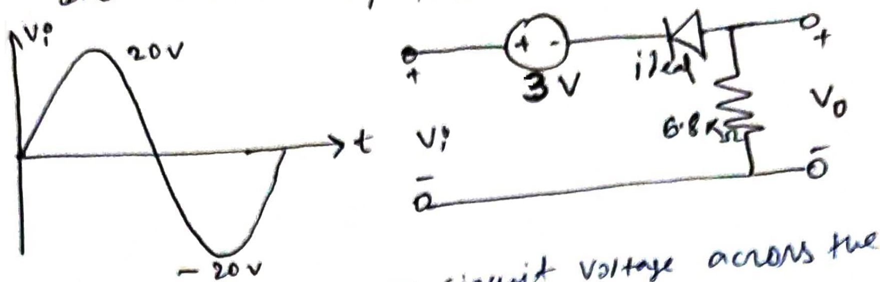
03 Dec 2022

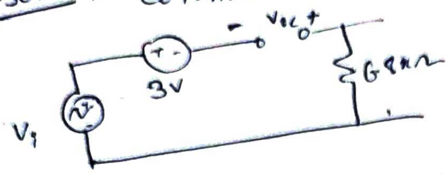
Solution of EE101 Tutorial 3

Q1.

Determine V_o, for the input shown



Sol^n: Consider the open circuit voltage across the Diode



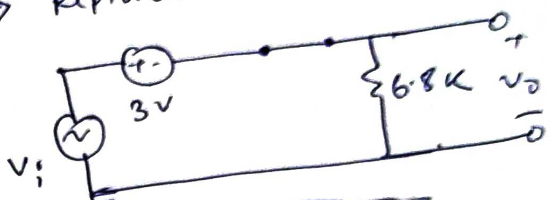
$V_{oc} = 3V - V_I$; $(V_{oc} = V_+ - V_-)$

Case-1: Diode - is ON, → Replace the Diode by short ckt

$V_{oc} > 0V$

$\Rightarrow 3 - V_i > 0$

$\Rightarrow V_I < 3V$



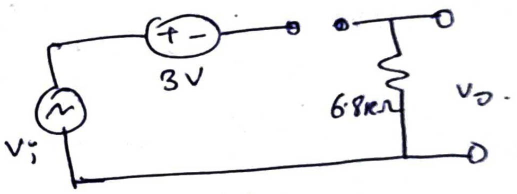
$\boxed{V_o = V_I - 3V}$

Case-2: Diode-off → Replace the Diode by open circuit

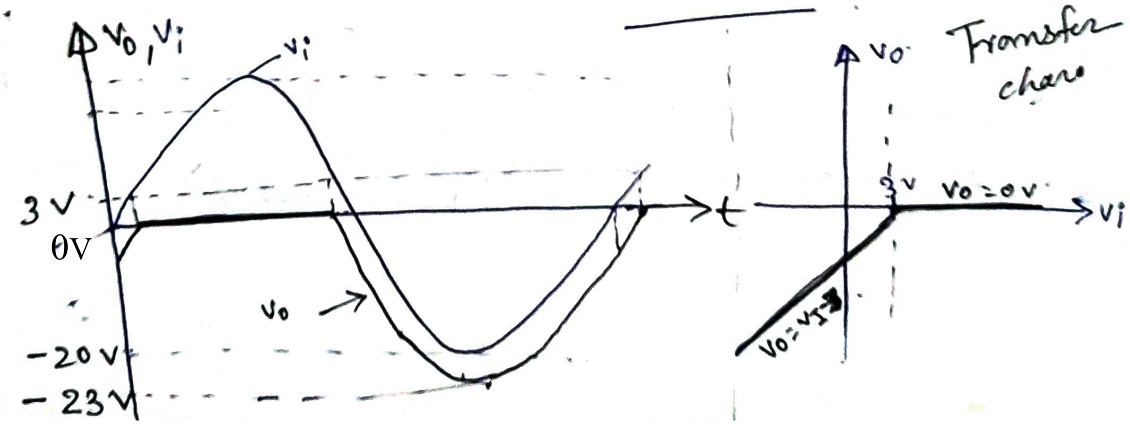
$V_{oc} < 0V$

$\Rightarrow 3 - V_i < 0V$

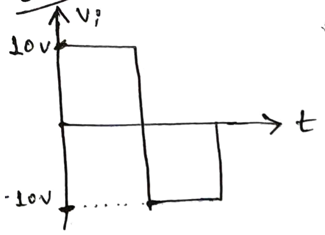
$\Rightarrow V_I > 3V$

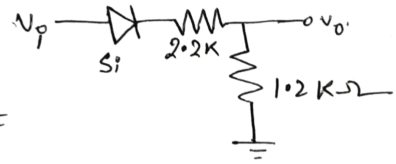


$V_o = 0V$



Q.No.2: Determine V_o for the input shown.



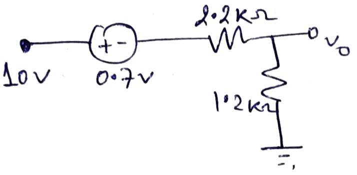


Soln: $V_{oc} = V_i - 0$

Case-1: Diode is ON → Replace the diode with V_g-Source of V_{ON}

$V_{oc} > V_{ON}$

$\Rightarrow V_i > 0.7V$



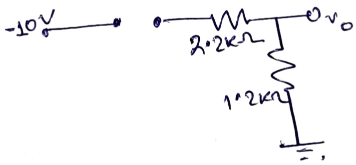
$\Rightarrow V_o = \frac{1.2K}{1.2+2.2}(9.3V)$

$\Rightarrow V_o = 3.28V$.

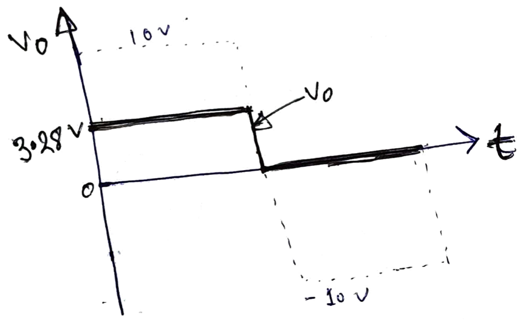
Case-2: Diode-off. → Replace the diode with open circuit

$V_{oc} < V_{ON}$.

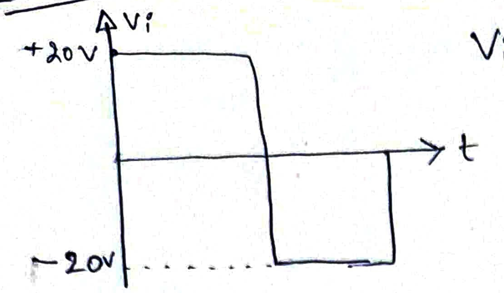
$V_i < 0.7V$

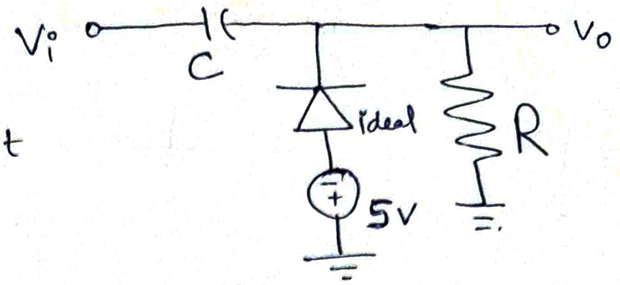


$\Rightarrow V_o = 0V$



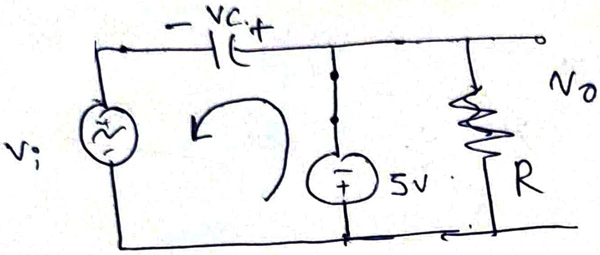
Q. No. 3 : Sketch V_o for the input shown in the fig.





Sol^n : [Note:- Start the Analysis of clamping networks by considering the part of input that will forward Bias the Diode]

Case-1 : during the -ve half cycle, (Diode - ON)



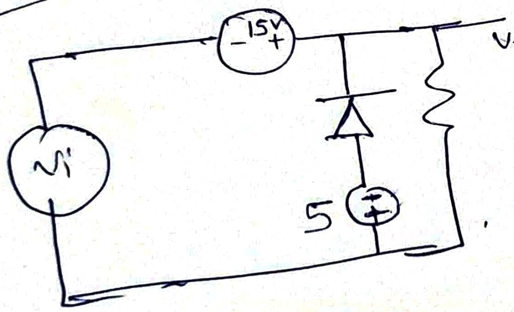
$V_i + V_C + 5 = 0$

$\Rightarrow V_C = -V_i + 5$

$\Rightarrow V_C = -(-20) + 5$

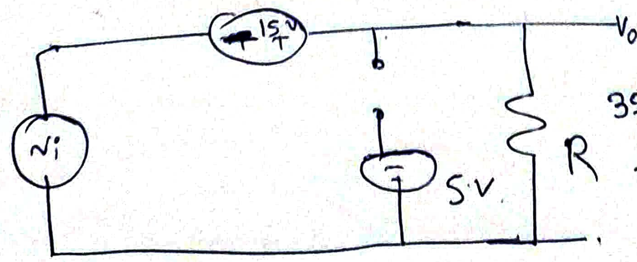
$\boxed{V_C = 15V}$

Now

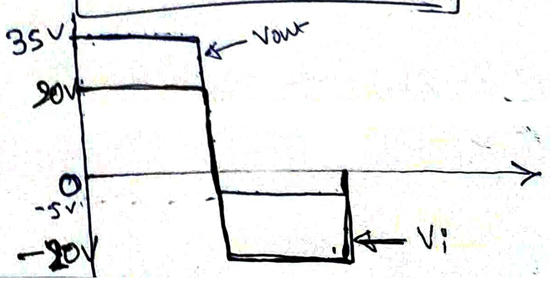


$\boxed{V_o = V_i + 15}$

Case-2 : during the +ve cycle (Diode - off)

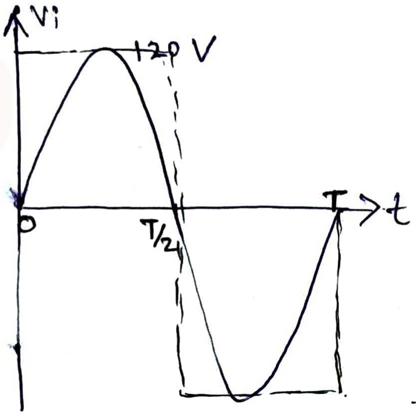


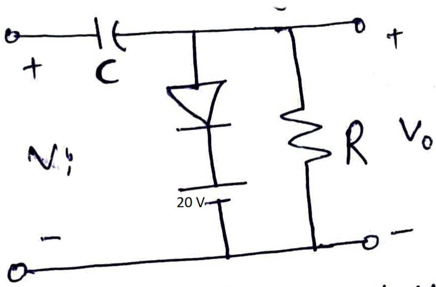
$\boxed{V_o = V_i + 15V}$



Q4.

Q. No



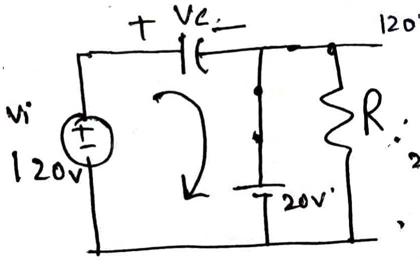


let: $5(RC) >> T/2$, and $V_{ON} = 0V$,

Sol^n :- Replace the given input sinusoidal waveform with square waveform Between the same two levels.

for $0 < t < T/2$

Applying KVL



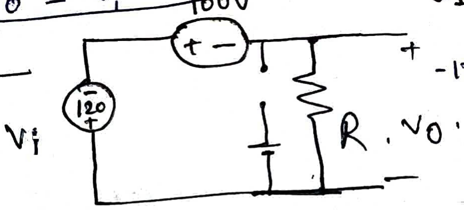
$120 - V_c - 20 = 0$

$\Rightarrow \boxed{V_c = 100V}$

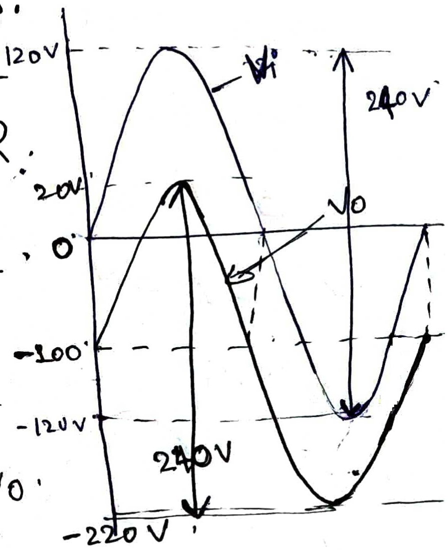
$\Rightarrow \boxed{V_o = V_i - 100}$

100V

for $T/2 < t < T$



$V_I - 100 - V_o = 0$



$\underline{V_o = V_i - 100V}$

even if we consider $V_o = 0.7V$, the peak voltages are much higher than V_{ON}, so. effective swing will Not change by significant amount

Q5. A.

$$I_X = 1^{mA} \Rightarrow I_{Q_1} = I_{Q_2} = 0.5^{mA}$$

$$I_{Q_1} = I_{S_1} e^{\frac{V_{BE_1}}{V_T}} \Rightarrow 5\times10^{-4} = 3\times10^{-16} e^{\frac{V_B}{26^{mV}}}$$

$$\Rightarrow V_B = 26^{mV} \ln\left(\frac{5}{3}\times10^{12}\right) \Rightarrow \boxed{V_B \simeq 731.7^{mV}}$$

B.

$$I_Y = I_{S_3} e^{\frac{V_B}{V_T}}$$

$$\Rightarrow I_{S_3} = I_Y e^{-\frac{V_B}{V_T}} = 2.5\times10^{-3} \times e^{-\frac{V_B}{26mV}} = 2.5\times10^{-3} \times \frac{1}{\frac{5}{3}\times10^{12}}$$

$$\Rightarrow \boxed{I_{S_3} = 1.5\times10^{-15} A}$$

Q6. A.

$$I_X = I_1 + I_2$$

$$I_X = I_{S_1} e^{\frac{V_B}{V_T}} + I_{S_2} e^{\frac{V_B}{V_T}} \Rightarrow I_X = (I_{S_1} + I_{S_2}) e^{\frac{V_B}{V_T}}$$

$$V_B = V_T \ln\left(\frac{I_X}{I_{S_1}+I_{S_2}}\right) \xrightarrow{I_{S_1}=2I_{S_2}} \boxed{V_B = V_T \ln\left(\frac{I_X}{\frac{3}{2} I_{S_1}}\right)}$$

$$V_B = 26\times10^{-3} \ln\left(\frac{1.2\times10^{-3}}{\frac{3}{2}\times5\times10^{-16}}\right) \Rightarrow \boxed{V_B \simeq 730.6\ mV}$$

B.

Transistors at the edge of the active mode $\Rightarrow V_C = V_B$

applying KVL, we have:

$$V_{CC} = R_C I_X + V_B \Rightarrow \boxed{R_C = \frac{V_{CC} - V_B}{I_X}}$$

$$\Rightarrow R_C = \frac{2.5 - 0.73}{1.2\times10^{-3}}$$

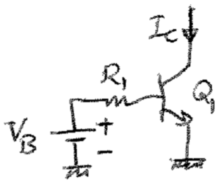
$$\Rightarrow \boxed{R_C \simeq 1475\ \Omega}$$

Q7.

$$
\begin{aligned}
V_{BE} &= 1.5\ \text{V} - I_E(1\ \text{k}\Omega) \\
&\approx 1.5\ \text{V} - I_C(1\ \text{k}\Omega)\ (\text{assuming } \beta \gg 1) \\
&= V_T \ln\left(\frac{I_C}{I_S}\right) \\
I_C &= 775\ \mu\text{A} \\
V_X &\approx I_C(1\ \text{k}\Omega) \\
&= \boxed{775\ \text{mV}}
\end{aligned}
$$

Q8.

From KVL,



$$V_B = R_1 I_B + V_{BE_{Q_1}}$$

$$I_B = \frac{I_C}{\beta} = \frac{1^{mA}}{100} \Rightarrow \boxed{I_B = 10^{-5} A}$$

$$V_{BE_{Q_1}} = V_T \ln\left(\frac{I_C}{I_S}\right) = 26\times10^{-3} \ln\left(\frac{10^{-3}}{7\times10^{-16}}\right)$$

$$\Rightarrow \boxed{V_{BE_{Q_1}} \simeq 727.7\ mV}$$

Therefore,

$$V_B = R_1 I_B + V_{BE_{Q_1}}$$

$$\simeq 10^{k\Omega} \times 10^{-5} A + 728\times10^{-3}$$

$$\Rightarrow V_B \simeq 0.1 + 0.728 \Rightarrow \boxed{V_B \simeq 0.828\ V}$$

Q9.

First, note that $V_{BE1} = V_{BE2} = V_{BE}$.

$$\begin{aligned}
V_B &= (I_{B1} + I_{B2})R_1 + V_{BE} \\
&= \frac{R_1}{\beta}(I_X + I_Y) + V_T \ln(I_X/I_{S1}) \\
I_{S2} &= \frac{5}{3} I_{S1} \\
\Rightarrow I_Y &= \frac{5}{3} I_X \\
V_B &= \frac{8R_1}{3\beta} I_X + V_T \ln(I_X/I_{S1}) \\
I_X &= \boxed{509\ \mu\text{A}} \\
I_Y &= \boxed{848\ \mu\text{A}}
\end{aligned}$$

Q10.

$$g_m = \frac{I_C}{V_T}$$

$$\Delta g_m = \frac{\Delta I_C}{V_T} = \frac{1}{V_T} \Delta\left(I_S e^{V_{BE}/V_T}\right) \simeq \frac{I_S}{V_T^2} e^{\frac{V_{BE}}{V_T}} \Delta V_{BE}$$

$$\Rightarrow \boxed{\Delta g_m \simeq \frac{I_C}{V_T^2} \Delta V_{BE}}$$

$$\Rightarrow \Delta g_m \simeq \frac{g_m}{V_T} \Delta V_{BE}$$

$$\Rightarrow \boxed{\frac{\Delta g_m}{g_m} \simeq \frac{1}{V_T} \Delta V_{BE}}$$

$$\left.\frac{\Delta g_m}{g_m}\right|_{I_C = 1\text{mA}} \overset{max}{=\!=} 0.1 \quad \Rightarrow \Delta V_{BE_{max}} = 0.1\, V_T$$

$$\Rightarrow \boxed{\Delta V_{BE} \leqslant 2.6\ \text{mV}}$$

Q11.

$$
\begin{aligned}
V_{BE} &= V_{CC} - I_B R_B \\
V_T \ln(I_C/I_S) &= V_{CC} - I_C R_B/\beta \\
I_C &= 1.67 \text{ mA} \\
V_{BC} &= V_{CC} - I_B R_B - (V_{CC} - I_C R_C) \\
&< 200 \text{ mV} \\
I_C R_C - I_B R_B &< 200 \text{ mV} \\
R_C &< \frac{200 \text{ mV} + I_B R_B}{I_C} \\
&= \frac{200 \text{ mV} + I_C R_B/\beta}{I_C} \\
R_C &< \boxed{1.12 \text{ k}\Omega}
\end{aligned}
$$