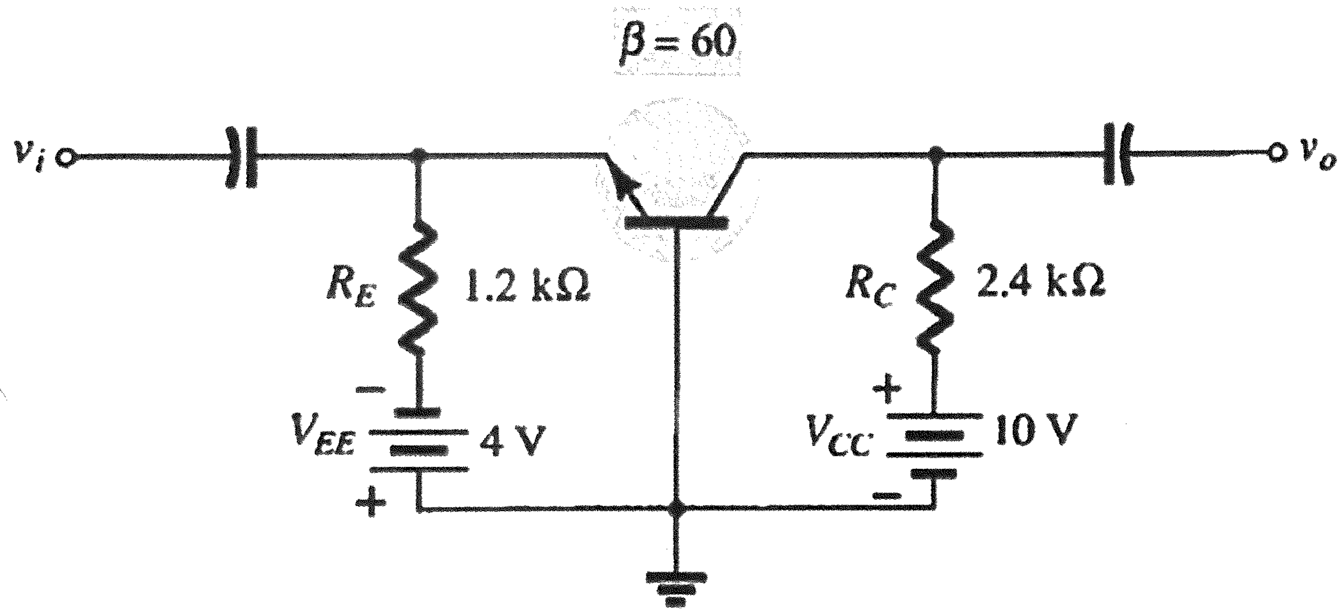

Figure Q1B

Question 2: [25 Marks]

(a) Explain the concept of Piecewise Linear Model in semiconductors and support your explanation with relevant diagram. **[5 Marks]**

(b) Identify the configuration of the bipolar junction transistor from the circuit in Figure Q2A; Analyse the circuit configuration; calculate the emitter voltage and the emitter current accordingly.

[5 Marks]

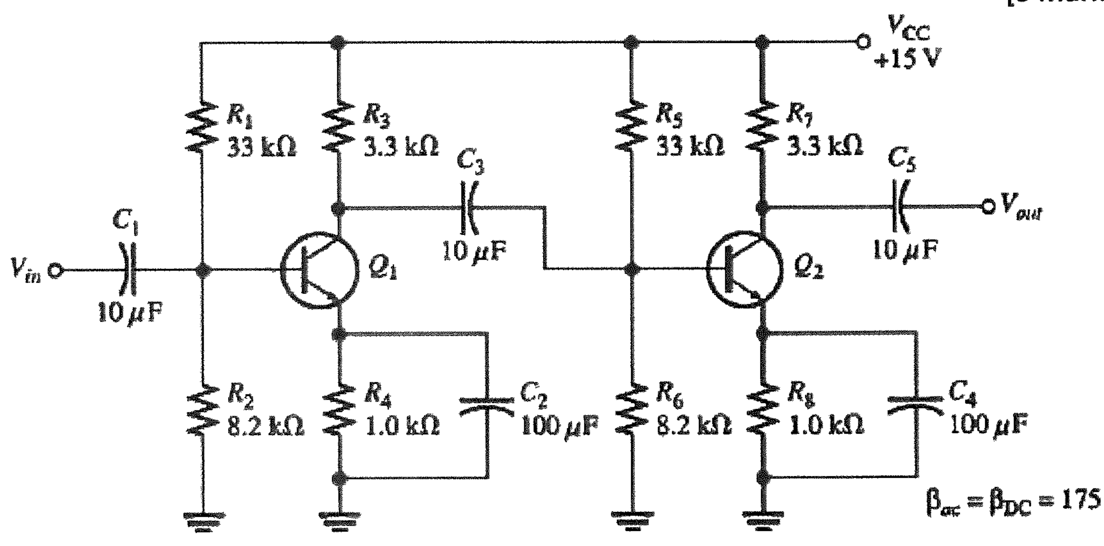

Figure Q2A

(c) With the aid of diagram only; indicate the basic element of optical transmission system and explain the analogue electronics component of this system and why they are important.

[5 Marks]

(d) Determine the current in each diode and the voltages V_A and V_B in the multi-diode circuit shown in Figure Q2B. Let $V\gamma$ = 0.7 V for each diode. **[10 Marks]**

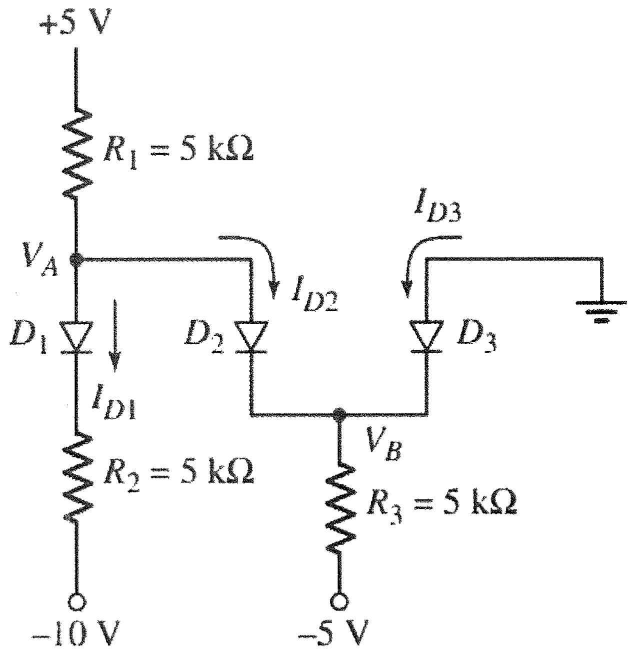

Figure Q2B

Question 3: [25 Marks]

(a) Explain the following concepts in details with respect to analogue electronics. Support your answers with diagram where necessary. **[10 Marks]**

(i) Barrier Potential, V_B
(ii) Leakage Current
(iii) Depletion Region
(iv) Average Forward-Current Rating, I_O
(v) Maximum forward-surge current rating, I_{FSM}

(b) Determine if the Zener diode of the circuit in figure Q3B is biased properly. If so, find Iz and the power dissipated by the diode.

[10 Marks]

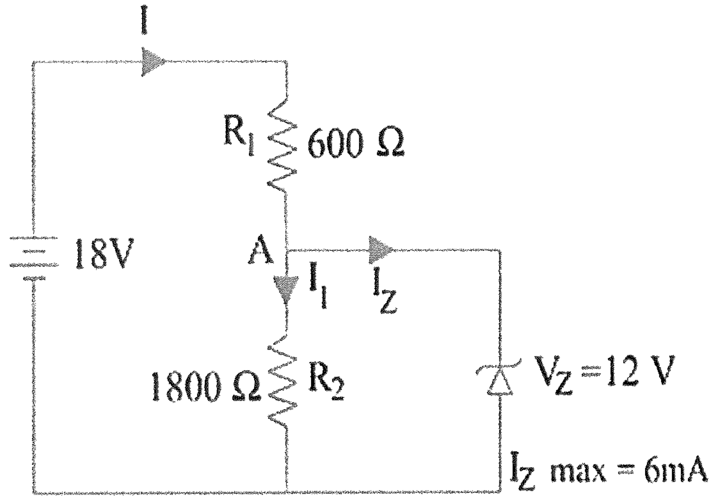

Figure Q3B

(c) A JFET in the Fig Q3C below has values of $V_{GS\,(off)} = -8V$, $V_{GS} = -5V$ and $I_{DSS} = 16$ mA. Determine the value of I_D for the circuit.

[5 Marks]

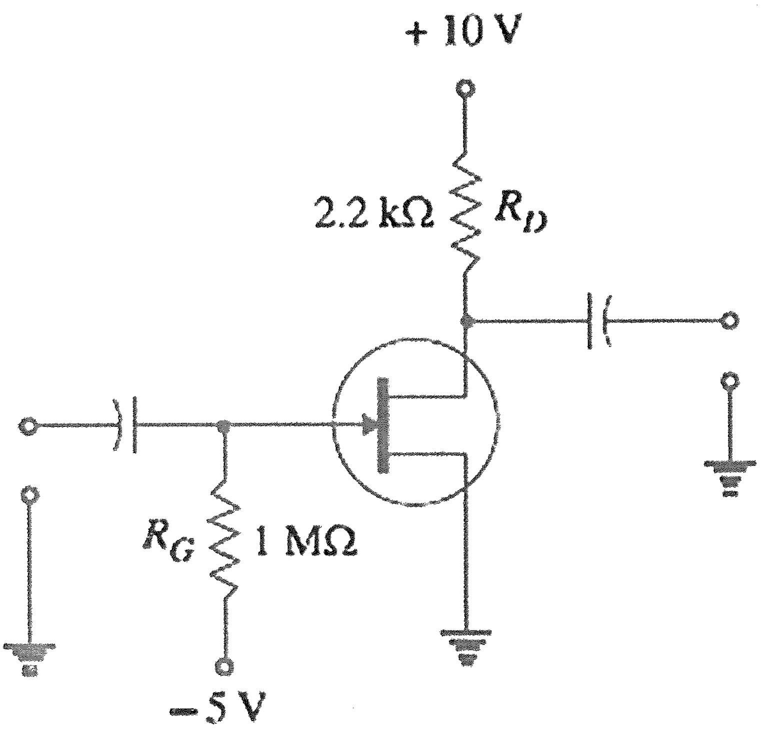

Figure Q3C

Question 4: [25 Marks]

(a) Determine the input and output impedances of the amplifier in Figure Q4A. The op-amp datasheet gives Z_{in} = 2M Ω, Z_{out} = 75 Ω, and A_{ol} = 200,000. **[10 Marks]**

(ii) Find the closed-loop voltage gain.

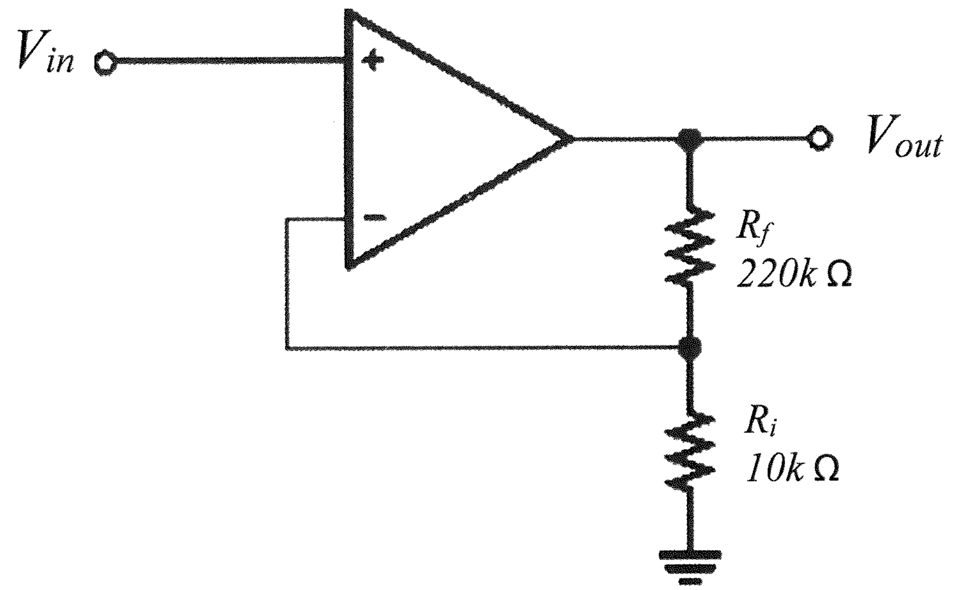

Figure Q4A

(b) In the JFET circuit shown in Fig. Q4b find the values of (i) V_{DS} and (ii) V_{GS}. **[5 Marks]**

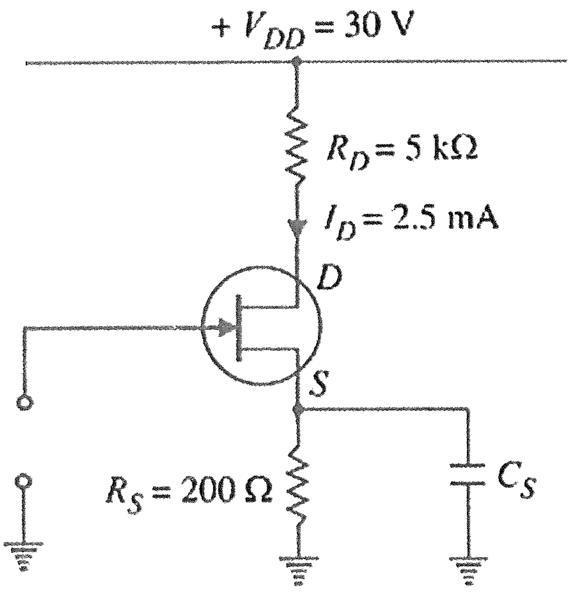

Figure Q4b

(c) A three-stage OP-amp circuit in figure Q4c is required to provide voltage gains of +10, –18 and –27. Design an OP-amp circuit to use a 270 kΩ feedback resistor for all three circuits. What output voltage will result for an input of 150 μV? **[10 Marks]**

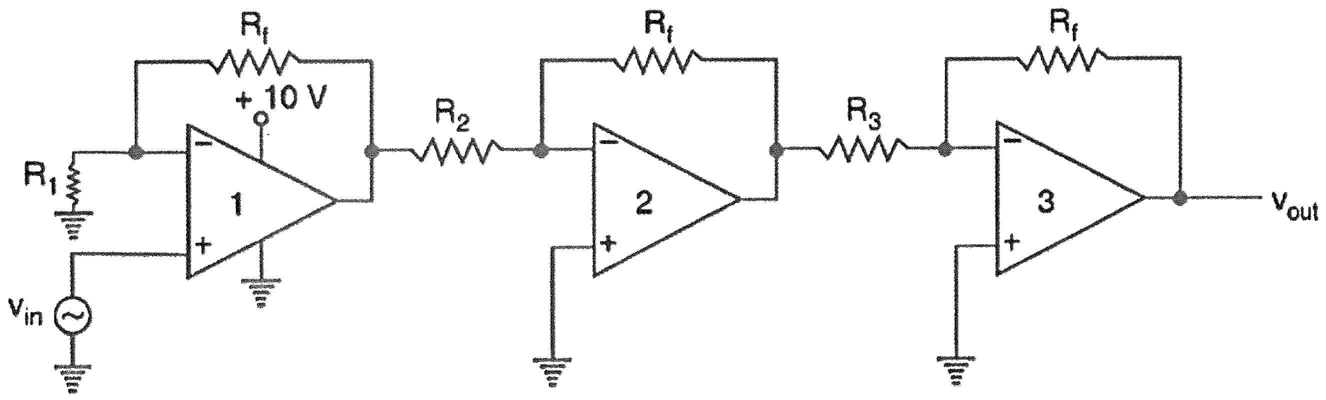

Figure Q4c

IMPORTANT EQUATIONS

$$\mathbf{CMRR} = \frac{A_{ol}}{A_{cm}}$$

$$\mathbf{CMRR} = 20\log\left(\frac{A_{ol}}{A_{cm}}\right)$$

$$I_{\mathrm{BIAS}} = \frac{I_1 + I_2}{2}$$

$$I_{\mathrm{OS}} = |I_1 - I_2|$$

$$V_{\mathrm{OS}} = I_{\mathrm{OS}} R_{in}$$

$$V_{\mathrm{OUT(error)}} = A_v I_{\mathrm{OS}} R_{in}$$

$$\textbf{Slew rate} = \frac{\Delta V_{out}}{\Delta t}$$

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2 = I_{DSS}\left(I-\frac{V_{GS}}{V_{GS(off)}}\right)^2$$

$$V_{GS} = -I_D R_S$$

$$\frac{I_{LM}}{\pi}$$

$$V_S = I_D R_S$$

$$V_D = V_{DD} - I_D R_L$$

$$V_{DS} = V_D - V_S$$

$V_{GS} = V_G - V_S$ OR $V_{GS} = -I_D R_S$ OR $V_{GS} = V_{SS} - I_D R_S$

$$V_{SS} = I_D R_S + V_{GS}$$

Output voltage is $V_0 = A(V_1 - V_2)$

$$g_m = -\frac{2I_{DSS}}{V_P}\left(1-\frac{V_{GS}}{V_P}\right)$$

$$g_{mo} = -\frac{2I_{DSS}}{V_P}$$

$$A_V = \frac{-g_m r_d R_L}{r_d + R_L}$$

$$C_i = C_{gs} + (1 - A_V)\, C_{gd}$$

$$Z_{in(NI)} = (1 + A_{ol}B)Z_{in}$$

$$Z_{out(NI)} = \frac{Z_{out}}{1 + A_{ol}B}$$

$$Z_{in(VF)} = (1 + A_{ol})Z_{in}$$

$$Z_{out(VF)} = \frac{Z_{out}}{1 + A_{ol}}$$

$$Z_{in(I)} \cong R_i$$

$$Z_{out(I)} = \frac{Z_{out}}{1 + A_{ol}B}$$

$$V_{L(dc)} = I_{L(dc)} \cdot R_L$$

$$I_{LM} = \frac{V_{sm} - V_B}{R_0 + R_L}$$

$V_{out} = A_{ol}(V_{in} - V_f)$ $\quad\therefore\quad$ Differential voltage gain, $A_{DM} = \dfrac{v_o}{v_{in}}$

Output voltage, $v_{out} = A_{CL} \times v_{in}$

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_{GS(off)}}\right)^2$$

$$n_i = BT^{3/2}\exp\left(\frac{-E_g}{2kT}\right)$$

$$V_E = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} - V_{BE}$$

$$I_{C(sat)} = \frac{V_{CC} - V_{LED} - V_{CE(sat)}}{R_C}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}}$$

IMPORTANT Parameters

Temperature, $T = 300K$,

For Gallium Arsenide,

Band gap energy is $E_g = 1.4\text{eV}$.

Specific semiconductor coefficient is $B = 2.10 \times 10^{14}\text{cm}^{-3}\text{K}^{-3/2}$.

Boltzmann's constant is $k = 86 \times 10^{-6}\text{eV/K}$.

For Germanium,

Band gap energy is $E_g = 0.66\text{eV}$.

Specific semiconductor coefficient is $B = 1.66 \times 10^{15}\ \text{cm}^{-3}\text{K}^{-3/2}$.

Boltzmann's constant is $k = 86 \times 10^{-6}\text{eV/K}$.