VISVESVARAYA NATIONAL INSTITUTE OF TECHNOLOGY, NAGPUR
Department of Electrical Engineering
Electronic Devices and Circuits (Code: ECL206)

Date: Sept 05, 2015
Time: 10:30–11:30 A.M.

Time: 1 hour | *Sessional Examination I* | Maximum Marks: 15
Weightage: 15 %

Important instructions:

- This is a closed book, closed notes examination.
- This question paper comprises total four questions printed on two pages.
- All the questions are compulsory.
- Maximum marks that can be obtained for a particular question are indicated on the right of the corresponding question.
- Non-programmable calculators are permitted for use during the examination.
- Please begin the answers to each main question on a new page of the answer booklet.
- Please indicate the important steps of reasoning/ calculations clearly.
- Unless otherwise specified, assume silicon semiconductor.
- The cut-in/ knee voltages for Si, Ge, and GaAs are 0.7 V, 0.3 V and 1.2 V respectively.
- Assume suitable data wherever necessary. Please mention the assumptions made, if any.

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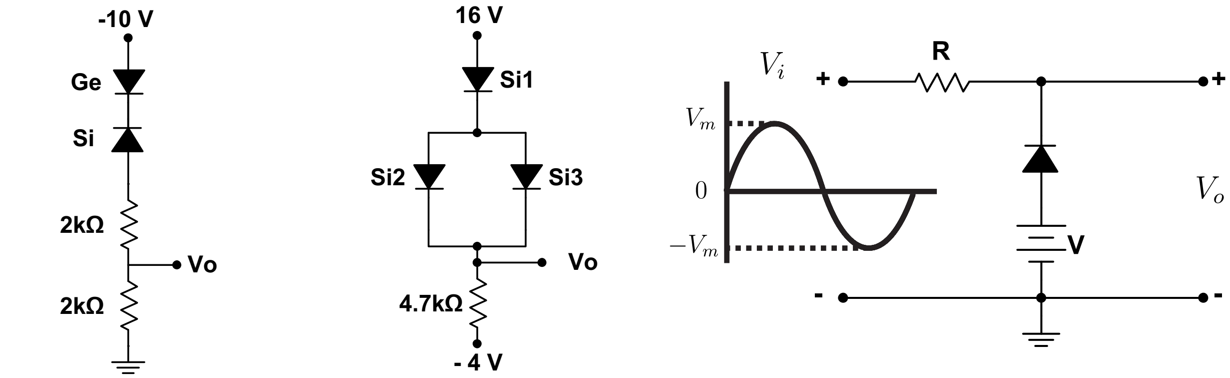
1. Answer the following. (No justification, No marks!)
   (a) The depletion region penetrates more towards the lightly doped region. True or False? Justify your answer. [1]
   (b) The two types of capacitive effects found in *pn*-junction diode are ______. [1]
   (c) At a certain temperature, the reverse saturation current for a *pn*-junction diode is found to be $25\mu A$. If the temperature is raised by an amount of 15°C, the new current is ______. [1]
2. Answer the following. (No justification, No marks!)
   (a) For the circuit shown in Figure 2a, **Si** and **Ge** indicates silicon and germanium *pn*-junction diodes respectively. Find V_o. [1]
   (b) For the circuit shown in Figure 2b, **Si1, Si2, Si3** indicates the silicon diodes. Find V_o and current through **Si1** [1]
   (c) For the circuit shown in Figure 2c, V_i indicates the sinusoidal input signal with the peak-to-peak voltage as $2V_m$. Neatly sketch and label the corresponding V_o such that $V < |V_m|$. Assume the diode shown to be an ideal *pn*-junction diode. [1]



(a) Figure for Q.2a (b) Figure for Q.2b (c) Figure for Q.2c

Figure 2: Figures for Q.2

3. For the circuit shown in Figure 3, assume $\beta = 100$
   (a) Find if the transistor is in cutoff, saturation or active region. [1]
   (b) Calculate the percentage change in base current (I_B), collector current (I_C) and collector to emitter voltage (V_{CE}) when β is reduced to 50. [1]
   (c) Repeat Part (a) and Part (b) for $RE = 0\Omega$. [2]
   (d) What change is observed when RE is changed from 2 $K\Omega$ to 0 Ω? Give proper explanation. [1]

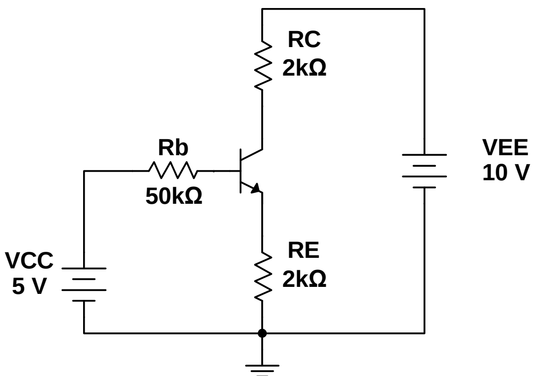


Figure 3: Figure for Q.3

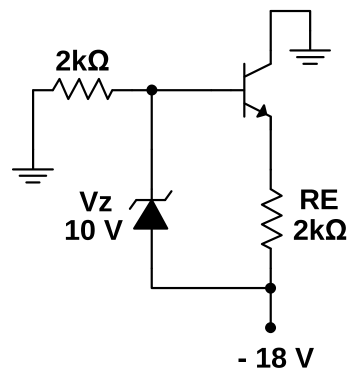


Figure 4: Figure for Q.4

4. For the circuit shown in Figure 4, assume transistor $\beta = 100$ and Zener breakdown voltage as 10 V.
   (a) Calculate transistor currents I_B, I_C, I_E [1]
   (b) Calculate V_{CE} [1]
   (c) Repeat Part (a) and Part (b) for $RE = 2\ \Omega$. [2]

Q1

a] TRUE. To maintain/satisfy the charge neutrality principle, the number of uncovered charges on each side of a junction must remain equal.

b] ① Transition / Depletion / space-charge capacitance.

② Diffusion / storage capacitance.

c] Given : $(T_2 - T_1) = 15°c$ & $I_1 = 25\ \mu A$

$\therefore\ I_2 = I_1 \times 2^{(T_2 - T_1)/10}$

$\therefore\ \boxed{I_2 = 25\ \mu A \times 2^{1.5} = 70.71\ \mu A}$

As the reverse saturation current doubles every 10°C rise in Temp.

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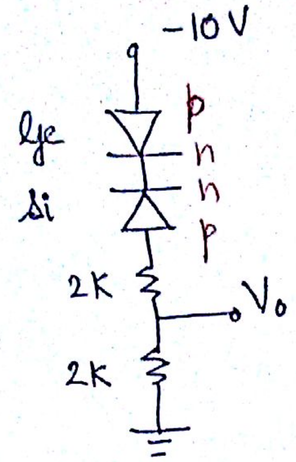
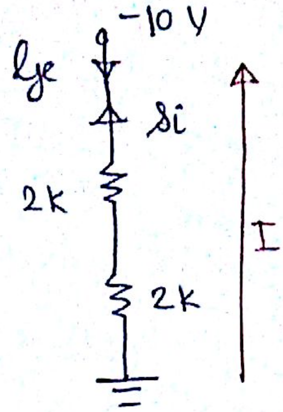
②

Q.2 a]



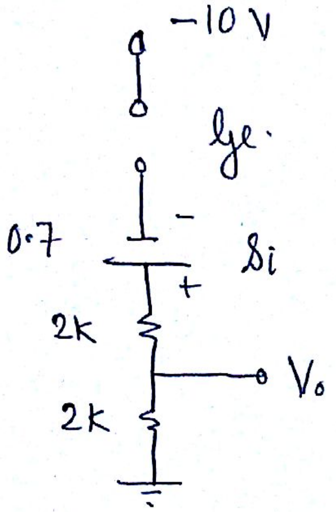
Step ① : Determine the state of the diodes (ON/OFF)



The direction of actual current flow is in sync/along the direction of Si diode current But opposite to the direction of Ge diode current.

Step ② :

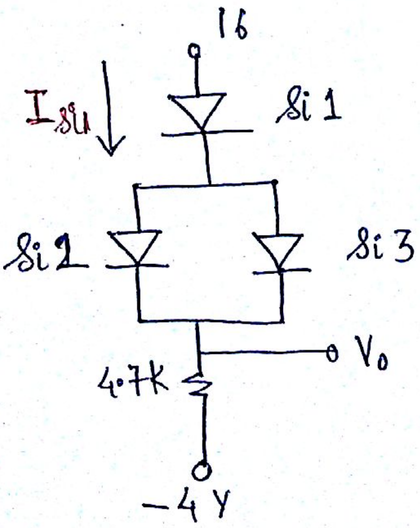
Therefore, the Si diode will be replaced by 0.7 V & Ge by an open circuit equivalents as shown.



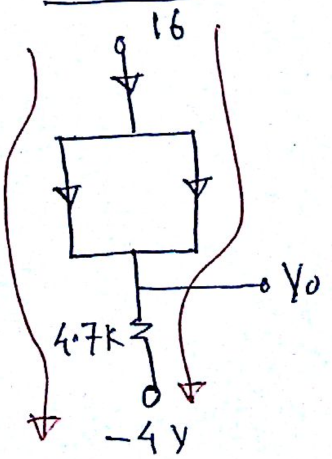
As the current flowing is zero, No voltage is dropped across 2K resistor.

$\therefore \boxed{V_0 = 0\,V}$

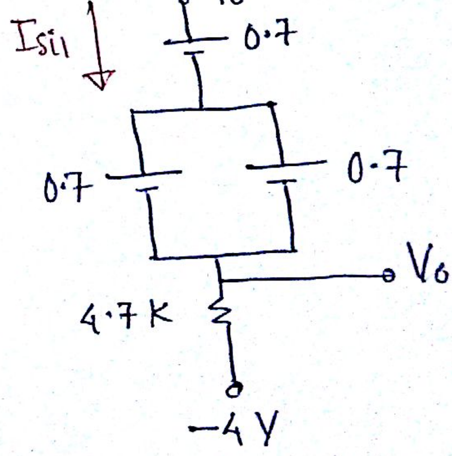
b]



Step ①



Step ②



$\therefore$ Applying KVL, $16 - 0.7 - 0.7 - 4.7K(I_{Si1}) + 4 = 0$

$\therefore \boxed{I_{Si1} = 3.957\ mA}$ $\quad V_0 = I_{Si1} \times 4.7k - 4 \quad \therefore \boxed{V_0 = 14.6\ V}$

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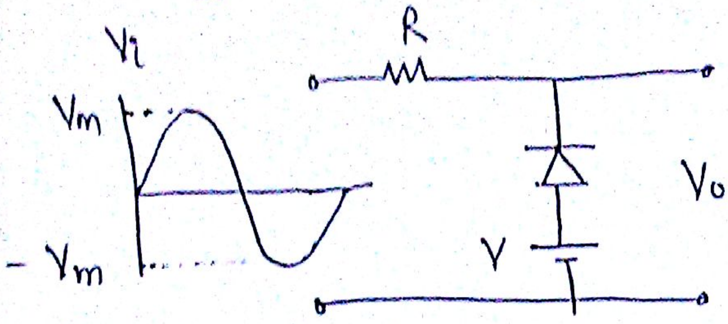
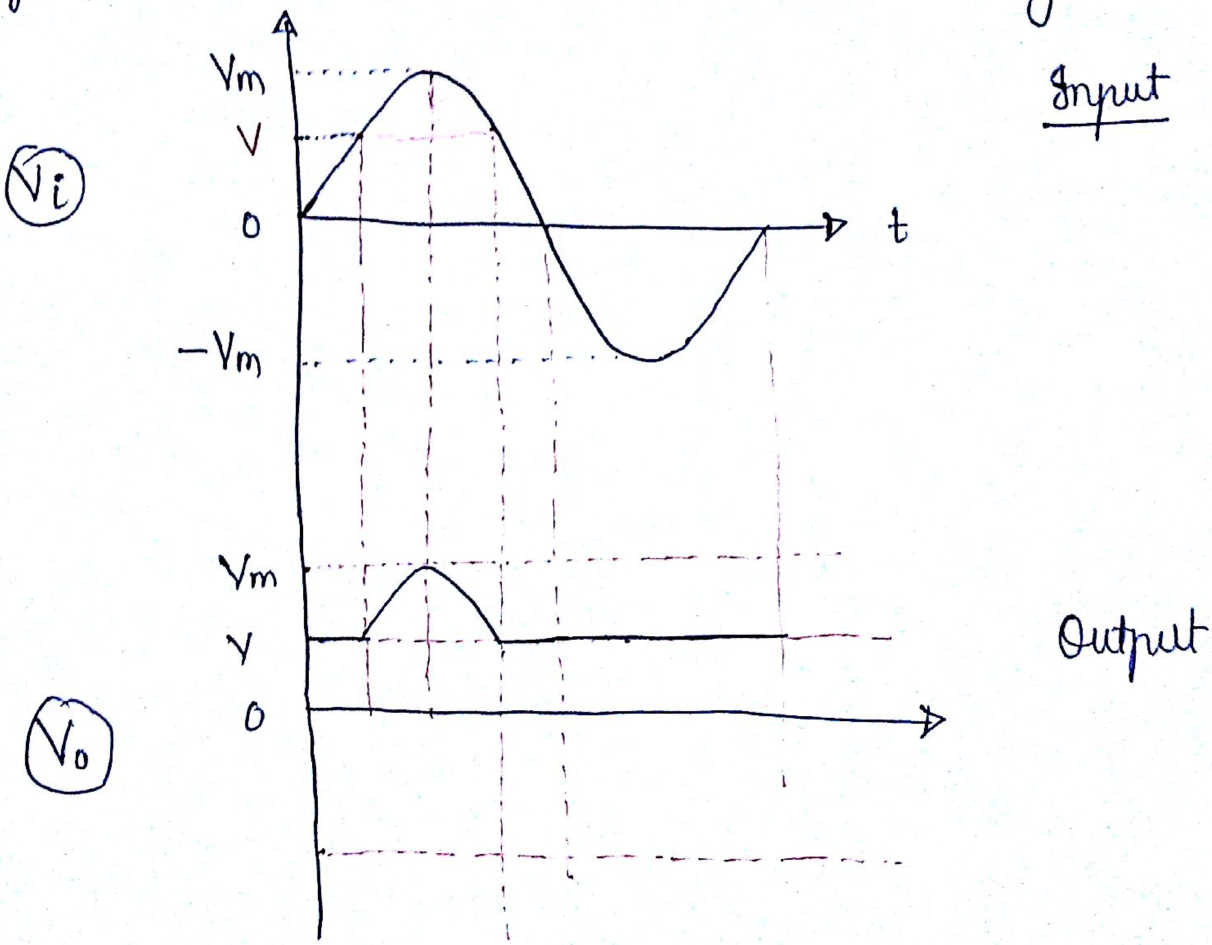
Q.2 c]



Step ① Determine the state of the diode.

Initially the diode is already forward biased. The diode being ideal, acts as a short circuit, till the input voltage reaches $V_i = V$. After which a constant voltage of V volts would be maintained, as shown, assuming $V < |V_m)$



During the negative half cycle, the diode continues to remain in ON state (thus short circuit, ideally).

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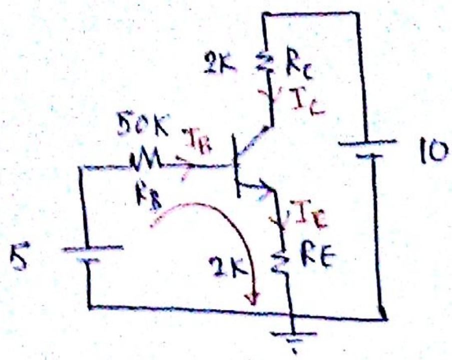
Q.3

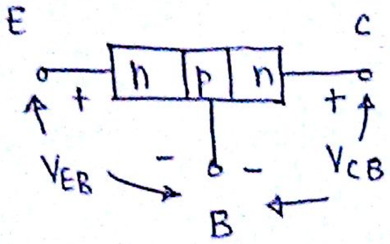


$\boxed{\beta = 100}$

Determining the region of Operation of a transistor.

Region	Emitter Junction	Collector Junction
Active	Forward	Reverse
Saturation	Forward	Forward
Cutoff	Reverse	Reverse.

For npn transistor:



Region	V_{EB}	V_{CB}
Active	$-ve$	$+ve$
Saturation	$-ve$	$-ve$
Cutoff	$+ve$	$+ve$

(a) Step ①: Calculate base current by applying KVL to base-emitter loop.

$$5 - 50K(I_B) - V_{BE} - I_E(2K) = 0$$

$$\therefore I_B = \frac{5 - 0.7}{50K + 101 \times 2K} \Rightarrow \boxed{I_B = 17.063\ \mu A}$$

Emitter Junction is forward bias i.e $V_{BE} = +ve$ OR $V_{EB} = -ve$

$$\therefore I_C = \beta I_B \Rightarrow \boxed{I_C = 1.7063\ mA}$$

$$I_E = (1+\beta) I_B \Rightarrow \boxed{I_E = 1.7234\ mA}$$

Step ②: To check the Collector Junction, apply KVL along Collector-base junction.

$$10 - 2K(I_C) - V_{CB} + 50K(I_B) - 5 = 0$$

$$\therefore V_{CB} = 5 - 2K(100 \times I_B) + 50K(I_B)$$

$$\therefore \boxed{V_{CB} = 2.453\ V}$$ i.e POSITIVE $\therefore$ The transistor is in ACTIVE REGION

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(5)

* **Verify:** Calculate I_{Csat},

$$I_{Csat} = \frac{10}{4K} = 2.5\ mA$$

As $\boxed{I_C = 1.7\ mA < I_{Csat} = 2.5\ mA}$

∴ The Transistor cannot be in saturation.

To calculate V_{CE}, apply KVL in collector emitter loop.

$$10 - 2k(I_C) - V_{CE} - 2k(I_E) = 0$$

$$\therefore \boxed{V_{CE} = 3.1414\ V}$$

(b) For $\beta = 50$,

$$I_B = \frac{5 - 0.7}{50k + (51) \times 2k} \Rightarrow \boxed{I_B = 28.28\ \mu A}$$

$$\boxed{I_C = 1.414\ mA} \quad \boxed{I_E = 1.4427\ mA}$$

$$V_{CB} = 5 - 2k(50 \times I_B) + 50k(I_B) \Rightarrow \boxed{V_{CB} = 0.888\ V}$$ POSITIVE

$$V_{CE} = 10 - 2k(I_C) - 2k(I_E)$$

$$\boxed{V_{CE} = 4.8346\ V}$$

$$\boxed{I_{Csat} = 2.5\ mA}$$

Comparison:

	$\beta = 100$	$\beta = 50$	% change
I_B	17.063 μA	28.28 μA	65.73 %
I_C	1.7063 mA	1.414 mA	20.67 %
V_{CE}	3.1414 V	4.8346 V	53.899 %
Status	Active	Active	—

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Q.3

[c] (i) For $RE = 0\,\Omega$ & $\beta = 100$

∴ The transistor is SATURATION

$5 - 50k(I_B) - V_{BE} = 0 \Rightarrow I_B = \frac{5-0.7}{50k} \Rightarrow \boxed{I_B = 86\,\mu A}$

$\boxed{I_C = 8.6\,mA}$ $\boxed{I_E = 8.686\,mA}$ $\boxed{I_{Csat} = 5\,mA}$

$V_{CB} = 10 - 2k(I_C) + 50k(I_B) - 5 \Rightarrow \boxed{V_{CB} = -7.9\,V}$

$V_{CE} = 10 - 2k(I_C)$

$\therefore \boxed{V_{CE} = -7.2\,V}$

(ii) For $RE = 0\,\Omega$ & $\beta = 50$

$5 - 50k(I_B) - V_{BE} = 0 \Rightarrow \boxed{I_B = 86\,\mu A}$

$\boxed{I_C = 4.3\,mA}$ $\boxed{I_E = 4.386\,mA}$ $\boxed{I_{Csat} = 5\,mA}$

$V_{CB} = 10 - 2k(I_C) + 50k(I_B) - 5$

$\boxed{V_{CB} = 0.7\,V}$

$V_{CE} = 10 - 2k(I_C)$

$= 10 - 2k(4.3m)$

$\boxed{V_{CE} = 1.4\,V}$

~~Region~~ Comparison :

	$\beta = 100$	$\beta = 50$	% change
I_B	$86\,\mu A$	$86\,\mu A$	0 %
I_C	$8.6\,mA$	$4.3\,mA$	100 %
V_{CE}	$-7.2\,V$	$1.4\,V$	119.4 %
Status	Saturation	Active	—

(d) For Fixed-bias configuration ($RE = 0\,\Omega$), change in β changes the operation region.

For Emitter-bias configuration ($RE \neq 0\,\Omega$), change in β ~~ch~~ retains the operating region.

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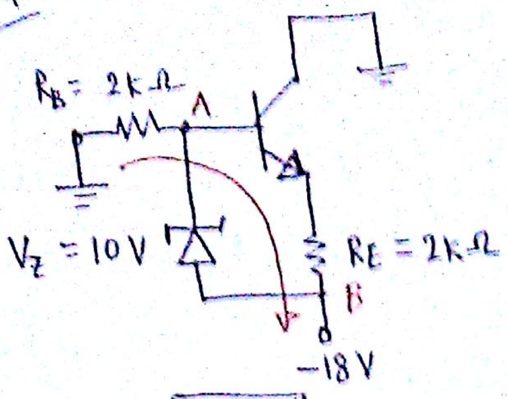
Q.4



$\boxed{\beta = 100}$

Step ① : First determine if the Zener diode region of operation.

$$-2k(I_B) - 0.7 - 2k(I_E) + 18 = 0$$

$$-2k(I_B) - 0.7 - 2k(10\cancel{1} \times I_B) + 18 = 0$$

$$I_B = \frac{18 - 0.7}{2K + 10\cancel{1} \times 2K}$$

$$\Rightarrow \boxed{I_B = 84.80\ \mu A} \boxed{I_E = 8.56\ mA}$$

$$V_{AB} = V_{BE} + R_E \times I_E \Rightarrow V_{AB} = 0.7 + 2k(8.65m)$$

Step ② : Calculate actual values: $V_{AB} = 17.83V$

As $V_{AB} > V_Z$, The Zener goes into break-down. maintaining

$$\boxed{V_{AB} = 10\ V} = V_Z$$

$$V_{RE} = 10 - 0.7 = 9.3\ V$$

$$I_E = \frac{9.3}{2K} \quad \therefore \boxed{I_E = 4.65\ mA}$$

$$\therefore V_{CE} = 2K(4.65m) - 18 \Rightarrow \boxed{V_{CE} = -8.70\ V}$$

For $R_E = 2\Omega$: Step① :

$$-2K(I_B) - 0.7 - 2(I_E) + 18 = 0$$

$$-2K(I_B) - 0.7 - 2(100 \times I_B) + 18 = 0$$

$$\therefore I_B = \frac{18 - 0.7}{2k + 100 \times 2} = \frac{18 - 0.7}{2K + 200} = \frac{17.3}{2.2K}$$

$$\therefore \boxed{I_B = 7.86\ mA} \boxed{I_E = 0.794\ A}$$

$$V_{RE} = 2 \times 0.794 \Rightarrow \boxed{V_{RE} = 1.58\ V}$$

$$\therefore V_{AB} = 0.7 + 1.58 \Rightarrow \boxed{V_{AB} = 2.28\ V}$$

$\therefore$ Zener diode is OFF

$$\therefore V_{CE} = V_{RE} - 18 \Rightarrow \boxed{V_{CE} = -15.71\ V}$$

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