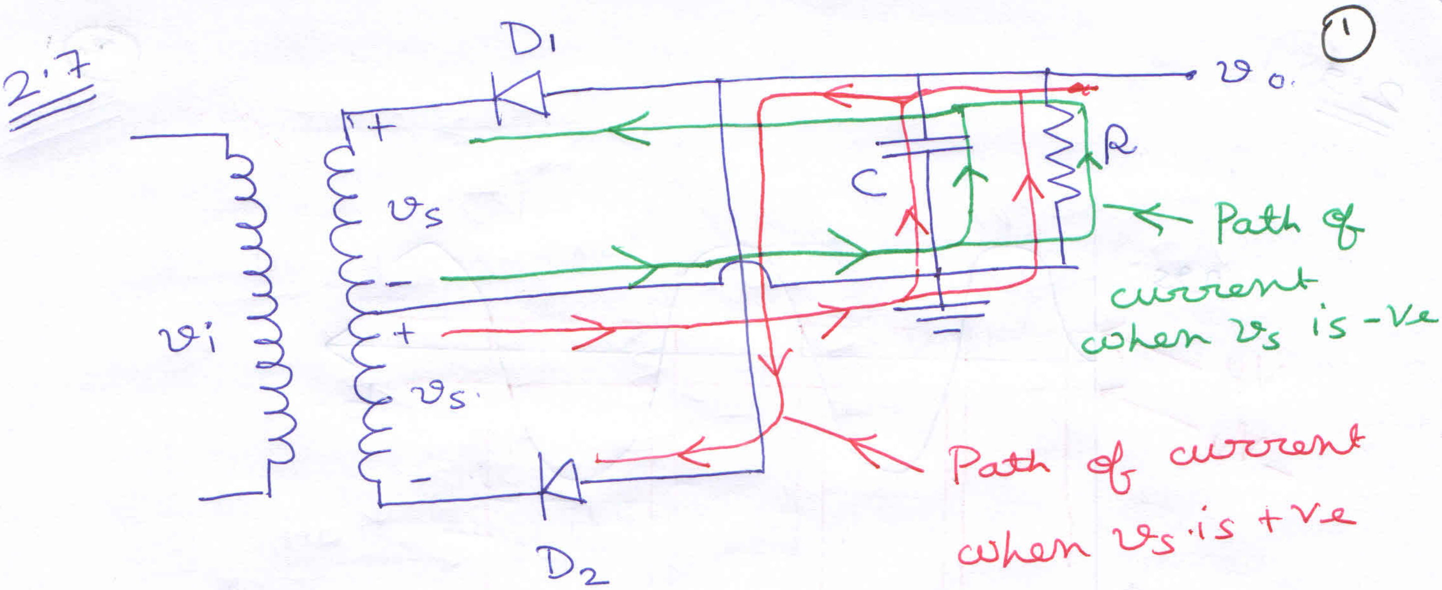
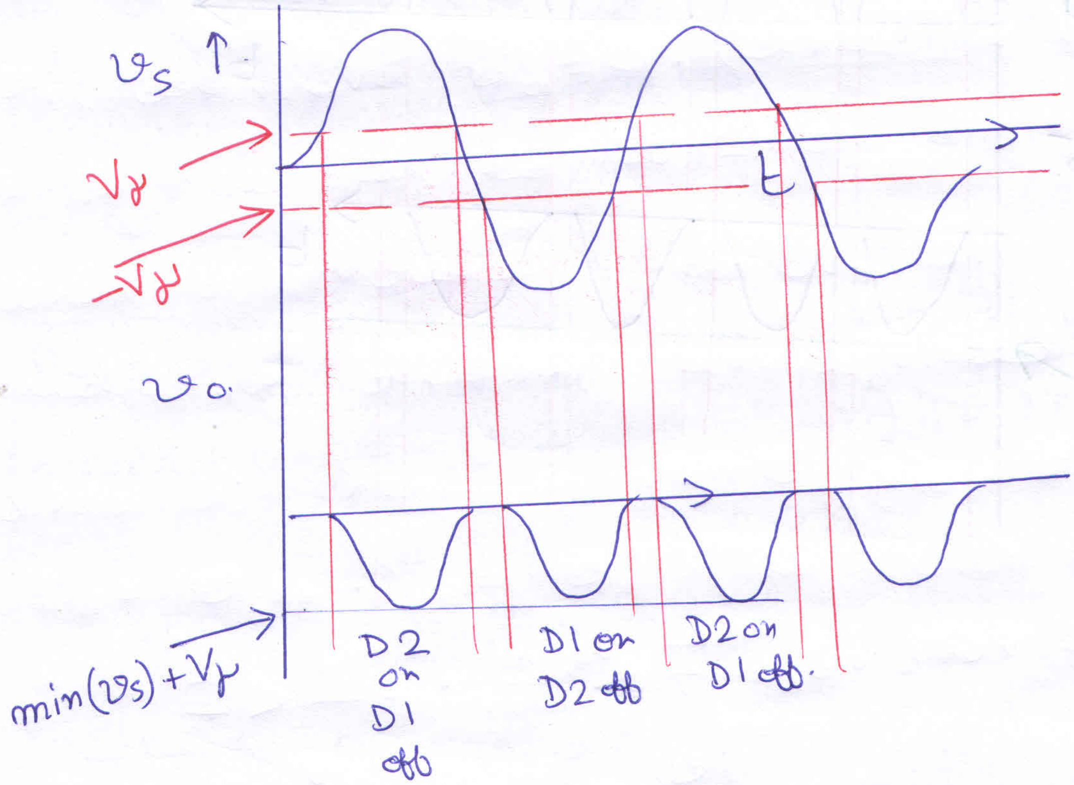
2.7





(a) Maximum value of v_o is 0V. ~~He If one~~

(b) $V_{RIPPLE} < 1V$

$$\Rightarrow \frac{|\min(v_s)+V_\gamma|}{2fRC} < 1V$$

$$\Rightarrow \frac{11.3}{120\times 10\times C} < 1$$

$$\Rightarrow C > \frac{11.3}{1200}\,F$$

$v_s^{rms} = 8.5V.$

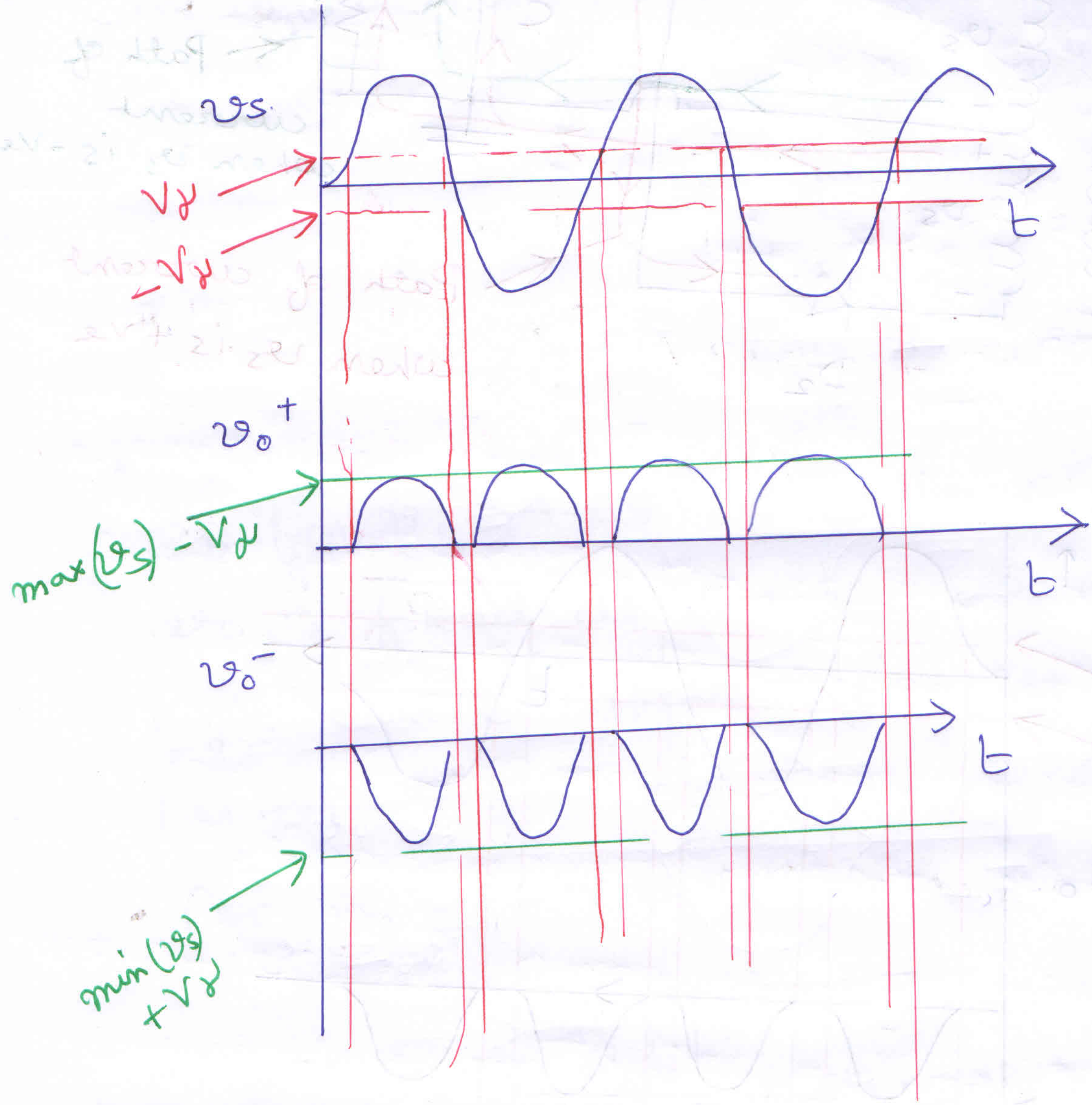
$\min(v_s)$

$= -\sqrt{2}\times 8.5V$

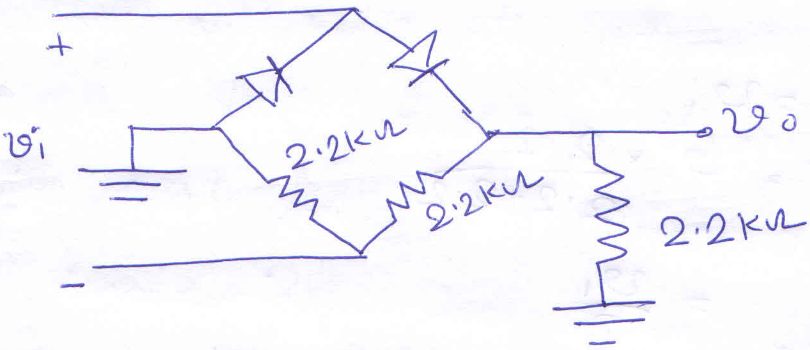
$\cong 12V$

PIV rating $= 2\max(v_s) - V_\gamma = 23.3V$

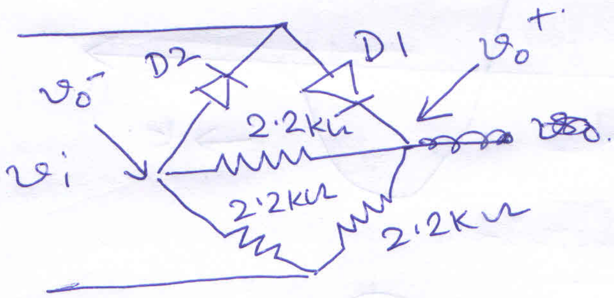
2.9



2.12



Equivalent circuit:



$v_o = v_o^+ - v_o^-$

Resistance faced by current path during forward bias (positive half cycle) $= (2.2\,K\Omega + 2.2\,K\Omega) \parallel 2.2\,K\Omega$

$= 4.4\,K\Omega \parallel 2.2\,K\Omega$

$= \frac{2}{3} \times 2.2\,K\Omega$

~~$v_o^+ = v$~~ For $v_i > 0$,

$v_o^+ = v_i$

$v_o^- = v_i \times \frac{2.2}{2.2+2.2}$

$= \frac{v_i}{2}$

So, $v_o = v_o^+ - v_o^- = \frac{v_i}{2}$

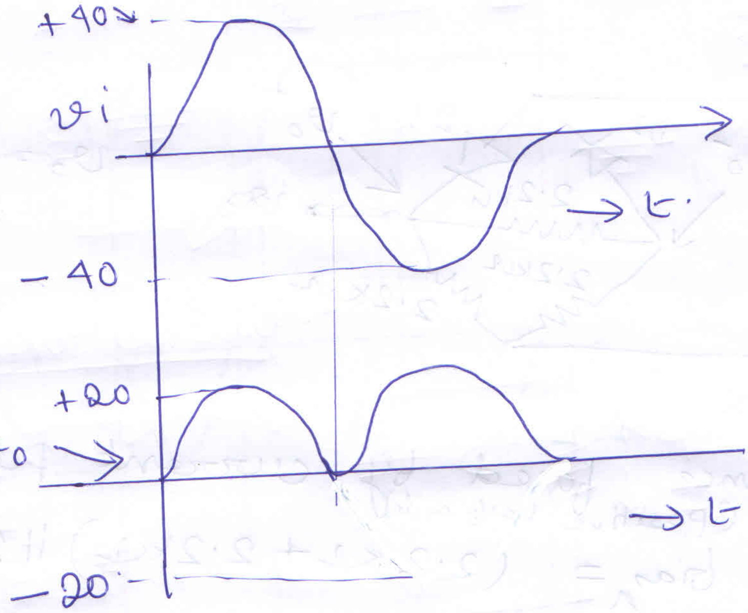
During ~~reverse bias~~ negative half cycle D2 is activated.

$$v_o^- = v_i$$

$$v_o^+ = v_i \times \frac{2.2}{2.2+2.2}$$

$$= \frac{v_i}{2}$$

So, $v_o = v_o^+ - v_o^- = -\frac{v_i}{2}$



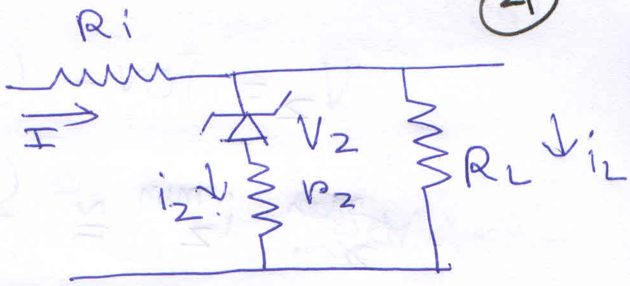
~~AM~~ rms value is independent of the polarity of each half cycle.

So, $v_o^{rms} = \frac{\max(v_o)}{\sqrt{2}}$

$$= \frac{20}{\sqrt{2}} V$$

$$= 14.14 V$$

2.21)



(a). Minimum Zener diode current is 5mA. ~~So,~~ The load current may vary from 0 to 20mA. So, to maintain regulation Ri must be able to pass $i_Z^{min} + i_L^{max}$ at V_{ps}^{min}. So, the value of Ri must be.

$$R_i \cong \frac{V_{ps}^{min} - V_Z}{i_Z^{min} + i_L^{max}} \qquad V_{ps}^{min} = 20V - .25 \times 20V = 15V$$

$$\cong \frac{15V - 10V}{5mA + 20mA} \quad (\text{Assume } V_Z \cong 10V)$$

$$\cong \frac{5V}{25mA}$$

$$\cong 200\Omega.$$

(b) The output voltage is minimum when i_Z is minimum and maximum when i_Z is maximum (due to the presence of r_Z). i_Z is minimum when V_{ps} is minimum and i_L is maximum. i_Z is maximum when V_{ps} is ~~minimum~~ maximum and i_L is minimum.

$$V_2 = 10V + (i_2 - 0.025) \times 5$$

$$\cancel{V_2^{max}} \quad i_2^{min} \cong \frac{(15-10)V}{200\Omega} - i_L^{max}$$

$$\cong 25mA - 20mA$$

$$= 5mA$$

$$i_2^{max} \cong \frac{V_{ps}^{max} - V_2}{200\Omega} - i_L^{min}$$

$$\cong \frac{25V - 10V}{200\Omega} - 0$$

$$\cong 75mA$$

$$V_2^{max} - V_2^{min} \cong (i_2^{max} - i_2^{min}) \times R_2$$

$$\cong (75-5)mA \times \cancel{100}\,5\Omega$$

$$= 0.070A \times \cancel{100}\,5\Omega$$

$$= \cancel{0.7V}\; 0.35\cancel{A}V$$

$$\text{Percent regulation} = \frac{V_2^{max} - V_2^{min}}{V_2^{min}} \times 100\%$$

$$\cong \frac{.35V}{10V} \times 100\%$$

$$\cong 3.5\%$$

2.22

$$V_S = 24V$$
$$V_\gamma = 0V$$
$$V_Z = 16V$$

$$I_L^{min} = 40mA \qquad I_L^{max} = 400mA$$

$$r_z = 2\Omega$$

$$I_Z^{min} = 40mA$$

I_Z is minimum when I_L is maximum.
For proper voltage regulation, R_i must be such that it can pass I_L^{max} while still maintaining breakdown, that is, providing I_Z^{min}.

So, $$R_i \cong \frac{V_S - V_Z}{I_L^{max} + I_Z^{min}}$$

$$= \cancel{25}\ \frac{24-16}{400+40} k\Omega$$

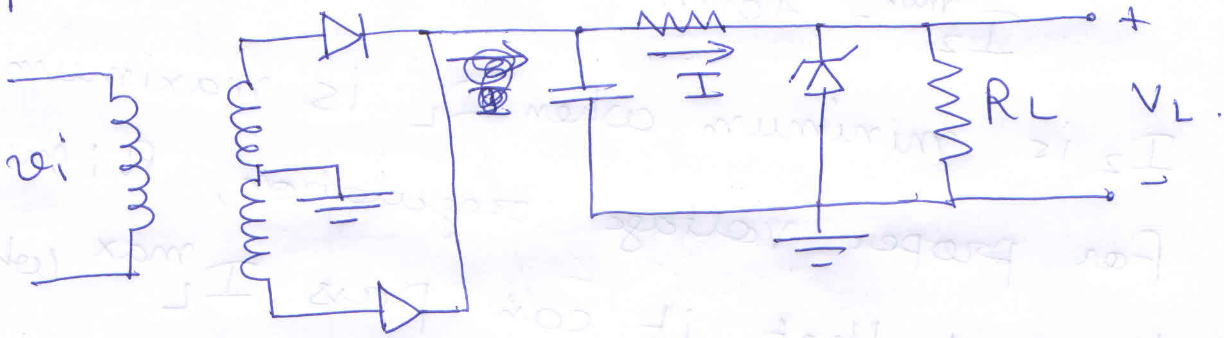
$$= \frac{8}{440} k\Omega$$

$$= \frac{1}{505} k\Omega$$

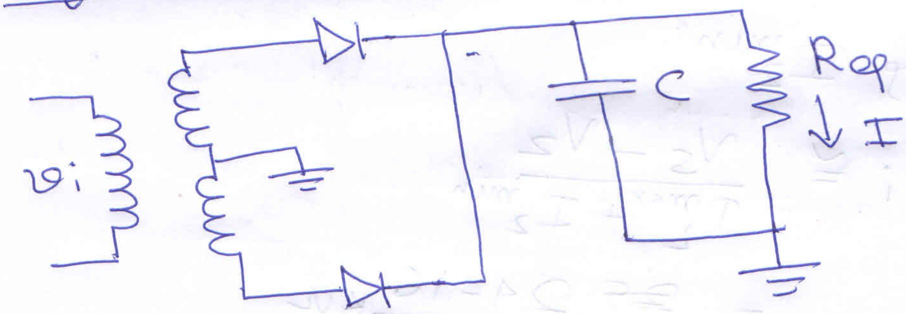
$$\doteq 18.18\Omega$$

This is the maximum ~~minimum~~ value of R_i.
r_z can be used for more accuracy.

Finding the ripple voltage in this case is a little tricky. To find the value of C, we will replace the entire part of the circuit to the left of the capacitor with an equivalent resistor



Equivalent circuit:-



$$R_{eq} = \frac{V_S}{I} = \frac{24\,V}{440\,mA} \cong 0.0545\,k\Omega$$

$$= 54.5\,\Omega$$

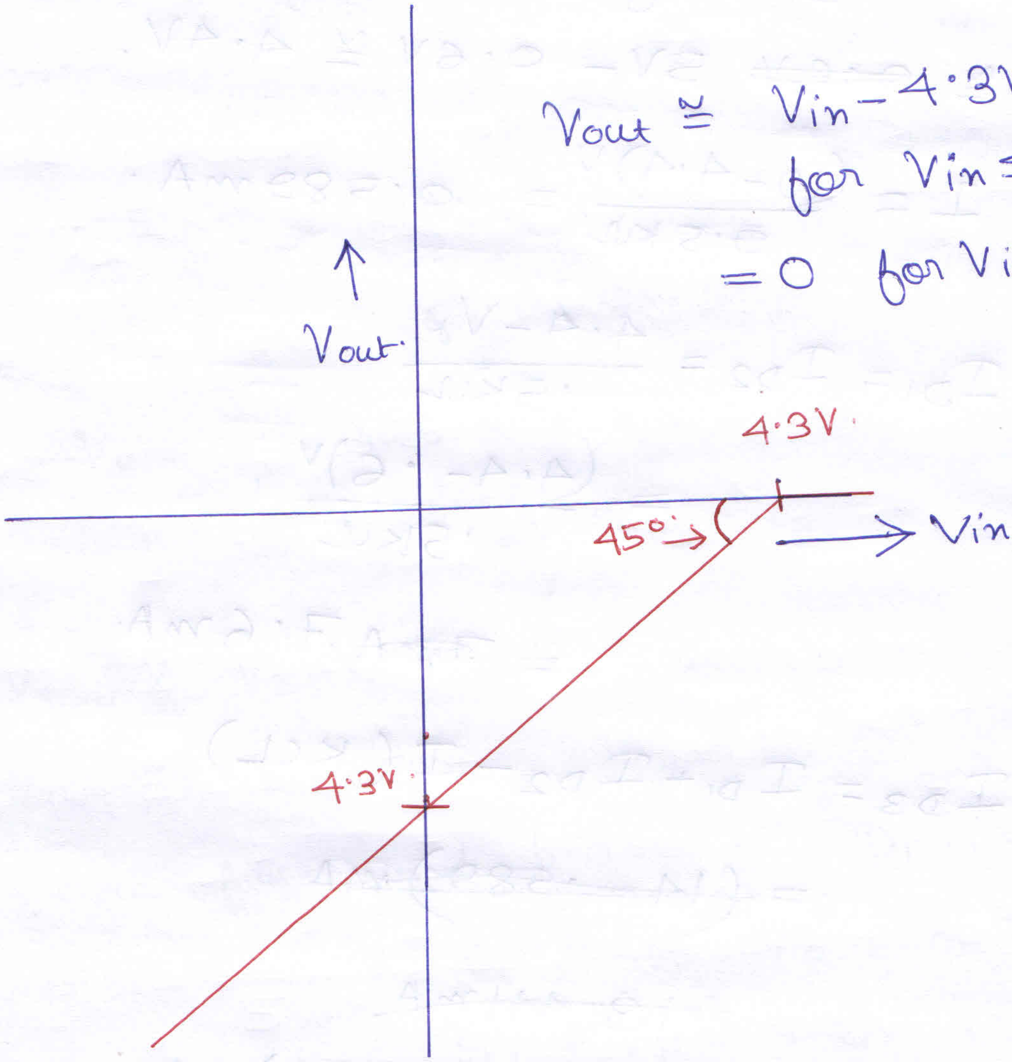
$$V_{RIPPLE} = \frac{V_S}{2fR_{eq}C} \leq 1V$$

Assume that $f = 60Hz$ (frequency of ac ~~curren~~ voltage in India).

$$\therefore \frac{24}{2 \times 60 \times 54.5 \times C} \leq 1$$

$$\Rightarrow C \geq \frac{24\,F}{2 \times 60 \times 54.5} = 0.003F$$

2.27



$V_{out} \cong V_{in} - 4.3V$ for $V_{in} \leq 4.3V$

$= 0$ for $V_{in} > 4.3V$.

2.39 $V_D = 0.6V$ $r_D \cong 0$.

(a) $V_1 = 0$, $V_2 = 0V$.

The diode D_3 will be forward biased.

(One way to understand this is to assume that D_3 is reverse biased and calculate V_o. If V_o is greater than $+5V$, then D_3 is indeed reverse biased, else it is forward biased)

Since D_3 is forward biased,

$V_0 \cong \cancel{0.6V}\ 5V - 0.6V \cong 4.4V.$

$$I = \frac{(10-4.4)V}{9.5K\Omega} = 0.589\,mA.$$

$$I_{D1} = I_{D2} = \frac{4.4 - V_\gamma}{.5K\Omega}$$

$$= \frac{(4.4 - .6)V}{.5K\Omega}$$

$$= \cancel{7mA}\ 7.6\,mA.$$

$$I_{D3} = I_{D1} + I_{D2} - I\ (KCL)$$

$$= \cancel{(14 - .589)\,mA}$$

$$\cancel{\cong 13.411\,mA}$$

$$= (7.6 \times 2 - .589)\,mA$$

$$\cong 14.6\,mA$$

(b) $V_1 = V_2 = 5V;$

D_3 is now reverse biased.

So, $I_{D3} \cong 0.$

$$\cancel{I_{D1} = I_{D2} = \frac{10 - 5 - V_\gamma}{}}$$

$$I = \cancel{2}I_{D1} + I_{D2} = 2I_{D1} = 2I_{D2}$$

$$= \frac{10 - 5 - V_\gamma}{9.5K\Omega + (.5 \| .5)K\Omega}$$

$$= \frac{4.4V}{9.75K\Omega}$$

$$= .451 mA$$

$$I_{D1} = I_{D2} = \frac{.451}{2} mA$$

$$= 0.225 mA$$

$$V_o = (0.225 \times .5) V + .V_\gamma + 5V.$$

$$\simeq 5.712V.$$

(c): $V_1 = 5V$, $V_2 = 0V$.

Here D_1 is reverse biased. D_2 and D_3 are forward biased. D_1 is reverse biased because V_o can never be greater than $5V - V_\gamma = \cancel{5.6V}\ 4.4V$.

So, $I_{D1} = 0$.

$$V_o = 5V - V_\gamma = 4.4V.$$

$$I = \frac{10V - 4.4V}{9.5K\Omega} = 0.589 mA.$$

$$I_{D2} = \frac{4.4V - V_\gamma}{.5K\Omega} = 7.6 mA.$$

So, $I_{D3} \simeq I_{D2} - I$ (KCL with $I_{D1} = 0$)

$$= 7.011 mA$$

(d) ~~This is the reverse case of (c). Just interchange the input terminals~~

2·39 d)

$V_1 = 5V, \; V_2 = 2V, \; V_\gamma = .7V.$

Just check that $v_0 \not> \cancel{5V}\ 4.3V.$

Just check the current.

$\cancel{I = \frac{5}{9.5}\ k\Omega}$

$\cancel{I_{D1} = \frac{5 - V_\gamma}{}}$

$$I = \frac{10 - 4.3}{9.5}\ mA = \frac{5.7}{9.5}\ mA = \frac{57}{95}\ mA.$$

$\cancel{I_{D1} = \frac{5 - 4.3}{.5}\ mA = \frac{7}{5}\ mA.}$

$I_{\cancel{D2}} = I_{D1} = 0$

$$I_{D2} = \frac{4.3 - 2 - V_\gamma}{.5}\ mA$$

$$= \frac{1.7}{.5}\ mA$$

$$= \frac{17}{5}\ mA$$

So, $I_{D1} + I_{D2} > I$

Hence v_0 must be less than or equal to 4.3 V.

So, that D_3 is forward biased.

D_1 is always reverse biased.

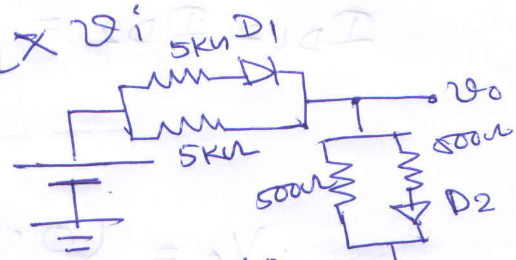
So, ~~v_0~~ Since D_3 is a diode,

$v_0 = 5V - V_\gamma = 4.3V.$

2.41

For $v_I < V_\gamma = .6V$, both D_1 and D_2 are below the cut-in voltage.

So, $v_o = \frac{.5K\Omega}{5K\Omega + .5K\Omega} \times v_i$



$= \frac{1}{11} v_i$

The drop across D_1 is hence $\frac{10}{11} v_i$

This continues till v_i crosses $\frac{11}{10} V_\gamma$
$= 0.66V$.

When v_i crosses $0.66V$, D_1 becoms forward biased. D_2 is still reverse biased.

So, The total current is to be solved by the equation:-

$$I_{tot} = \frac{v_i - v_o}{5K\Omega} + \frac{v_i - v_o - V_\gamma}{5K\Omega}$$

$$v_o = .5 \times I_{tot} \quad (I_{tot} \text{ is in mA})$$

$$\therefore I_{tot} = \frac{v_i - .5 I_{tot}}{5} + \frac{v_i - .5 I_{tot} - V_\gamma}{5}$$

$$\Rightarrow 5 I_{tot} = v_i - .5 I_{tot} + v_i - .5 I_{tot} - V_\gamma$$

$$\Rightarrow 6 I_{tot} = 2v_i - V_\gamma.$$

$$\Rightarrow I_{tot} = \frac{v_i}{3} - \frac{V_\gamma}{6}.$$

$= \left(\frac{v_i}{3} - 0.1\right) mA.$

$v_o = 0.5 \times I_{tot}$

$= \left(\frac{v_i}{6} - \cancel{0.5}\ 0.05\right) V.$

This continues till v_o reaches $0.6V$. when D_2 be comes forward biased and crosses the cut-in voltage.

when $v_o = .6V$, $v_i = 3.9V$.

For $v_i > 3.9V$, D_2 is forward biased.

~~Bo~~ The total current is now solved by solving the following equation :-

$$I_{tot} = \frac{v_i - v_o}{5} + \frac{v_i - v_o - V_\gamma}{5} = \frac{v_o}{.5} + \frac{v_o - V_\gamma}{.5}$$

(I_{tot} is in mA)

$\Rightarrow \cancel{(v_o - V_\gamma)}$

$\Rightarrow \cancel{(v_o - V_\gamma)\left(\frac{1}{.5} - \frac{1}{5}\right)}$

$\cancel{\frac{2 v_i}{5}}$

$$\Rightarrow \frac{2 \times v_i}{5} - \frac{V_\gamma}{5} + \frac{V_\gamma}{0.5} = \frac{2 \times v_o}{.5} + \frac{2 v_o}{5}$$

$$\Rightarrow \frac{2}{5} v_i + \frac{9}{5} V_\gamma = 4 v_o + \frac{2}{5} v_o = 4.4 v_o$$

$$\Rightarrow 0.4 v_i + 1.8 V_\gamma = 4.4 v_o$$

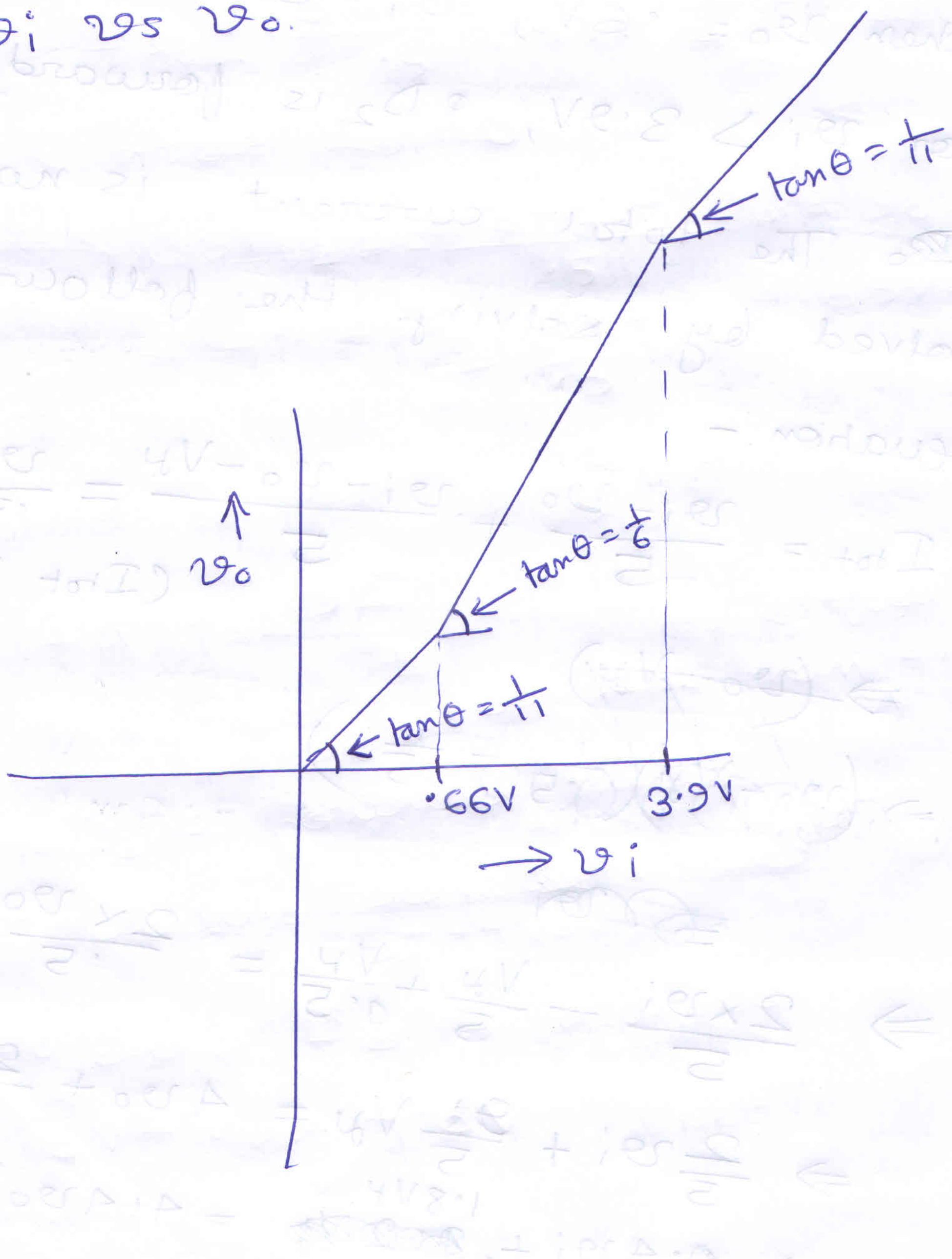
$$\Rightarrow v_o = \frac{0.4 v_i + 1.8 V_\gamma}{4.4}$$

$$= \cancel{\frac{v_i}{11} - \frac{V_r}{2}}$$

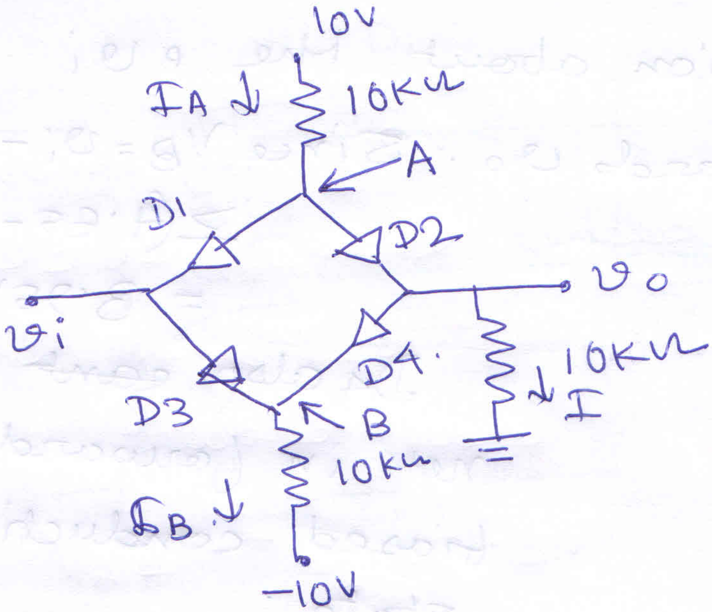
$$= \frac{4v_i + 18V_r}{44}$$

$$= \cancel{\frac{v_i}{11}} \; \frac{v_i}{11} + \frac{9}{22} V_r .$$

Depending on the expression of v_o for different range of v_i, you can plot v_i vs v_o.



2.42



Assume
$V_\gamma = .7V$.

In the absence of the ~~sour~~ input source v_i, we have $v_o = 0$. (Since the circuit is symmetrical. So, $I = 0$.

When v_i increases from 0V, D1 imediately becomes reverse biased.

When v_i increases from 0, $V_A = v_i - 0.7V$.

$v_o = V_A - V_\gamma = v_i$. This continues till $I_A > I$, so that $I_{D1} \geq 0$.

$$I_A = \frac{v_i - V_\gamma}{10K}\,mA, \quad I_L = \frac{v_i}{10}\,mA.$$

$v_o = v_i$ continues till $I = I_L$.

$$I_L \simeq \frac{v_i}{10}\,mA, \quad I_A = \frac{10 - v_i - .7}{10}\,mA.$$

$$\Rightarrow \frac{v_i}{10} = \frac{9.3 - v_i}{10} \Rightarrow v_i = \frac{9.3}{2} = 4.65V.$$

When v_i increases beyond 4.65V, D1 becomes reverse biased.

So, the information about the v_i cant flow towards v_o. Since $V_B = v_i - 0.7V$,
$\geq (4.65 - 0.7)V$
$= 3.95V$,
D4 also ~~cant~~ is not in forward biased conducting state.

So, for $v_i > 4.65V$, $I_L = I$. Hence v_o is fixed at $4.65V$. Similar logic can be applied for $v_i < 0$.

For ~~v_i~~ $0 > v_i > -4.65V$, $v_o = v_i$

For $v_i < -4.65V$, $v_o = -4.65V$.