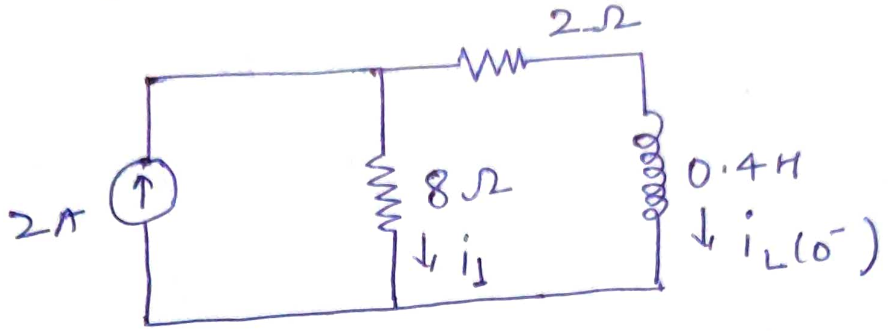
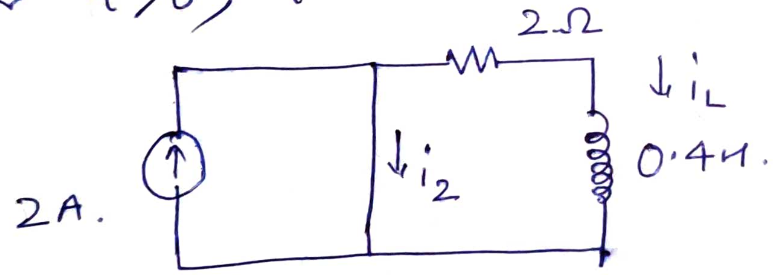
Ans-1 For $t<0$, the initial condition of current $i_L(0^-)$, $i_1(0^-)$ and $i_2(0^-)$ is calculated from the figure :-



In steady state inductor can be represented by short circuit. So $i_2(0^-)=0$

0.5MARKS → $i_1(0^-) = \frac{2}{10}\times 2 = \frac{2}{5}$ A, $i_L(0^-) = \frac{8}{10}\times 2 = \frac{8}{5}$ A

for $t>0$, the circuit can be redrawn as:-



The current i_L flowing through the inductor is :-

$$i_L(\infty) = i_L(\text{final}) + \left[i_L(\text{initial}) - i_L(\text{final})\right]\exp\left(\frac{-t}{\tau}\right)$$

Time constant $\tau = \frac{L}{R} = \frac{0.4}{2} = \frac{1}{5}$ sec. → 0.5MARKS

$$i_L(\text{final}) = i_L(\infty) = 0\text{ A}$$

$$i_L(0^+) = i_L(0^-) = \frac{8}{5}\text{ A.}$$

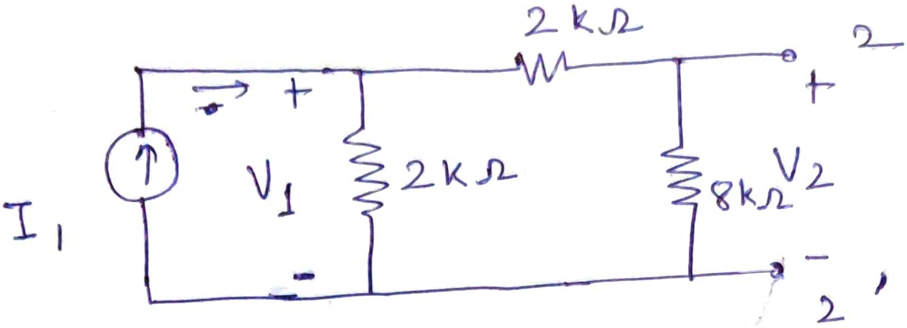
$$i_L(t) = \frac{8}{5}\exp\left(-\frac{t}{\tau}\right) = \frac{8}{5}\exp(-5t).$$

$$i_L(0.15s) = \frac{8}{5}\exp(-0.75) = 0.754\text{ A}$$ 1MARK

$$i_2(0.15\text{sec}) = 2\text{ A} - 0.754\text{ A} = 1.25\text{ A}$$ 1MARK

$$i_1(0.15\text{sec}) = 0\text{ A}$$

Ans-2 To calculate Z_{11} and Z_{21} we open circuit the port-2.

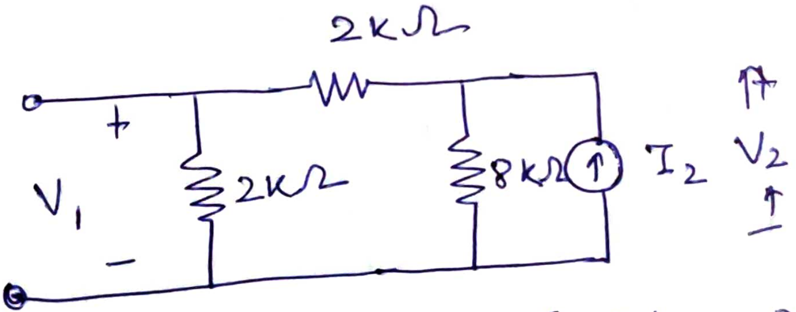


1.5 MARK

$$Z_{11} = \frac{V_1}{I_1} = \frac{\left[\frac{\cancel{10k}^{\,5}}{\cancel{12k}_{\,6}} \times \cancel{I_1}\right] \times 2k}{\cancel{I_1}} = \frac{5}{3}\ k\Omega$$

$$Z_{21} = \frac{V_2}{I_1} = \frac{\left[\frac{2k}{12k} \times I_1\right] \times 8k}{I_1} = \frac{4}{3}\ k\Omega$$

To calculate Z_{12} and Z_{22}, we open circuit port-1.



1.5 MARK

$$Z_{12} = \frac{V_1}{I_2} = \frac{\left[\frac{8k}{12k} \times 2k\right] \times \cancel{I_2}}{\cancel{I_2}} = \frac{4}{3}\ k\Omega$$

$$Z_{22} = \frac{V_2}{I_2} = \frac{\left[\frac{4k}{12k} \times 8k\right] \times \cancel{I_2}}{\cancel{I_2}} = \frac{8}{3}\ k\Omega.$$

Ans-3 In the circuit, we will first determine the equivalent input resistance R_{eq} of the shaded part as shown below

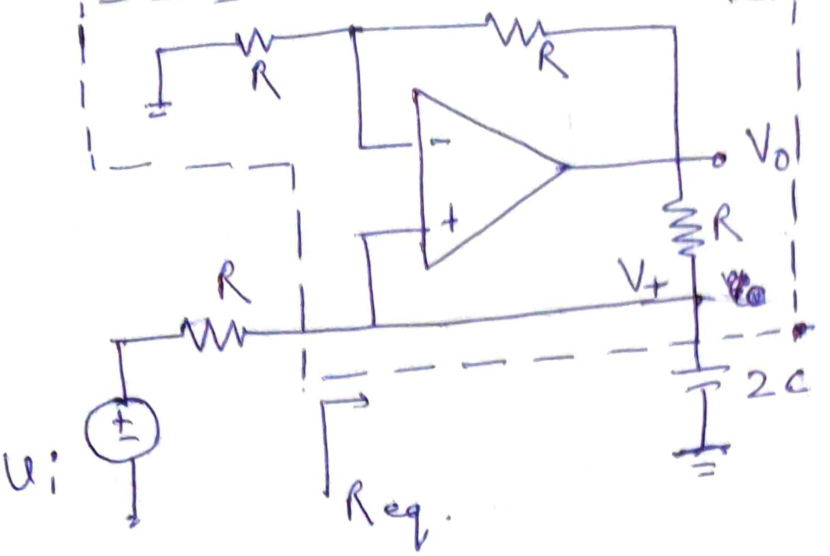
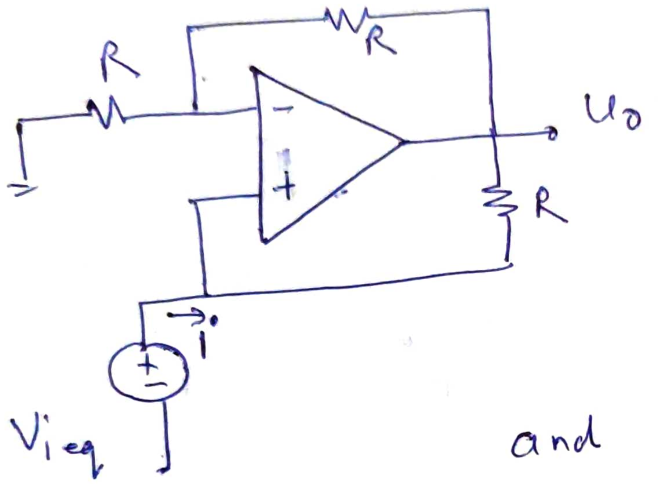


fig. 1



~~Vo~~ =

Applying KVL we get

$$U_o = U_{ieq} - iR$$

or $U_{ieq} = U_o + iR$. — (1)

and we know:-

$$\frac{U_o}{U_{ieq}} = \left[1 + \frac{R}{R}\right] = 2.$$

or $U_o = 2U_{ieq}$. — (2)

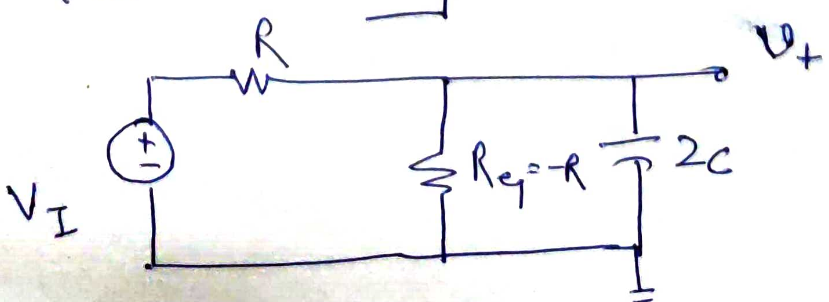
putting (2) in (1) we have:-

$$U_{ieq} = 2U_{ieq} + iR.$$

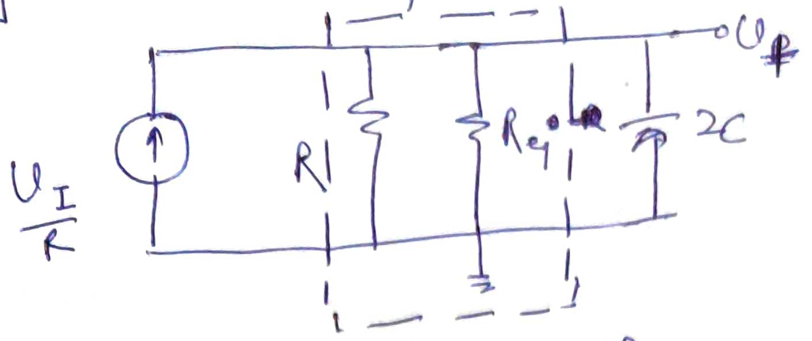
$$R_{eq} = \frac{U_{ieq}}{i} = -R \quad \text{— (3)}$$

1MARK

Now the remaining circuit with Req is:-



By source transformation we can redraw :-



$$R_{total} = \frac{R \times -R}{R - R} = \infty.$$

$R_{total} = \infty.$

All current $\frac{U_I}{R}$ will flow through the capacitor so :-

$$U_+ = \frac{U_I}{R} \times \frac{1}{2SC} = \frac{U_I}{2SRC}. \quad -(4)$$ — 1 MARK

Now from the circuit in fig. 1, we have :-

$$U_o = \left[1 + \frac{R}{R}\right] \times U_+$$

Replacing eq-4 in above expression :

$$U_o = \left[1 + \frac{R}{R}\right] \times \frac{U_I}{2SRC}$$

$$\boxed{\frac{U_o}{U_I} = \frac{1}{SRC}}$$ — 1 MARK

Ans-4 a) Hall constant $R_H = \frac{V_H d}{I_H B_z}$

$$R_H = \frac{6 \times 10^{-3} \times 0.4}{7.5 \times 10^{-3} \times 5 \times 10^{-5}}$$

$$R_H = 6.4 \times 10^{3} \text{ cm}^3 \text{ columb}^{-1}.$$ — 1 MARK

R_H is positive, so semiconductor is of P-type

b) Hole concentration P_o is given by :-

$$P_o = \frac{1}{q \cdot R_H} = \frac{1}{1.6\times10^{-19}\times 6.4\times10^{3}}$$

$$P_o = \frac{1}{10.24\times10^{-16}} = 9.76\times10^{14}\ cm^{-3}$$ $\boxed{1\ MARK}$

c) Hall mobility μ_H is given as :-

$$\mu_H = \frac{l}{w}\left(\frac{V_H}{V_x B_z}\right) = \frac{2\times 6\times10^{-3}}{0.4\times1.5\times5\times10^{-5}}$$

$$\mu_H = 400\ cm^2\,V^{-1}\,sec^{-1}.$$ $\boxed{1\ MARK}$

Ans-5 We will assume that all the dopants are ionized, then :

a) $$n_o - P_o = N_D - N_A = (6-2)\times10^{15} = 4\times10^{15}$$

This is much higher then n_i, i.e

$$(N_D - N_A)^2 \gg 4n_i$$

so $$n_o = \frac{1}{2}\left[(N_D-N_A)+(N_D-N_A)\right]$$

$$n_o = N_D - N_A = 4\times10^{15}$$

and $$P_o = \frac{n_i^2}{n_o} = 5.625\times10^{4}\ cm^{-3}$$ $\boxed{1\ MARK}$

b) $$E_F = E_i + KT\ln\frac{4\times10^{15}}{1.5\times10^{10}}$$

$$E_F - E_i = 0.324\ eV.$$

so $$E_C - E_F = 0.56 - 0.324 = \underline{0.236\ eV}$$

$\boxed{1\ MARK}$

Ans 6. a) The excess charges concentration Δn and ΔP is :-

$$\Delta P = \Delta n = G_L \tau_p$$

$$= 2 \times 10^{19} \times 1 \times 10^{-6} = 2 \times 10^{-13} \text{ pairs/cm}^3$$

1 MARK

b) Sample is doped with $N_D = 6 \times 10^{14}$ cm^{-3}, and assuming they all are ionized.

$$n_0 = 6 \times 10^{14} \text{ cm}^{-3}$$

$$P_0 = \frac{n_i^2}{n_0} = \frac{2.25 \times 10^{20}}{6 \times 10^{14}} = 3.75 \times 10^5 \text{ cm}^{-3}$$

so

$$n = n_0 + \Delta n = 6 \times 10^{14} + 2 \times 10^{13}$$

$$= 6.2 \times 10^{14} \text{ cm}^{-3}$$

$$P = P_0 + \Delta P = 2 \times 10^{13} \text{ cm}^{-3}$$

$$\sigma = q(n \mu_n + P \mu_p)$$

$$= 1.6 \times 10^{-19} (1350 \times 6.2 \times 10^{14} + 480 \times 2 \times 10^{13})$$

$$\sigma = 0.1354 \text{ s/cm.}$$

$$\boxed{\rho = \frac{1}{\sigma} = 7.38\ \Omega\text{-cm}}$$

2 MARK

Ans-7

• Built-in potential $\phi_{bi} = \frac{KT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)$

$$= 26 \times 10^{-3} \ln\left(\frac{2 \times 10^{30}}{2.25 \times 10^{20}}\right)$$

$$\phi_{bi} = 0.592\text{V}.$$

In equilibrium conditions the fermi Level of P and N side after its quasi fermi level condition will get aligned. for P-side semiconductor the position of fermi Level is :-

$$E_{Fp} - E_i = -KT \ln\left(\frac{N_A}{n_i}\right) = -KT\ln\left(\frac{10^{15}}{1.5\times10^{10}}\right)$$

$$E_{Fp} - E_i = -0.026 \times 11.10$$

$$= -0.28 \text{ eV}.$$

1.5 MARK

$$\text{So} \quad E_V - E_{FP} = -0.56 \text{ eV} + 0.28 \text{ eV}$$

$$E_V - E_{FP} = -0.28 \text{ eV}$$

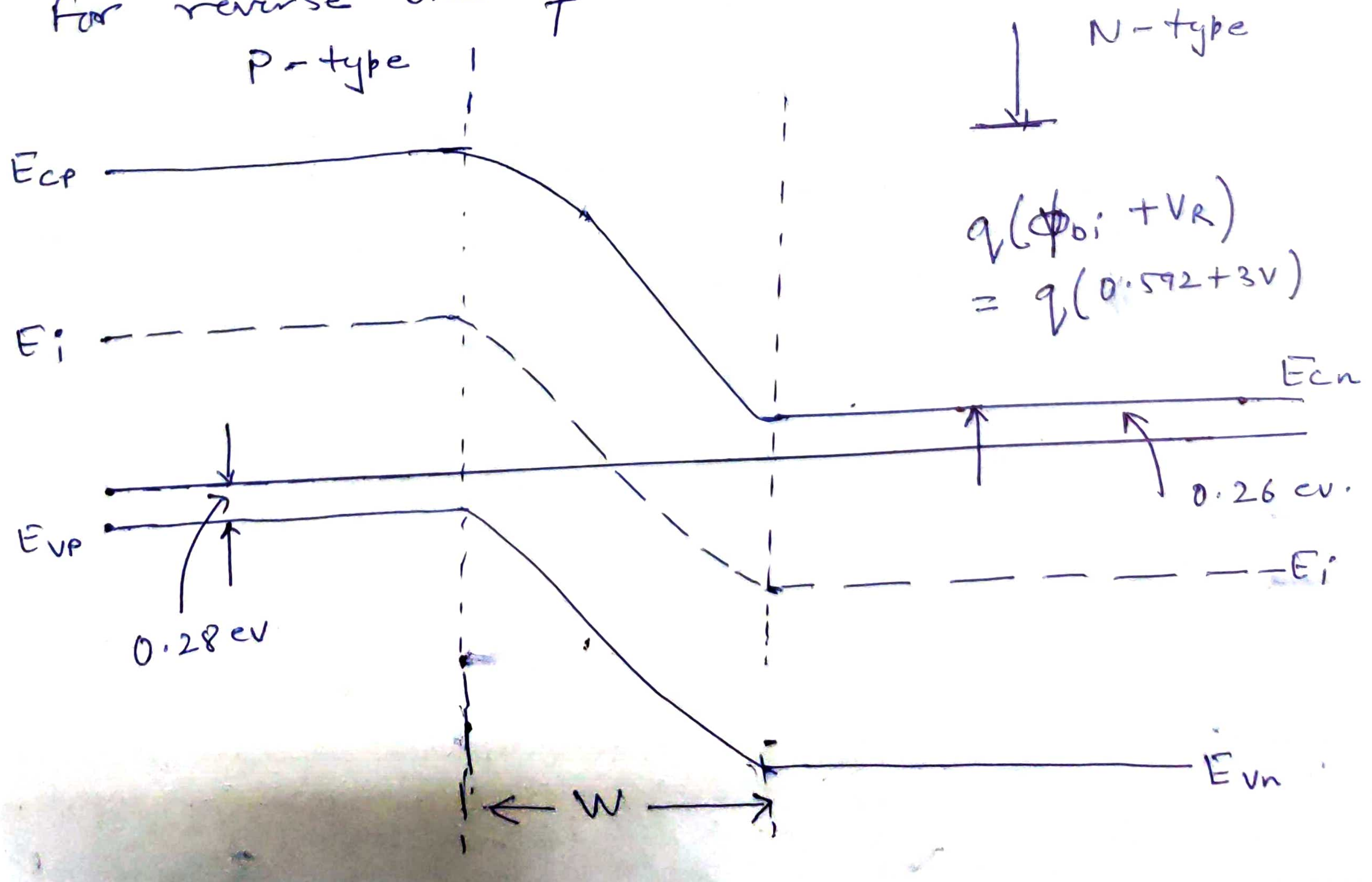
Similarly for N-side :-

$$E_{Fn} - E_i = KT \ln\left(\frac{2\times10^{15}}{1.5\times10^{10}}\right)$$

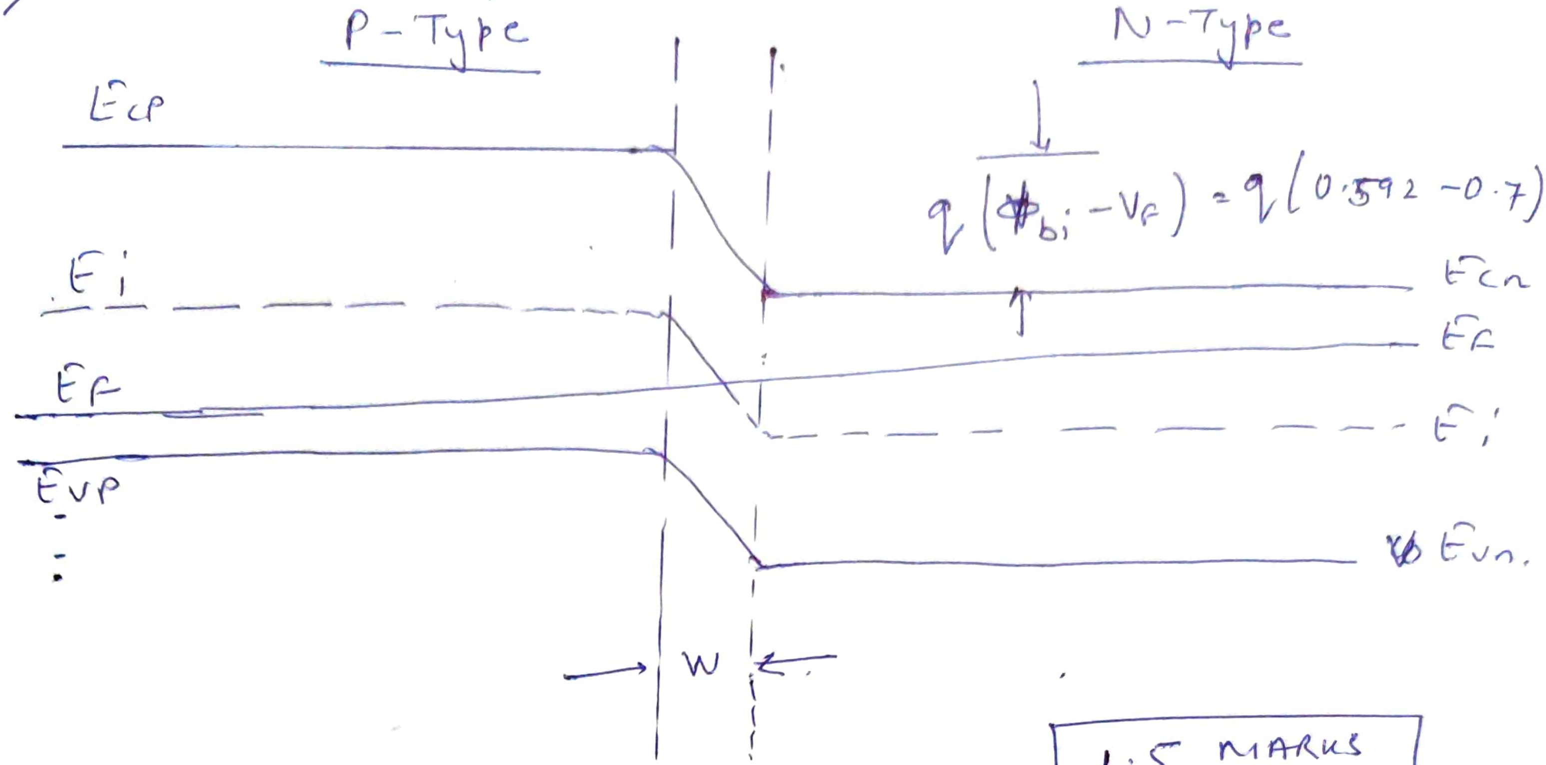
$$E_{Fn} - E_i = 0.30 \text{ eV}.$$

$$\text{So} \quad E_C - E_{Fn} = 0.56 - 0.30 = 0.26 \text{ eV}.$$

for reverse bias of 3V :-



b) For forward bias of 0.7V



$\boxed{\text{1.5 MARKS for BOTH}}$

Ans-8 a) $V_{max} = \sqrt{2} \times V_{rms} = \sqrt{2} \times 120 = 169.7$

$I_{max} = \dfrac{V_{max} - 1.4}{R_L} = 168.3\,mA$

$I_{DC} = \dfrac{2I_m}{\pi} = 107.14\,mA$, $V_{dc} = I_{dc} \times R_L = 107.14$ $\boxed{\text{1 MARK}}$

b) $PIV = V_{max} = 169.7V$ — $\boxed{\text{1 MARK}}$

c) $I_{max} = 168.3\,mA$ — $\boxed{\text{1 MARK}}$

d) $\cancel{P_{max} = V_o \times I_{o,max} = 0.7 \times 168.3 = 117.81 mW}$

Input AC power $= V_{rms} \times I_{rms} = 120 \times \left(\dfrac{168.3}{\sqrt{2}}\right) mW$

output DC power $= V_{DC} \times I_{DC}$

$= 107.14\,mA \times 107.14\,V$

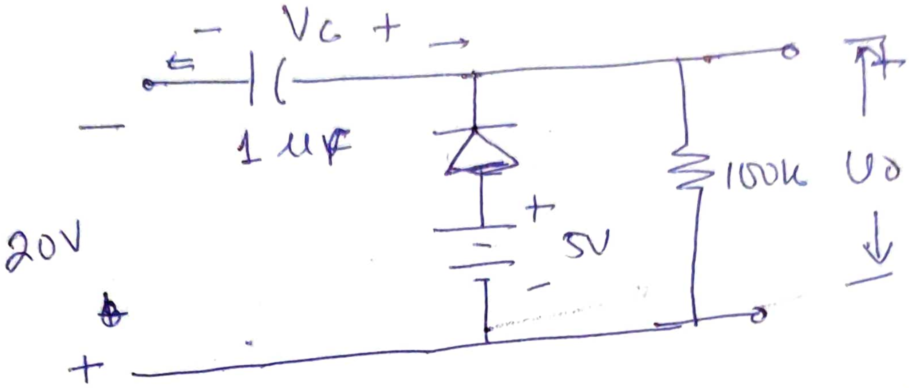
$= 11478.98\,mW$

Power dissipated in 4 diodes is:-

$\dfrac{120 \times 168.3}{\sqrt{2}} - 11478.98\,mW = 2801.75\,mW$

power dissipated in each diode $= 700.44\,mW$
or (power rating of diode) — $\boxed{\text{1 MARK}}$

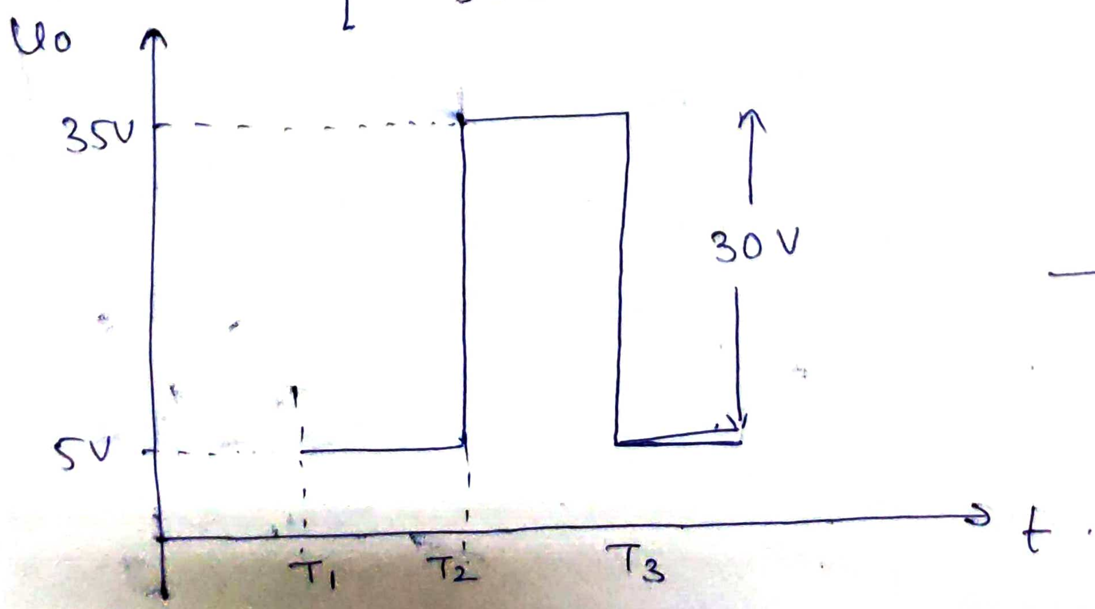
Ans 8-b In between time interval 0 to T_1, the capacitor is not charged. We will wait for time for capacitor charging. In between time interval T_1 to T_2, the voltage V_{in} is $-20V$, as shown below:-



The diode will conduct and capacitor will charge to $V_C = 5V + 20V = 25V$, And o/p voltage is $+5V$. During time interval T_2 to T_3, the diode is switched off as it is reverse biased, so o/p voltage $U_o = 25V + 10V = 35V$.

$$U_o = \begin{cases} \text{Not charged} & 0 < t < T_1 \\ 5V & T_1 < t < T_2 \\ 35V & T_2 < t < T_3 \end{cases}$$

— $\boxed{2 \text{ MARKS}}$



— $\boxed{1 \text{ MARK}}$

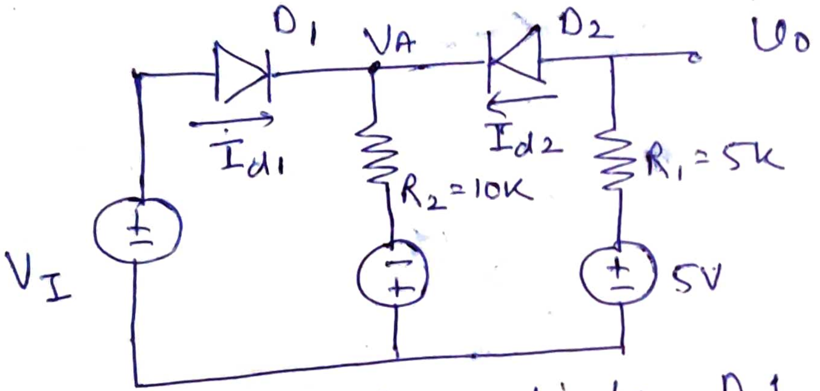
Ans-9 a) Assuming D_1 is off as $V_I = 0$, $I_{d1} = 0A$

$$I_{R1} = I_{R2} = I_{d2} = \frac{5-(-5)}{R_1+R_2} = \frac{10}{10K+5K}$$

$$= \frac{10}{15K} = 0.666\ mA$$ — $\boxed{1\ MARK}$

So $V_o = 5 - 0.62\ mA \times 5K\Omega$

$V_o = 1.9V.$ — $\boxed{1\ MARK}$



The node Voltage V_A is $V_o - 0$

$V_A = 1.9V$

Therefor diode D 1 is reverse biased, thus assumption that D 1 is off is verified.

b) If $V_I = 4V$, Assuming D 1 and D 2 are ON. The output voltage $V_o = V_I = 4V.$ — $\boxed{1\ MARK}$

$\boxed{1\ MARK}$ ←

$$I_{R1} = I_{D2} = \frac{5-4}{5K} = 0.2\ mA$$

$$I_{R2} = \frac{4-(-5)}{10K} = \frac{9}{10K} = 0.9\ mA$$

$$I_{D1} = I_{R2} - I_{R1} = 0.9mA - 0.2\ mA$$

$$= 0.7\ mA$$

Ans-10 a) The Eber's-Moll model of BJT, describe the behaviour of BJT by a set of governing Ebers-Moll equations. The equation of PNP BJT are:-

$$I_E = I_{ES}\left[\exp\left(\frac{qV_{EB}}{KT}\right)-1\right] - \alpha_I I_{CS}\left[\exp\left(\frac{qV_{CB}}{KT}\right)-1\right] \quad \text{--- (1)}$$

1 MARKS

$$I_C = -\alpha_N I_{ES}\left[\exp\left(\frac{qV_{EB}}{KT}\right)-1\right] + I_{CS}\left[\exp\left(\frac{qV_{CB}}{KT}\right)-1\right] \quad \text{--- (2)}$$

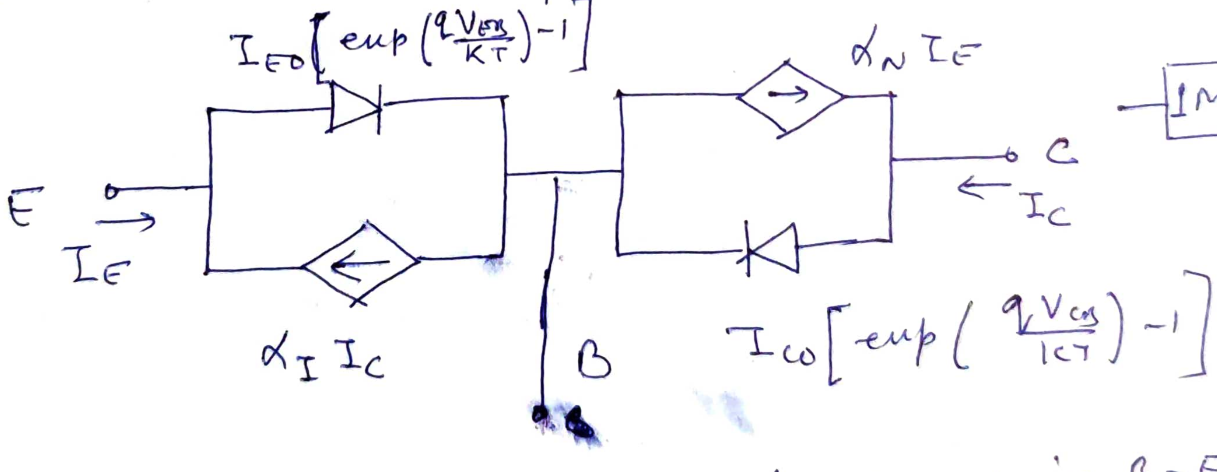
If we eliminate $\exp\left(\frac{qV_{CB}}{KT}\right)-1$ from eq^n (1) & eq (2) then we obtain:

$$I_E = I_{EO}\left[\exp\left(\frac{qV_{EB}}{KT}\right)-1\right] - \alpha_I I_C \quad \text{--- (3)}$$

and if we eliminate $\exp\left(\frac{qV_{EB}}{KT}\right)-1$ from eq (1) & (2) then:-

$$I_C = I_{CO}\left[\exp\left(\frac{qV_{CB}}{KT}\right)-1\right] - \alpha_N I_E \quad \text{--- (4)}$$

The model obtained from eq^n (3) and eq^n (4) is as:-



1 Marks

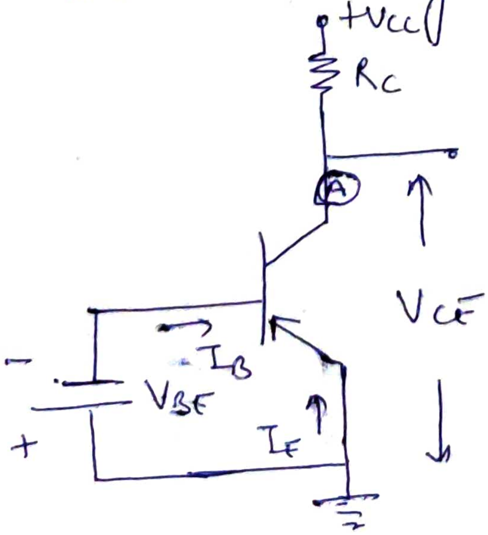
where I_{EO} is reverse saturation current in B-E Junction when B-C junction is open circuit. And I_{CO} is reverse saturation current in B-C junction when B-E Junction is open circuit.

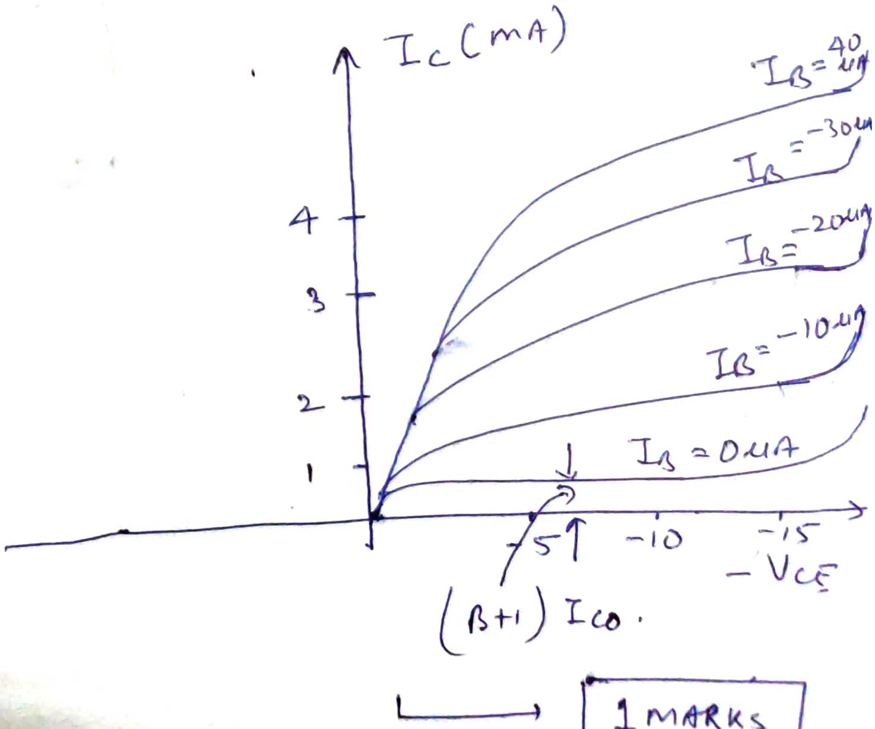
b) In normal active mode of BJT operation the B-C Junction is reverse biased. The depletion region spreads into the base, Let W_{BO} is the width of base, when B-C junction is not reverse bias. Since depletion region W is function of applied Voltage by:-

$$W = \sqrt{\frac{2\varepsilon_s \left(V_{bi}+V_{BC}\right)}{q N_E}}$$

when B-C which is reverse biased, it increases W increases, so effective Base width $W_B = W_{BO} - W$, start decreasing. This decrease or narrowing of base width is called base width modulation. This phenomena in transistor was first studied by J. M. Early, and is all called Early Effect. — 1 MARKS

Ans-C The o/p characteristics of common Emitter PNP ~~transistor~~ transistor is plotted between I_C Versus V_{EC} or I_C Versus $-V_{CE}$, with base current constant. In active region I_C is independent of V_{CE}.





1 MARKS