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EC100: Assignment 3

(Q.19 of 2.2)

Q.1 By how much does built-in potential V_0 changes if N_A or N_D is increased by a factor of 10?

Built-in potential V_0 is given by

$$V_0 = V_T \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right) \quad \text{— (I)}$$

Suppose N_A is increased by a factor of 10.

$$V_0' = V_T \ln\left(\frac{10\, N_A \cdot N_D}{n_i^2}\right) \quad \text{— (II)}$$

from (I) and (II),

$$V_0' - V_0 = V_T \left\{ \ln 10 + \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right) - \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right) \right\}$$

$$V_0' - V_0 = V_T \ln 10$$

$$= 0.026 \times 2.303$$

$$\simeq 0.0599 \text{ V}$$

Hence, V_0 changes by 0.0599 V at room temperature if N_A or N_D is increased by a factor of 10.

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(23 of 2.2)

Q.2 Electrons in some conductor have a density of 10^{20}/cm^3, and a mobility of 800 $cm^2 V^{-1} s^{-1}$. If a uniform electric field of 1 V/cm exists across this conductor determine electron current density.

current density is given by

$$J = n q \mu E$$

$$J = 10^{20} \, cm^{-3} \times 1.6 \times 10^{-19} C \times 800 cm^2 V^{-1} s^{-1} \times 1 \, V/cm$$

$$= 1.28 \times 10^{4} \quad A \, cm^{-2}$$

Hence, electron current density in the conductor is equal to $1.28 \times 10^4 \, A cm^{-2}$.

Q.3 (21 of 2.2) Calculate I_s and the current I for $V = 700$ mV for a p-n junction for which $N_A = 10^{17}$/cm^3, $N_D = 10^{16}$/cm^3, $A = 200 \, um^2$, $n_i = 1.5 \times 10^{10} \, cm^{-3}$, $L_p = 5$ um, $L_n = 10$ um, $D_p = 10 \, cm^2 s^{-1}$ and $D_n = 18 \, cm^2 s^{-1}$.

The reverse saturation current I_s is given by

$$I_s = \left[\frac{q A D_p}{L_p} \frac{n_i^2}{N_D} + \frac{q A D_n}{L_n} \frac{n_i^2}{N_A} \right]$$

$$I_s = q A n_i^2 \left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]$$

Putting values

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$$I_s = 1.6\times10^{-19} \times 200\times10^{-8}\,(cm^2)\,(1.5\times10^{10})^2\,(cm^{-6})$$

$$\left[\frac{10\ cm^2 s^{-1}}{5\times10^{-4}\,cm\times10^{16}\ cm^{-3}} + \frac{18\ cm^2 s^{-1}}{10\times10^{-4}\,cm\times10^{17}\ cm^{-3}}\right]$$

$$I_s = 720\times10^{-7}\,(cm^{-4})\left[2\times10^{-12}\ cm^4 s^{-1} + 1.8\times10^{-13}\ cm^4 s^{-1}\right]$$

$$I_s = 720\times10^{-7}\left[2\times10^{-12} + 0.18\times10^{-12}\right]\ A$$

$$I_s = 720\times 2.18\times10^{-19}\ A$$

$$I_s = 1569.6\times10^{-19}\ A$$

$$= 1.5696\times10^{-16}\ A$$

Hence , $I_s = 1.5696\times10^{-16}\ A$

Now, I can be calculated by using the formula

$$I = I_s\left[e^{\frac{V}{\eta V_T}} - 1\right]$$

$\eta = 2$ for ~~[illegible]~~ Silicon, for low current.

$$I = 1.5696\times10^{-16}\left[e^{\frac{0.7}{2\times0.026}} - 1\right]$$

$$= 1.5696\times10^{-16}\left[7.015\times10^{5} - 1\right]$$

$$= 11.010\times10^{-11}\ A$$

$$= 1.1010\times10^{-10}\ A$$

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Q.4 (1 of 3.1) Determine ac resistance for a germanium semiconductor diode having a forward bias of 200 mV and reverse saturation current of 1 uA at room temperature.

the diode equation is

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

$$\therefore \frac{dI}{dV} = \frac{I_s}{\eta V_T} e^{\frac{V}{\eta V_T}}$$

$$\text{ac resistance} = \frac{dV}{dI} = \frac{\eta V_T}{I_s e^{V/\eta V_T}}$$

Putting values
$\eta = 1$ for germanium

$$\text{ac resistance} = \frac{1 \times 0.026}{10^{-6} \times e^{(0.2/1\times 0.026)}}$$

$$= \frac{0.026}{10^{-6} \times 2190.75}$$

$$= 11.868\ \Omega$$

Hence, ac resistance of the semiconductor is 11.868 Ω in given situation.

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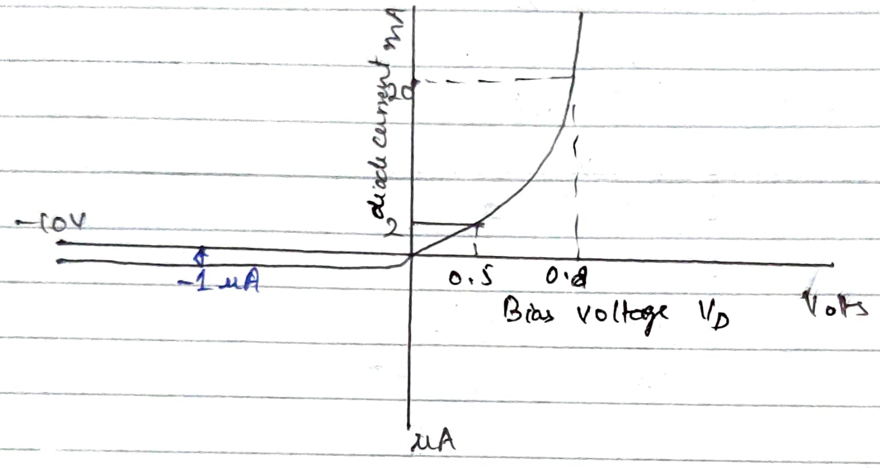
Q.5 (2 of 3.1) Explain the static and dynamic resistances in a p-n junction diode. Determine dc resistance levels for the diode of following figure at (i) $I_D = 2\,mA$ (ii) $I_D = 20\,mA$, (iii) $V_D = -10\,V$



Static Resistance -: The ratio of DC voltage applied across the diode to the DC current flowing through the diode is defined as static resistance.

Dynamic Resistance -: The resistance offered by diode when an AC source which depends on DC polarisation of p-n junction is connected to it. is defined as dynamic resistance.

(i) dc resistance or static resistance at $I_D = 2mA$

$$R = \frac{V_D}{I_D} = \frac{0.5\,V}{2 \times 10^{-3}\,A} = 250\,\Omega$$

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(ii) dc resistance at $I_D = 20\,mA$

$$R = \frac{V_D}{I_D} = \frac{0.8}{20\times10^{-3}} = 40\,\Omega$$

(iii) dc resistance at $V_D = -10\,V$

$$R = \frac{V_D}{I_D} = \cancel{-1\times10^{-6}A}\ \frac{\cancel{-}10}{\cancel{-}10^{-6}\,A} = 10\,M\Omega.$$

Q.6 (3 of 3.1) Find the dynamic resistance of a P-N junction diode at a forward current of 2 mA. Assume $\frac{K'T}{e} = 25\,mV$

the diode equation is

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

$$\frac{dI}{dV} = \frac{I_s}{\eta V_T}\,e^{\frac{V}{\eta V_T}}$$

$$\frac{dI}{dV} = \frac{I + I_s}{\eta V_T}$$

$$\therefore \text{dynamic resistance} = \frac{dV}{dI} = \frac{\eta V_T}{I + I_s}$$

Since, reverse saturation current is very small as compared to forward current it can be neglected.

$$\therefore \text{dynamic resistance} = \frac{\eta V_T}{I}$$

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$\because$ $\eta = 1$ for germanium
and $V_T = \frac{K'T}{e} = 25 \text{ mV}$

$\therefore$ dynamic resistance $= \frac{1 \times 25 \times 10^{-3}}{2 \times 10^{-3}}$

$= 12.5 \ \Omega$

Hence, the dynamic resistance is $12.5 \ \Omega$ for the diode in given situation.

Q.7 (8 of 3.1) A germanium diode draws 50 mA with a forward bias of 0.27 V. The junction is at room temperature of 27°C. Determine reverse saturation current of the diode.

Germanium diode, therefore $\eta = 1$
forward current $(I) = 50 \text{mA}$
forward voltage $= 0.27 \text{ V}$
At room temperature $V_T = 0.026 \text{ V}$

Using diode equation,

$$I = I_s \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

$$50 \times 10^{-3} = I_s \left(e^{\frac{0.27}{1 \times 0.026}} - 1 \right)$$

$$50 \times 10^{-3} = I_s \, (32356.46)$$

$$I_s = \frac{50 \times 10^{-3}}{3.2356 \times 10^{4}}$$

$$= 15.45 \times 10^{-7}$$

$$I_s = 1.545 \ \mu A$$

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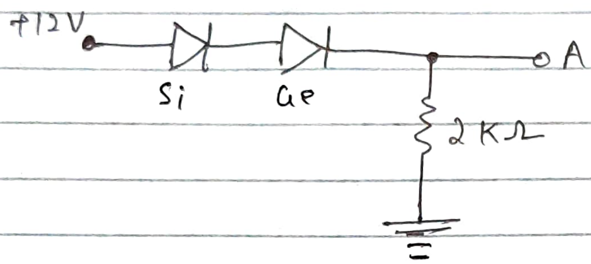
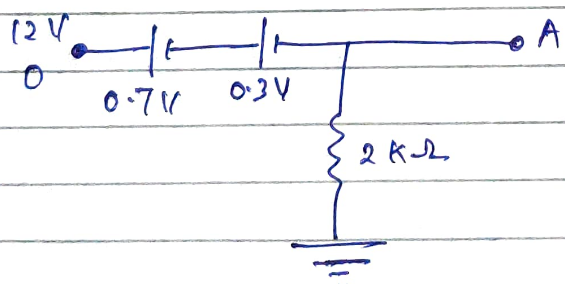
Hence, reverse saturation current for the diode is 1.545 μA.

Q.8 (14 of 3.1) Determine the current flowing in the circuit shown in Figure. Also, determine the potential of point A.



By observing the circuit, we can say that both the diodes are forward biased because assuming this gives the current in right direction i.e. from 12 V to A (say V_A volt).

Now, using second approximation we can replace Si diode with 0.7V & Ge diode with 0.3 V battery.



$$12 - 0.7 - 0.3 = V_A$$

$$\boxed{\therefore \; V_A = 11\,V}$$

and current $I = \frac{V_A - 0}{R} = \frac{11}{2 \times 10^3} = 5.5\,mA$

Hence, the voltage at A is 11 V and the current through 2 kΩ resistance is 5.5 mA

Q.9 (15 of 3.1) A silicon diode has a saturation current of 5 μA at room temperature of 300 K. Determine its value at 400 K.

For every 10°K rise in temperature, reverse saturation current is doubled.

$$\therefore I_{o(T_2)} = I_{o(T_1)} \left\{ 2^{\left(\frac{T_2 - T_1}{10}\right)} \right\}$$

$$\therefore (I_o)_{400K} = (I_o)_{300K} \left\{ 2^{\left(\frac{400-300}{10}\right)} \right\}$$

$$(I_o)_{400K} = 5 \times 10^{-6} \times 2^{10}$$

$$= 5120 \times 10^{-6}$$

$$= 5.12\ mA.$$

Hence, reverse saturation current at 400 K is 5.12 mA.

Q.10 (22 of 3.1) Calculate the built in voltage of a junction in which the p and n regions are doped equally with 10^{16} ~~cm^{-3}~~ atoms/cm^3. Assume $n_i = 1.5 \times 10^{10}\ cm^{-3}$. With the terminals left open, what is the width of the depletion region, and how far does it extend into the p and n regions?

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If the cross-sectional area of the junction is $100\ um^2$, find the magnitude of the charge stored on either side of the junction.

The built-in potential V_0 is given by

$$V_0 = V_T \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right)$$

$$= 0.026 \ln\left(\frac{10^{16} \times 10^{16}}{1.5 \times 1.5 \times 10^{20}}\right)$$

$$= 0.026 \ln\left(\frac{10^{12}}{2.25}\right)$$

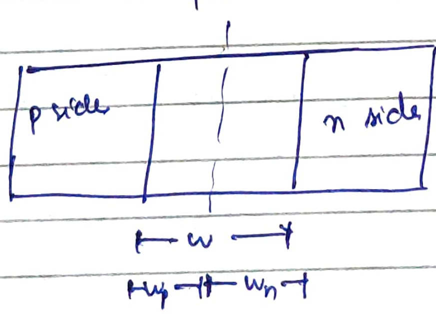
$$= 0.026 \times 2.303 \log\left(\frac{10 \times 10^{11}}{2.25}\right)$$

$$= 0.05988 \left\{\log(4.445) + \log(10^{11})\right\}$$

$$= 0.05988 \left\{0.6478 + 11\right\}$$

$$= 0.6974\ V \approx 0.7\ V$$

Hence, built in potential is approximately 0.7 V.



the width of depletion region w is given by

$$w = \sqrt{\frac{2\varepsilon V_0}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)}$$

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$$\therefore \quad w = \sqrt{\frac{2 \times 1.04 \times 10^{-12} \times 0.7}{1.6 \times 10^{-19}} \times 2 \times 10^{-16}}$$

value of ϵ for Si is 1.04×10^{-12} F/cm

$$w = \sqrt{1.82 \times 10^{-9}}$$

$$w = \sqrt{18.2 \times 10^{-10}}$$

$$= 4.266 \times 10^{-5} \text{ cm} = 4.266 \times 10^{-7} \text{ m}$$

$$= 0.426 \ \mu m$$

Hence, width of depletion region is $0.426 \ \mu m$.

the width of depletion region on p-side is given by

$$w_p = \frac{N_A \ w}{N_A + N_D}$$

$$w_p = \frac{\cancel{10^{16}}}{2 \times \cancel{10^{16}}} \times 0.426 \ \mu m$$

$$= 0.213 \ \mu m$$

and, width of depletion region on n side

$$w_n = w - w_p$$

$$= 0.426 \mu m - 0.213 \ \mu m$$

$$= 0.213 \ \mu m$$

Hence, width of depletion region on n-side and on p-side is $0.213 \ \mu m$.

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charge stored at p-junction is $N_A q (A w_p) = Q_p$

charge stored at n-junction is $N_D q (A w_n) = Q_n$

$\therefore Q_p = 10^{16} cm^{-3} \times 1.6 \times 10^{-19} C \times 10^{-6} cm^2 \times 0.213 \times 10^{-4}$

$= 0.3408 \times 10^{-13}$

$\boxed{Q_p = 3.408 \times 10^{-14} C}$

and $Q_n = 10^{16} cm^{-3} \times 1.6 \times 10^{-19} C \times 10^{-6} cm^2 \times 0.213 \times 10^{-4}$

$\boxed{Q_n = 3.408 \times 10^{-14} C}$

Q.11 (24 of 3.1) Estimate the total charge stored in 0.1 um depletion region on one side of a 10 um × 10 um junction. The doping concentration on that side of junction is 10^{16} cm^{-3}.

$A = 10 um \times 10 um = 10^{-6} cm^2$

$N = 10^{16} cm^{-3}$

$w = 0.1 \times 10^{-4} cm$

$\therefore Q_{total} = N \times q \times A \times w$

$= 10^{16} cm^{-3} \times 1.6 \times 10^{-19} C \times 10^{-6} cm^2 \times 0.1 \times 10^{-4} cm$

$= 1.6 \times 10^{-14} C$

Hence, the total charge stored in the depletion layer is 1.6×10^{-14} C.

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Q.12 (26 of 3.1) A pn junction operating in forward-bias region with a current I of 1 mA is found to have a diffusion capacitance of 10 pF. What diffusion capacitance do you expect this junction to have at I = 0.1 mA? What is the mean transit time for this junction?

As the diode is forward biased, diffusion capacitance C_D will come into role,

$$C_D = \frac{\tau I_D}{\eta V_T}$$

$C_D = 10\,pF$ when $I = 1\,mA$

Let us assume $C_D = C_D'$ when $I = 0.1\,mA$

$$C_D = \frac{\tau \times 1\,mA}{\eta V_T}$$

$$C_D' = \frac{\tau \times 0.1\,mA}{\eta V_T}$$

$$\frac{C_D'}{C_D} = \frac{0.1\,mA}{1\,mA}$$

$$C_D' = \frac{C_D}{10} = \frac{10\,pF}{10} = 1\,pF$$

Hence, diffusion capacitance at $I = 0.1\,mA$ is 1 pF.

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Mean transit time will be,

$$\tau = \frac{C_D \eta V_T}{I}$$

$C_D = 10\,pF$ when $I = 1\,mA$
and $V_T = 0.026V$ at room temperature
for Ge, $\eta = 1$

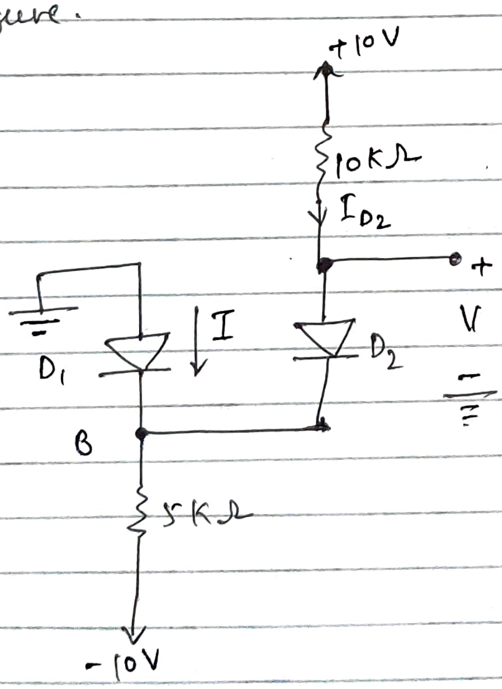
$$\tau = \frac{10 \times 10^{-12} \times 1 \times 0.026}{10^{-3}}$$

$$\tau = 2.6 \times 10^{-10} \text{ seconds}$$

Hence, mean transit time is 2.6×10^{-10} seconds.

Q.13 (27 of 3.1) Assuming the diodes to be ideal, find the values of I and V in the circuits of figure.

(a)



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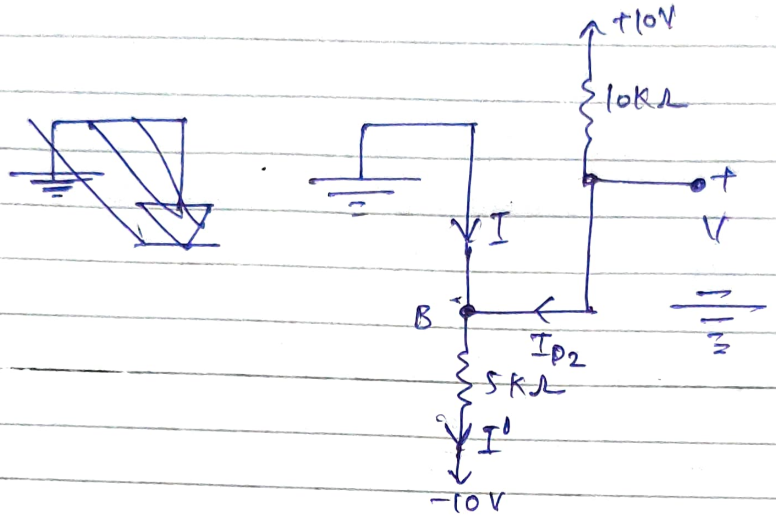
Assuming diode D_1 and D_2 in forward biased state, so equivalent circuit is



Assuming $V = 0$, we get,

$$I' = \frac{0 - (-10)}{5} \times 10^{-3} = 2 mA$$

and $I_{D_2} = \frac{(10-0)}{10} \times 10^{-3} = 1 mA$

Since, we got positive values of I_{D_2} so our assumption is correct, hence D_2 is forward biased.

By KCL at B

$$I + I_{D_2} = I'$$
$$I + 1mA = 2mA$$
$$I = 1 mA$$

Since, I is positive, hence our assumption that D_1 is forward biased is correct.

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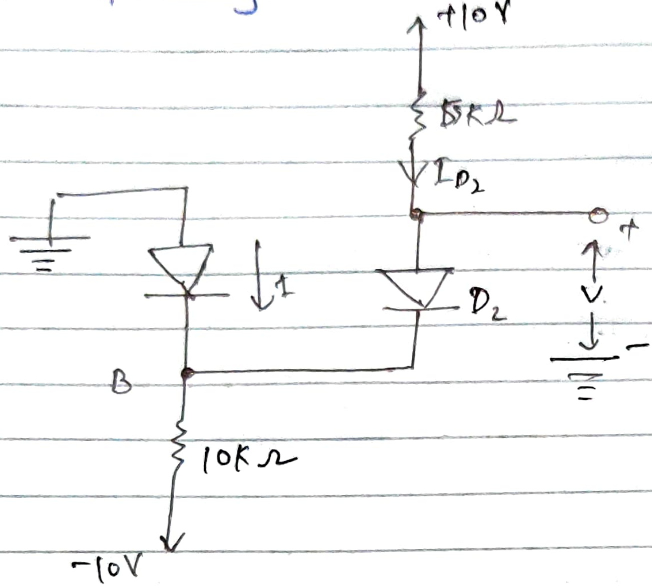
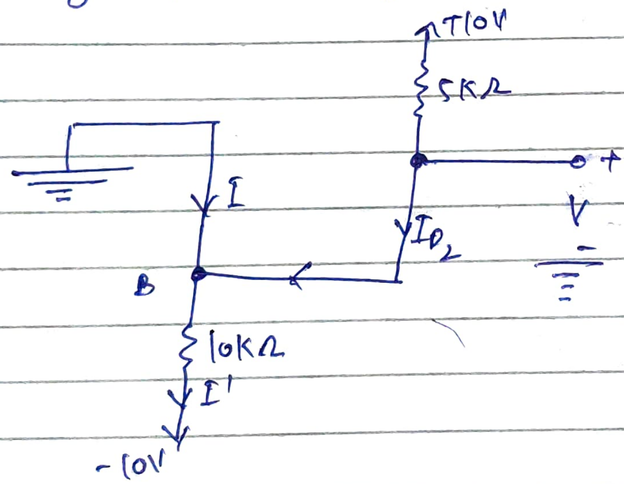
Hence, the value of I and V are 1 mA and 0 V respectively.

(b)



Assuming D_1 and D_2 in forward bias,



Assuming V = 0,

$$\therefore \quad I_{D_2} = \frac{10-(0)}{5\ K\Omega} = 2\ mA$$

and $$I' = \frac{0-(-10)}{10\ K\Omega} = 1\ mA$$

Applying KCL at B,

$$I_{D_2} + I = I' \Rightarrow I = -1\ mA$$

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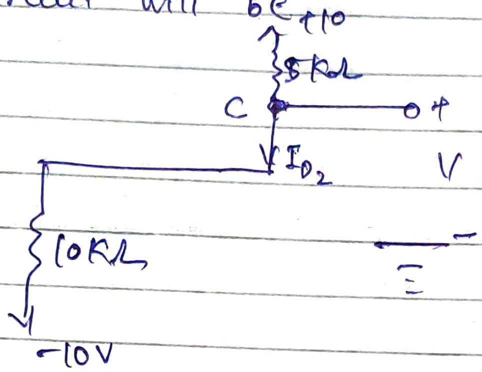
$\because$ I_{D_2} is positive Diode D_2 is forward biased but I is negative hence diode D_1 is reverse biased.

Now, the circuit will be



$\cancel{I_{D_2} = 2\,mA}$

$\cancel{\frac{10-(V)}{5k\Omega} = 2\times10^{-3}}$

Hence, $I = 0$

Now, potential at C is V.

$$\therefore \quad \frac{10-V}{5k\Omega} = \frac{V+10}{\cancel{10k\Omega}\;2}$$

$$20 - 2V = V + 10$$

$$V = \frac{10}{3}\,V$$

Hence, $V = \frac{10}{3}\,V$ and $I = 0$

Q.14 (34 of 3.1) In many commercial applications, temperatures of electronic circuits can vary from $-50^\circ C$ to $125^\circ C$. To maintain a constant current in a diode over this temperature region, by how much will the

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diode voltage have to change?

For every $1^\circ C$ rise in temperature, V-I characteristics shifts left by 2.5 mV.

so, $\frac{dV}{dT} = -2.5\ mV/^\circ C$

$$\therefore \frac{dV}{\{125-(-50)\}^\circ C} = \frac{-2.5\ mV}{^\circ C}$$

$$dV = -2.5 \times 175\ mV$$

$$|dV| = 437.5\ mV$$

so, when ~~temperature~~ is increased from $-50^\circ C$ to $125^\circ C$, voltage shifts left by 437.5 mV.

Q.15 (43 of 3.1) The current flowing through a certain germanium P-N junction at room temperature when reverse biased (bias voltage being large in comparison to V_T) is $0.15\ \mu A$. Determine the current flowing through the germanium diode when applied voltage is 0.12 V.

the reverse saturation current $(I_s) = 0.15\ \mu A$
temperature: $T = 300\ K$

$\therefore V_T = 0.026\ V$

for Ge, $\eta = 1$

applied voltage $V = 0.12\ V$.

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using diode equation

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

$$I = 0.15 \times 10^{-6}\left(e^{\frac{0.12}{0.026}} - 1\right)$$

$$= 0.15 \times 99.988 \times 10^{-6}$$

$$= 1.4998 \times 10^{-5}$$
$$= 14.998\ \mu A \simeq 15\ \mu A$$

Hence, current flowing through the diode is 15 μA.

Q.16 (16 of 3.2) At what forward voltage does a diode for which $\eta = 2$ conduct a current equal to 1000 I_s? In terms of I_s, what current flows in same diode when its forward voltage is 0.7 V?

diode equation

$$I = I_s\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

given $I = 1000\ I_s$

$$1000\ \cancel{I_s} = \cancel{I_s}\left(e^{\frac{V}{\eta V_T}} - 1\right)$$

$$1001 = e^{V/\eta V_T}$$

$$\ln(1001) = \frac{V}{\eta V_T}$$

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$\therefore \quad V = \eta V_T \ln(1001)$

$$= 2 \times 0.026 \times \ln(1001)$$
$$= 0.359 \text{ V}$$

Forward voltage at which forward current is $1000 I_s$ is 0.359 V.

Now, at forward voltage $V = 0.7$

$$I = I_s \left[e^{\frac{0.7}{2 \times 0.026}} - 1 \right]$$

$$I = I_s (701515.7)$$

$$\therefore \quad I = 7.015 \times 10^5 \, I_s$$

Hence, forward current is $7.015 \times 10^5 I_s$ if forward voltage of 0.7 is applied.

Q.17 (1 of 3.3) A half-wave rectifier uses a diode with a forward resistance of 100Ω. If the input ac voltage is 220 V (rms) and load resistance is of 2 kΩ, determine.

i) I_{max}, I_{dc} and I_{rms}
(ii) peak inverse voltage when diode is ideal
(iii) load output voltage
(iv) dc output power and ac input power
(v) ripple factor
(vi) transformer utilisation factor, and
(vii) rectification efficiency.

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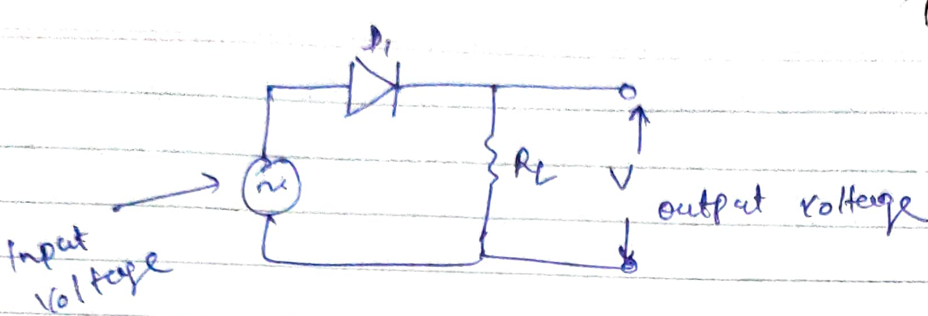

Diode forward resistance $(R_f) = 100\,\Omega$
load resistance $(R_L) = 2000\,\Omega$

RMS input voltage $= 220\,V$

(i) I_{max}

On input side $I_{rms} = \dfrac{I_{max}}{\sqrt{2}}$

Since $V_{rms} = 220V$

$$I_{rms} = \frac{220}{R_f + R_L} = \frac{220}{2100} \approx 104.76\ mA$$

$$\therefore \quad I_{max} = \sqrt{2} \times I_{rms} = 148.15\ mA$$

$$\Rightarrow I_{DC} = \frac{I_{max}}{\pi} = \frac{148.15\ mA}{3.14} = 47.16\,mA$$

$$\Rightarrow (I_{rms})_{output} = \frac{I_{max}}{2} = \frac{148.15\ mA}{2} = 74.075\ mA$$

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(ii) peak inverse voltage is maximum reverse biased voltage. In half-wave rectifier it is equal to V_{max}.

so, $V_{max} = \sqrt{2}\, V_{rms} = 311.12\ V$

$V_{max} = PIV = 311.12V$.

(iii) Load output voltage i.e. voltage across R_L.

so, $V = I_{DC} \times R_L = 47.16 \times mA \times 2k\Omega$
$= 94.32\ V$

(iv) DC output power $= (I_{DC})^2 \times R_L$

$= (47.16\ mA)^2 \times 2000\ \Omega$

$= 4448.13 \times 10^{-3}$

$= 4.45\ W$

AC input power $= (I_{AC})^2 \times R$

$= (I_{rms})^2 \times (R_f + R_L)$

$= (74.075\ mA)^2 \times 2.1 \times 10^3$

$= 11.524\ W$

(v) Ripple factor $= \dfrac{I_{AC}}{I_{DC}}$

Now, $I_{rms}^2 = I_{AC} + I_{DC}$

$I_{AC} = \sqrt{I_{rms}^2 - I_{DC}^2}$

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$$\therefore \text{Ripple factor} = \frac{\sqrt{I_{rms}^2 - I_{DC}^2}}{I_{DC}}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{DC}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{\frac{I_{max}}{2}}{\frac{I_{max}}{\pi}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{\pi}{2}\right)^2 - 1}$$

$$= 1.21$$

Hence, ripple factor for half-wave rectifier is 1.21.

(vi) $\text{TUF} = \frac{\text{output dc power}}{\text{AC rating of secondary winding}}$

AC rating of secondary winding = V_{rms} across winding $\times$ I_{rms} across winding

$$\therefore \text{TUF} = \frac{P_{DC}}{V_{rms} \times I_{rms}}$$

$$= \frac{I_{DC}^2 \times R_L}{\frac{V_{max}}{\sqrt{2}} \times \frac{I_{max}}{2}}$$

$$\because \quad V_{max} = I_{max}(R_f + R_L)$$

$$\text{and } I_{DC} = \frac{I_{max}}{\pi}$$

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$$TUF = \frac{2\sqrt{2}}{\pi^2} \quad \frac{R_L}{R_f + R_L}$$

$$= 0.287 \times \frac{2000}{2100} = 0.2724$$

Hence, TUF = 0.2724.

(vii) Rectification Efficiency $= \frac{\text{DC output power}}{\text{AC input power}} \times 100\%$

$$= \frac{4.45\ W}{11.524\ W} \times 100\%.$$

$$= 38.6\%.$$

Q.18 (6 of 3.3) A full wave bridge rectifier with 120 V_{rms} sinsoidal input has a load resistor of $1 k\Omega$.

(i) If silicon diodes are applied, what is dc voltage available at load.
(ii) Determine required PIV voltage of each diode.
(iii) Find maximum current through each diode during conduction.
(iv) What is required power rating of each diode?

We have a full wave rectifier with $V_{rms} = 120\ V$

Since $V_{rms} = \frac{V_{max}}{\sqrt{2}}$

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$V_{max} = \sqrt{2}\, V_{rms} = 120 \times 1.41 = 169.2\,V$

Now we have silicon diodes : with built in as 0.7 V.

So, $V_{max} = 169.2 - 0.7 = 168.5\,V.$

(i) DC voltage at load. $= \frac{1}{2\pi}\int_0^{2\pi} 2\, V_{max} \sin(\omega t)\, dt$

$$V_{DC} = \frac{2V_m}{\pi}$$

$$= \frac{2 \times 168.3}{3.14}$$

$$= 107.19\,V$$

(ii) PIV in full wave bridge rectifier is equal to V_{max}.

$\therefore$ PIV $= V_{max} = 168.50\,V.$

(iii) max current through each diode

$$I_{max} = V_{max} \times R_L = 168.5 \times \frac{1}{1000}\,A$$

$$= 168.5\,mA$$

(iv) Required power rating for each diode

$$= V_{max} \times I_{max}$$

$$= \frac{168.5 \times 168.5}{1000}$$

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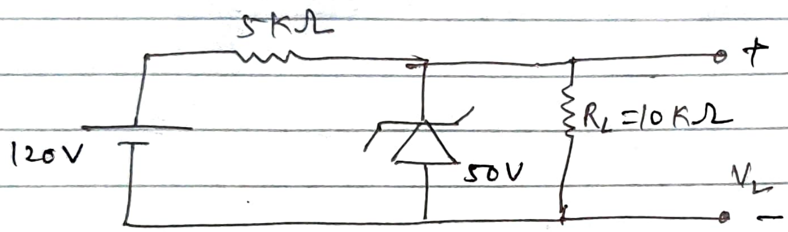
Required Power = 28.39 W

Hence, required power rating for each diode is 28.39 W.

Q.19 (16 of 3.3) For the circuit shown in figure, find
a) output voltage
b) voltage drop across R_s
c) current through zener diode



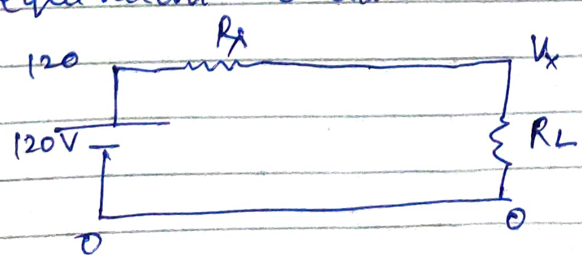
Firstly we need to check whether the zener diode is in reverse biased region or breakdown region

If in breakdown region ⇒ $V_o = 50V$
If in reverse biased region ⇒ $V_o = V_x$

∴ reverse ⟶ $V_x < V_z$
breakdown ⟶ $V_x > V_z$

Consider open diode and calculate V_x.

∴ Equivalent circuit is



$$V_x = I_x \times R_L$$

$$= \frac{120}{R_L + R_S} \times R_L$$

$$= \frac{120 \times 10}{10 + 5}$$

$$V_x = 80\ V$$

$\because$ $V_x > V_Z$, diode is in breakdown region and it won't exceed V_Z.

(a) so output voltage across R_L is V_Z

$\therefore$ $V_{output} = 50\ V$.

(b) Zener diode maintains constant output voltage of 50V across R_L

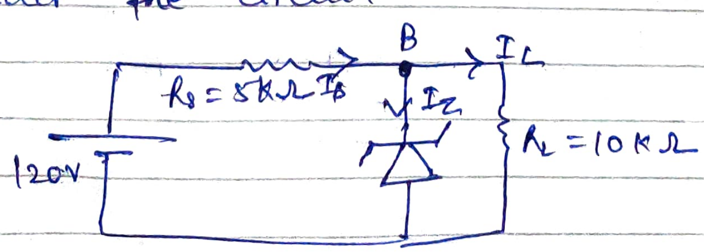
Using KVL,

$$120 - V_{R_S} - 50 = 0$$

$$V_{R_S} = 70\ V$$

$\therefore$ voltage across R_s is 70V.

(c) consider the circuit



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we have to find I_Z .

Applying KCL at node B,

$$I_S = I_L + I_Z$$

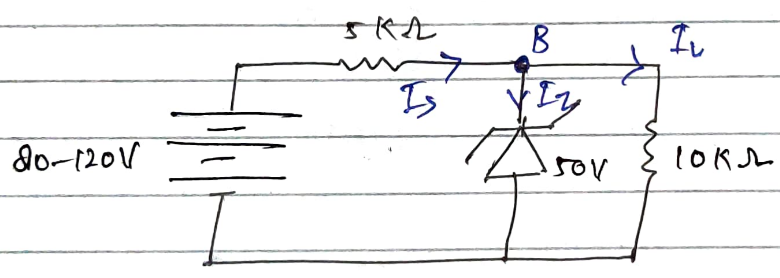
$$I_S = \frac{V_S}{R_S} = \frac{70}{5000} = 14\,mA$$

$$I_L = \frac{V_L}{R_L} = \frac{50}{10000} = 5\,mA$$

$$\therefore\ I_Z = I_S - I_L$$
$$= 9\,mA$$

Hence, current through zener diode is 9 mA.

Q-20 (17 of 3.3) For the circuit shown, find the maximum and minimum values of Zener diode current.



Maximum current through zener diode will occur when V_{input} is 120 V.

So, consider, V_{input} = 120 V and apply KCL at node B

$$I_S = I_L + I_Z$$

Zener diode maintains constant voltage of 50 V across R_L.
$\therefore$ Voltage across R_s = 70 V

$$\therefore I_L = \frac{50}{10000} A \quad \text{and} \quad I_s = \frac{70}{5000} A$$

$$I_L = 5 mA \quad \text{and} \quad I_s = 14 mA$$

$$\therefore (I_Z)_{max} = 9 mA$$

and, zener diode current will be minimum when V_{input} = 80 V.

Zener diode maintains constant voltage of 50 V across R_L.
$\therefore$ voltage across R_s = 30 V.

$$\therefore I_L = \frac{50}{10000} A \quad \text{and} \quad I_s = \frac{30}{5000} A$$

$$I_L = 5 mA \quad \text{and} \quad I_s = 6 mA$$

$$\therefore (I_Z)_{min} = I_s - I_L$$
$$= 6 mA - 5 mA$$
$$= 1 mA$$

Hence, maximum and minimum current through the zener diode is 9 mA and 1 mA respectively.