$$N_D = 2 \times 10^{14} \qquad T = 300$$

$$n_i = 5.2 \times 10^{15} \times (300)^{3/2} \times e^{\left(\frac{-0.6 \times 1.6 \times 10^{-19}}{2 \times 300 \times 1.38 \times 10^{-23}}\right)} = 2.5 \times 10^{14} \qquad .1$$

$$N_A = \frac{(n_i)^2}{N_D} = \frac{(2.5 \times 10^{14})^2}{4.5 \times 10^{14}} = 1.3 \times 10^{14} \qquad (\ \underline{\quad})1$$

$$\sigma = q(\mu_n n + \mu_p P) \qquad \mu_n = \mu_n' \ , \ \mu_p = \mu_p' \qquad (\underline{\quad})$$

$$\frac{\sigma_{imp}}{\sigma_{int}} = \frac{\mu_n n + \mu_p P}{\mu_n' n' + \mu_p' P'} = \frac{n + P}{n' + P'} = \frac{\times 10}{(1.3 + 4.5) \times 10^{14}} = 1.16 \ \checkmark$$

$$I_D = I_S \exp\left(\frac{V_D}{\eta V_T}\right) - 1 \qquad . 2$$

$$\underline{I_{D_1} = 5 \, mA} \qquad V_{D_1} = 0.7 \qquad V_{D_2} = 0.8 \qquad \eta = 2$$

$$5 \times 10^{-3} = I_S \cdot \exp\left(\frac{0.7 \times 10^3}{2 \times 25}\right) - 1 \longrightarrow I_S = 8.356 \times 10^{-7}$$

$$I_{D_2} = 8.356 \times 10^{-7} \times \exp\left(\frac{0.8 \times 10^3}{2 \times 25}\right) - 1 \longrightarrow I_{D_2} = 6.42$$

$N = 10^{17}$

$T = 400$

$$n_i = 5.2 \times 10^{15} \times (400)^{3/2} \times \exp\left(-\frac{1.6 \times 10^{-19} \times 1.12}{2 \times 1.38 \times 10^{-23} \times 400}\right) \qquad \text{(a}$$
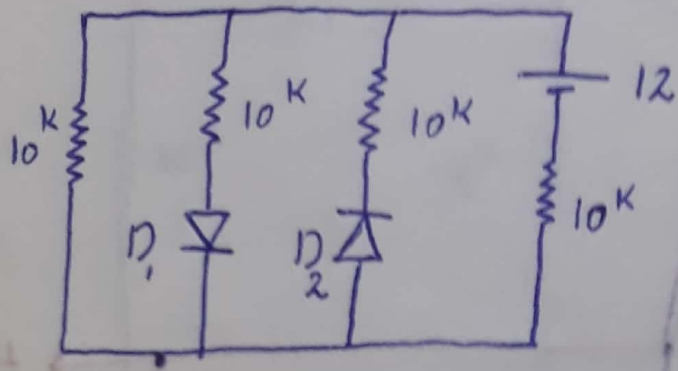
$$= 3.7 \times 10^{12} \; \frac{1}{cm^3}$$

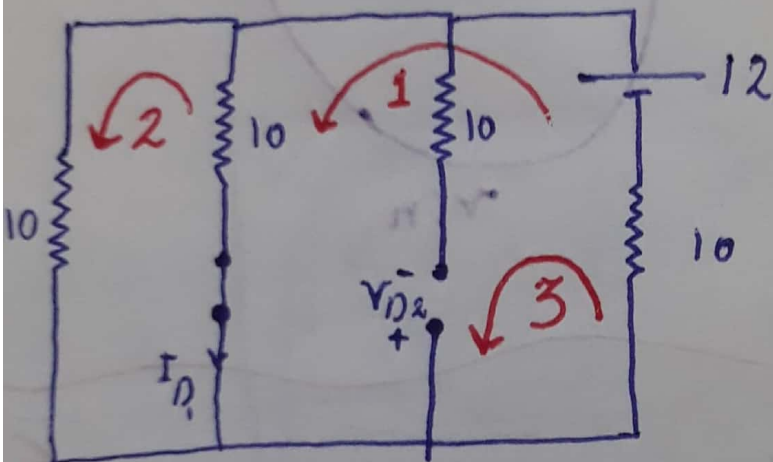$$n = N_D = 10^{17} \qquad P = \frac{n_i^2}{N_D} = 1.37 \times 10^{8}$$

$$\rho = \frac{1}{q(\mathcal{J}_n n + \mathcal{J}_p \times P)} = \frac{1}{1.6 \times 10^{-19} \times 1500 \times 10^{17}} = 0.04166 \qquad \text{(b}$$

$$R = \rho \frac{\ell}{A} = \rho \times \frac{\ell}{wh} = 0.04166 \times \frac{10^{cm}}{1^{cm} \times 10^{-2} cm} = 4.17 \, \Omega \qquad \text{(c}$$

$$I = \frac{V_0}{R + R_0} = 1.93 \, A$$

I deal : D_1 ON & D_2 off

KVL @ 1: $10 I_1 - 12 + 10(I_1 - I_2) = 0$ I

KVL @ 2: $10(I_2 - I_1) + 10 I_2 = 0 \longrightarrow I_1 = 2 I_2$ II

II in I $50 I_2 = 12 \longrightarrow I_2 = 0.4$ $I_1 = 0.8$

$I_{D_1} = I_1 - I_2 = 0.4 > 0$ ✓

KVL @ 3: $-12 + 8 - V_{D_2} = 0 \longrightarrow V_{D_2} = -4 < 0$ ✓

Constant Voltage

Assumption D_1 ON & D_2 off
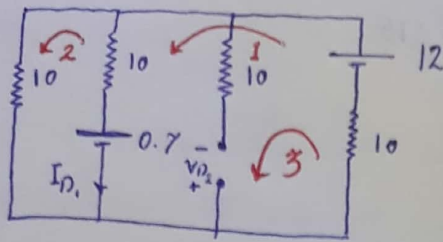
KVL @ 1: $10I_1 - 12 + 10(I_1 - I_2) + 0.7 = 0$ $\mathbf{I}$

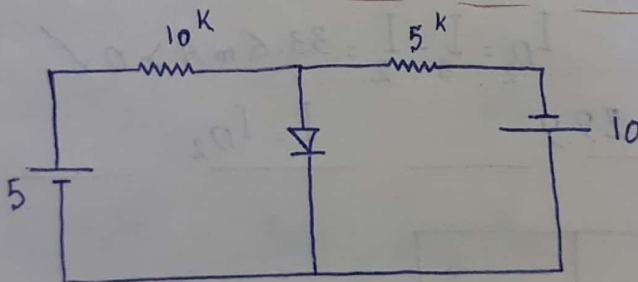KVL @ 2: $-0.7 + 10(I_2 - I_1) + 10I_2 = 0 \longrightarrow 10I_1 = 20I_2 - 0.7$ $\mathbf{II}$

$\mathbf{II}$ in $\mathbf{I}$ $I_2 = 0.42$ $I_1 = 0.77$

$I_{D_1} = 0.35 \checkmark > 0$
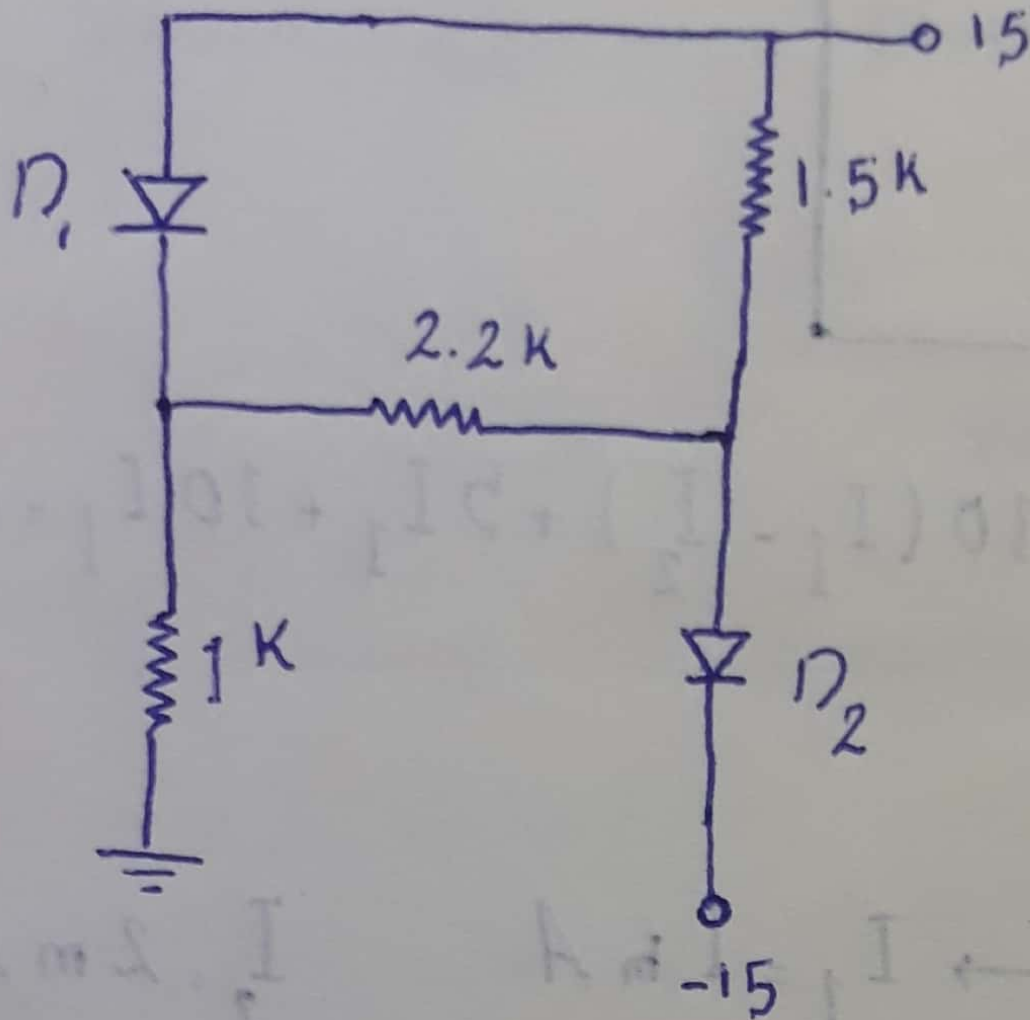
KVL @ 3: $V_{D_2} = -4.3 < 0.7 \checkmark$

Ideal & constant voltage
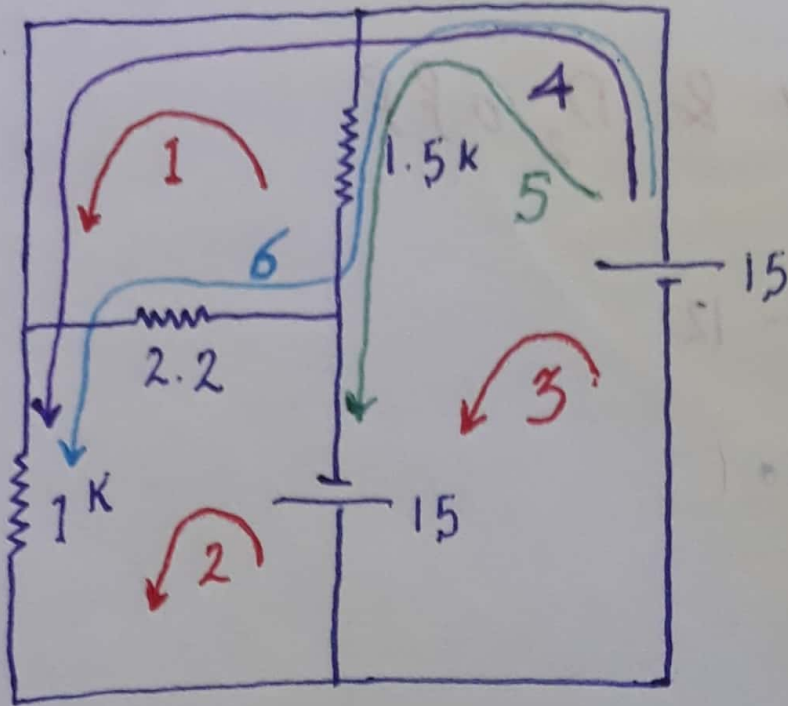
Assumption D_1 off
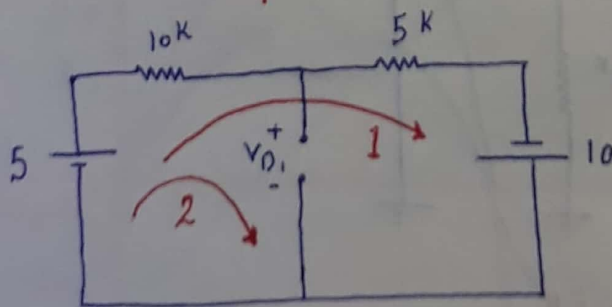
KVL @ 1: $-5 + 10I_1 + 5I_1 - 10 = 0 \longrightarrow I_1 = 1mA$

KVL @ 2: $-5 + 10 + V_{D_1} = 0 \longrightarrow V_{D_1} = -5 < 0 \checkmark \& -5 < 0.7 \checkmark$

5

Assumption D_1 & D_2 ON

KVL @ 4: $-15 + I_2 = 0 \longrightarrow I_2 = 15\,mA$ **I**

KVL @ 5: $-15 + 1.5(I_3 - I_1) - 15 = 0 \longrightarrow I_3 = 20 + I_1$ **II**

KVL @ 6: $-15 + 1.5(I_3 - I_1) + 2.2(I_2 - I_1) + I_1 = 0$ **III**

I & II in III

$I_1 = 28.6\,mA$ $I_3 = 48.6\,mA$

$I_{n_1} = I_1 > 0 \checkmark$ $I_{n_2} = I_3 - I_2 = 33.6\,mA > 0 \checkmark$

$V = 2.2(I_1 - I_2) = 29.9$ $I = I_{n_2}$
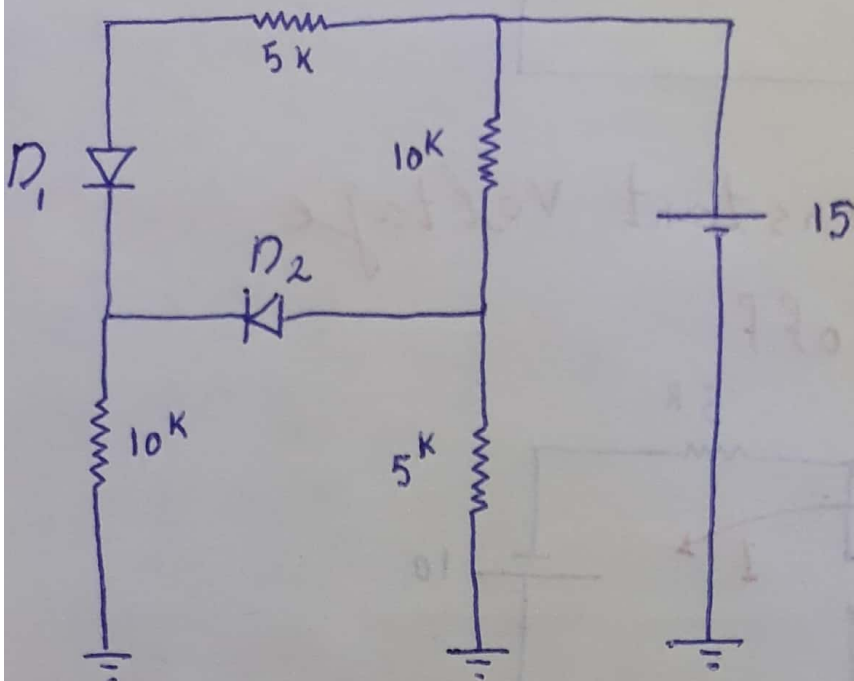
D_1 ON & D_2 off
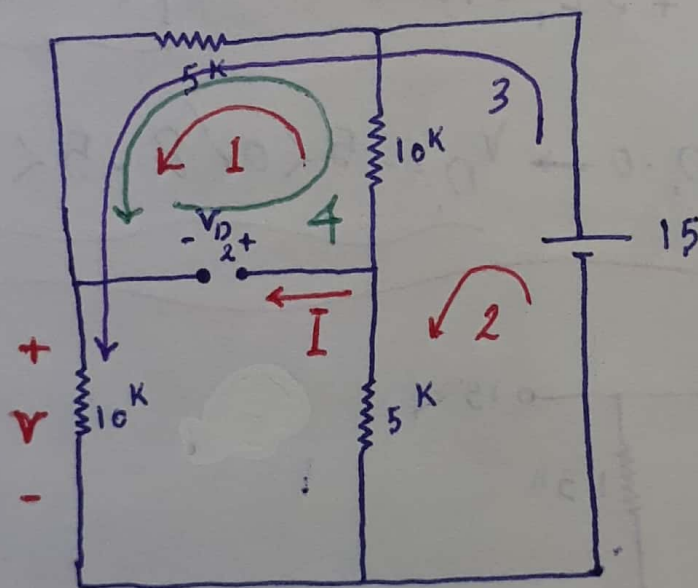
KVL @ 1: $5(I_1 - I_2) + 10(I_1 - I_2) + 5I_1 + 10 I_1 = 0$

$I_2 = 2 I_1$

KVL @ 3: $-15 + 15 I_1 = 0 \longrightarrow I_1 = 1 \, mA \qquad I_2 = 2 mA$

$I_1 = I_{D_1} = 1 mA > 0 \checkmark \qquad I = 0 \qquad V = 10 V$

KVL @ 4: $V_{D_2} = 10(I_1 - I_2) + 5I_1 \Rightarrow V_{D_2} = -5 < 0 \checkmark$
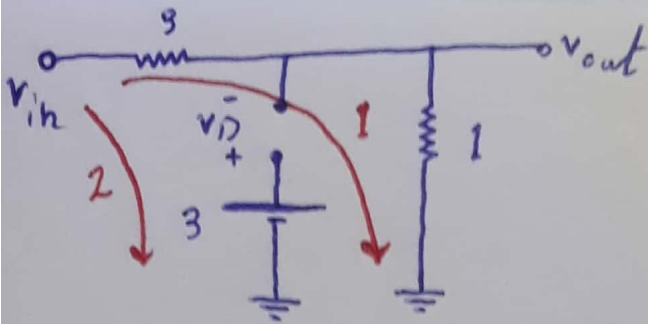
$V_{out} = \dfrac{V_{in}}{4}$

$KVL : -V_{in} + 4I = 0 \implies I = \dfrac{V_{in}}{4}$

$KVL @ 2 : -V_{in} + 3I - V_D + 3 = 0$

$V_D = -\dfrac{3V_{in}}{4} + 3 < 0.8$

$V_{in} > 8.8 \qquad V_{out} = \dfrac{V_{in}}{4}$

$V_{in} < 8.8 \qquad V_{out} = 2.2$

2.5

2.2

2.2

8.8

$\dfrac{1}{4}$

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