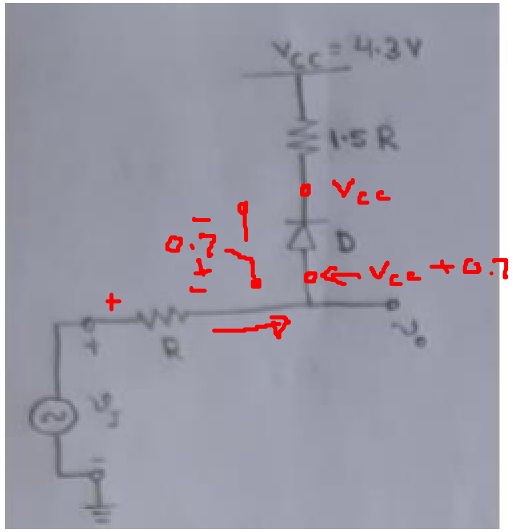
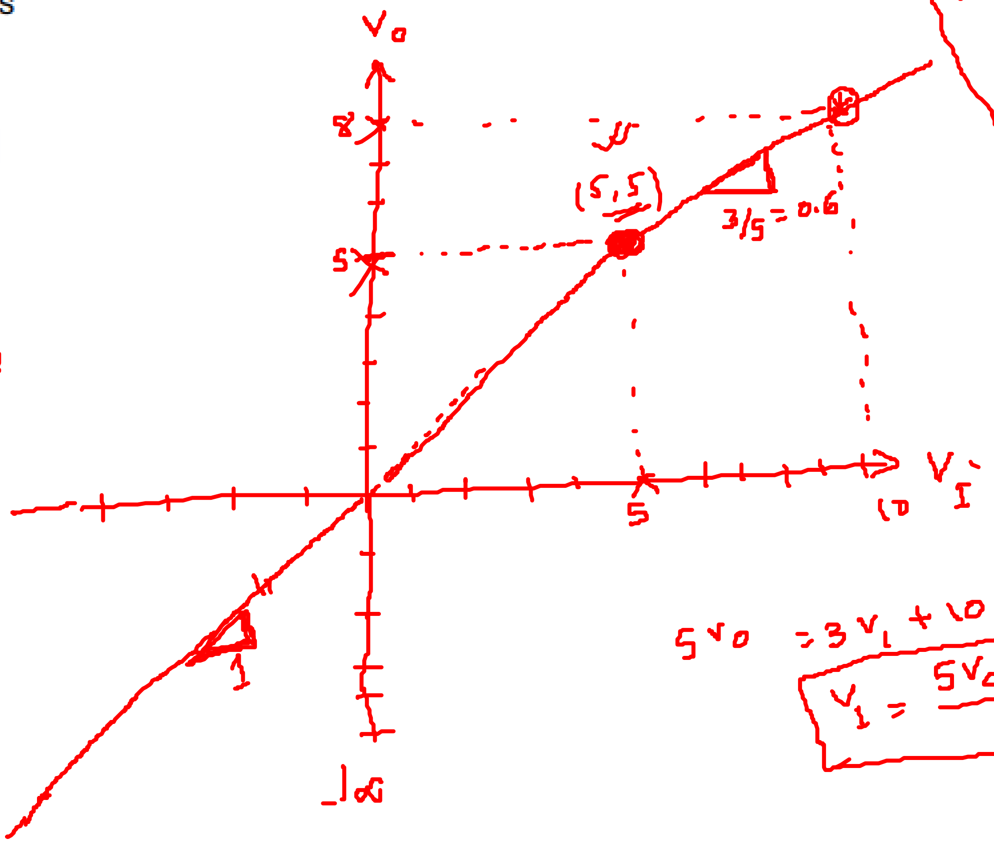
Q1. Consider a wave shaping circuit powered by a supply voltage $V_{cc} = 4.3\ V$ and assume that each diode in the circuit has a constant forward voltage drop of $V_D = 0.7\ V$. Ideal

Task:

1. Derive the mathematical expression for the transfer characteristics, i.e., the relationship between the input voltage V_I and the output voltage V_O.
2. Plot the transfer curve (V_I vs. V_O), clearly indicating:
   - The slopes of each segment
   - The coordinates of all breakpoints





If D is OFF

$\boxed{v_I = v_o}$

$v_o = V_I$

Transfer curve

$v_o < V_{cc} + 0.7$

$V_o < 4.3 + 0.7$

$\boxed{V_o < 5\ V}$

condition

If D is ON

$\boxed{v_o \geq 5}$

KVL:

$+v_I - IR - 0.7 - 1.5R = 4.3$

$V_I - 5 = 2.5IR$

$I = \frac{V_I - 5}{2.5R}$

$v_o = V_I - IR = V_I - \frac{V_I - 5}{2.5R}R$

$= \frac{2.5V_I - V_I + 5}{2.5}$

$= \frac{1.5V_I}{2.5} + 2$

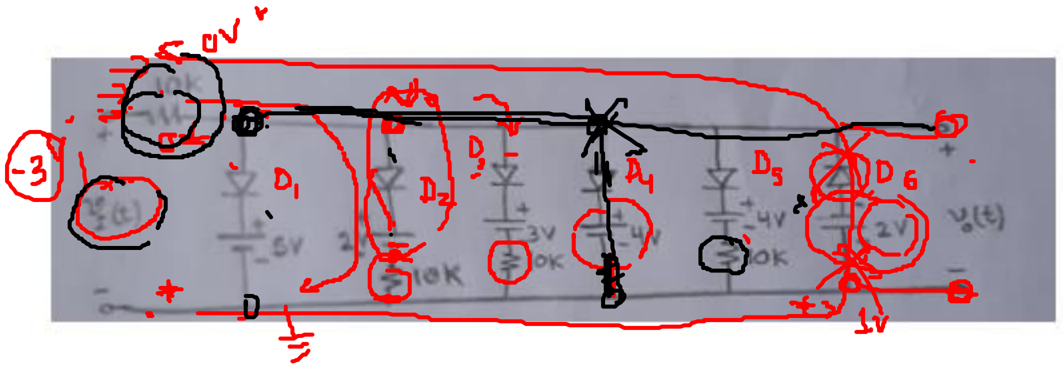
$5V_o = 3V_I + 10$

$\boxed{V_I = \frac{5V_o - 10}{3}} \iff \boxed{V_o = \frac{3}{5}V_I + 2}$

say, $V_I = 10\ V$

$V_o = 8$

Q2. Plot the transfer characteristics of the following circuit. Assume all diodes are ideal.



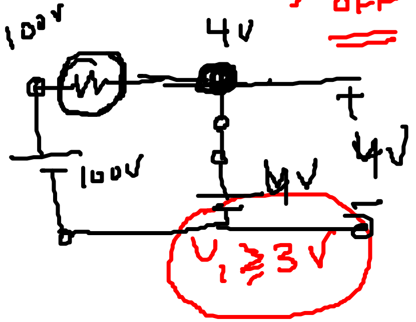
$V_I \rightarrow -\alpha$ to $+\alpha$

At negative V_I, $D_1 - D_5$ are off

D_6 ON — $V_I > 2V$ — $V_o = -2V$

OFF → $V_I < 2V$ $V_o = V_I$

negative



$V_1 \geq 3V$

$V_I \rightarrow$ Positive

$V_I > 2$, $D_2 \rightarrow$ ON $D_1, D_3 - D_6$ OFF

$$\frac{V_1 - V_o}{10} = \frac{V_o - 2}{10}$$

$V_1 - V_o = V_o - 2$

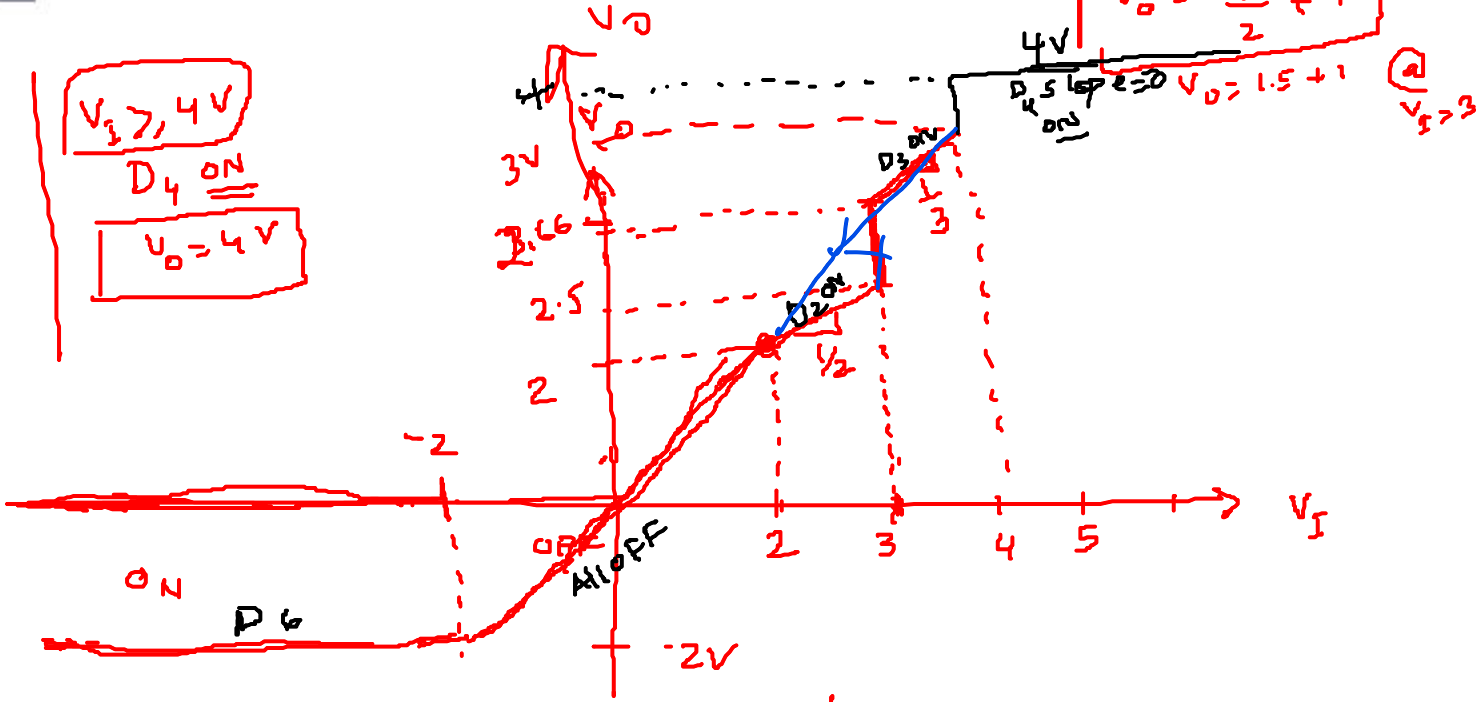
$2V_o = V_1 + 2$

$$\boxed{V_o = \frac{V_1}{2} + 1}$$

$\boxed{V_I \geq 4V}$

D_4 ON

$\boxed{V_o = 4V}$



$D_2 + D_3 \rightarrow$ ON

$$\frac{V_1 - V_o}{10} = \frac{V_o - 2}{10} + \frac{V_o - 3}{10}$$

$V_1 - V_o = V_o - 2 + V_o - 3$

$V_1 = 3V_o - 5$

$$V_o = \frac{V_1}{3} + \frac{5}{3}$$

1.66

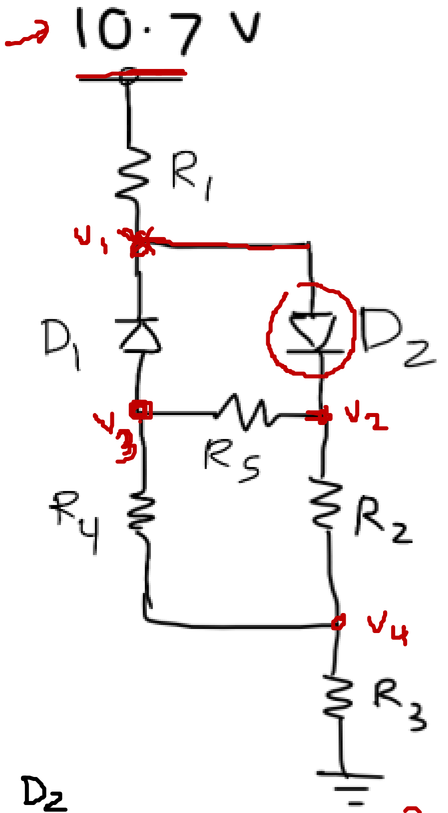
$V_1 = 3$, $V_o = 2.66$

$V_1 = 4$ $V_o = 3$

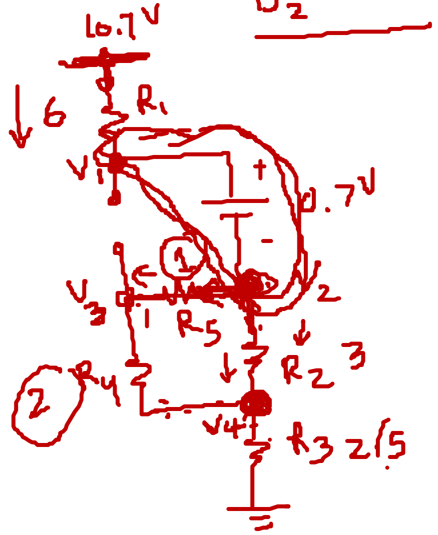
Sorry, I found a mistake here.

please see the solution posted on d2L

Q3. In the diode circuit of the following figure, D_1 and D_2 are silicon diodes with on-state voltage drop may be assumed constant at 0.7V. If R_1= 6kΩ, R_2= 3kΩ, R_3= 2.5kΩ, R_4 = 2kΩ and R_5 = 1kΩ, determine all node voltage.



Assume D_1 OFF
D_2 ON



$R_T = (R_5 + R_4) \parallel R_2 + R_3 + R_1$

$= (1+2)\parallel 3 + 2.5 + 6$

$= 1.5 + 2.5 + 6 = 10$ V

$I = \frac{10.7 - 0.7}{10} = 1$ mA

$V_1 = 10.7 - 6\times 1 = 10.7 - 6 = \cancel{3}4.7$ V

$V_2 = V_1 - 0.7 = 4.7 - 0.7 = 4$ V

D_1	D_2
OFF	OFF
ON	OFF
OFF	ON
ON	ON

D_2 ON

$10.7 > V_1 > V_2 > V_3 > V_4$

D_1 OFF

$\frac{10.7 - V_1}{6} = \frac{V_1 - 0.7 - V_4}{3} + \frac{V_1 - \cancel{V_3}\,0.7 - V_3}{1}$

$\frac{V_2 - V_4}{3} + \frac{V_3 - V_4}{2} = \frac{V_4}{2.5}$

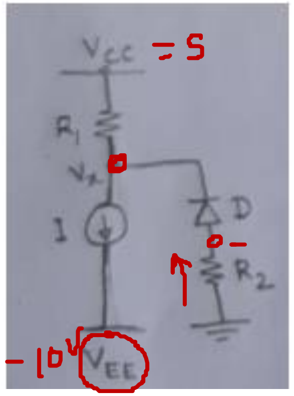
$V_2 = V_1 - 0.7$

$V_4 = 2.5 \times 1 = 2.5$ V

$I_{R2} = \frac{V_2 - V_4}{R_2} = \frac{4 - 2.5}{3} = \frac{1.5}{3} = 0.5$ mA

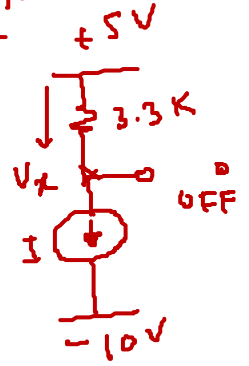
$V_3 = V_2 - 1\times 0.5 = 4 - 0.5 = 3.5$ V

Q4. In the following circuit, D is a silicon diode with on-state voltage drop VD= 0.7V. If VCC=5V, VEE=−10V, R1=3.3 kΩ, R2=2.2 kΩ and I=4.0 mA, determine Vx.



Q5

D OFF



$v_x = 5 - 3.3\,I$

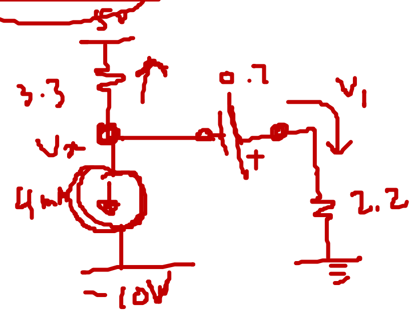
$= 5 - 3.3 \times 4$

$= 5 - 13.2 = -8.2\ V$

$V_d = 0 - (-8.2) = 8.2 > 0.7\ V$

(inconsisted)

D ON



Nodal equation

$$\frac{V_x - 5}{3.3} + \frac{v_x + 0.7}{2.2} + 4 = 0$$

$$\frac{V_x - 5}{3} + \frac{v_x + 0.7}{2} + 4.4 = 0$$

$$2V_x - 10 + 3V_x + 2.1 + 26.4 = 0$$

$$5V_x = -18.5\ V$$

$$V_x = \frac{-18.5}{5} = -3.7\ V$$

$$I_{2.2} = \frac{-3.7 + 0.7}{2.2} = \frac{-3}{2.2} = -1.36\ mA$$

$$V_1 = 1.36 \times 2.2 = 3\ V$$

$$V_d = 3 - (-3.7) = 6.7\ V > 0.7$$

consisted

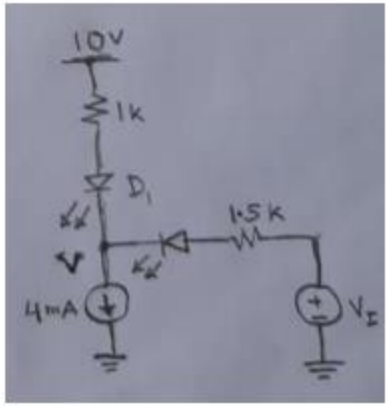
Optional work

Q5.

Assuming VDcutt−in=2.2 Vand VD=2.5 V, find states of D_1 and D_2. Also calculate V. If

a. Vin=0 V, and

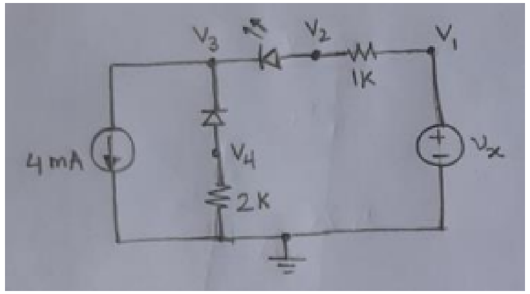
b. Vin=16.5 V



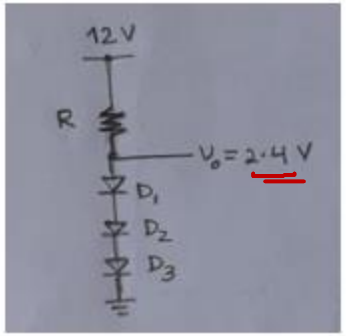
Q6. VD1=0.7 V and the LED D2 starts to glow at 2.2V forward voltage. Find V_1, V_2, V_3, V_4

a. if V_x is so negative that LED is dark.

b. If V_x is gradually increased until D_2 starts to glow.



Q7. In the following circuit, diodes exhibit a forward voltage drop of 0.65V at 0.1mA. Determine R and power consumption in R such that $V_o = 2.4$ V.



exponential diode model

$v_o = 2.4$

$v_D = \frac{2.4}{3} = 0.8$ V

$I_d = I_S e^{v_D/V_T}$

$\frac{I}{0.1} = e^{\frac{v_{D2} - v_{D1}}{V_T}} = e^{\frac{0.8 - 0.65}{0.025}}$

$V_T = 25$ mV

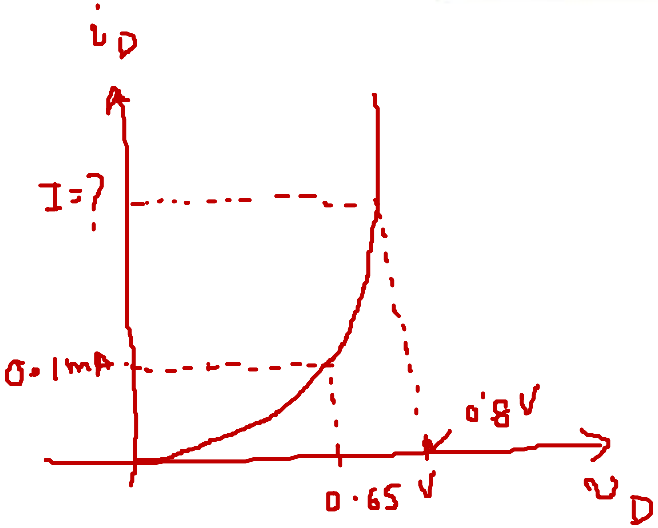
$I = 40.34$ mA

$R = \frac{12 - 2.4}{40.34} = 238\ \Omega$

$P = I^2 R$

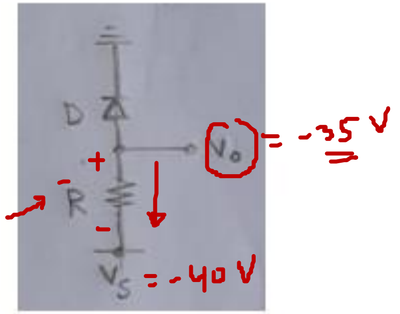
$= (40.34)^2 \times 238$

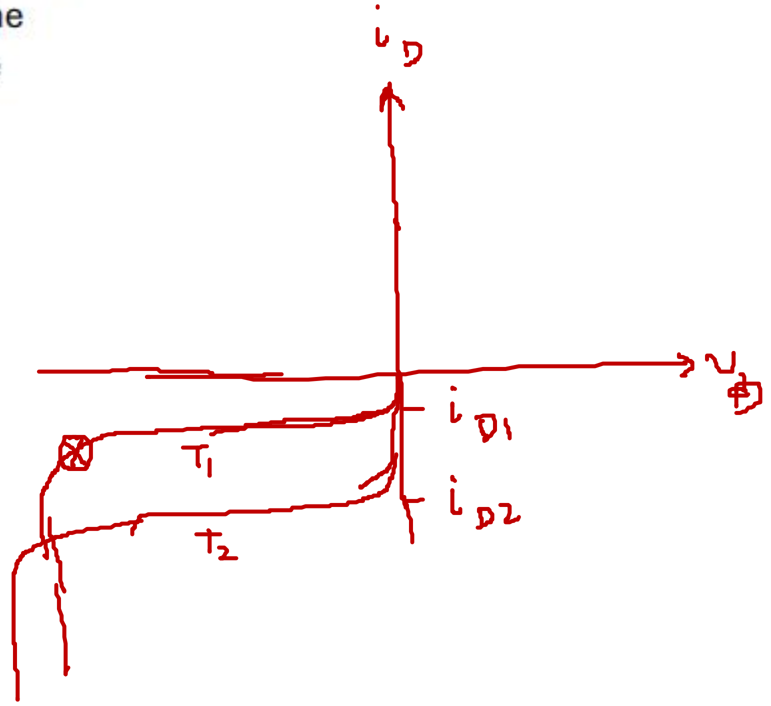
$= 0.387$ W



Temperature dependence circuits

Q1. In the circuit below, V_s = - 40 V and D is a typical silicon diode. If V_o = -35V at an ambient temperature of 30°C, determine Vo at 50°C. Assume that the reverse current of the diode does not depend upon the voltage across the diode and that the diode does not enter its breakdown region.





30°C

$T_2 > T_1$

$V_o = -40 + 20$

$= -20\,V$

Current doubles every 10°C increase in temperature at RB condition.

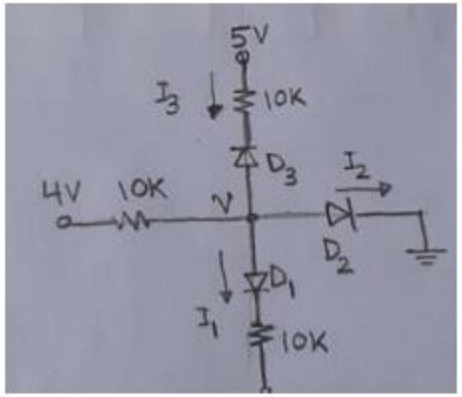
$i_{D2} = 4\, i_{D1}$

$i_{D1}R = -35 - (-40) = 5\,V$ @ 30°C

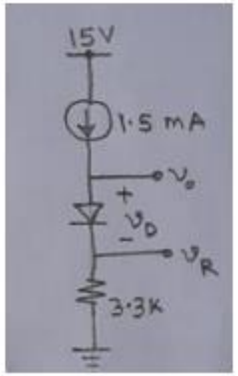
at 50°C $\quad V_R = ~~4~~\, i_{D2}R = 4 i_{D1}R = 20\,V$

Q2. In the following circuit, $V_s = -20$ V, $V_o = -12$ V at 20°C, find V_o at 40°C and 0°C temperature. Assume, the diode is not in reverse breakdown.

Q4. In the circuit shown below, the diodes have a constant forward voltage drop V_D=0.7 V. Determine the current I_1, I_2, I_3, and V.



Q3. For the following circuit, find V_D at 40°C, 80°C, and 0°C. At 20°C, Vo=5.7V and V_R=4.95V.



Rectifier and regulator circuits

Q1. The following figure shows an isolated bridge rectifier feeding a load. The load voltage Vo is regulated by a Zener diode with Izk=3.0 mA. The Zener diode is energized by a current source, I, and the load current iL can be variable, but it does not depend on the load voltage. Diodes exhibit an on-state voltage drop 0.7V, C=100uF, $\hat{v}_{rec}$=20V and v_r=4V.

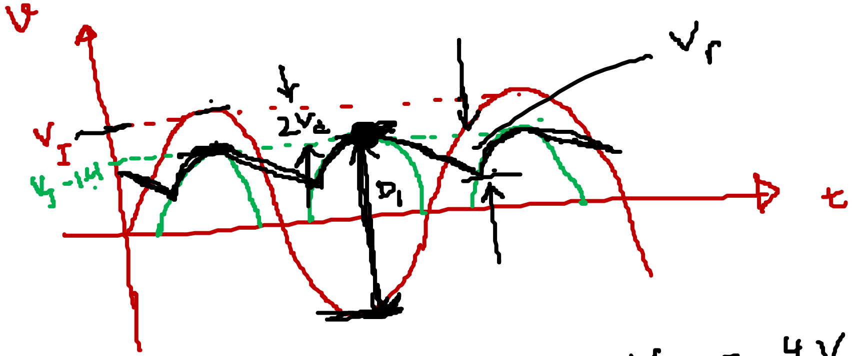
a. Determine the rms value of the secondary transformer (120: 15) voltage v_I,the reading of a DC voltmeter of V_{rec}, and the maximum current that the load is permitted to draw if this circuit is to function properly.

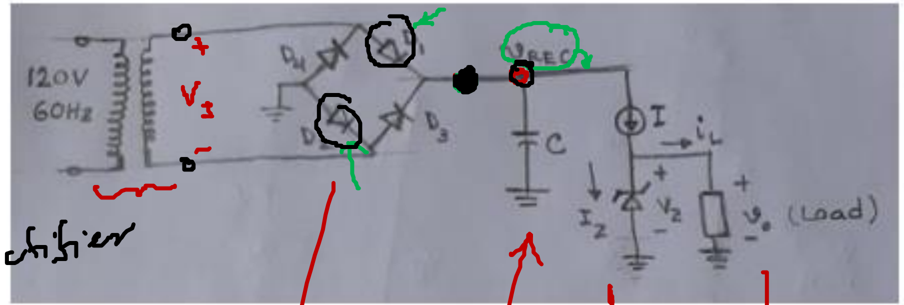
b. Determine V_{zo} and r_z = 4 Ω of the Zener diode if the regulated voltage is desired to be 10V for a load current of 25mA. The load voltage variation is to be 160mV when the load current varies from zero to 40mA. Finally, for a load current of 25mA, draw the waveform of the load voltage v_o.

$\hat{v}$ = peak voltage

$\check{v}$ = minimum voltage

$\bar{v}$ = average voltage





Rectifier

Filter

Regulator

DC o/p of rectifier $= \frac{2\hat{V}}{\pi} = \frac{2\times 20}{\pi} = 12.73$ ← before the capacitor

$\hat{V}_{rec} = 20$ V , $V_r = 4$ V

minimum $\check{V}_{rec} = 20 - 4 = 16$ V

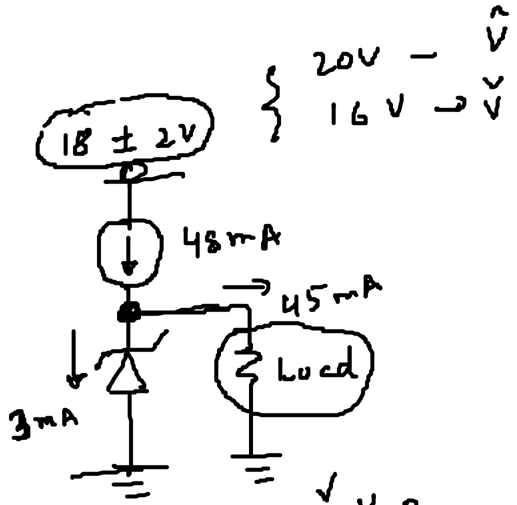
$\bar{V}_{rec} = \frac{20+16}{2} = 18$ V

$V_I = 20 + 1.4 = 21.4$ V

$\boxed{V_{I,rms} = \frac{21.4}{\sqrt{2}} = 15.13 \text{ V}}$

Reading of DC Voltmeter

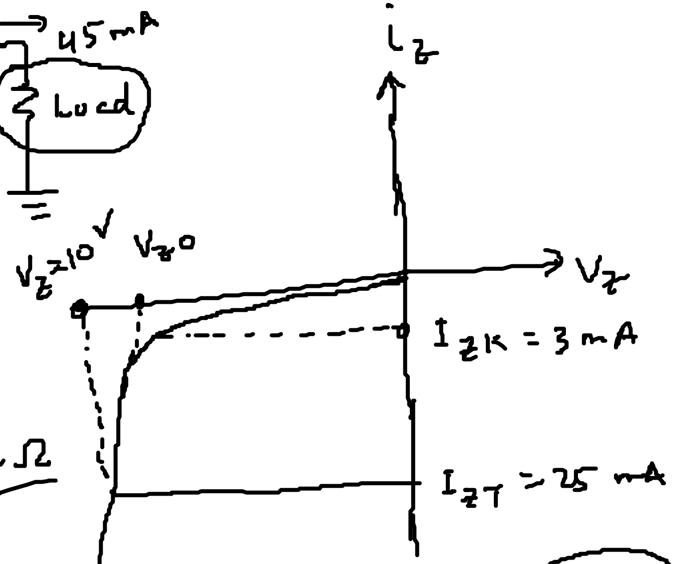
$V_{DC} = 18$ V $= \bar{V}_{rec}$ ← after capacitor



$V_r = \frac{I}{2fC}$

$4 = \frac{I}{2\times 60\times 100\times 10^{-6}}$

$I = 0.048 = 48$ mA



$I_{L-max} = 48 - \underline{\underline{I_{ZK}}}$

$= 48 - 3 = 45$ mA

R_{L-min}

$= \frac{10}{\underline{\underline{45}}\text{ mA}} = \underline{\underline{222\,\Omega}}$

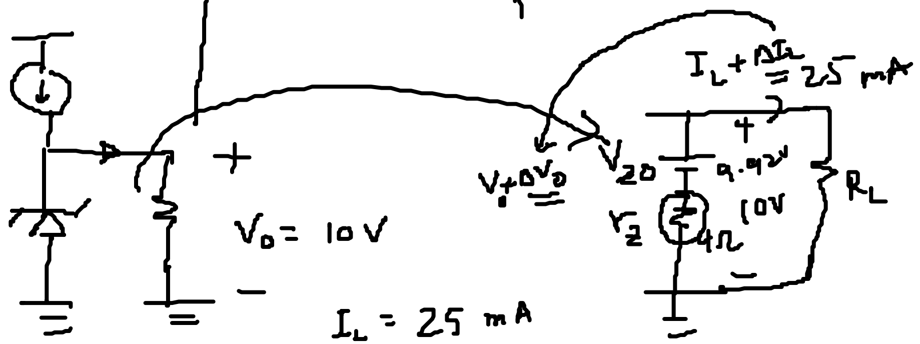
$V_Z = V_{Z0} + (I_Z - \underline{\underline{I_{ZK}}})\, r_Z$

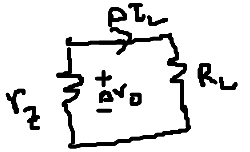
$I_Z = 48 - 25$

$= 23$ mA

$10 = V_{Z0} + (23 - 3)\, r_Z$

$V_{Z0} = 10 - 20\times 4\times 10^{-3} = 9.92$ V





$r_Z = \frac{\Delta V_0}{\Delta I_L} = \frac{160}{40} = \underline{4\,\Omega}$

$\Delta V_0 = \Delta I_L r_Z = 25\times 4$ mV

$= 100$ mV

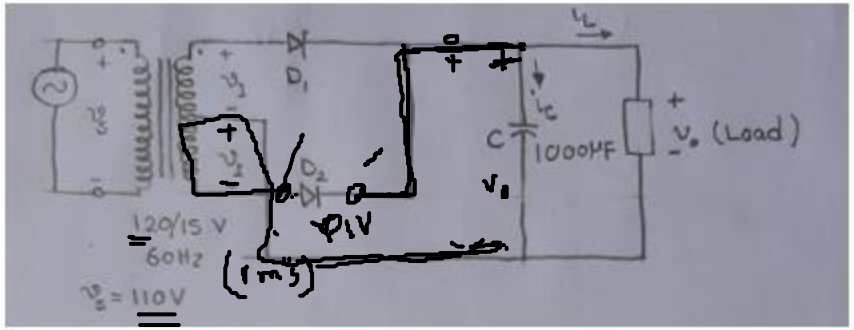
$= 0.1$ V

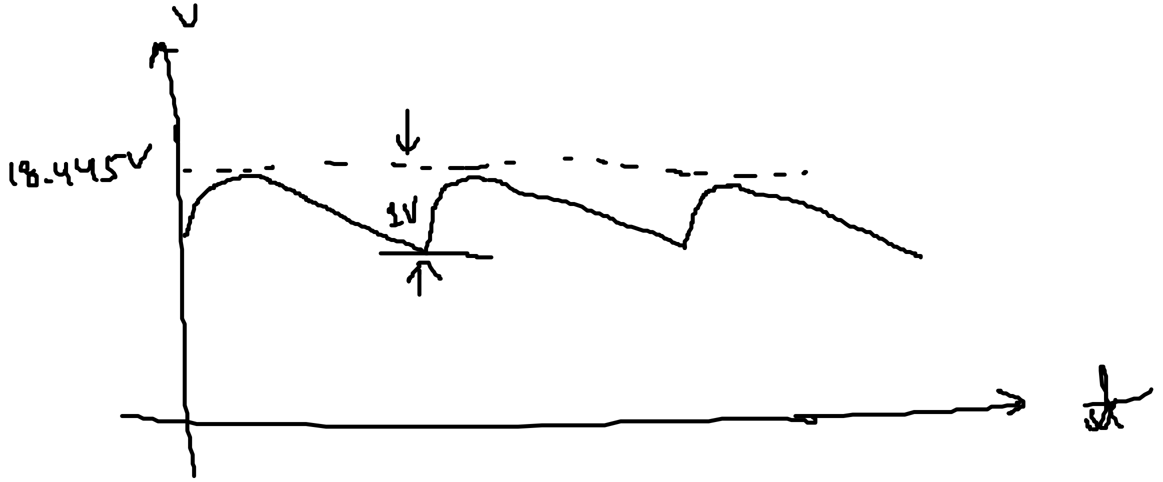
Q2. In the following full-wave rectifier circuit, the forward voltage of diode is V_D=1 V.

a. If i_L=120 mA, find $\bar{v}_o$ and V_r.

b. If R_L=82 Ω, find v_o and V_r.

c. Calculate PIV using the results obtained in part (b).





$PIV - V_o - V_I = 0$ $\quad$ $PIV = V_o + V_I$

$= 18.445 + 19.445$

$= 37.89\ V$

$v_I = \frac{110 \times 15}{120} = 13.75\ V$ (rms) $\quad V_{I(peak)} = \hat{V}_I = 13.75\sqrt{2} = 19.445\ V$

$\hat{V}_o = 19.445 - \underset{\uparrow \text{drop of diode}}{1} = 18.445$

$\check{V}_o = 17.445$

$\bar{V}_o = 17.945\ V$

$v_o = 12.75\ V$

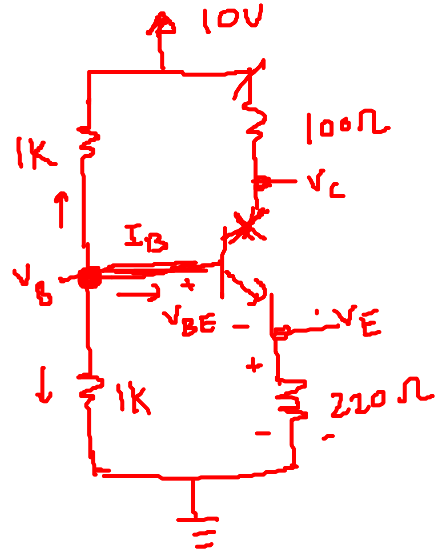
$V_r = \frac{I_L}{2fC} = \frac{120\ mA}{2 \times 60 \times 1000\ \mu F} = 1\ V$

(b)

$V_r = \frac{\hat{V}_o}{2fR_LC}$

$= \frac{18.445}{2 \times 60 \times 82 \times 1000 \times 10^{-6}} = 1.88\ V$

$\bar{V}_o = 18.445 - \frac{1.88}{2} = 17.50\ V$



$\beta = 100$
$V_{BE} = 0.7\,V$

KCL :

$$\frac{V_B - 10}{1\,K} + \frac{V_B - 0}{1K} + I_B = 0$$

$$V_B - 10 + V_B + I_B = 0$$

$$2V_B + I_B = 10 \quad \text{—— (i)}$$

$$V_B - 0.7 - 0.220\, I_E = 0$$

$$V_B - 0.22(\beta + 1) I_B = 0.7$$

$$V_B - 22.22\, I_B = 0.7 \quad \text{—— (ii)}$$

$V_B = 4.9\,V$

$I_B = 0.189\ mA$

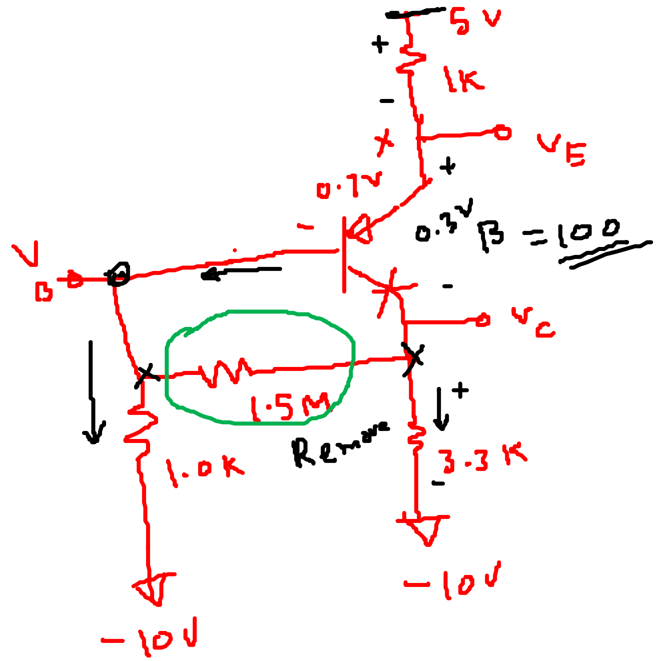
$$V_C = 10 - I_C R_C = 10 - \beta I_B \times 0.1$$
$$= 10 - 100 \times 0.189 \times 0.1$$
$$= 8.11\ V$$

$$V_E = 0.22 \times (\beta + 1) I_B$$
$$= 0.22 \times 61 \times 0.189$$
$$= 4.12\ V$$

$$V_{CE} = V_C - V_E$$
$$= 8.11 - 4.12 = \underline{3.99} > V_{CE.\,sat}\ (0.3V)$$

$\boxed{\text{BJT is in Active mode}}$

$$\beta_{forced} = \frac{I_C}{I_B} = \frac{1.98}{6.15}$$



BJT in saturation mode

$$5 - I_E(1) - 0.3 - I_C \times 3.3 = -10$$

$$5 - I_E(1) - 0.7 = V_B$$

$$V_B = -10 + I_B(1)$$

$$I_E = I_C + I_B$$

$$-I_E - 3.3 I_C = -14.7$$

$$-I_E - I_B = -14.3$$

$$I_E - I_B - I_C = 0$$

$$I_B = \frac{V_B - (-10)}{1.0}$$

$$V_B + 10 = I_B$$

$$V_B - I_B = -10 \quad \text{—— (1)}$$

$$I_B = 6.15 \text{ mA}$$

$$I_E = 8.14 \text{ mA}$$

$$I_C = 1.98 \text{ mA}$$

$$5 - 1 I_E - 0.7 = V_B$$

$$V_B + (\beta + 1) I_B = 4.3$$

$$V_B + 101 I_B = 4.3 \quad \text{—— (1)}$$

$$V_B = -9.86 \text{ V} = -9.86 \text{ V}$$

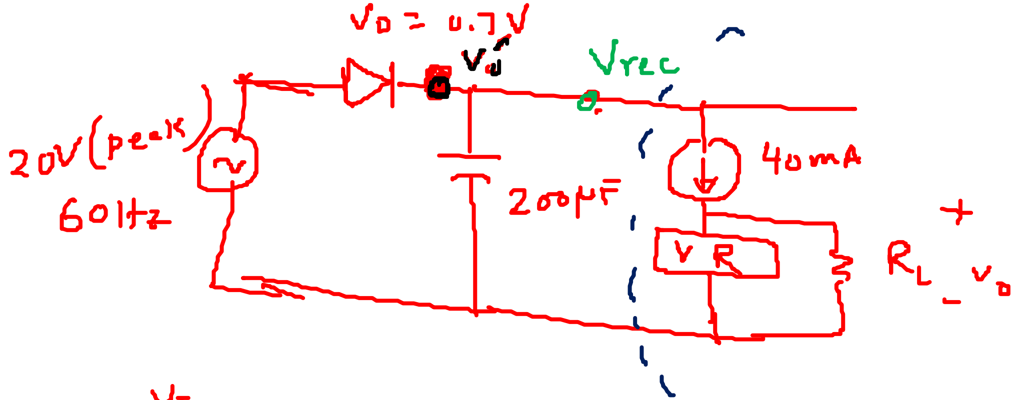
$$I_B = \cancel{0.0538 \text{ mA}}$$

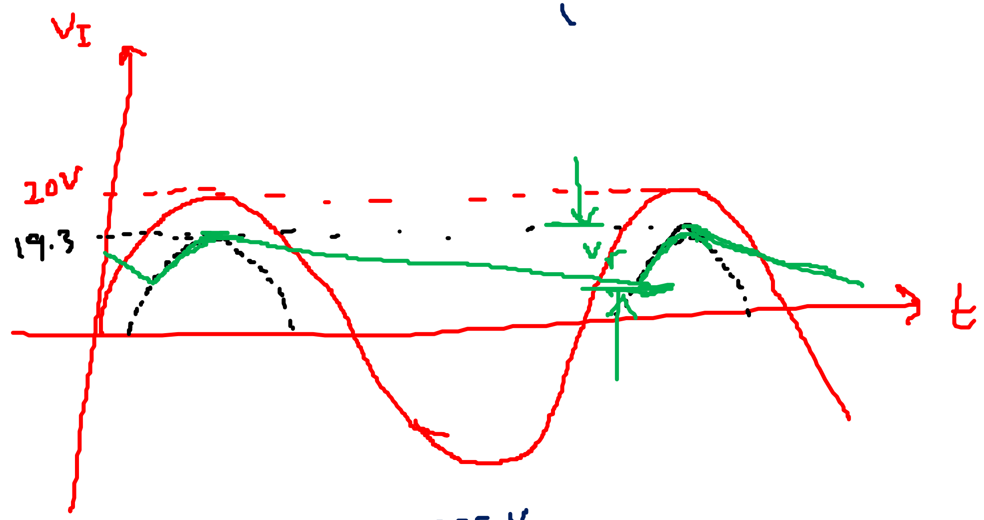
$$= 0.1402 \text{ mA}$$

$$V_E = 5 - 1 \times 101 \times 0.1402 = -9.16 \text{ V}$$

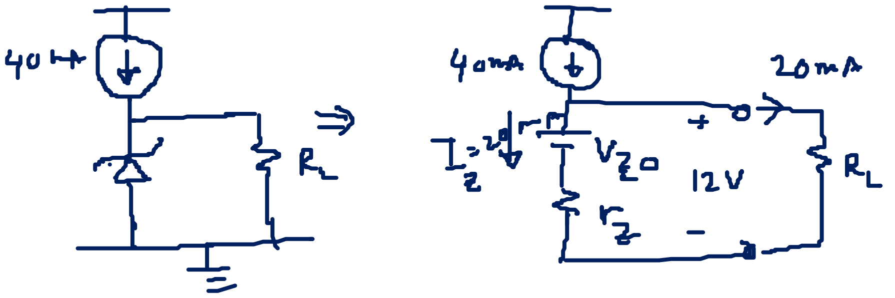
$$V_C = -10 + \beta I_B \times 3.3 = 36.26$$

$$V_{EC} = -9.86 - 36.26 < V_{EC,sat}$$

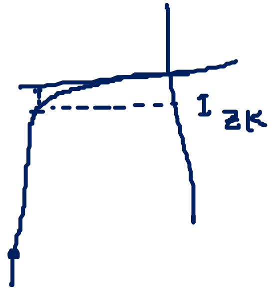




18.465 ± 0.835 V



$V_{z0} = ?$



$20 - 0.7 = 19.3$ V

$\hat{V}_o' = 19.3$ V

$V_o'\ dc = \frac{\hat V_o'}{\pi} = \frac{19.3}{\pi} = 6.14$ V (before capacitor)

$\hat V_{rec} = \hat V_o' = 19.3$ V

$V_r = \frac{I}{2fC} = \frac{40\times10^{-3}}{2\times60\times200\times10^{-6}}$

$V_r = 1.67$ V

Another mistake $V_r = \frac{I}{fC}$

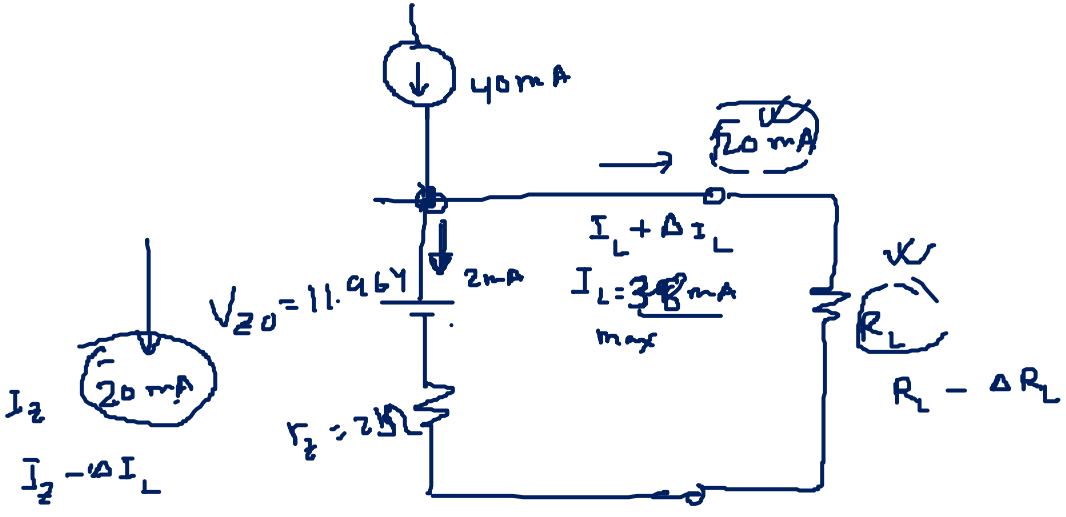
see midterm solution.

$\check V_{rec} = 19.3 - 1.67 = 17.63$ V

$\bar V_{rec} = \hat V_o' - \frac{V_r}{2} = \frac{19.3 + 17.63}{2} = 18.465$ V

$V_z = V_{z0} + (I_z - I_{ZK}) r_z$ $\qquad r_z = 2\ \Omega$

$12 = V_{z0} + (20 - 2)\times 2\times10^{-3} = 11.964$ V



$R_{L,min}$

$R_{L,min} = \frac{12}{38 mA} = 316\ \Omega$

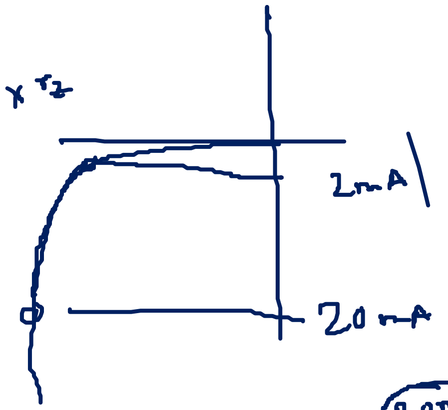
Rated Load $= \frac{12}{20 mA} = 0.6\ k\Omega$

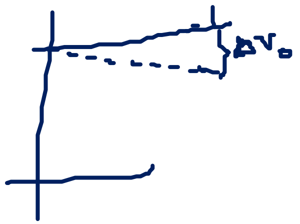
at load

$V_0 = V_{Z0} + 40 \times r_Z$

$V_0 = V_{Z0} + 10 \times r_Z$

$\Delta V_0 =$





$\Delta I_L = 30\ mA$

$-\Delta V_0 = -\Delta I_L \times r_Z = -30 \times 2 = -60 mV$

% Voltage regulation $= \frac{60 \times 10^{-3}}{12} \times 100$

$= 0.5\ \%$