SOLVED PROBLEMS ON ELECTRONICS

1)A sample of germanium is doped to the extent of 10^{14} donor atoms/cm^3 and $2x10^{14}$ acceptor atoms/cm^3. At the temperature of the sample the conductivity of pure (intrinsic) germanium is 0.02 $(\Omega\text{-cm})^{-1}$. If the total conduction current density is 0.128*A/cm*^{2}, find the applied electric field intensity. (μ_p=1800cm^2/V.s and μ_n=1800cm^2/V.s at 300^{o}K).

Solution:

The current density J that results from an electric field ε is obtained by:

$$J = q\,(n\mu_n + p\mu_p)\,\varepsilon = \delta\,\varepsilon \quad A\backslash cm^2$$

To find n and p, we first find n_i

$$\rho = \frac{1}{\delta} = \frac{1}{q(n\mu_n + p\mu_p)}$$

For intrinsic germanium, p = n = n_i

$$\sigma_i = qn_i(\mu_n + \mu_p)$$

$$n_i = \frac{\sigma_i}{q(\mu_n + \mu_p)} = \frac{0.02}{1.6\times10^{-19}(1800+1800)} = 2.23\times10^{13}cm^{-3}$$

From mass action law and neutral equation

$N_D + p = N_A + n$

$n + (N_A - N_D) - p = 0$

$n\,p = n_i^2 \rightarrow p = n_i^2/n$

$n + (N_A - N_D) - (n_i^2/n) = 0$

Multiplying both sides by n

$n^2 + (N_A - N_D)n - n_i^2 = 0$

$$n = \frac{-(N_A - N_D) + \sqrt{(N_A - N_D)^2 + 4n_i^2}}{2}$$

$$n = \frac{-(2\times10^{14}-10^{14})+\sqrt{(3\times10^{14}-2\times10^{14})^2+4(2.23\times10^{13})^2}}{2}$$

n = $0.351\text{x}10^{14}$cm-3

p = n + (N_A - N_D) = $1.351\text{x}10^{14}\text{cm}^{-3}$

$$J = q(n\mu_n + p\mu_p)\varepsilon$$

$$0.128 = 1.6\times10^{-19}(0.351\times10^{14}\times 3800 + 1.351\times10^{14}\times1800)\times\varepsilon$$

$$\therefore \varepsilon = 4.16\,V/cm$$

2) What PIV rating is required for the diodes in a Full-Wave Center-Tapped Rectifier that produces an average output voltage of 60 V?

Solution:

$$\because V_{ave} = 60V = \frac{2V_{P(rec)}}{\pi}$$

$$\therefore V_{P(rec)} = \frac{60\times3.14}{2} = 94.2V$$

$$PIV = 2V_{p(rec)} + V\gamma = 188.4\text{V} + 0.6 = 189\text{V}$$

3) Determine the ripple factor for the filtered rectifier with a load as indicated in Figure -1. What minimum PIV rating must the diodes have? (Vγ = 0.7V)

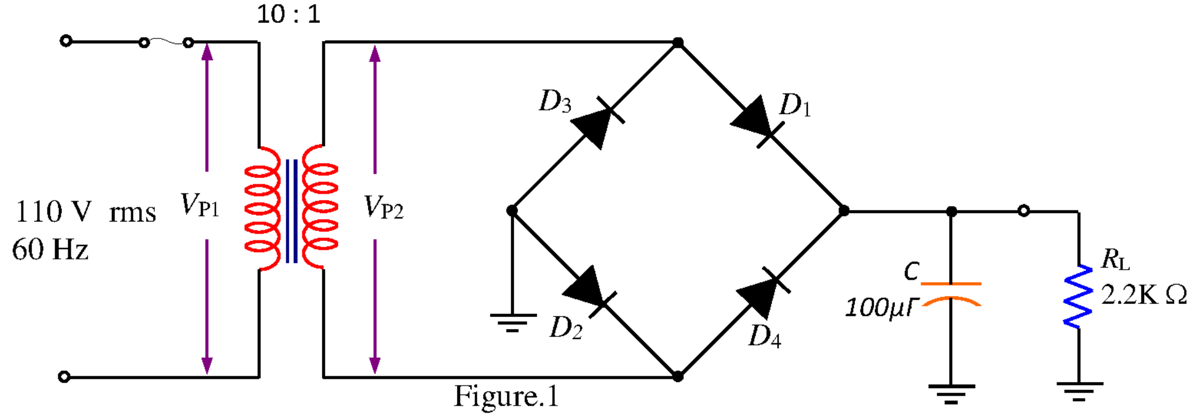


Figure.1

$$V_{P1} = \sqrt{2}V_{rms} = (1.414)(110)\text{V} = 155.5\text{V}$$

$$V_{P2} = \left(\frac{N_2}{N_1}\right)V_{P1} = \left(\frac{1}{10}\right)155.5\text{V} = 15.55\text{V}$$

$$V_{P(rect)} = V_{P2} - 1.4\text{V} = 15.55\text{V} - 1.4\text{V} = 14.15\text{V}$$

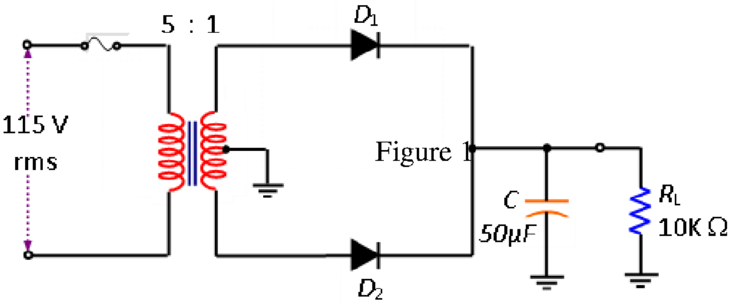
$$V_{r(PP)} = \left(\frac{1}{f_O R_L C}\right)V_{P(rect)} = \left(\frac{1}{(120\text{Hz})(2.2\text{K}\Omega)(100\mu\text{F})}\right)14.15\text{V} = 0.536\text{V}$$

$$V_{DC} = \left(1 - \frac{1}{2f_O R_L C}\right)V_{P(rect)} = \left(1 - \frac{1}{2(120\text{Hz})(2.2\text{K}\Omega)(100\mu\text{F})}\right)14.15\text{V} = 13.88\text{V}$$

$$r = \frac{V_{r(PP)}}{V_{DC}} = \frac{0.536\text{V}}{13.88\text{V}} = 0.039 = 3.9\%$$

$$\text{PIV} = V_{P2} - 0.7\text{V} = 15.56\text{V} - 0.7 = 14.86\text{V}$$

4) Determine the ripple factor for the filtered rectifier with a load as indicated in Figure -1. What minimum PIV rating must the diodes have? (Vγ = 0.7V)



Solution:

$$V_{P1} = \sqrt{2}V_{rms} = (1.414)\ (115V) = 163V$$

$$V_{P2} = \left(\frac{N_2}{N_1}\right)V_{P1} = \left(\frac{1}{10}\right)\ 163V = 32.6V$$

$$V_{P(\text{rec})} = (V_{P2}/2) - 0.7V = 15.6V$$

$$V_{r(PP)} = \left(\frac{1}{f_O R_L C}\right)V_{P(rect)} = \{1/\ (120HZ \times 50\mu F \times 10K\Omega)\}15.6V = 0.26V$$

$$V_{DC} = V_{P(\text{rec})} - 0.5V_{r(PP)} = 15.47V$$

$$r = V_{r(PP)}\ /\ V_{DC} = 1.68\%$$

$$PIV = V_{P2} - 0.7V = 32.6V - 0.7 = 31.9V$$

5) What value of filter capacitor is required to produce a 1% ripple factor for a full-wave rectifier having a load resistance of 1.5KΩ? Assume the rectifier produces a peak output of 18V from a 60 Hz ac source.

Solution:

$$r = 0.01 = \frac{V_{r(PP)}}{V_{DC}}$$

$$V_{r(PP)} = \left(\frac{1}{f_O R_L C}\right) V_{P(rect)}$$

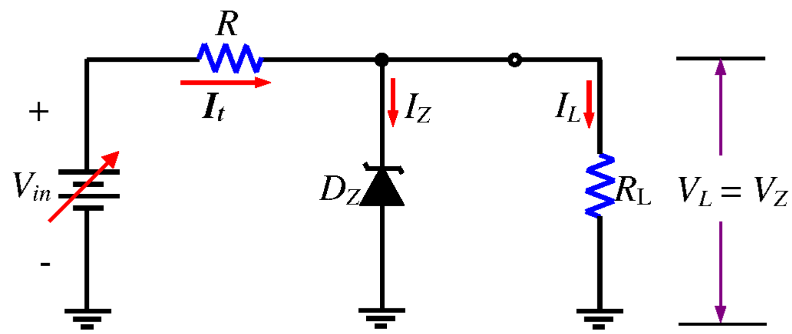
$$V_{DC} = \left(1 - \frac{1}{2 f_O R_L C}\right) V_{P(rect)}$$

$$r = 0.01 = \frac{V_{r(PP)}}{V_{DC}} = \frac{\frac{1}{f_o R_L C}}{1 - \frac{1}{2 f_o R_L C}} = \frac{1}{f_o R_L C - 0.5}$$

$$\therefore 0.01 f_o R_L C = 1.005$$

$$\therefore C = \frac{1.005}{0.01 \times 120Hz \times 1500\Omega} = 5.56 \times 10^{-4} F$$

6) For the voltage regulator shown in Figure.2, assume that V_Z=30V, R=50Ω, r_Z =0, and R_L=450Ω. Voltage V_i varies between 40 and 60V.



1- The maximum current passing through the resistance R is equal to
   (a) 200mA (b) 400mA (c) 600mA *(d)* 800mA
2- The minimum current passing through the resistance R is equal to
   (a) 200mA (b) 400mA (c) 600mA *(d)* 800mA
3- The current passing through the load resistance R_L is equal to
   (a) 50mA (b) 100mA (c) 150mA *(d)* 200mA
4- The minimum and maximum currents for the zener diode are equal to
   (a) 50mA&250mA (b) 100mA&350mA (c) 50mA &350mA *(d)* 100mA&400mA
5- the maximum power dissipated in resistance R is given by
   (a) 12W (b) 15W (c) 18W *(d)* 9W
6- the maximum power dissipated in the zener diode is given by
   (a) 8W (b) 13.5W (c) 12W *(d)* 10W

(i)

$$I_t = I_Z + I_L$$

$$I_{Z(\max)} = I_{t(\max)} - I_L \qquad\qquad I_{Z(\min)} = I_{t(\min)} - I_L$$

$$I_{t(\min)} = \frac{V_{in(\min)} - V_Z}{R} = \frac{48\text{V} - 40\text{V}}{40\Omega} = 0.2\text{A}$$

$$I_{t(\max)} = \frac{V_{in(\max)} - V_Z}{R} = \frac{60\text{V} - 40\text{V}}{40\Omega} = 0.5\text{A}$$

$$I_L = \frac{V_Z}{R_L} = \frac{40\text{V}}{400\Omega} = 0.1\text{A}$$

$$\therefore I_{Z(\max)} = 0.5\text{A} - 0.1\text{A} = 0.4\text{A}$$

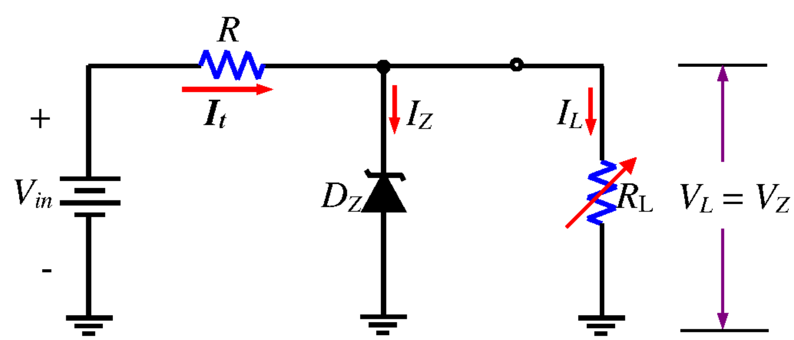
$$\therefore I_{Z(\min)} = 0.2\text{A} - 0.1\text{A} = 0.1\text{A}$$

(ii)

$$P_{R(\max)} = I_{t(\max)}{}^2\,\text{R} = (0.5\text{A})^2(40\Omega) = 10\text{W}$$

$$P_{Z(\max)} = V_Z\, I_{Z(\max)} = (40\text{V})(0.4\text{A}) = 16\text{W}$$

7) For the voltage regulator shown in figure.2, assume that V_Z=30V, V_{in}=150V, R= 600Ω, r_Z=0, and I_{ZK} = 10 mA, I_{ZM} = 190 mA. Determine:
(i) the variation in R_L over which the load voltage is still regulated at the Zener voltage.
(ii) the maximum power dissipated in resistance R_L and in the zener diode ($P_{L(\max)}$ and $P_{Z(\max)}$)



Solution:

(a)

$$I_t = \frac{V_{in} - V_Z}{R} = \frac{30\text{V} - 20\text{V}}{50\Omega} = 200\text{mA}$$

$$I_{L(\max)} = I_t - I_{Z(\min)}$$

$$= 200\text{mA} - 10\text{mA} = 190\text{mA}$$

$$\therefore R_{L(\min)} = \frac{V_Z}{I_{L(\max)}} = \frac{30\text{V}}{190mA} = 157.9\Omega$$

$$I_{L(\min)} = I_t - I_{Z(\max)}$$

$$= 200\text{mA} - 190\text{mA} = 10\text{mA}$$

$$\therefore R_{L(\max)} = \frac{V_Z}{I_{L(\min)}} = \frac{30\text{V}}{10\text{m}A} = 3K\Omega$$

$$\therefore R_L = 157.9\Omega \rightarrow 3k\Omega$$

(b)

$$P_{RL(\max)} = I_{L(\max)} V_Z = (190\text{mA})(30\text{V}) = 5.7\text{W}$$

$$P_{Z(\max)} = I_{Z(\max)} V_Z = (190\text{mA})(30\text{V}) = 5.7\text{W}$$

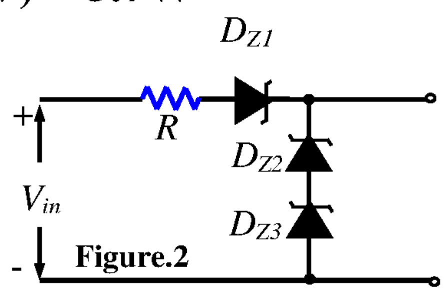


Figure.2

8) For the circuit shown in Figure-2 I_{o1}=2µA, I_{o2}=1µA, I_{o3}=3µA, V_{Z1} =20V, V_{Z2} =30V, V_{Z3} =50V, r_{Z1}=10Ω, r_{Z2}=30Ω, r_{Z3}=20Ω, $V_{\gamma 1}$=$V_{\gamma 2}$=0.6V, $V_{\gamma 3}$= 0.5V, and R=10kΩ. Calculate the current passing through the circuit if V_{in} = -10V, V_{in} = +10V, V_{in} = -60V and V_{in} = 60V.

Solution:

- **when V_{in} = -10V D1 is reverse and D2 , D3 are forward**

  $I = I_{o1}$ =2 µA

- **when V_{in} = 10V D1 is forward and D2 , D3 are reverse**

  $I = I_{o2}$ =1µA

- **when V_{in} = -60V D1 is in breakdown and D2 , D3 are forward**

$$I = (-60V + V_{Z1} + V_{\gamma 2} + V_{\gamma 3})/(R + r_{Z1}) = 3.89mA$$

- when V_{in} = 60V D_1 is forward, D_2 in breakdown and D_3 is reverse

$$I = I_{o3} = 3\mu A$$

9) For the circuit shown in Figure-2 R_{r1}=1MΩ, R_{r2}=100KΩ, R_{r3}=2MΩ, R_{f1}=100Ω, R_{f2}=50Ω, R_{f3}=60Ω, V_{Z1} =20V, V_{Z2}=30V, V_{Z3}=50V, r_{Z1}=10Ω, r_{Z2}=30Ω, r_{Z3}=20Ω, $V_{\gamma 1}=V_{\gamma 2}$=0.6V, $V_{\gamma 3}$= 0.5V, and R=10kΩ. Calculate V_{out} if V_{in} = -10V, V_{in} = +10V, V_{in} = -60V and V_{in} = 60V.

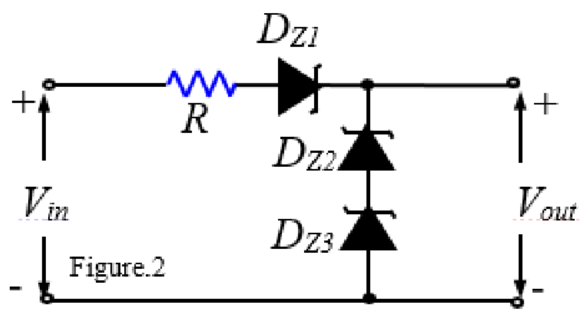


Figure.2

Solution:

- when V_{in} = -10V D_1 is reverse and D_2 , D_3 are forward

$$I = (-10V + V_{\gamma 2} + V_{\gamma 3})/(R + R_{r1} + R_{f2} + R_{f3}) = -8.8\ \mu A$$

$$V_o = I\,(R_{f2} + R_{f3}) - (V_{\gamma 2} + V_{\gamma 3}) = -1.1009V$$

- when V_{in} = 10V D_1 is forward and D_2 , D_3 are reverse

$$I = (10V - V_{\gamma 1})/(R + R_{f1} + R_{r2} + R_{r3})$$

$$V_o = I\,(R_{r2} + R_{r3}) \simeq 9.4V$$

- when V_{in} = -60V D_1 is in breakdown and D_2 , D_3 are forward

$I = (-60V + V_{Z1} + V_{\gamma 2} + V_{\gamma 3})/(R + r_{Z1} + R_{f2} + R_{f3}) = -3.84mA$

$V_o = I\,(R_{f2} + R_{f3}) - (V_{\gamma 2} + V_{\gamma 3}) = -1.1038V$

- **when $V_{in} = 60V$ D_1 is forward, D_2 in breakdown and D_3 is reverse**

$I = (60V - V_{\gamma 1} - V_{Z2})/(R + R_{f1} + R_{Z2} + R_{r3}) = 14.6\,\mu A$

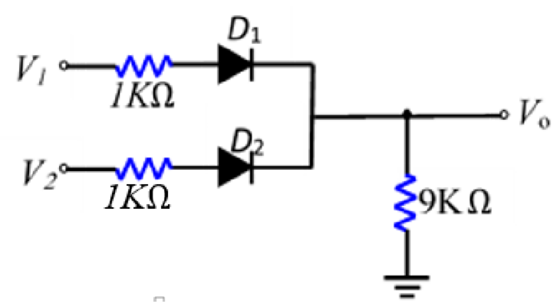
$V_o = I\,(R_{Z2} + R_{r3}) + V_{Z2} = 59.2V$

10) For the circuit shown in fig.2, the cutin voltage of the diode V_γ is 0.6V, $R_f = 30\Omega$ and $R_r \to \infty$. Calculate V_o for the following input voltages and indicate the state of each diode (on or off). Justify your assumptions about the state of each diode.

(i) $V_1 = V_2 = 0V$

(ii) $V_1 = 5V$, $V_2 = 0V$

(iii) $V_1 = 5V$, $V_2 = 10V$



Solution:

for $V_1 = 0V$, $V_2 = 0V$

D_1 & D_2 are off

$\therefore Vo = 0V$

(ii) *for* $V_1 = 5V$, $V_2 = 0V$

Assume D_1 is on & D_2 is off

$5 - 0.6 = (1000 + 9000 + 30)\,I$

$\therefore I = 4.4V/10030\Omega = 0.4\,27\ mA$

$\therefore Vo = (9\,K\Omega \times 0.427\ mA) = 3.843\ V$

With Vo =3.843V and V2 =0V, D2 is reverse biased or off.

With Vo =3.843V and V1 = 5V, D1 is forward biased or on.
∴Our assumption is true

(iii) *for* $V_1 = 5V$, $V_2 = 10$ V

Assume D_1 is off & D_2 is on

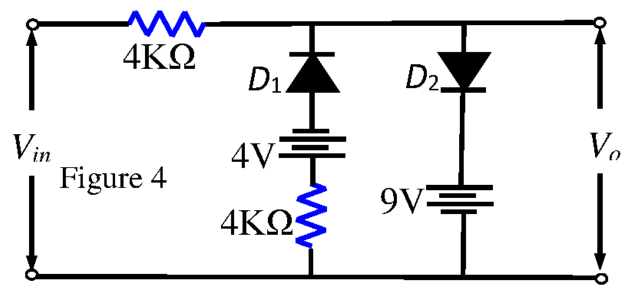
$10 - 0.6 = (1000 + 9000 + 30)\, I$

$\therefore I = 9.4V/10030\Omega = 0.937$ mA

$\therefore Vo = (9\ K\Omega \times 0.937\ mA) = 8.43$ V

With Vo =8.43V and V1 =5V, D1 is reverse biased or off.
With Vo =8.43V and V2 = 10V, D2 is forward biased or on.
∴Our assumption is true

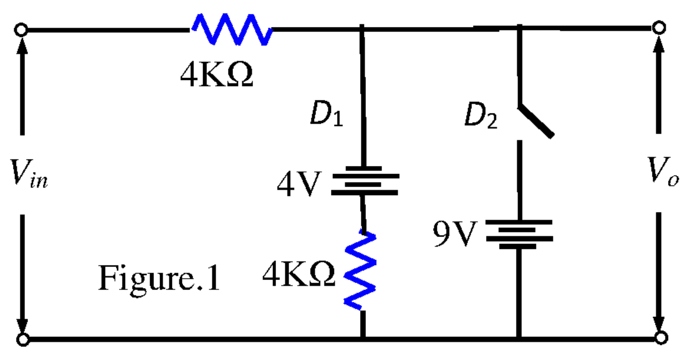
11) The diodes shown in Figure.4 are ideal. Sketch the transfer characteristics for $-20 \leq V_i \leq +20$V. Indicate the state of each diode (on or off) over each region of the characteristic.



Solution:

D_1 on for $V_{in} < -4$V and D_2 on for $V_{in} > 9$V

- *For* $-20 \leq V_i < -4$V , D_1 on and D_2 off



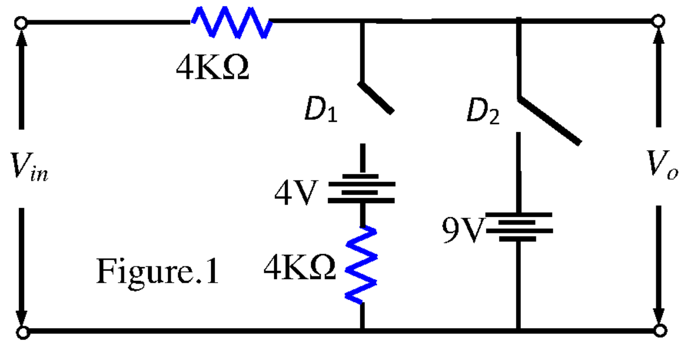
$$V_o = [[4k\Omega / (4k\Omega + 4k\Omega)]\ (V_{in} + 4V)] - 4V = [(V_{in} + 4V)/2] - 4V$$

$$= (V_{in} - 4V)/2$$

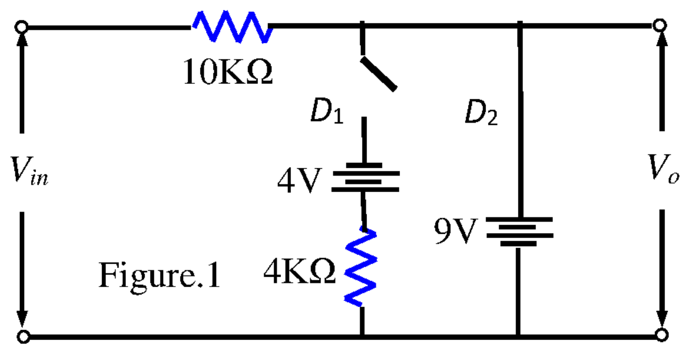
At V_{in} = - 20V →Vo = -12V

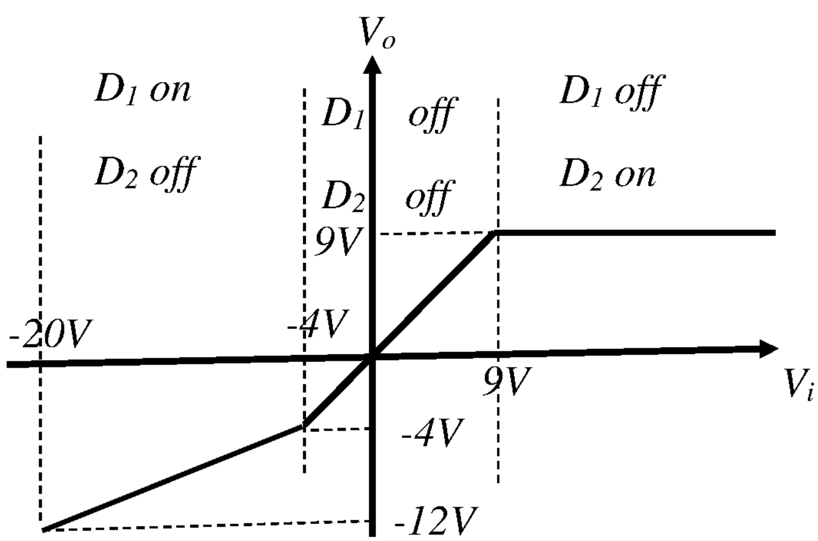
At V_{in} = - 4V →Vo = - 4V

- *For* $-4 \leq V_i \leq 9$, D_1 and D_2 are off and $V_o = V_{in}$



- *For* $9 < V_i \leq 20$V , D_1 off and D_2 on and $V_o = 9$V





12) **The diodes shown in Figure.1 are ideal. Sketch the transfer characteristics for $0 \leq V_i \leq 100V$. Indicate the state of each diode (on or off) over each region of the characteristic.**

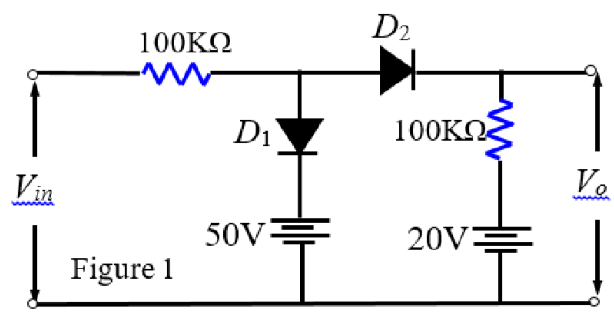


Figure 1

Solution:

D_2 on for V_{in} >20V and D_1 on for V_o > 50V

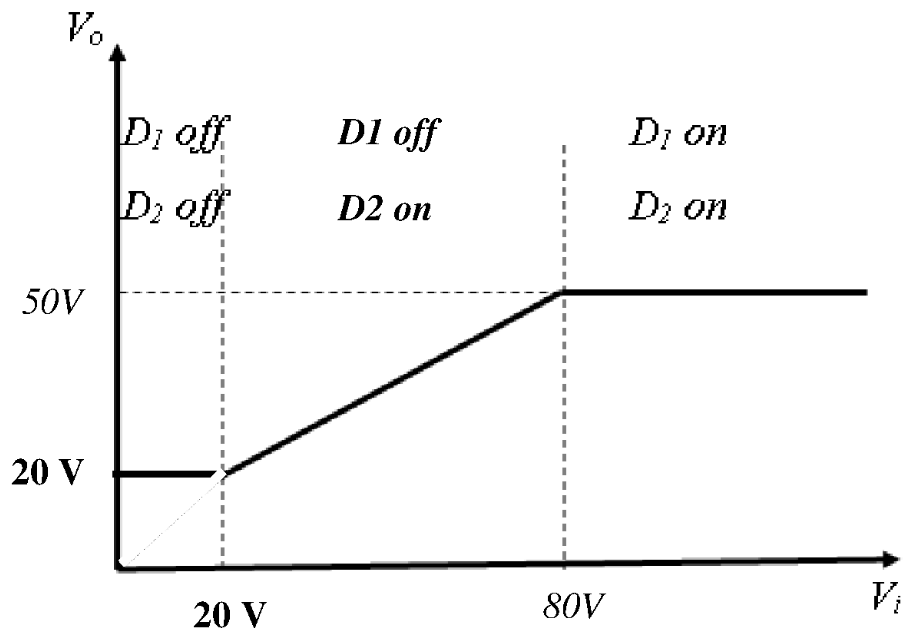
- *For* $0 < V_i \leq 20V$, D_1 and D_2 are off and $V_O = 20V$
- *For* $20 < V_i \leq ??$, D_2 on and D_1 off

$$V_o = [[100k\Omega / (100k\Omega + 100k\Omega)]\,(V_{in} - 20V)] + 20V$$

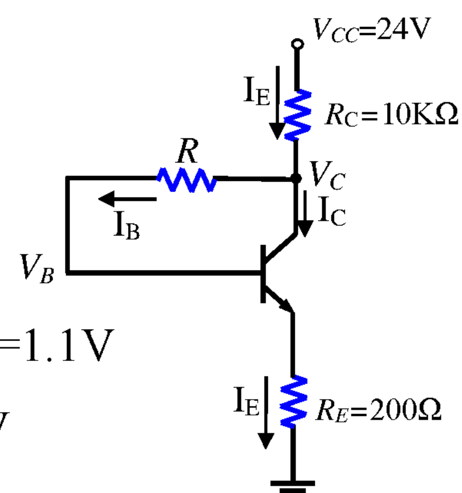
$$= [(V_{in} - 20V)/2] + 20V = (V_{in} + 20V)/2$$

At $V_o = 50V \rightarrow V_{in} = 80V$

- *For* $20 < V_i \leq 80V$, D_2 on and D_1 off and $V_o = (V_{in} + 20V)/2$
- *For* $80 < V_i \leq 100V$, D_1 and D_2 are on and $V_o = 50V$



13) If $\beta = 45$, I_E =2mA and V_{BE} =0.7V, find R in the circuit shown in figure.1



Solution:

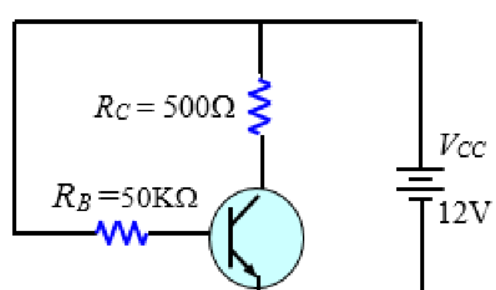
$$\because V_B = V_{BE} + I_E R_E = 0.7\text{V} + (2\text{mA})\,(0.2\text{K}\Omega) = 1.1\text{V}$$

$$V_C = V_{CC} - I_E R_C = 24\text{V} - (2\text{mA})(10\text{K}\Omega) = 4\text{V}$$

$$I_B = I_E / (1+\beta) = 2\text{ mA} / (1+45) = 0.0435\text{ mA}$$

$$R = (V_C - V_B) / I_B = (4\text{V} - 1.1\text{V}) / 0.0435\text{ mA} = 66.67\text{ K}\Omega$$

14) Determine whether or not the transistor shown in Figure 3 in



saturation. Assume V_{CE}(sat.) = 0.2 V and β =150.

Solution:

Applying KVL to input circuit, we get

$V_{CC} = I_B R_B + V_{BE}$

I_B = (12V – 0.7)/50KΩ=0.225mA

Applying KVL to output circuit, we get

$V_{CC} = I_C R_C + V_{CE(sat)}$

$12V = (0.5k\Omega) I_C + 0.2V$

$$\therefore I_C = \frac{12\text{V} - 0.2\text{V}}{0.5k\Omega} = \frac{11.8\text{V}}{0.5k\Omega} = 23.6\text{mA}$$

$I_{B(\min)} = I_C / \beta_{dc}$ = 23.6 mA / 150 = 0.158 mA

$\because I_B$ = 0.225mA > $I_{B(\min)}$ = 0.158 mA

Therefore, the transistor is in saturation