Q1

(a) Due to the fact that Silicon is doped with As we also know that As is "+5" Value in Semiconductors

⇒ When doped with Silicon, there exists many electrons

⇒ Thus, the material is n-type

(b) $n_i = BT^{\frac{3}{2}} e^{\frac{-E_g}{2kT}}$

$= (5.23\times10^{15})(300)^{\frac{3}{2}} e^{\frac{-1.1}{2(86\times10^{-6})(300)}}$

$= 1.5\times10^{10}\ cm^{-3}$

$n_d = n_{electron} = 5\times10^{16}\ cm^{-3}$

$n_o = n_{hole} = \frac{n_i^2}{n_d}$

$= \frac{2.25\times10^{20}}{5\times10^{16}}$

$= 4.5\times10^{3}\ cm^{-3}$

⇒ In Summary $\begin{cases} \text{electron: } 5\times10^{16}\ cm^{-3} \\ \text{hole: } 4.5\times10^{3}\ cm^{-3} \end{cases}$

(C.) $n_i = BT^{\frac{3}{2}} e^{\frac{-E_g}{2kT}}$

$= (5.23\times10^{15})(350)^{\frac{3}{2}} \cdot e^{\frac{-1.1}{2(86\times10^{-6})\cdot 350}}$

$= 3.97\times10^{10}\ cm^{-3}$

$n_d = n_{electron} = 5\times10^{16}\ cm^{-3}$

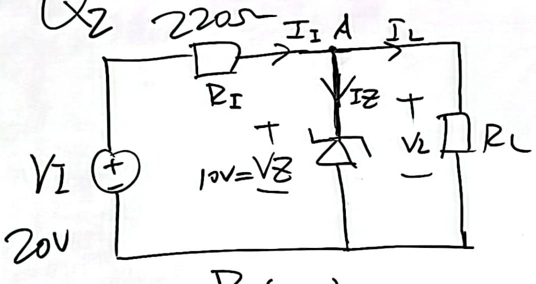
$n_o = n_{hole} = \frac{n_i^2}{n_d}$

$= \frac{(3.97)^2\times10^{20}}{5\times10^{16}}$

$= 3.15\times10^{3}\ cm^{-3}$

⇒ In Summary $\begin{cases} \text{electron: } 5\times10^{16}\ cm^{-3} \\ \text{hole: } 3.15\times10^{3}\ cm^{-3} \end{cases}$

Q2



$P_Z(max) = 440mW$

(a) Apply KCL to node A

$\Rightarrow I_I = I_L + I_Z$

$\Rightarrow I_Z = I_I - I_L$

$$I_Z = I_I - I_L, \quad I_I = \frac{V_I - V_Z}{R_I}, \quad I_L = \frac{V_Z}{R_L}$$

$\Rightarrow I_Z = \frac{V_I - V_Z}{R_I} - \frac{V_Z}{R_L}$

$\Rightarrow I_Z = \frac{20-10}{220} - \frac{10}{380}$

$\Rightarrow I_Z = \frac{1}{22} - \frac{1}{38}$

$\Rightarrow I_Z = \frac{4}{209} A = 19.14mA$

$\Rightarrow I_L = \frac{V_Z}{R_L} = \frac{1}{38} A = 26.32mA$

$\Rightarrow I_I = I_Z + I_L = \frac{1}{22} A = 45.45mA$

(b) From (a)

$\Rightarrow I_Z = \frac{V_I - V_Z}{R_I} - \frac{V_Z}{R_L}$

$\Rightarrow I_Z = \frac{1}{22} - \frac{10}{R_L}$

$P_{Z(max)} = V_Z \cdot I_Z$

$V_Z = 10$

$P_{Z(max)} = 440mW$

$\Rightarrow 44\ mW = \frac{1}{22} - \frac{10}{R_L}$

$\Rightarrow R_L = 6875\ \Omega$

(c) From (b)

$\Rightarrow I_Z = \frac{V_I - V_Z}{R_I} - \frac{V_Z}{R_L}$

$\Rightarrow I_Z = \frac{10}{175} - \frac{10}{R_L}$

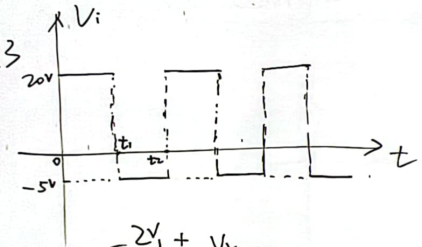
$P_{Z(max)} = V_Z \cdot I_Z$

$V_Z = 10V$

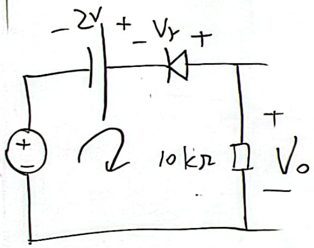
$P_{Z(max)} = 440mW$

$\Rightarrow R_L = 760.87\Omega$

Q3



(a)



Let us analyze the situation in a period ($0 \sim t_2$)

1° when $0 \le t \le t_1$

$\Rightarrow$ Diode is cut-off

$\Rightarrow$ $i_D = 0$

$\Rightarrow$ $V_o = i_D \cdot 10k\Omega = 0\ V$

2° when $t_1 < t \le t_2$

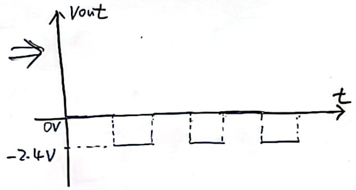
$\Rightarrow$ Diode is on.

$\Rightarrow$ Apply KVL to this loop

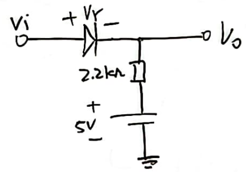
$\Rightarrow$ $2 + V_r - V_o + V_i = 0$

$\Rightarrow$ $V_o = -2.4V$

$\Rightarrow$



(b)



Let us analyze the situation in a period ($0 \sim t_2$)

1° When $0 \le t \le t_1$

$\Rightarrow$ Diode is on

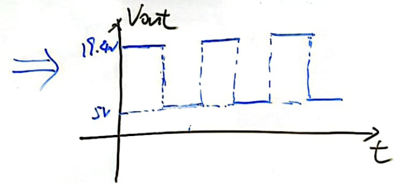
$\Rightarrow$ $V_o = V_i - V_r = 19.4V$

2° when $t_1 < t \le t_2$

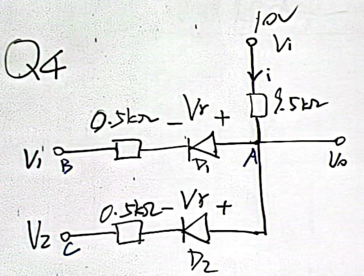
$\Rightarrow$ Diode is cut-off

$\Rightarrow$ $V_o = V_i = -5V$

$\Rightarrow$



Q4



(a) $V_1 = 10V ; V_2 = 0\,V$

$\frac{10-0.6}{10k\Omega} = \frac{9.4}{10k\Omega}$

$\left.\begin{array}{l} V_1 = 10V \\ V_i = 10V \end{array}\right\} \Rightarrow D_1$ is cut-off

$\Rightarrow I_{D1} = 0\,A$

$\left.\begin{array}{l} V_2 = 0V \\ V_i = 10V \end{array}\right\} \Rightarrow D_2$ is on

$\Rightarrow I_{D2} = \frac{V_i - V_r}{10k\Omega} = 0.94mA$

AB path is open

$\Rightarrow V_o = V_r + I_{D2} \cdot 0.5k\Omega$

$\Rightarrow V_o = 1.07V$

$\Rightarrow$ In summary

$\left\{\begin{array}{l} V_o = 1.07V \\ I_{D1} = 0\,A \\ I_{D2} = 0.94mA \end{array}\right.$

(b) $V_1 = V_2 = 10V$

$\left.\begin{array}{l} V_1 = V_2 = 10V \\ V_i = 10V \end{array}\right\}$

$\Rightarrow$ both D_1 and D_2 are cut-off

$\Rightarrow I_{D1} = I_{D2} = 0A$

$\Rightarrow$ AB, AC paths are open

$\Rightarrow V_o = V_i = 10V$

$\Rightarrow$ In Summary $\left\{\begin{array}{l} V_o = 10V \\ I_{D1} = 0\,A \\ I_{D2} = 0\,A \end{array}\right.$

(c) $V_1 = V_2 = 0V$

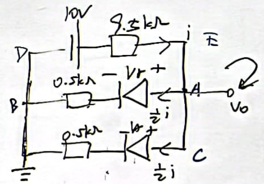
$\left.\begin{array}{l} V_1 = V_2 = 0V \\ V_i = 10V \end{array}\right\}$

$\Rightarrow$ both D_1 and D_2 are on

Because the components on path AB and Path AC are totally same

$\Rightarrow I_{D1} = I_{D2} = \frac{1}{2} i$

$\Rightarrow$ The circuit can be simplified to



$\Rightarrow$ Apply KVL to closed loop ABDEA

$\Rightarrow 10 - V_r = 9.5k\, i + 0.5k \cdot \frac{1}{2} i$

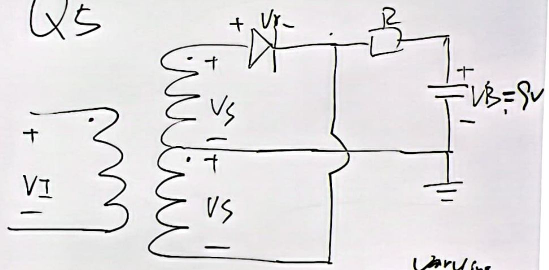
$\Rightarrow i = 0.96mA$

$\Rightarrow \frac{1}{2} i = I_{D1} = I_{D2} = 0.48mA$

$\Rightarrow V_o = V_r + \frac{1}{2} i \cdot 0.5k\Omega = 0.84V$

$\Rightarrow$ In Summary $\left\{\begin{array}{l} V_o = 0.84V \\ I_{D1} = 0.48mA \\ I_{D2} = 0.48mA \end{array}\right.$

Q5



varying

(a) $V_s = 15\sin[2\pi(60)t]$

$V_s(\text{peak}) = 15V$

$R = \dfrac{V_s(\text{peak}) - V_r - V_B}{1.2A}$

$R = 4.42\ \Omega$

(b) From (C)

$\Rightarrow \begin{cases} t_1 = \dfrac{40.29\pi}{180 \cdot 120\pi} = 1.87ms \\ t_2 = \dfrac{139.71\pi}{180 \cdot 120\pi} = 6.47ms \end{cases}$

$\Rightarrow \Delta t = 4.6\ ms$

$\left.\begin{aligned} i(t) &= \dfrac{V_s - 9.7}{R} \\ Q &= \int_{t_1}^{t_2} i(t) \end{aligned}\right\}$

$\Rightarrow Q = \int_{1.87m}^{6.47m} \dfrac{15\sin 120\pi t - 9.7}{4.42}$

$\Rightarrow Q = (-3.39)\left[\dfrac{\cos(120\pi)t}{120\pi}\right]_{t_1}^{t_2} - 2.19\int_{t_1}^{t_2} dt$

$\Rightarrow Q = 13.67m - 10.07m = 3.6m\ C$

$(m = 10^{-3})$

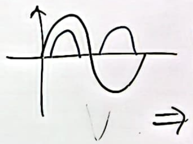
$\Rightarrow I_{ave} = \dfrac{Q}{t_2 - t_1} = \dfrac{3.6 \times 10^{-3} C}{(6.47 - 1.87) \times 10^{-3} s}$

$\Rightarrow I_{ave} = 0.78A$

$\Rightarrow$ Thus: Average Charging Current is 0.78A

(C) $V_s = 15\sin[2\pi(60)t]$

Fraction of Diode Conduction Circle



$V_s - V_B \geq V_r$

$\Rightarrow 15\sin 120\pi t \geq 9.7$

$\Rightarrow 15\sin 120\pi t_1 = 9.7$

$\Rightarrow wt_1 = 40.29^\circ$

$\Rightarrow wt_2 = 180 - 40.29^\circ = 139.71^\circ$

$\Rightarrow \text{Fraction} = \dfrac{139.71^\circ - 40.29^\circ}{360^\circ} \times 100\%$

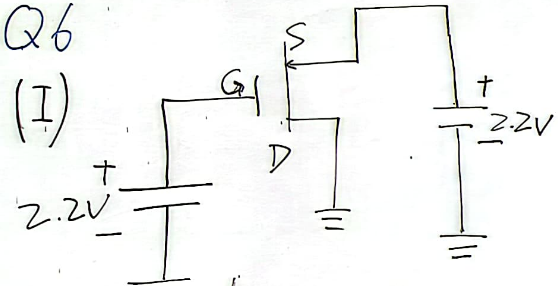
$= 27.62\%$

Because it is a Full wave Rectifier, each diode conducts for the same time in $0 \sim \frac{T}{2}$ and $\frac{T}{2} \sim T$

$\Rightarrow$ Thus the fraction of time that each diode is conducting is 27.62%

Q6

(I)



$V_{TP} = -0.4V$

$V_G = 2.2V$

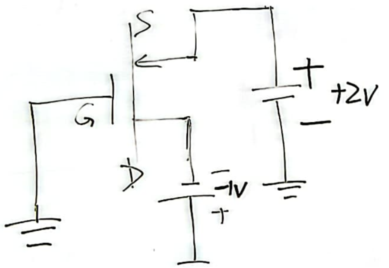
$V_S = 2.2V$

$\Rightarrow V_{SG} = V_S - V_G = 0V$

$V_{SG} + V_{TP} = -0.4V < 0$

$\Rightarrow$ Transistor is cut-off

(II)



$V_G = 0V$

$V_S = 2V$

$\Rightarrow V_{SG} = V_S - V_G = 2V$

$V_{SG} + V_{TP} = 1.6V > 0$

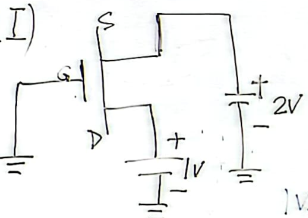
$\Rightarrow$ Transistor is on.

$\left.\begin{array}{l} V_D = 1V \\ V_S = 2V \end{array}\right\}$

$\left.\begin{array}{l} \Rightarrow V_{SD} = V_S - V_D = 1V. \\ 1V = V_{SD} < V_{SG} + V_{TP} = 1.6V \end{array}\right\}$

$\Rightarrow$ Transistor is in Nonsaturation Region

(III)



$V_G = 0V$

$V_S = 2V$

$\Rightarrow V_{SG} = V_S - V_G = 2V$

$V_{SG} + V_{TP} = 1.6V > 0$

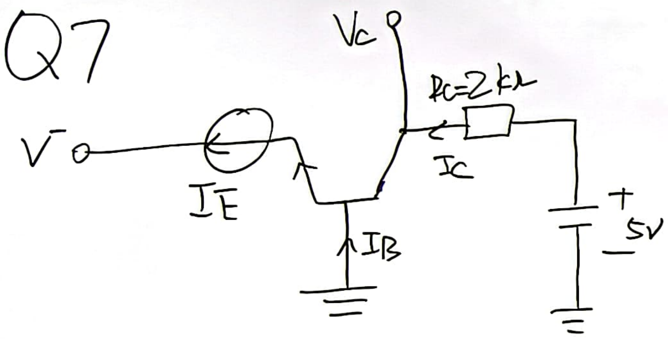
$\Rightarrow$ Transistor is on.

$\left.\begin{array}{l} V_D = 1V \\ V_S = 2V \end{array}\right\}$

$\left.\begin{array}{l} \Rightarrow V_{SD} = V_S - V_D = 1V \\ 1V = V_{SD} < V_{SG} + V_{TP} = 1.6V \end{array}\right\}$

$\Rightarrow$ Transistor is in Nonsaturation Region.

Q7



$\beta = 80$

(a) $I_E = (1+\beta) I_B$ }
$I_E = 1.2mA, \beta = 80$

$\Rightarrow I_B = \frac{1.2}{81} mA$

$= \frac{1200}{81} \mu A$

$I_C = \beta I_B$ }
$\beta = 80 ; I_B = \frac{1.2}{81} mA$

$\Rightarrow I_C = \frac{96}{81} mA$ }
$I_C = \alpha I_E$

$\Rightarrow \alpha = \frac{I_C}{I_E} = \frac{\frac{96}{81} mA}{1.2 mA}$

$\Rightarrow \alpha = \frac{80}{81}$

$V_C = 5 - I_C R_C$ }
$I_C = \frac{96}{81} mA ; R_C = 2k\Omega$

$\Rightarrow V_C = 5 - \frac{192}{81} = \frac{213}{81} V$

In Summary

$\Rightarrow \begin{cases} I_B = \frac{1.2}{81} mA = 14.81 \mu A \\ I_C = \frac{96}{81} mA = 1.19 mA \\ \alpha = \frac{80}{81} = 0.99 \\ V_C = \frac{213}{81} V = 2.63 V \end{cases}$

(b) $I_E = (1+\beta) I_B$ }
$\beta = 8 ; I_E = 0.8 mA$

$\Rightarrow I_B = \frac{0.8}{81} mA$

$= \frac{800}{81} \mu A$

$I_C = \beta I_B$ }
$\beta = 80 ; I_B = \frac{0.8}{81} mA$

$\Rightarrow I_C = \frac{64}{81} mA$ }
$I_C = \alpha I_E$

$\Rightarrow \alpha = \frac{I_C}{I_E} = \frac{\frac{64}{81} mA}{0.8 mA}$

$\Rightarrow \alpha = \frac{80}{81}$

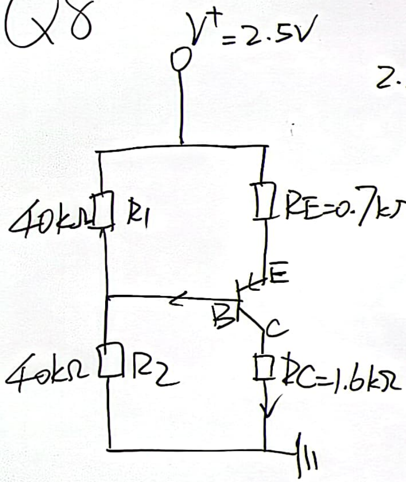
$V_C = 5 - I_C R_C$ }
$I_C = \frac{64}{81} mA ; R_C = 2k\Omega$

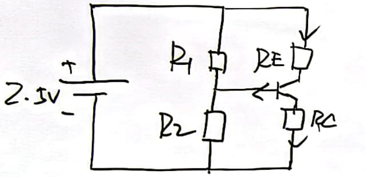
$\Rightarrow V_C = 5 - \frac{128}{81} = \frac{277}{81} V$

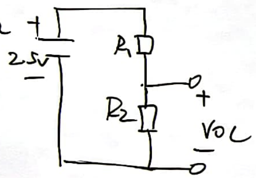
In Summary

$\Rightarrow \begin{cases} I_B = \frac{800}{81} \mu A = 9.88 \mu A \\ I_C = \frac{64}{81} mA = 0.79 mA \\ \alpha = \frac{80}{81} = 0.99 \\ V_C = \frac{277}{81} V = 3.42 V \end{cases}$

Q8



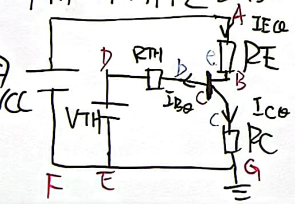




$\Rightarrow V_{OC}=V_{TH}=1.25V$

$\Rightarrow R_{TH}=R_1 \parallel R_2=20k\Omega$

The circuit can be simplified into $\Rightarrow$



Apply KVL to loop (ABCDEFA)

$\Rightarrow V_{CC}-V_{EB(on)}-V_{TH}=I_{EQ}\cdot R_E+I_{BQ}\cdot R_{TH}$

$V_{CC}=2.5V;\ V_{EB(on)}=0.7V$

$V_{TH}=1.25V;\ R_E=0.7k\Omega$

$I_{EQ}=(1+\beta)I_{BQ}=91I_{BQ}$

$\Rightarrow I_{BQ}=6.571\mu A$

$I_{EQ}=91I_{BQ}=0.598mA$

$\Rightarrow I_{CQ}=90I_{BQ}=0.591mA$

Apply KVL to loop (ABCG)

$2.5-V_{ECQ}=I_{EQ}\cdot R_E+I_{CQ}\cdot R_C$

$\Rightarrow V_{ECQ}=2.5-I_{EQ}\cdot R_E-I_{CQ}\cdot R_C$

$\Rightarrow V_{ECQ}=2.5-0.598mA\cdot 0.7k\Omega-0.591mA\cdot 1.6k\Omega$

$\Rightarrow V_{ECQ}=2.5-0.419-0.946$

$\Rightarrow V_{ECQ}=1.135V$

$\Rightarrow$ In summary

$R_{TH}=20k\Omega$

$V_{TH}=1.25V$

$I_{BQ}=6.571\mu A$

$I_{CQ}=0.591\ mA$

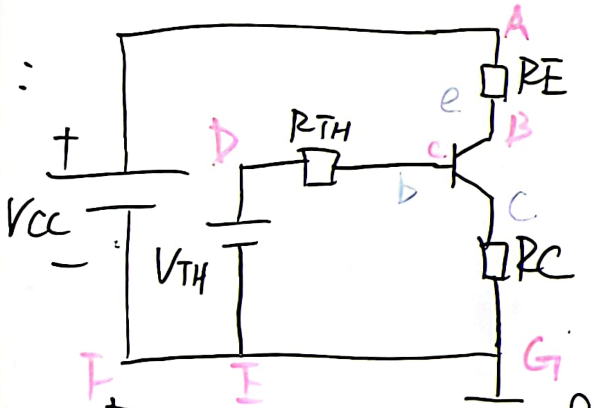
$V_{ECQ}=1.135V$

Q8

(b) From (a)

⇒ the circuit can be simplified into

:



Despite the change of β

⇒ $\begin{cases} V_{TH} \text{ keeps } 1.25V \text{ as (a)} \\ R_{TH} \text{ keeps } 20k\Omega \text{ as (a)} \end{cases}$

Apply KVL to loop (ABCDEFA)

ℭ

$$\left.\begin{aligned} &\Rightarrow V_{CC} - V_{EB(on)} - V_{TH} \\ &= I_{EQ} \cdot R_E + I_{BQ} \cdot R_{TH} \\ &V_{CC} = 2.5V;\ V_{EB(on)} = 0.7V \\ &V_{TH} = 1.25V;\ R_E = 0.7k\Omega \\ &I_E = (1+\beta) I_{BQ} = 151 I_{BQ} \end{aligned}\right\}$$

$\Rightarrow I_{BQ} = 4.375\mu A$

$I_{EQ} = 0.661\ mA$

$\Rightarrow I_{CQ} = 0.656\ mA$

Apply KVL to loop (ABCG)

$\Rightarrow 2.5 - V_{ECQ} = I_{EQ} \cdot R_E + I_{CQ} \cdot R_C$

$\Rightarrow V_{ECQ} = 2.5 - I_{EQ} \cdot R_E - I_{CQ} \cdot R_C$

$\Rightarrow V_{ECQ} = 0.988\ V$

In Summary

β	I_{CQ}	V_{ECQ}
90	0.591 mA	1.135V
150	0.656mA	0.988v
Δ%	$\frac{0.656-0.591}{0.591} \times 100\%$	$\frac{0.988-1.135}{1.135} \times 100\%$
Result	$= +10.998\%$	$= -12.952\%$