PROBLEMS - UNIT I

1. When a large reverse bias is applied, the current flowing through a p-n junction diode at temperature 27°C is 3×10^{-7}A. Calculate the current flowing through the diode when 200mV forward bias is applied. Determine the ac resistance at 200mV forward bias. Calculate the increase in forward current when temperature is increased by 70°C.

Soln:- Diode current equation is given by

$$I_D = I_S\left[\exp\frac{V_D}{\eta V_T} - 1\right]$$

$$V_T = \frac{kT}{q} = \frac{1.38\times10^{-23}\times300}{0.026}$$

$$V_T = 0.026V.$$

given $I_S = 3\times10^{-7}$ and $V_D = 200mV = 0.2V$].

$$\therefore I_D = 3\times10^{-7}\left[e^{0.2/0.026} - 1\right] = 657\mu A$$

I_S doubles for every 10°C raise in temperature,

$\therefore$ for 10°C rise $\rightarrow$ $I_S' = 3\times10^{-7}\times2$

for 20°C $\longrightarrow$ $I_S' = 3\times10^{-7}\times2\times2$

$\Rightarrow$ for 70°C $\rightarrow$ $I_S' = 3\times10^{-7}\times2^7$

$I_S' = 3\times10^{-7}\times128$

$I_S' = 384\times10^{-7}$A

new diode current,

$$I_D' = I_S'\left[\exp\left(V_D/\eta V_T\right) - 1\right]$$

$$V_T = \frac{kT}{q} = \frac{1.38\times10^{-23}\times(273+97°C)}{1.6\times10^{-19}} = 0.032V$$

$$I_D' = 384 \times 10^{-7}\left(e^{0.2/0.032} - 1\right) = 19.9\,mA.$$

$$\Delta I_D = I_D' - I_D = (19.9 - 0.657) \times 10^{-3}$$

$$\boxed{\Delta I_D = 19.24\,mA}$$

ac resistance at 200 mV $= \frac{0.026}{I_D} = \frac{0.026}{657 \times 10^{-6}}$

$$\boxed{r_{ac} = 39.57\,\Omega}$$

2) A crystal diode having internal resistance $r_d = 20\,\Omega$ is used for half wave rectification as shown in figure. If the applied voltage $V = 50 \sin\omega t$ and load resistance $R_L = 800\,\Omega$ find,

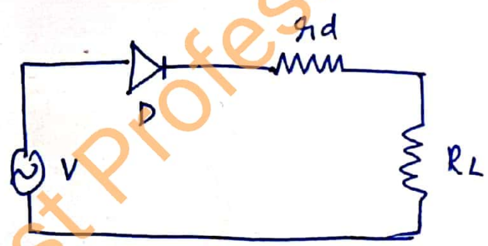
i) I_m, I_{dc}, I_{rms}

ii) P_{ac}, P_{dc}

iii) V_{dc}

iv) Efficiency

v) ripple factor



Soln: $V = 50 \sin\omega t$ $V_m = 50\,V$

$$I_m = \frac{V_m}{r_d + R_L} = \frac{50}{20 + 800}$$

$$I_m = 61\,mA$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{61 \times 10^{-3}}{\pi} = 19.4\,mA$$

$$I_{rms} = \frac{I_m}{2} = 30.5\,mA$$

$$P_{ac} = I^2_{rms}(r_d + R_L) = (30.5 \times 10^{-3})^2 [20 + 800] = 0.763\,W$$

$$P_{dc} = I^2_{dc} R_L = (19.4 \times 10^{-3})^2 \times 800 = 0.301\,W$$

$V_{dc} = I_{dc} R_L = 19.4 \times 10^{-3} \times 800 = 15.52V.$

$$\eta = \frac{P_{DC}}{P_{AC}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (r_d + R_L)} \times 100 = 39.47\%.$$

$$\text{ripple factor} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} = 1.21$$

3) A full wave rectifier has a load of $2K\Omega$. The AC voltage applied to the diode is 200-0-200V. Assuming ideal diodes. Calculate
i) average dc current ii) average dc voltage
iii) ripple voltage
If a capacitor of value $500\mu F$ is connected across the load, what is the new value of ripple voltage. Assume $f = 50Hz$.

Soln:- $R_L = 2K\Omega$ $V_{rms} = 200V$ $f = 50Hz$

$$V_m = V_{rms}\sqrt{2} = \sqrt{2}\,200 = 282.8427V$$

$$I_m = \frac{V_m}{R} = \frac{282.8427}{2 \times 10^3} = 0.1414A$$

$$I_{DC} = \frac{2I_m}{\pi} = 0.09A$$

$$V_{dc} = I_{dc} R_L = 0.09 \times 2 \times 10^3 = 180V$$

for full wave,

$RF = 0.483$ $\gamma = \frac{V_{rms}}{V_{DC}}.$

$$\therefore V_{rms\,ripple} = V_{dc} \times \gamma = 0.483 \times 180 = 86.4V$$

∴ ripple voltage = 86.4 V

If capacitor filter of C = 500 μF is used then,

$$\gamma = \frac{1}{4\sqrt{3} f C R_L} = \frac{1}{4\sqrt{3} \times 50 \times 500 \times 10^{-6} \times 2 \times 10^{3}}$$

$$\gamma = 2.8867 \times 10^{-3}$$

new ripple voltage = $2.8867 \times 10^{-3} \times 180 = 0.5196V$

4) A bridge rectifier uses four identical diodes of forward resistance each of 2Ω. It is supplied from a transformer with output voltage of 20V (rms) and secondary winding resistance 5Ω. Calculate

i) output dc voltage at dc load current of 100mA

ii) percentage regulation for a full load dc current of 200mA

iii) efficiency of rectifier

Soln :- DC voltage at I_{dc} of 100mA

$$V_{dc} = \frac{2V_m}{\pi} - I_{dc}(R_s + 2R_F)$$

$$V_{dc} = \frac{2\sqrt{2} \times 20}{\pi} - 100 \times 10^{-3}[5 + 2\times2]$$

$$V_{dc} = \frac{2\sqrt{2} \times 20}{\pi} - 100 \times 10^{-3}[9]$$

$$V_{dc} = 17.106V$$

ii) V_{dc} at 200mA

$$V_{dc} = \frac{2\sqrt{2} \times 20}{\pi} - 200 \times 10^{-3}[5+4]$$

$$V_{dc} = 16.20V$$

$$R_L = \frac{V_{dc}}{I_{dc}} = \frac{16.2}{200 \times 10^{-3}} = 81\Omega$$

percentage regulation $= \frac{2R_F + R_S}{R_L} = \frac{2 \times 2 + 5}{81} \times 100 = 11.11\%$

iii) $\eta = \frac{8}{\pi^2}\left[\frac{R_L}{2R_F + R_S + R_L}\right] \times 100\% = 73\%$

5) An ac supply of 230V is applied to a HWR circuit through transformer of turns ratio 10:1 find Vdc PIV. Assume ideal diode.

Soln i) Vdc secondary voltage,

$V_2 = V_1 \times \frac{N_2}{N_1} = 230 \times \frac{1}{10} = 23V$

$V_m = \sqrt{2} V_2 = \sqrt{2} \times 23 = 32.2V$

$V_{dc} = \frac{V_m}{\pi} = 10.3V$

$PIV = V_m = 32.2V$

6) In a HWR the input voltage is 230V and transformer ratio is 2:1. determine the maximum and average values of power delivered to the load. Take $R_L = 200\Omega$

Soln:- $V_1 = 230V$ $\frac{N_2}{N_1} = \frac{1}{2} \Rightarrow R_L = 200V$

rms value of secondary voltage is

$V_2 = \frac{N_2}{N_1} \times V_1 = \frac{1}{2} \times 230 = 115V$

$V_m = \sqrt{2} V_2 = \sqrt{2} \times 115 = 162.6V$

$I_m = \frac{V_m}{R_L} = \frac{162.6}{200} = 0.813A$

maximum power to load $= P_{max} = I_m^2 \times R_L$

$= (0.813)^2 \times 200$

$= 132.3W$

$$V_{dc} = \frac{V_m}{\pi} = \frac{162.6}{\pi} = 51.7V$$

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{51.7}{200} = 0.26A$$

$$P_{dc} = I_{dc}^2 \times R_L = 13.4V$$

7) A HWR is used to supply 100V dc to a load of 800Ω. The diode has a resistance of 20Ω. Calculate

a> ac voltage required

b> efficiency of rectification

Soln: Given $V_{dc} = 100V$ $R_L = 800Ω$ $r_f = 20Ω$

a> DC voltage $V_{dc} = \frac{V_m}{\pi} = \frac{I_m(R_L + r_f)}{\pi}$

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{100}{800} = 0.125A$$

$$I_{dc} = \frac{I_m}{\pi} \Rightarrow I_m = I_{dc} \times \pi = 0.125 \times \pi$$

$$I_m = 0.39275A$$

$$V_m = I_m(R_L + r_f) = 0.39275(800+25)$$

$$V_m = 321.85V$$

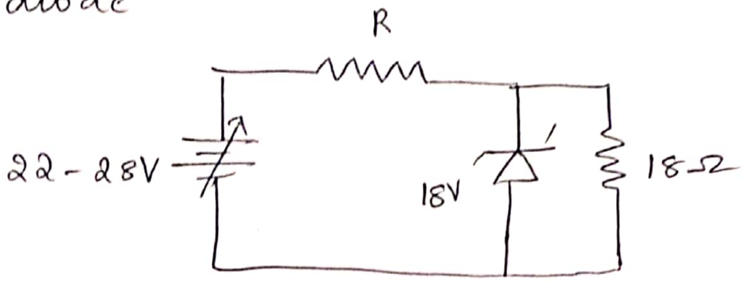
b> rectification efficiency is given by,

$$\eta = \frac{0.406}{1 + r_f/R_L} = 39.6\%.$$

8) The zener diode shown in figure has a fixed voltage of 18V across it so long as the zener current is maintained between 200mA and 2A.

i) find the value of R so that the load voltage remains 18V as the input voltage is free to vary from 22V to 28V.

ii) find the maximum power dissipated by the zener diode



Soln :- min voltage across R = 22 - 18 = 4V

∴ current through R, when I_L max flows through R_L

$$I_{L(max)} + I_{Zmin} = \frac{18V}{18\Omega} + 200m = 1200mA$$

$$\therefore R = \frac{V}{I} = \frac{4}{1200 \times 10^{-3}} = 3.33\Omega$$

max current through R,

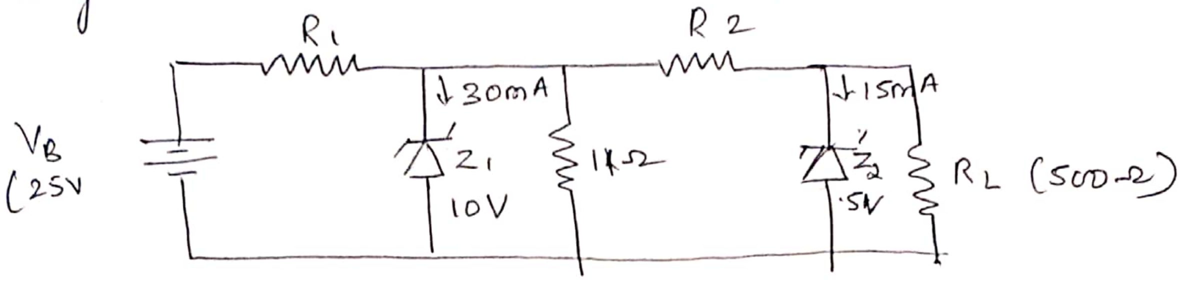
$$R = \frac{28-18}{3.33} = 3000mA$$

$$I_{Zmax} = 3000 - 1000 = 2000mA$$

maximum power dissipated = $V_Z I_Z = 18 \times 2000 = 36W$

9) Consider the circuit, the operating currents of the two zener diodes Z_1 and Z_2 are 30mA ($V_Z = 10V$) and 15mA ($V_Z = 5V$) respectively. Calculate the values of the limiting resistances R_1 and R_2. If the maximum operating current (knee current) of the zener Z_1 is 5mA ($V_Z = 10V$). Find the lowest power supply V_B

for which the current through R_L will remain nearly constant.



Soln: current through R_L, $R_L = \frac{5}{500}$ Ω.

current through $R_2 = 15mA + \frac{5V}{500\Omega} = 25\,mA$

Voltage across $R_2 = 10 - 5 = 5V$

∴ resistance $R_2 = \frac{5}{25 \times 10^{-3}} = 200\,\Omega$

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current through $R_1 = 30m + \frac{10}{1K} + 25m = 65\,mA$

voltage across $R_1 = 25 - 10 = 15V$

Resistance $R_1 = \frac{15}{65 \times 10^{-3}} = 230.77\,\Omega$.

given knee current of $Z_1 = 5mA$

∴ current through $R_1 = 5m + \frac{10V}{1K} + 25m = 40mA$

Voltage drop across $R_1 = 40mA \times 230.77 = 9.23V$

$V_B(min) = V_{Z1}$ + Voltage drop across R_1

$= 10 + 9.23 = 19.23\,V$

1) In a zener regulator, the input DC is 20V of 40%. The output requirements are 5V, 20mA. Assume I_{zmin} and I_{zmax} as 10mA and 100 mA. Design the zener regulator.

Soln: Given $V_i = 20 \pm 40\% = 20 \pm 8 \Rightarrow V_{imin} = 20 - 8 = 12V$

$V_{imax} = 20 + 8 = 28V$

$V_z = V_o = 5V \quad I_L = 20mA \quad I_{zmin} = 10mA, \; I_{zmax} = 100mA$

since load current is constant, we have,

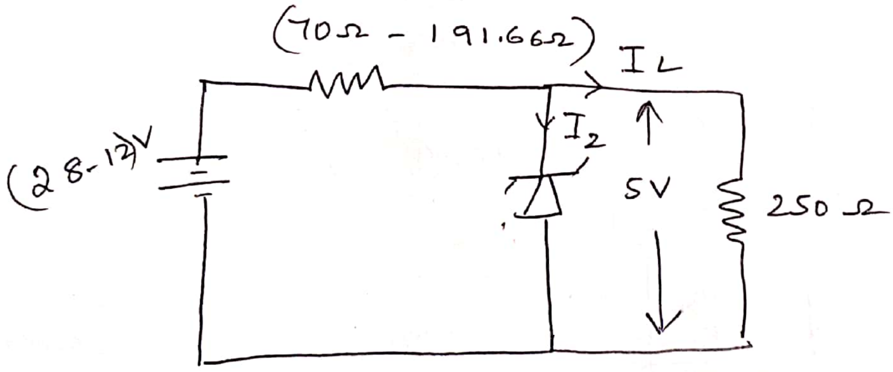
$$R_L = \frac{V_o}{I_L} = \frac{5V}{20mA} = 250\Omega$$

series resistance $R_{s\,max} = \dfrac{V_{imin} - V_o}{I_{zmin} + I_L} = \dfrac{12 - 5}{(10 + 20) \times 10^{-3}}$

$$R_{s\,max} = 70\Omega$$

$$R_{s\,min} = \frac{V_{imax} - V_o}{I_{zmax} + I_L} = \frac{28 - 5}{(100 + 20) \times 10^{-3}}$$

$$R_{s\,max} = 191.66\,\Omega$$



1) Design a zener regulator for the following specification, output voltage $V_o = 5V$ i/p $V_i = 12 \pm 3V$, load current $I_L = 20mA$ and Zener wattage $P_Z = 500mW$.

Soln :-

$V_i = 12 \pm 3 \Rightarrow V_{i\,min} = 9V$ $P_Z = 500mW$.

$V_{i\,max} = 15V$

wkt $P_Z(max) = V_Z \times I_{Zmax}$

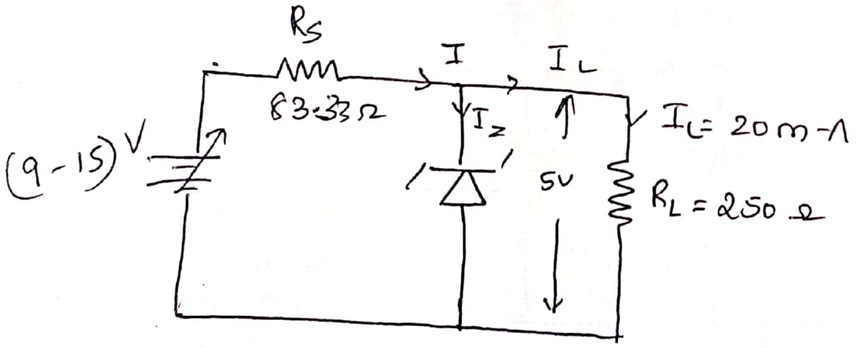
$$I_{Zmax} = \frac{P_Z}{V_Z} = \frac{500 \times 10^{-3}}{5} = 100mA$$

$$R_L = \frac{V_o}{I_L} = \frac{5}{20 \times 10^{-3}} = 250\Omega$$

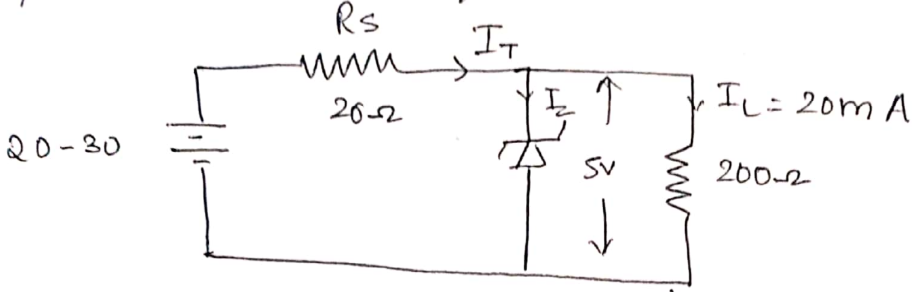
$$I_L + I_{Zmax} = \frac{V_{i\,max} - V_o}{R_S} = \frac{(15-5)V}{R_S}$$

$$\Rightarrow R_S = \frac{10V}{(20+100) \times 10^{-3}} = 83.3\Omega$$

$$I_{Zmin} = \frac{V_{i\,min} - V_Z}{R_S} - I_{L\,max} = \frac{9-5}{83.33} - 20 = 28mA$$



12) In the circuit shown in figure below if V_i can vary from 20V to 3V. find the minimum and maximum currents in zener diode, the minimum and maximum power dissipated in the diode and the minimum rated power dissipation for the series resistor.



Soln: Given $R_S = 20\Omega$ $V_Z = 18V$ $R_L = 200\Omega$ $V_{imin} = 20V$

$V_{imax} = 30V$.

$$I_{zmax} + I_{Lmin} = \frac{V_{imax} - V_Z}{R_S} = \frac{30-18}{20}$$

$$I_{zmax} = 0.6V \qquad [\because I_{Lmin} = 0]$$

and

$$I_{Lmax} + I_{zmin} = \frac{V_{imin} - V_Z}{R_S} = 0.1A$$

$$I_{Lmax} = \frac{18}{200} = 0.09A$$

$$I_{zmin} = 0.1 - 0.09 = 0.01A$$

power rating $P_{zmin} = V_Z \times I_{zmin}$

$$= 18 \times 0.01 = 0.18W$$

$$P_{zmax} = V_Z \times I_{zmax} = 18 \times 0.6 = 10.8W$$

minimum rated power dissipation for series resistor.

$$P_{Rsmin} = I^2_{min} \times R_S = [I_{zmax} + I_{zmin}]^2 R_S$$

$$= (0.1)^2 \times 20 = 0.2W$$

(13) Ideal diodes used in a bridge rectifier with a source of 230V, 50Hz. If the load resistance is 200Ω and turns ratio of transformer is 1:4. Find the dc output voltage and pulse frequency of the output.

Soln :- Given $V_P = 230V$, $f = 50Hz$ $R_L = 200\Omega$, $\frac{N_S}{N_P} = \frac{1}{4}$.

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

rms secondary voltage,

$$V_S = V_P \times \frac{N_S}{N_P} = 230 \times \frac{1}{4} = 57.5V$$

$$V_S = V_{rms} = 57.5V.$$

max voltage across secondary, $V_m = V_{rms} \times \sqrt{2} = 57.5 \times \sqrt{2}$

$$V_m = 81.3V.$$

average current $I_{dc} = \frac{2V_m}{\pi R_L} = \frac{2 \times 81.3}{3.14 \times 200} = 0.26A$

DC output voltage $V_{dc} = I_{dc} \times R_L = 0.26 \times 200 = 52V$

There are two output pulses for each complete cycle of the input ac voltage in full wave rectification, the output frequency is twice that of the ac supply frequency $f_{out} = 2f_{in} = 2 \times 50 = 100Hz$

NOTE :-

	HWR	Bridge FWR
Secondary line to line voltage	$\frac{V_m}{\sqrt{2}}$	$\frac{V_m}{\sqrt{2}}$