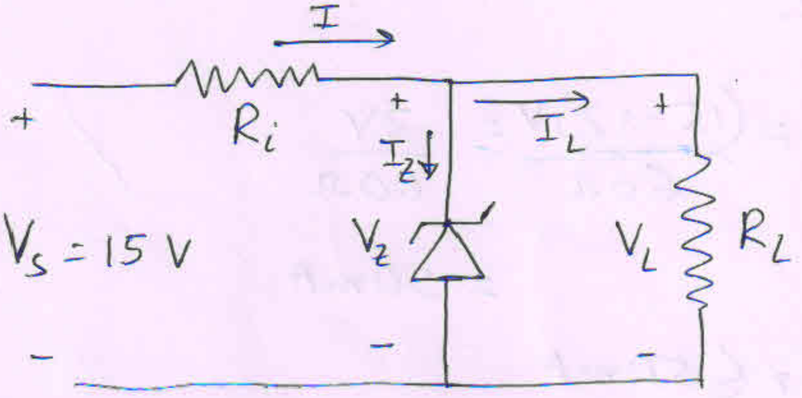
ESC 201 Solutions - Assignment 6

Ans 1.



$V_Z = V_L = 12\text{V}$ (Zener mode)

$I_{Z,min} = 2\,mA$

$P_{Z,max} = 0.6\,W = V_Z \cdot I_{Z,max}$

$$\Rightarrow (12V)\, I_{Z,max} = 0.6\,W$$

$$\Rightarrow I_{Z,max} = \left(\frac{0.6}{12}\right) A = 50\,mA$$

$$\Rightarrow 2\,mA \leq I_Z \leq 50\,mA \quad [\text{Zener mode}]$$

By KCL,

$$I_Z = I - I_L$$

$$= \frac{V_s - V_Z}{R_i} - I_L$$

$$= \frac{(15-12)V}{R_i} - I_L = \frac{3V}{R_i} - I_L$$

$$2\,mA \leq I_Z \leq 50\,mA$$

$$\Rightarrow 2\,mA \leq \frac{3V}{R_i} - I_L \leq 50\,mA$$

$$\Rightarrow \frac{3V}{50mA + I_L} < R_i < \frac{3V}{2mA + I_L}$$

$\therefore$ Minimum R_i (i.e. for $I_L \to 0$; for ~~large~~ $R_L \to \infty$)

$$= \boxed{R_{i,min} = \frac{3V}{50mA} = 60\,\Omega}$$

With $R_i = 60\,\Omega$

$$I = \frac{V_s - V_z}{R_i} = \frac{(15-12)V}{60\,\Omega} = \frac{3V}{60\,\Omega}$$

$$= 50mA.$$

$$2mA \leq I_z \leq 50mA$$

$$\Rightarrow 2mA \leq I - I_L \leq 50mA$$

$$\Rightarrow -48mA \leq -I_L \leq 0 \quad [\text{Using } I = 50mA]$$

$$\Rightarrow \quad 0 \leq I_L \leq 48mA.$$

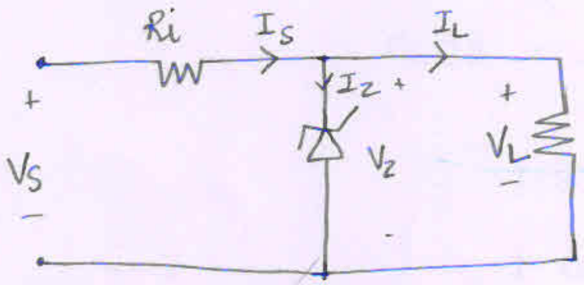
Also, $I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{12V}{R_L}$

$$\Rightarrow \quad 0 \leq \frac{12V}{R_L} \leq 48mA$$

$$\Rightarrow \frac{12V}{48mA} \leq R_L < \infty$$

$$\Rightarrow \boxed{R_{L,min} = \frac{12V}{48mA} = 250\,\Omega}.$$

Ans 2.



$V_L = 12V$, $V_S = 20V$,

$0 \leq I_L \leq 100mA$

$$I_S = \frac{V_S - V_L}{R_i} = \frac{V_S - V_Z}{R_i} \quad (\because V_Z = V_L)$$

Also, $I_S = I_Z + I_L$

$$\therefore \quad I_Z + I_L = \frac{V_S - V_Z}{R_i}$$

$$\Rightarrow I_L = \frac{V_S - V_Z}{R_i} - I_Z$$

Also,

$$0 \leq \frac{V_S - V_Z}{R_i} - I_Z \leq 0.1$$

$$\Rightarrow -\frac{V_S - V_Z}{R_i} \leq -I_Z \leq 0.1 - \frac{V_S - V_Z}{R_i}$$

$$\Rightarrow \frac{V_S - V_Z}{R_i} \geq I_Z \geq \frac{V_S - V_Z}{R_i} - 0.1$$

$$P_{Z,max} = V_Z \cdot I_{Z,max}$$

Since, $\frac{V_S - V_Z}{R_{imin}} \geq I_{Z}max. \geq \frac{V_S - V_Z}{R_{imin}} - 0.1$

The value of I_{Z} max is set by its lower limit being ≥ 0. This restric the minimum $P_{Z,max}$

$$\therefore \min(I_{Z,max}) \; \cancel{(I_{Z,min})} = \frac{20-12}{R_{imin}} - 0.1$$

Since $I_{Z,max}$ cannot be negative, minimum value of I_{Zmax} is 0

$$\therefore \frac{20-12}{R_{imin}} - 0.1 = 0$$

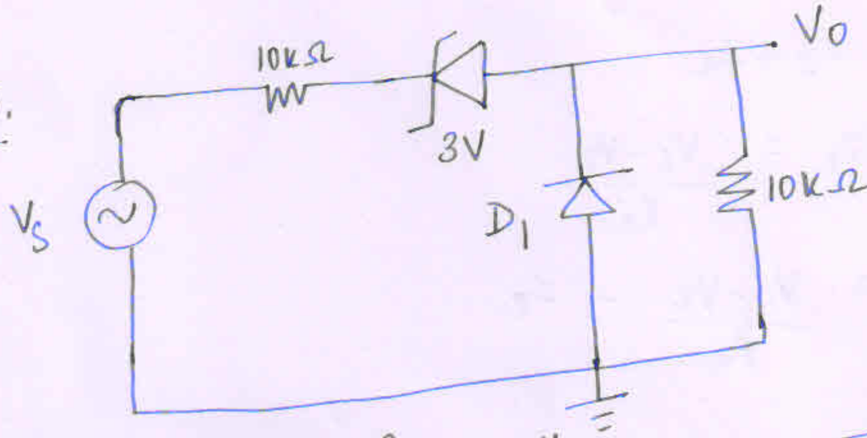
$$\Rightarrow \frac{8}{R_{imin}} = 0.1$$

or $R_{imin} = \frac{8}{0.1}\,\Omega = 80\,\Omega$

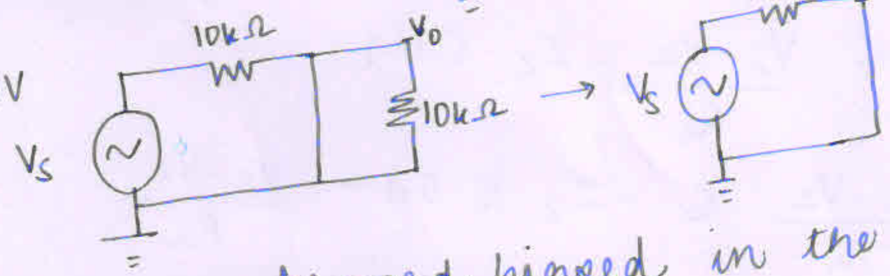
Because $I_{Z,max} \leq 0.1$

$$P_{zmax} = V_Z \cdot 0.1$$
$$= 12 \times 0.1\ W$$
$$\Rightarrow P_{zmax} = 1.2\ W$$

Ans 3.



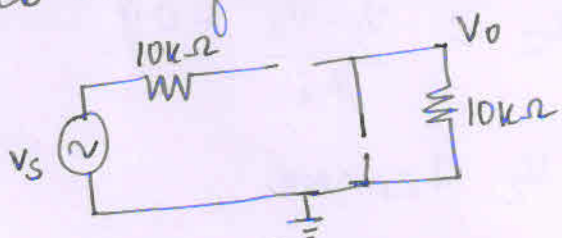
For $V_S < 0V$



$\therefore V_0 = 0V$

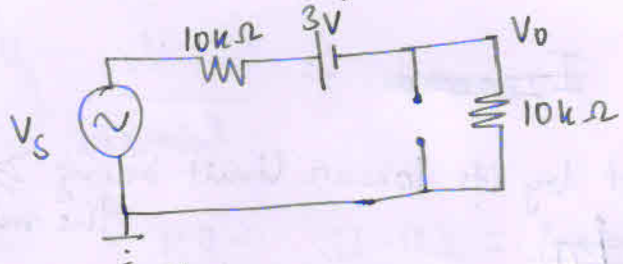
Both diodes are forward biased in the negative cycle.

for $0 < V_S < 3V$



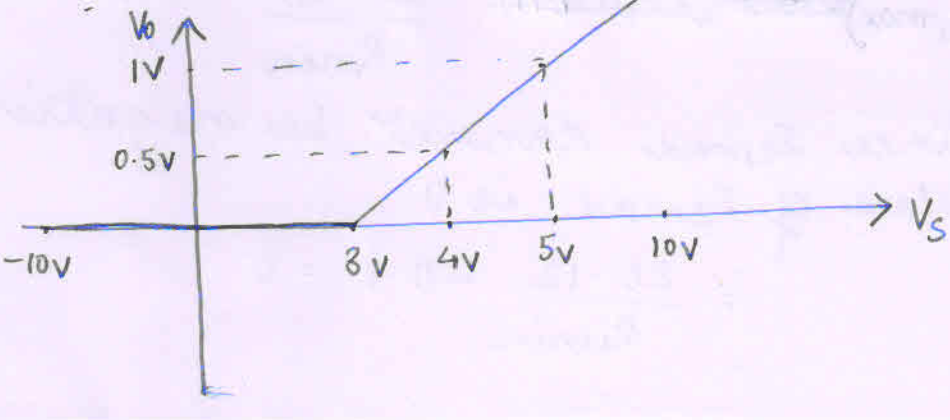
$V_0 = 0V$ as both diodes are reverse biased.

for $V_S > 3V$

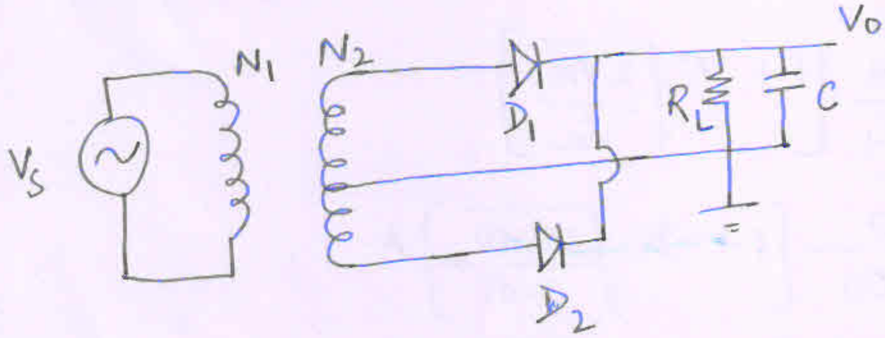


$$\therefore V_0 = \frac{(V_S - 3) \times 10}{20}$$

$$\Rightarrow V_0 = 0.5 V_S - 1.5$$



Ans 4.



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

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

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

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

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

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

$$\Rightarrow C \geq 0.5mF$$

$$R_LC = \frac{1000 \times 5}{10000} s = 0.05s$$

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

$\therefore R_LC \geq \frac{T}{2}$ is satisfied.

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

$= 20 + 0.7V = 20.7V$

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

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

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

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

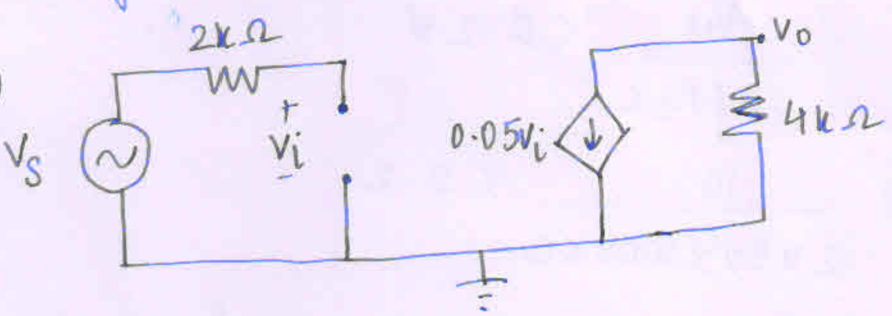
$$\Rightarrow i_{D,max} = 0.32 A$$

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

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

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

Ans 5. (i)



$$V_i = V_S$$

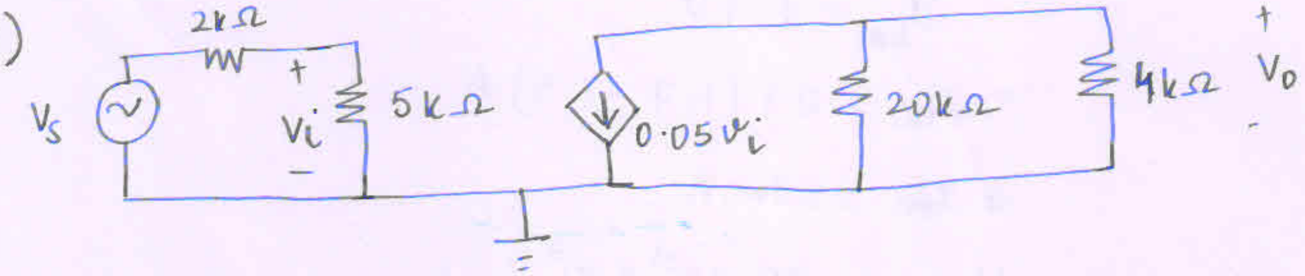
$$V_O = -0.05 V_i \times 4 \times 10^3 \ V$$

$$\Rightarrow V_O = -0.05 \times 4 \times 10^3 \times V_S \ V$$

$$\Rightarrow \frac{V_O}{V_S} = -\frac{5}{100} \times 4 \times 1000$$

$$\Rightarrow \frac{V_O}{V_S} = -200$$

(ii)



$$v_i = \frac{V_s \times 5}{5+2} = \frac{5V_s}{7}$$

$$v_o = -0.05 v_i \left(20k\Omega \| 4k\Omega\right)$$

$$\Rightarrow v_o = \frac{-0.05 \times 20 \times 4 \times 1000}{24} v_i$$

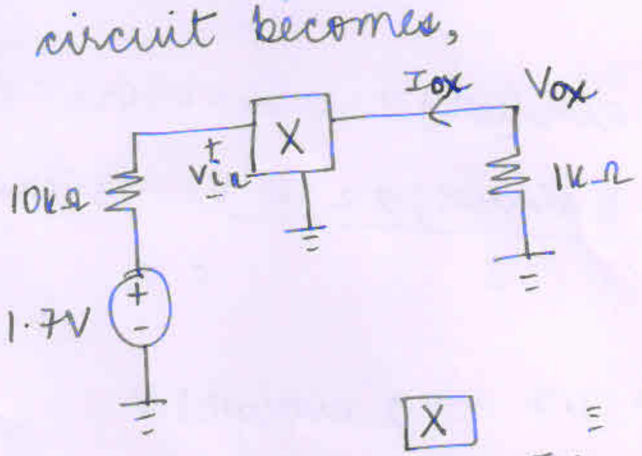
$$\Rightarrow v_o = \frac{-0.05 \times 20 \times 4 \times 1000}{24} \times \frac{5}{7} v_s$$

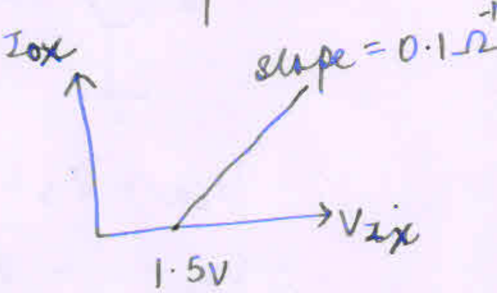
$$\Rightarrow \frac{v_o}{s} = -\frac{5 \times 20 \times 4 \times 1000 \times 5}{100 \times 24 \times 7}$$

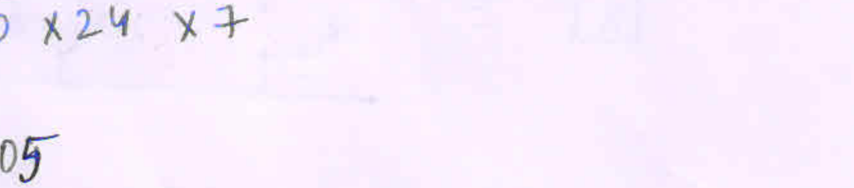
$$\Rightarrow \frac{v_o}{V_S} = -119.05$$

<u>Ans 6.</u> <u>DC analysis</u> : Open circuit capacitors.

So, the circuit becomes,







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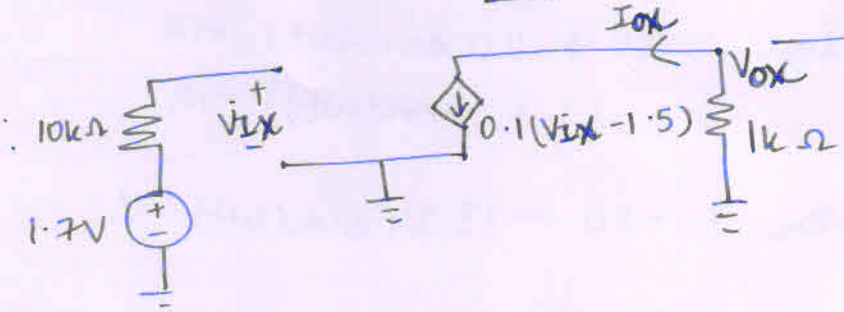


$V_{Ix} = 1.7\,V$

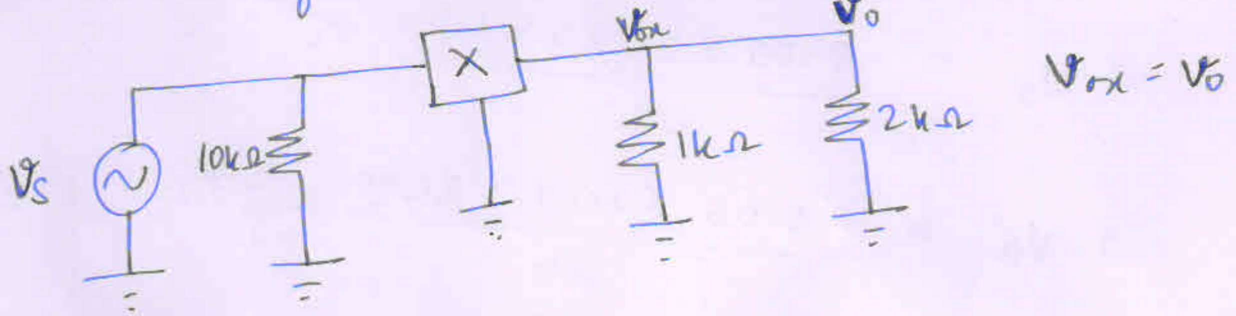
$\therefore I_{ox} = 0.1\,(1.7 - 1.5)\,A$

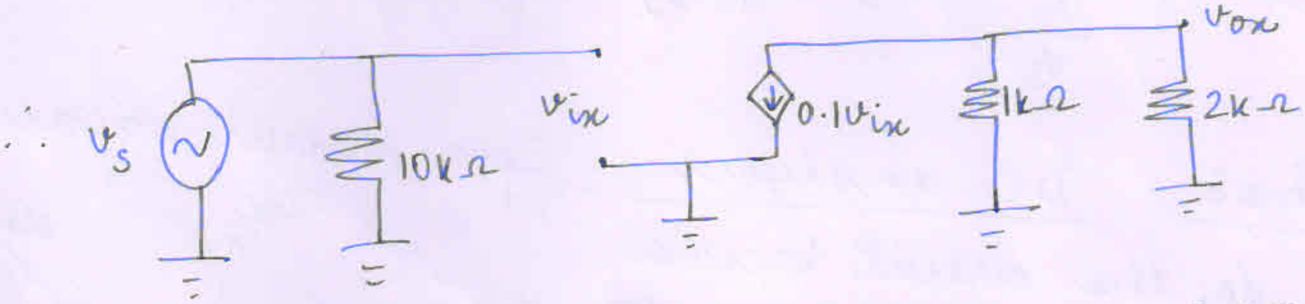
$\Rightarrow I_{ox} = 20\,mA$

$\therefore V_{ox} = -20 \times 10^{-3} \times 10^{3}\,V$

$\Rightarrow V_{ox} = -20\,V$

AC analysis : Short circuit capacitors and DC sources. Therefore, the circuit becomes,





$v_{ix} = v_S = 0.2 \sin(\omega t)\,V \Rightarrow i_{ox} = 0.1 v_{ix} = 0.02 \sin(\omega t)\,A$

$\therefore v_{ox} = -\dfrac{0.1 \times 0.2 \sin(\omega t) \times 2 \times 10^{3}}{3}\,V = -13.34 \sin(\omega t)\,V$

$= v_o$

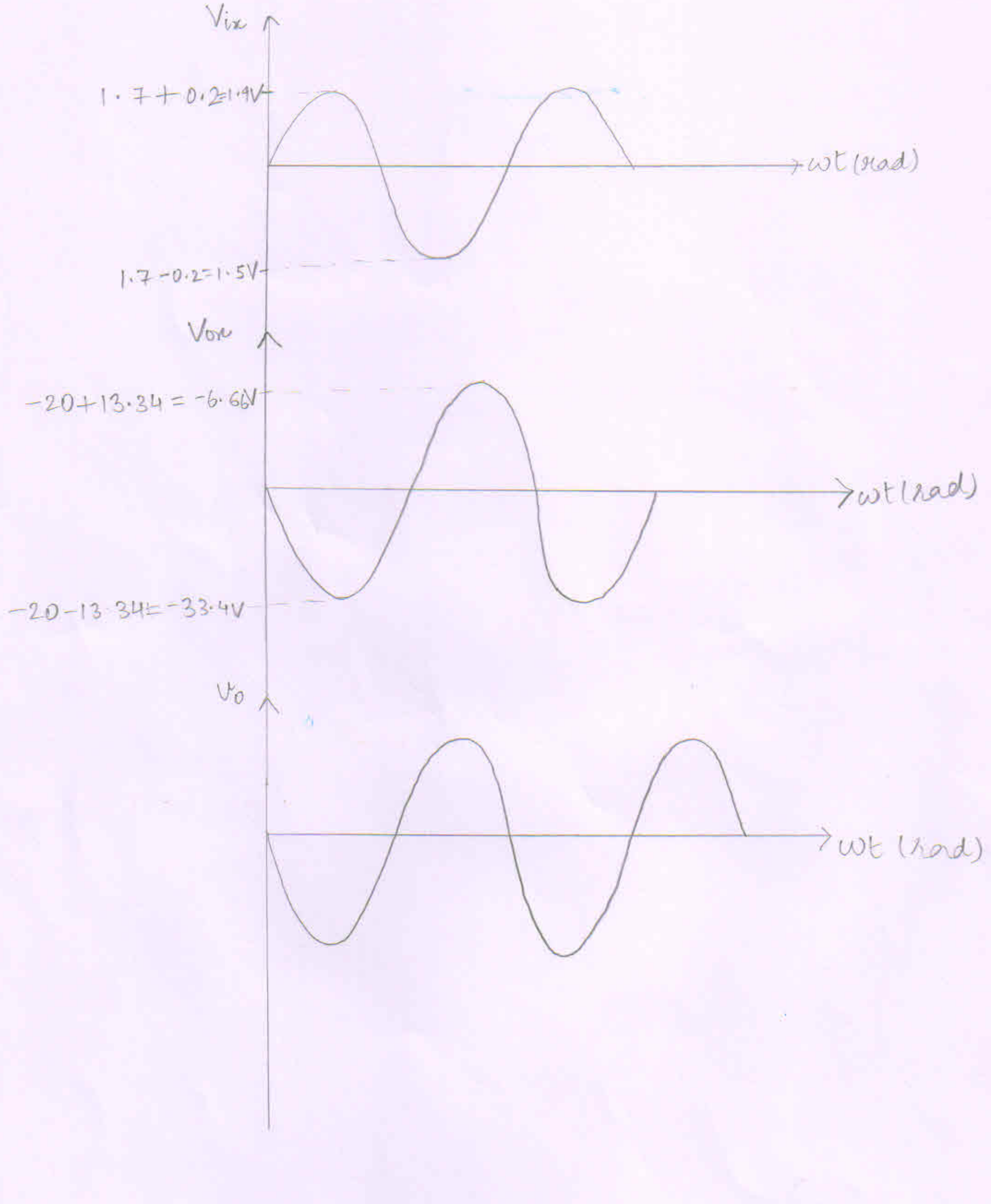
Net values,

$V_{ix} = V_{Ix} + v_{ix} = 1.7 + 0.2 \sin(\omega t)\,V$

$I_{ox} = I_{Ox} + i_{ox} = 20 + 20 \sin(\omega t)\,mA$

$= 20(1 + \sin(\omega t))\,mA$

$V_{ox} = V_{Ox} + v_{ox} = -20 - 13.34 \sin(\omega t)\,V$



Vin
1.7+0.2=1.9V
1.7-0.2=1.5V
ωt (rad)
Von
-20+13.34 = -6.66V
-20-13.34=-33.4V
ωt (rad)
v_0
ωt (rad)