THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

SECOND SEMESTER EXAMINATION 2021

EE222 ANALOG ELECTRONICS AND CIRCUITS

ELECTRICAL & COMMUNICATIONS ENGINEERING – YEAR 2 (BEEL)

TIME ALLOWED: THREE (3) HOURS

INFORMATION FOR STUDENTS:

1. You have **TEN (10)** minutes to read the paper.
   You must **NOT** begin answering during this time.

2. This is a closed book exam, only drawing instruments and calculators are allowed. No **ELECTRONIC DEVICES PERMITTED.**

3. There are 5 questions in this paper. Answer **ALL** questions.

4. All questions carry equal marks as shown. The paper is worth 50 marks.

5. If you are found cheating in the examination, the penalties specified by the University shall apply.

6. All **MOBILE** phones must be turned off before the start of the examination and remain **OFF** during examination period.

QUESTION ONE: [3+5+2=10]

a) Calculate the intrinsic carrier concentration in germanium at T = 300 K. Some parameters you may need for your calculation are provided below.

Semiconductor constants		
Material	***Eg* (eV)**	***B* (cm^{-3} K$^{-3/2}$)**
Silicon (Si)	1.1	5.23 x 10^{15}
Gallium arsenide (GaAs)	1.4	2.10 x 10^{14}
Germanium (Ge)	0.66	1.66 x 10^{15}

Boltzmann's constant (k) = (86 × 10^{-6} eV/K)
Electron charge, e = 1 eV = 1.6 × 10^{-19} joules

b) Calculate the majority and minority carrier concentrations in germanium at T = 300 K for:

(i) $N_d = 2 \times 10^{16}$ cm^{-3} and
(ii) $N_a = 10^{15}$ cm^{-3}

c) Current flow in a semiconductor are caused by two basic processes. What are the two processes and what causes the current flow in each case?

QUESTION TWO: [5+5=10]

a) Calculate the built-in potential barrier, V_{bi}, for a Germanium pn junction at T = 300 K for $N_a = 10^{16}$ cm^{-3} and $N_d = 10^{17}$ cm^{-3}.

b) A silicon pn junction at T = 300 K is doped at $N_d = 10^{16}$ cm^{-3} and $N_a = 10^{17}$ cm^{-3}. The junction capacitance is to be C_j = 0.8pF when a reverse-bias voltage of V_R = 5V is applied. Find the zero-biased junction capacitance, C_{jo}.

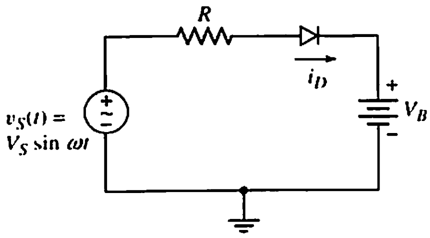
QUESTION THREE: [4+6=10]

a) A silicon pn junction diode at T = 300 K has a reverse-saturation current of I_S = 2 x 10^{-12} A. Determine the required forward-bias voltage to produce a current of

(i) I_D = 50 μA
(ii) I_D = 1 mA.

Assume n = 1.

b) For the circuit given below, assume V_B = 4.5 V, R = 250 Ω, V_γ = 0.6 V, and $v_S(t) = 12 \sin\omega t$ (V).

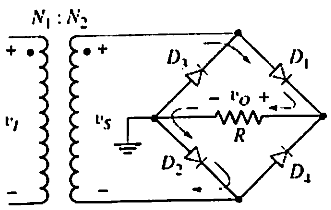


Determine:

(i) the peak diode current
(ii) the maximum reverse-bias diode voltage
(iii) the fraction of the cycle over which the diode is conducting.

QUESTION FOUR: [5+5=10]

a) The bridge circuit shown below has an input voltage of $v_S = V_M \sin\omega t$. Assuming a diode cut-in voltage of $V_\gamma = 0.7V$, determine the fraction (percent) of time diode $D1$ is conducting for a peak sinusoidal voltage of $V_M = 4$ V.



b) Assume the input signal to a rectifier circuit has a peak value of $V_M = 12$ V and is at a frequency of 60 Hz. Assume the output load resistance is $R = 2$ kΩ and the ripple voltage is to be limited to $V_r = 0.4$ V. Determine the capacitance required to yield this specification for a (i) full-wave rectifier and (ii) half-wave rectifier.

QUESTION FIVE: [10]

Design a full-wave rectifier which will supply a peak output voltage of 12 V, deliver 120 mA to the load, and produce a ripple output of not more than 5 percent. The input line voltage for the rectifier will be 120 V (rms) at 60 Hz.

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$$n_i = \quad ^{3/2}e(\quad) \tag{1.1}$$

$$n_o p_o = n_i^2 \tag{1.2}$$

$$V_{bi} = \frac{kT}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right) = V_t \ln\left(\frac{N_a N_d}{n_i^2}\right) \tag{1.16}$$

$$C_j = C_{jo}\left(1 + \frac{V_R}{V_{bi}}\right)^{-1/2} \tag{1.17}$$

$$i_D = I_S\left[e^{\left(\frac{v_D}{nV_T}\right)} - 1\right] \tag{1.18}$$

Hints for Question 3 (b) and Question 4 (a):

Solve using Kirchhoff's Voltage Law

i_D(peak) =

v_R(max) =

wt_1 =

By symmetry, wt_2 =

Percentage time =

$$V_r = \frac{V_M}{2fRC} \tag{2.9}$$

Hints for Question 5:

RL =

v_S(max) =

v_S(rms) =

N1/N2 =

V_r =

C =

$$i_{D,\text{peak}} \cong \frac{V_M}{R}\left(1 + \pi\sqrt{\frac{2V_M}{V_r}}\right) \quad \textbf{(2.21)}$$

$$i_D(\text{avg}) = \frac{1}{\pi}\sqrt{\frac{2V_r}{V_M}}\frac{V_M}{R}\left(1 + \frac{\pi}{2}\sqrt{\frac{2V_M}{V_r}}\right) \quad \textbf{(2.25)}$$

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