ESC201A Assignment 5

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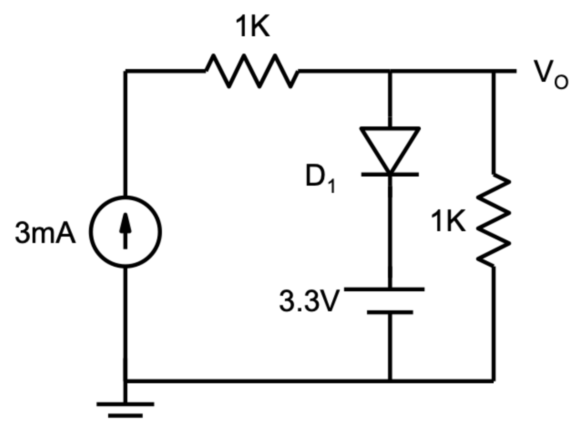
2023-2024 Semester I

Topics

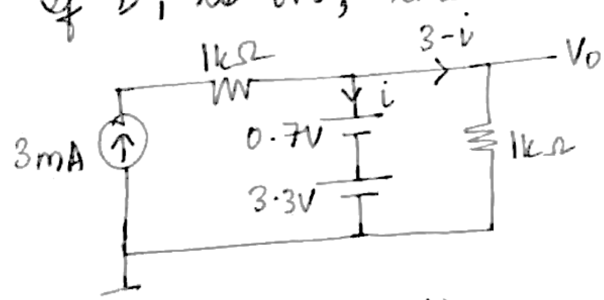
Diodes, Applications

Questions

1. Determine the output voltage with reference to ground for the circuits shown below assuming that cut-in voltage of the diode is 0.7V



Case i) If D_1 is on, the circuit becomes:



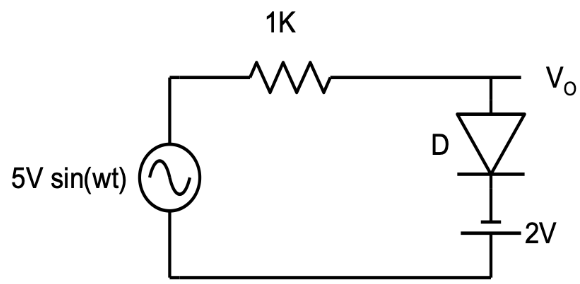
Apply KVL, $4 - (3-i)1 = 0$ which is not possible

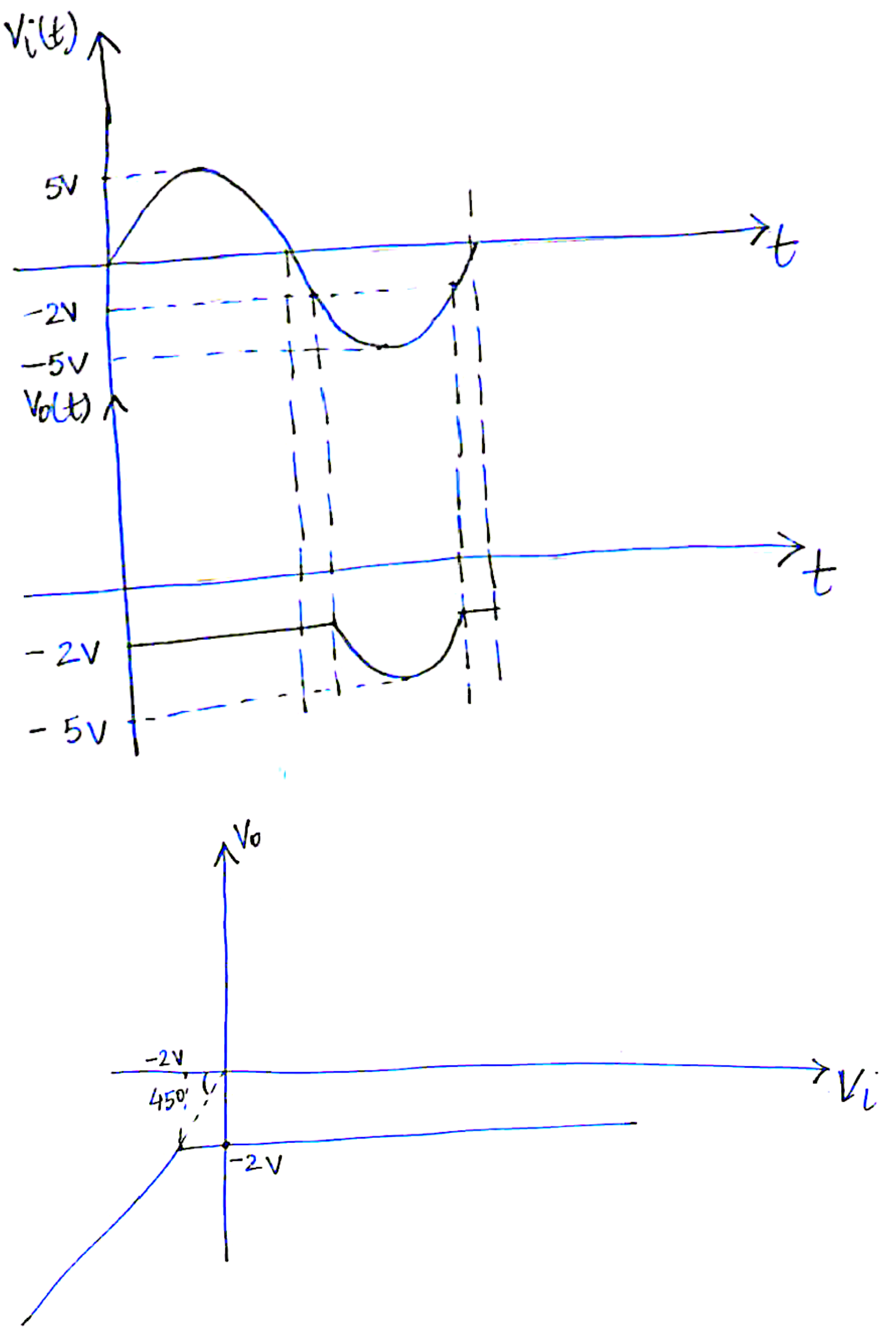
or $i = \cancel{1A}\ -1mA$

$\therefore$ D_1 is off.

Case ii) D_1 is off, $V_0 = 3V$.

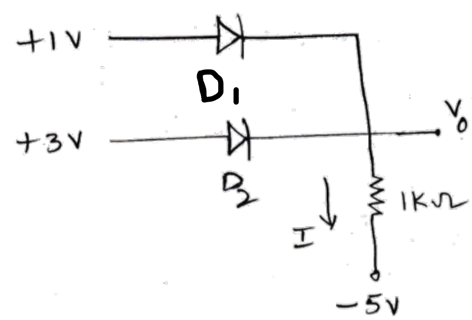
2. Sketch the output voltage vs. input voltage characteristics for the circuit shown below assuming ideal diode.





3. For circuits shown below, using ideal diodes, find the voltage (V_0) and current (I) indicated

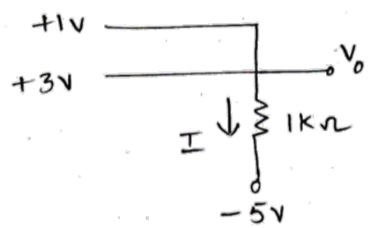
(a)



case (i) :—

Assume both D_1 and D_2 are ON.

Then the circuit reduces to,

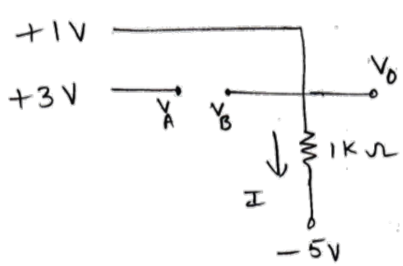


It can be seen that the case is contradicting. This implies D_1 & D_2 cannot be 'ON' simultaneously. Hence, the assumption is false.

case (ii) :—

Assume D_1 is ON and D_2 is OFF.

Then the circuit reduces to,



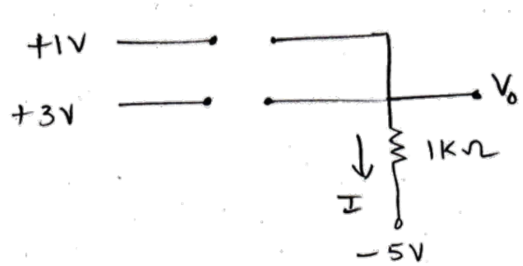
Here, $V_o = +1V = V_B$

But $V_A = 3V >> V_B \Rightarrow D_2$ must be ON.

Hence, our assumption is False.

case (iii) :—

Assume both D_1 and D_2 are OFF.

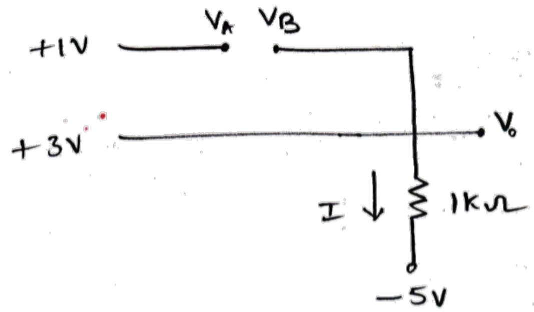


Here $V_o = -5V \Rightarrow$ this implies D_1 and D_2 must be ON [∵ as in case (i)]. Again the assumption fails.

case (iv):-

Assume D_1 is OFF and D_2 is ON.

Then the circuit reduces to,



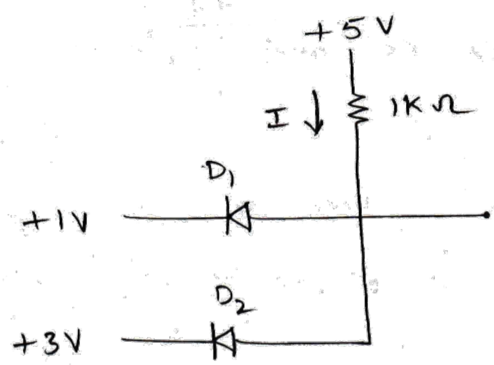
Here, $V_o = +3V \Rightarrow$ which implies D_1 is OFF $[V_B > V_A]$

Hence the assumption is true.

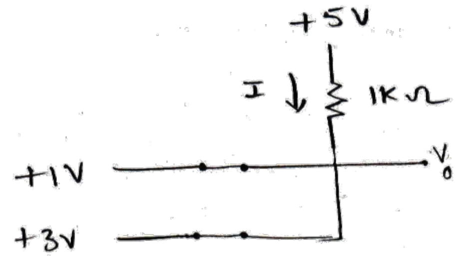
$$\Rightarrow I = \frac{V_o - (-5V)}{1k\Omega} = \frac{3V - (-5V)}{1k\Omega} = 8mA$$

$\therefore$ $\boxed{\begin{aligned} V_o &= 3V \\ I &= 8mA \end{aligned}}$

(b)



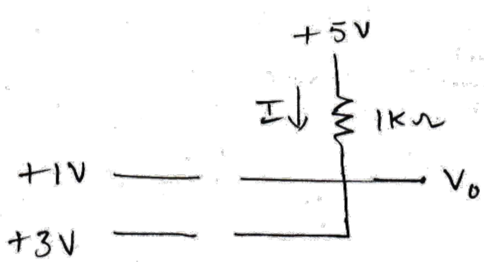
case (i):- Assume both D_1 & D_2 are 'ON'



It can be seen that the case is contradicting and the two diodes cannot be 'ON' simultaneously.

Hence, the assumption is False.

case (ii):- Assume both D_1 & D_2 are OFF.

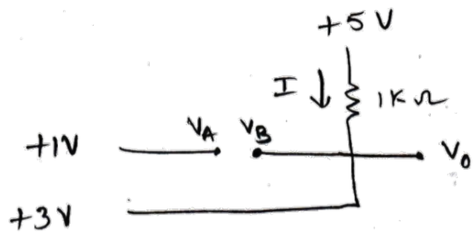


Then $V_0 = 5V$, which forces D_1 and D_2 to be forward biased; which again is a malcondition.

So, the assumption fails.

Case (iii) :-

Assume D_1 is OFF and D_2 is ON.

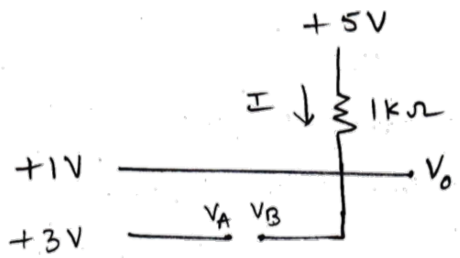


Here, $V_o = 3V$ which forces D_1 to be ON. $[V_B > V_A]$

Hence, the assumption is incorrect.

Case (iv) :-

Assume D_1 is ON and D_2 is OFF.



Here, $V_o = 1V$ which forces D_2 to be OFF. $[V_B < V_A]$

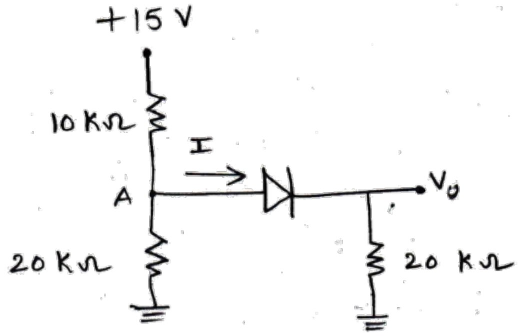
So the assumption is correct.

Now,

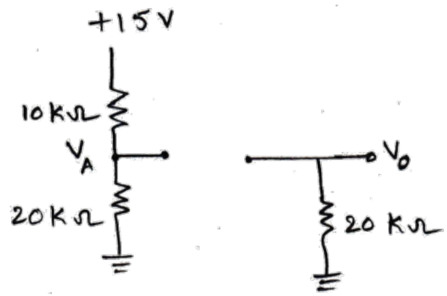
$$I = \frac{5 - V_0}{1K} = \frac{5-1}{1K} = 4mA.$$

$$\therefore \boxed{\begin{aligned} V_0 &= 1\ V \\ I &= 4mA \end{aligned}}$$

(c)



Assume the diode is OFF. Then,



$$V_A = 15 \times \frac{20\,K}{20K + 10K}$$

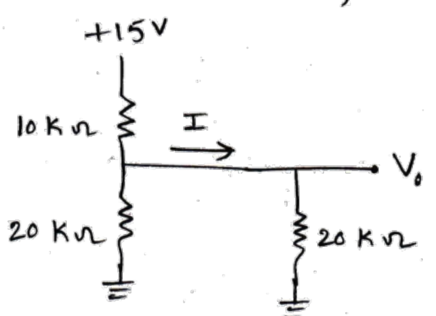
$$= 15 \times \frac{20}{30} = 10V$$

and $V_o = 0$

Since $V_A > V_o \Rightarrow$ Diode is Forward Biased.

So the assumption is False.

When the diode is ON,



$$V_o = 15 \times \frac{(20K \parallel 20K)}{10K + [20K \parallel 20K]}$$

$$= 15 \times \frac{10K}{20K} = 7.5\,V$$

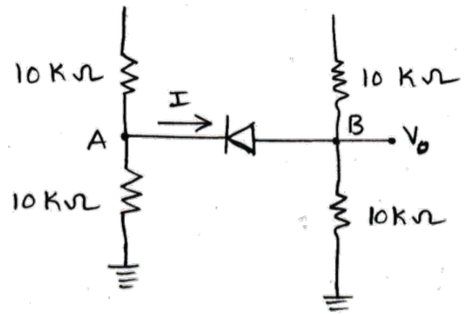
and,

$$I = \frac{V_o}{20K} = \frac{7.5}{20K\Omega} = 0.375\,mA$$

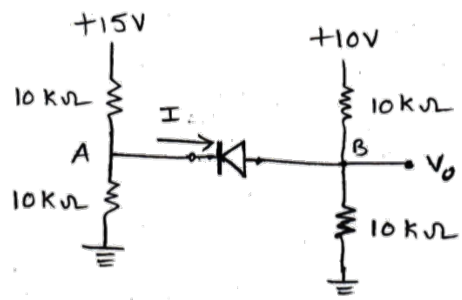
$\therefore$

$$\boxed{\begin{aligned} V_o &= 7.5\ V \\ I &= 0.375\,mA \end{aligned}}$$

(d)



Assume that, the diode is OFF. Then,



Now,

$$V_A = 15 \times \frac{10K}{10K+10K} = \frac{15}{2} = 7.5V$$

$$V_B = 10 \times \frac{10K}{10K+10K} = 10 \times \frac{1}{2} = 5V \Rightarrow V_B = 5V$$

Since $V_A > V_B$ i.e., Diode is reverse biased i.e OFF.

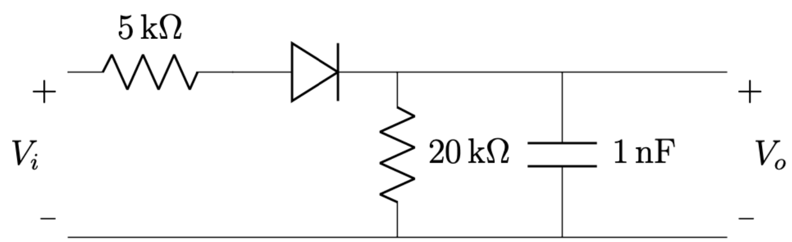
So, the assumption is correct and as the diode is reverse-biased, no current will flow through it i.e, I=0.

$\therefore V_0 = V_B = 5V$

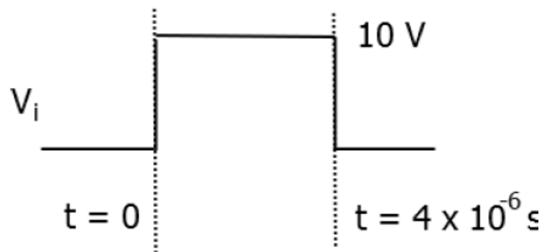
$\therefore$

$$\boxed{\begin{aligned} V_0 &= 5V \\ I &= 0A \end{aligned}}$$

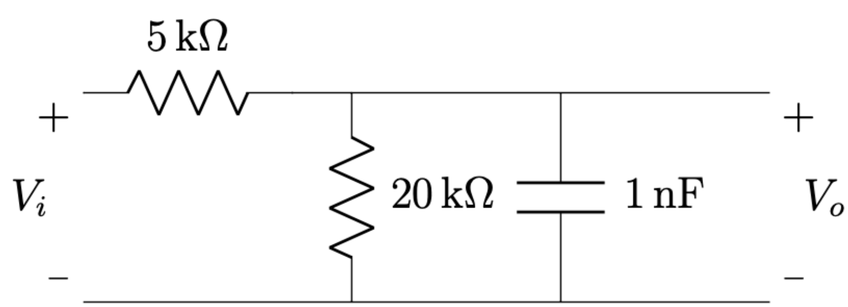
4. A rectangular pulse of 10 V amplitude and duration 4 μs is applied as V_i at the input of circuit given. Determine and sketch $V_o(t)$ for $t > 0$ assuming that the diode is ideal and the initial voltage across the capacitor is zero.



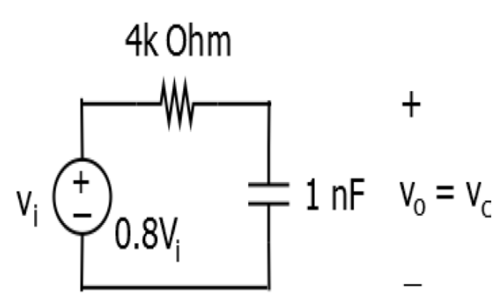
Solution: The pulse is shown as following.



For initial 4 us, the equivalent circuit is



Using thevenin equivalent, we can simplify it as



Hence,

$$v_o = (v_c(0) - v_c(\infty))\, e^{-t/\tau} + v_c(\infty)$$

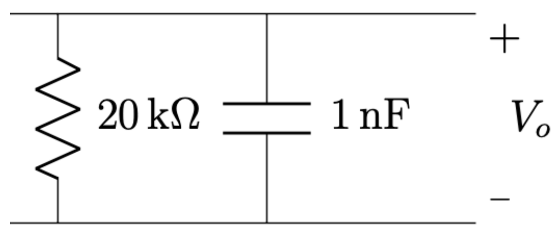
Here $v_c(0) = 0\,V$; $v_c(\infty) = 0.8\,V_i = 8\,V$ and $\tau = RC = 4 \times 10^3 \times 10^{-9} = 4\,\mu s$.

$$v_o = 8\left(1 - e^{-t/4\times10^{-6}}\right)$$

At $t = 4\,\mu s$, $v_o = 8\left(1 - e^{-1}\right) = 5.05\,V$

For $t > 4\,\mu s$, the diode is reverse biased and hence off.

Hence, the equivalent circuit is

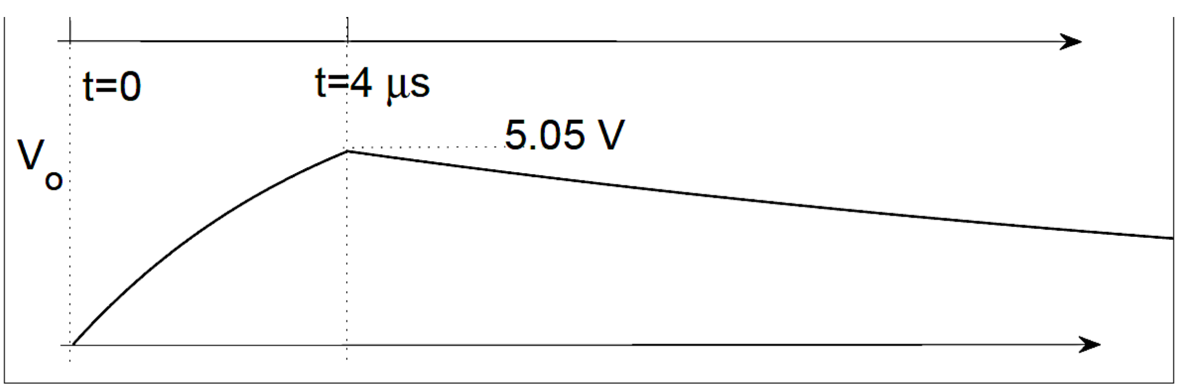


For this circuit, $\tau' = 20 \times 10^3 \times 10^{-9} = 20\,\mu s$ and $t' = t - 4 \times 10^{-6}$

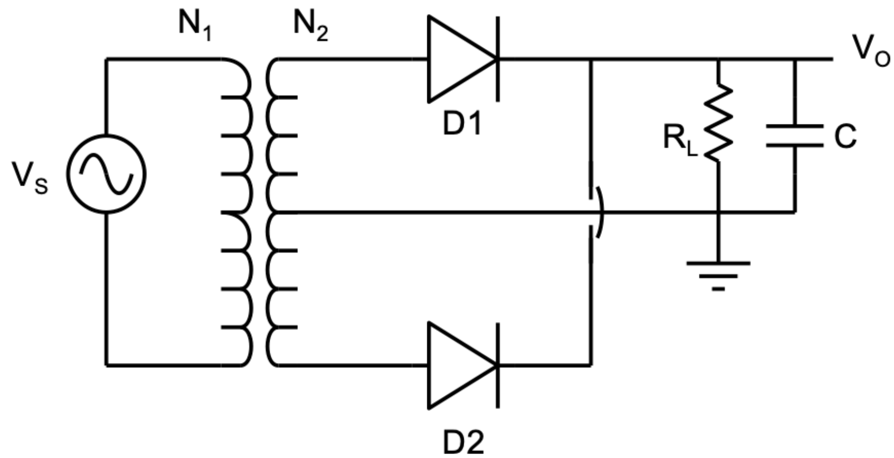
$$\begin{aligned} v_o &= 5.05\, e^{-t'/\tau'} \\ &= 5.05\ \exp\left[-\left(\frac{t - 4\times10^{-6}}{20\times10^{-6}}\right)\right] \end{aligned}$$

Hence, we get

$$\begin{aligned} v_o(t) &= 8\left(1 - e^{-t/4\times10^{-6}}\right) \qquad for\ \ 0 \le t \le 4\times10^{-6}s \\ &= 5.05\, e^{-\left(t-4\times10^{-6}\right)/20\times10^{-6}} \quad for\ \ t \ge 4\times10^{-6}s \end{aligned}$$



5. Design the power supply circuit shown below that will supply 10V to a load of 1000Ω with ripple voltage less than 0.2V. As part of the design, determine transformer turns ratio, value of capacitance, diode peak current and peak inverse voltage. Assume that input is 220V rms with a frequency of 50Hz. Assume constant voltage-drop model (0.7 V) for diodes.



$V_\gamma = 0.7V$, $V_0 = 10V$

$\therefore V_i = V_0 + V_\gamma = 10 + 0.7\ V = 10.7V$

$$\frac{N_1}{N_2/2} = \frac{V_s}{V_i} = \frac{220 \times \sqrt{2}}{10.7}$$

$$\therefore \frac{N_1}{N_2} = \frac{110 \times \sqrt{2}}{10.7} = 14.53$$

Ripple voltage, $V_r = \dfrac{V_M}{2fR_LC}$

Also, $V_r \leq 0.2V$

$$\therefore \frac{V_M}{2fR_LC} \leq 0.2V$$

$$\Rightarrow \frac{10}{2 \times 50 \times 1000 \times C} \leq 0.2$$

or $C \geq \dfrac{10}{100 \times 1000 \times 0.2}$ F

$\Rightarrow C \geq 0.5 mF$

$R_L C = \dfrac{1000 \times 5}{10000} s = 0.05 s$

$\dfrac{T}{2} = \dfrac{1}{2 \times 50} s = 0.01 s$

$\therefore R_L C \geq \dfrac{T}{2}$ is satisfied.

Peak Inverse Voltage, PIV $= 2V_M + V_\gamma$

$= 20 + 0.7 V = 20.7 V$

$$i_{D,max} = \frac{V_M}{R_L}\left[1 + \pi\sqrt{\frac{2V_M}{V_r}}\right]$$

$$\Rightarrow i_{D,max} = \frac{10}{1000}\left[1 + \pi\sqrt{\frac{2 \times 10}{0.2}}\right] A$$

$$\Rightarrow i_{D,max} = \frac{10}{1000}\left[1 + (\pi \times 10)\right] A$$

$$\Rightarrow i_{D,max} = \frac{10}{1000}(1 + 31.4) A$$

$$\Rightarrow i_{D,max} = 0.32 A$$

$$i_{D,avg} = \frac{1}{2}\left(\frac{V_M}{R_L}\right)$$

$$\Rightarrow i_{D,avg} = \frac{1}{2} \times \frac{10}{1000} A$$

$$\Rightarrow i_{D,avg} = 5 mA$$