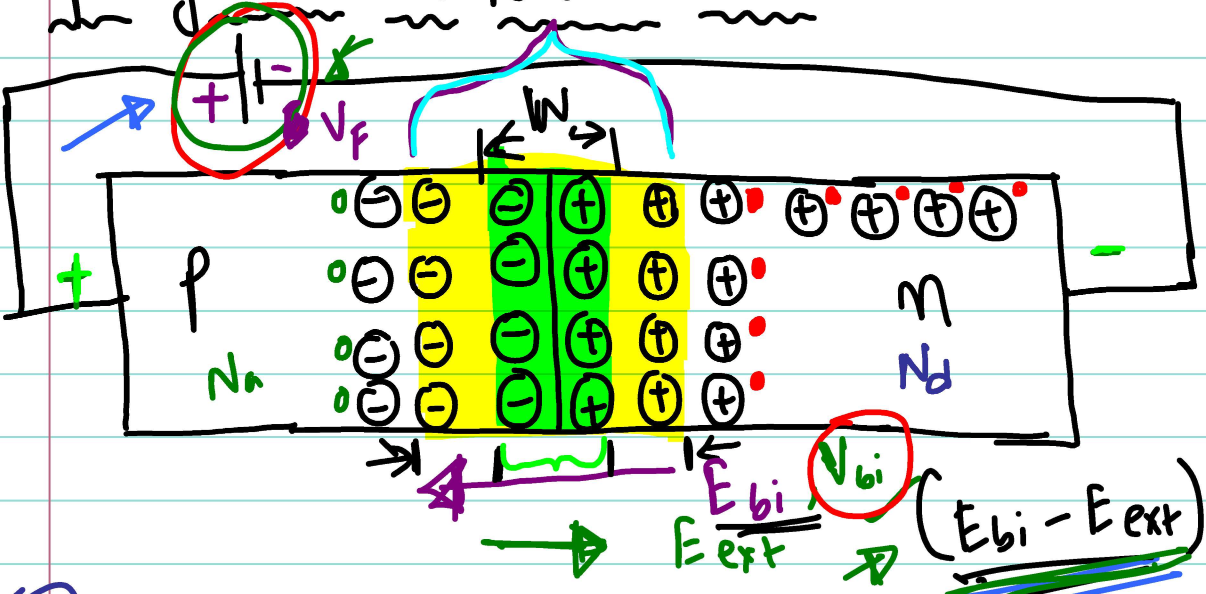
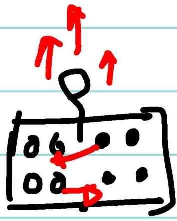
Lec-5

pn junction in forward Bias





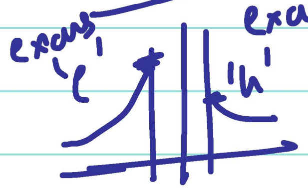
$(E_{bi} - E_{ext})$; $E_{bi} > E_{ext}$

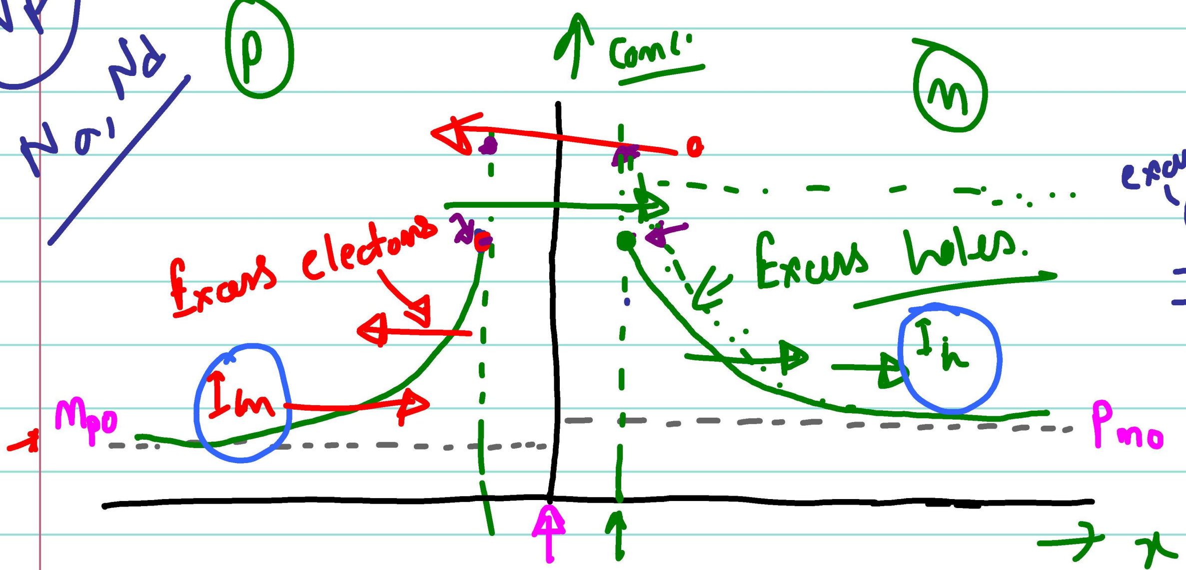
As.

V_F

N_a, N_d

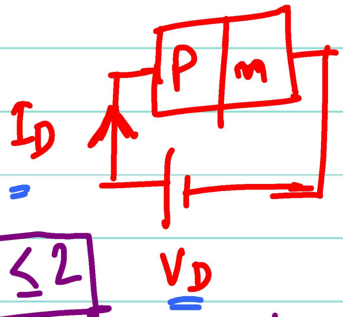
$N_d >> N_a$





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

$V_T = \frac{kT}{q}$



η = ideality factor or emission coefficient

$\eta = 1$

$\boxed{1 \leq \eta \leq 2}$ → "$\eta = 1$"

I_s = Reverse-bias saturation current

$= 10^{-13}$ A to 10^{-9} A

Current - Voltage characteristics of pn junction:

$$I_D = I_s \left[\exp\left(\frac{V_D}{m V_T} \right) - 1 \right]$$

; $m = 1$; $I_s \simeq 10^{-12}$ A

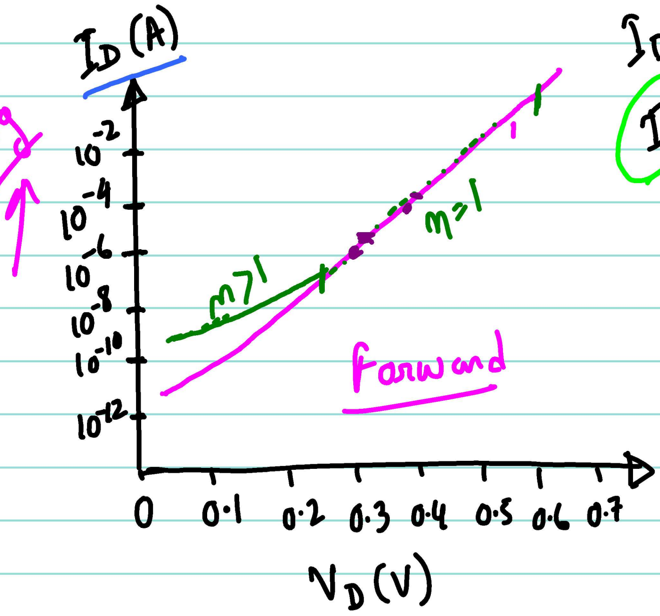
-0.05 V

$I_D = I_s \left[\exp\left(\frac{-0.1}{0.026} \right) - 1 \right]$

$I_D = -0.98 I_s$

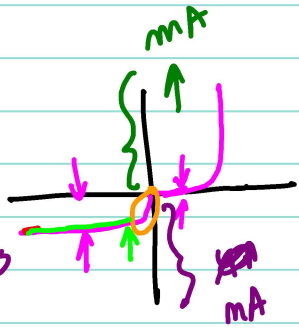
$I_D = I_s \left[\exp\left(\frac{-0.5}{0.026} \right) - 1 \right]$

$I_D = -0.999 I_s$



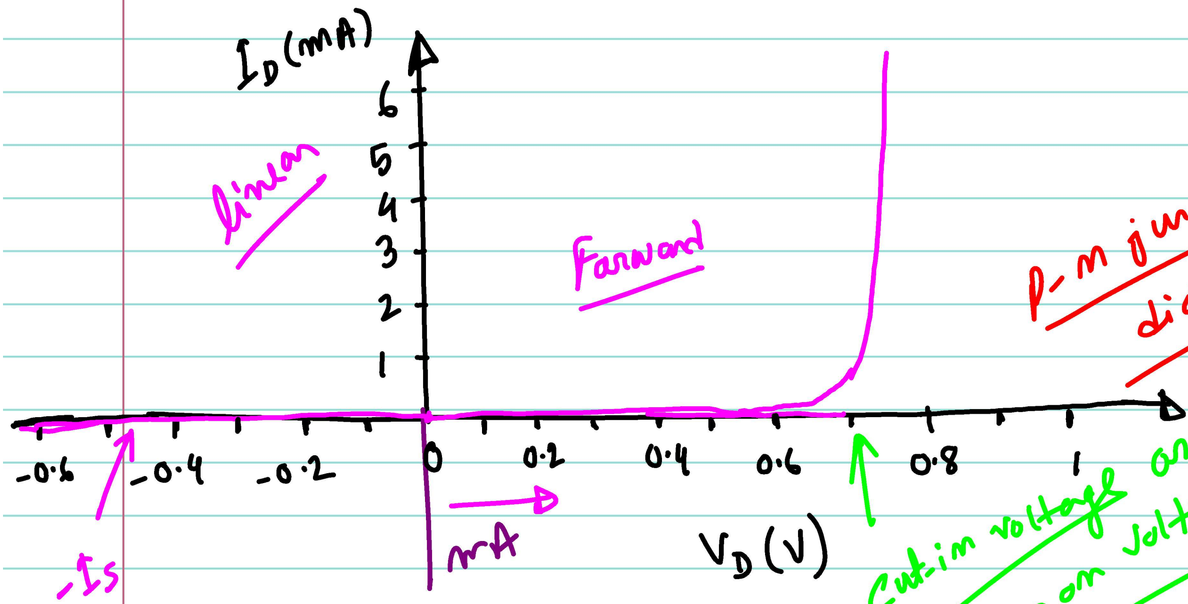
$V_D > 3 V_T$

$V_T = 0.026$ V.



$$I_D = I_s \left[\exp\left(\frac{V_D}{V_T} \right) \right]$$

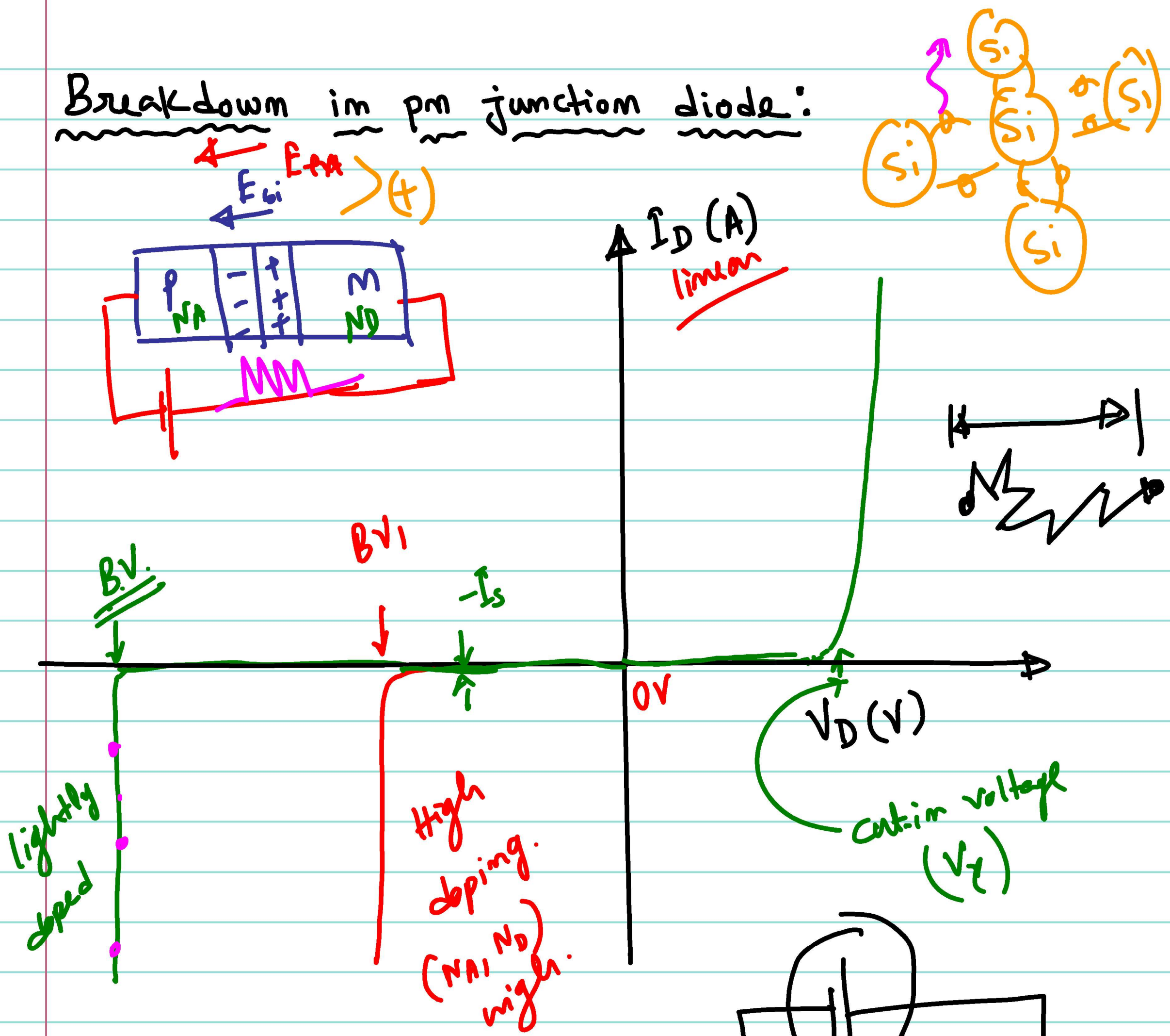
increase V_D by 60 mV, I_D increase by 10 times

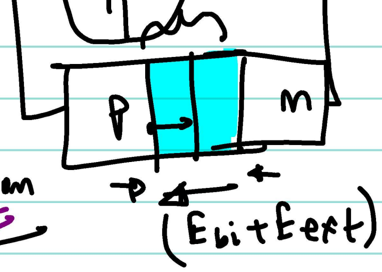


p-n junction diode

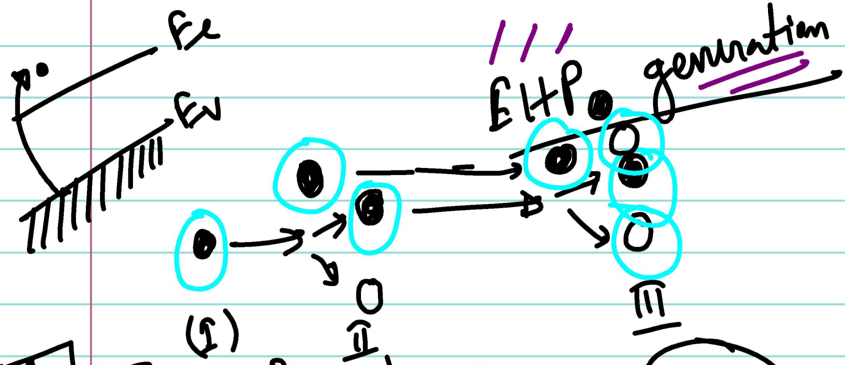
Cut-in voltage or turn on voltage 0.6 V - 0.7 V typically.

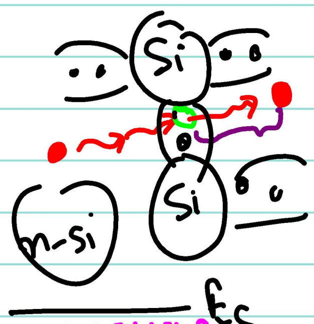
Breakdown in pn junction diode:





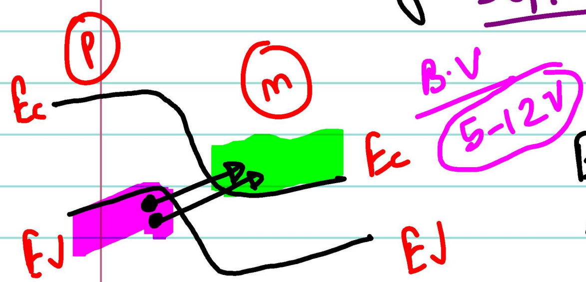
Avalanche Breakdown:

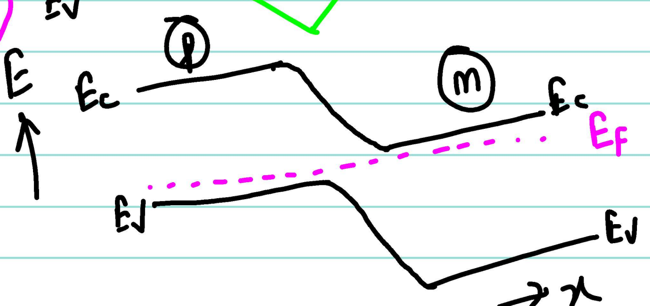




Zener Breakdown:

Tunneling, Doping conc. high.



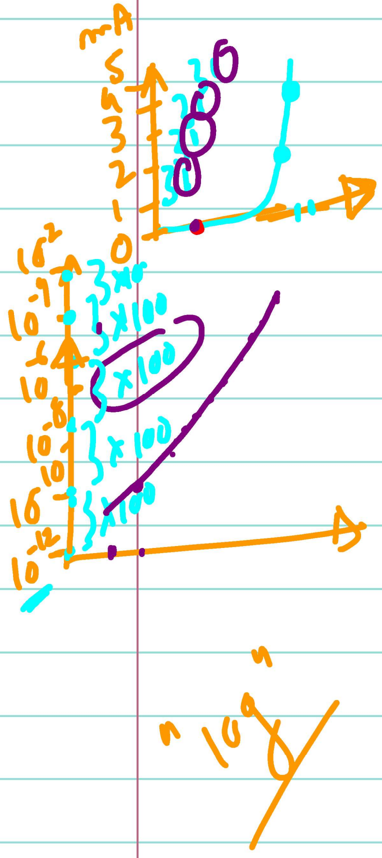


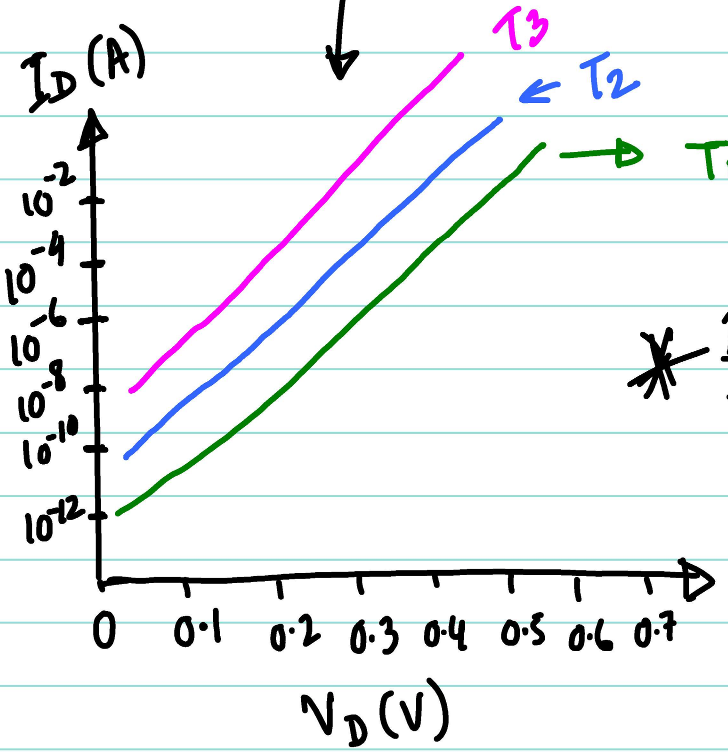
$$I_S = Aq\left(\frac{D_n}{L_n}\frac{n_i^2}{N_A} + \frac{D_p}{L_p}\frac{n_i^2}{N_D}\right)$$

$$n_i = BT^{3/2}\exp\left(-\frac{E_g}{2kT}\right)$$

Effect of temperature:

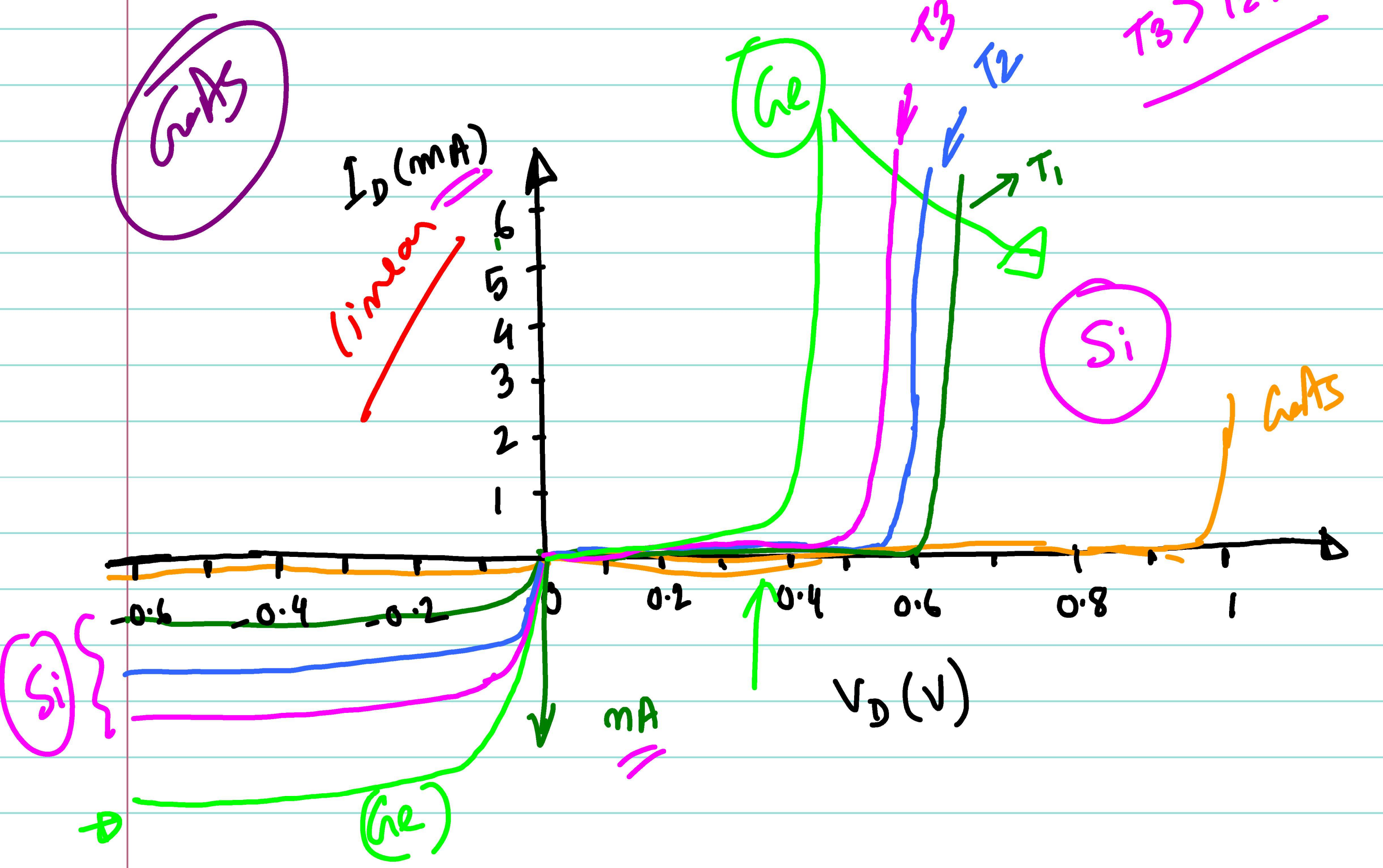
$$I_D = I_S\left[\exp\left(\frac{V_D}{V_T}\right) - 1\right]$$

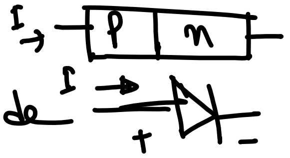




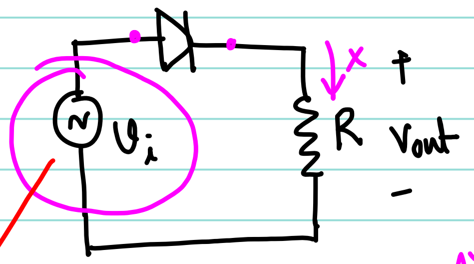
$T_3 > T_2 > T_1$

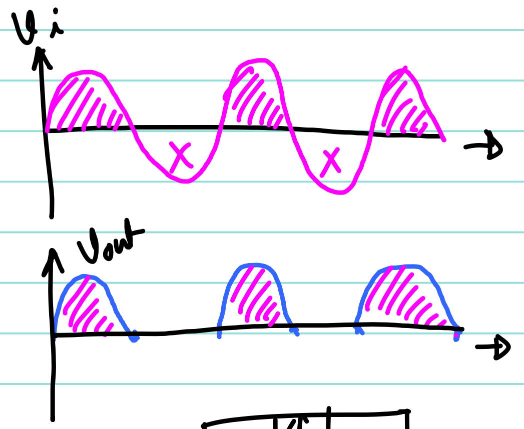
* I_S doubles for every 10°c rise in Temp.

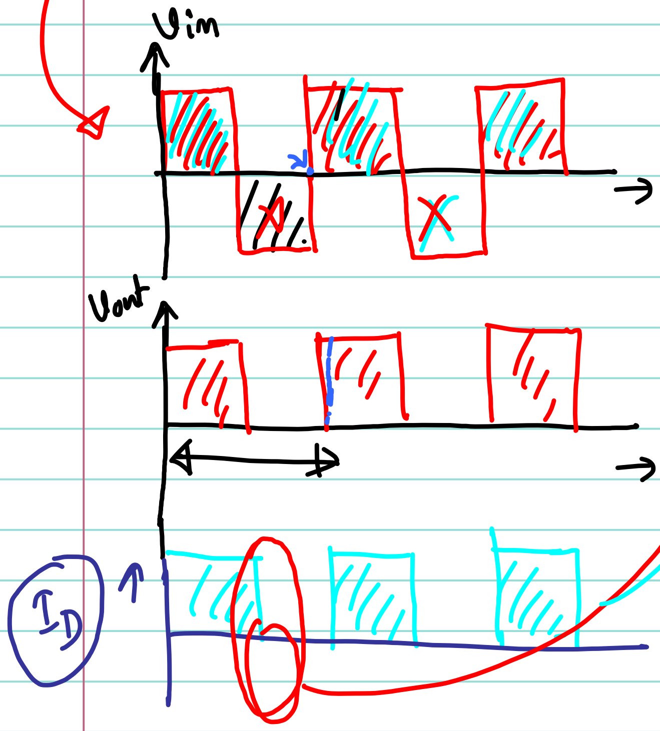


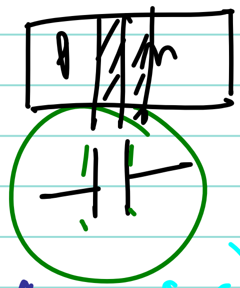


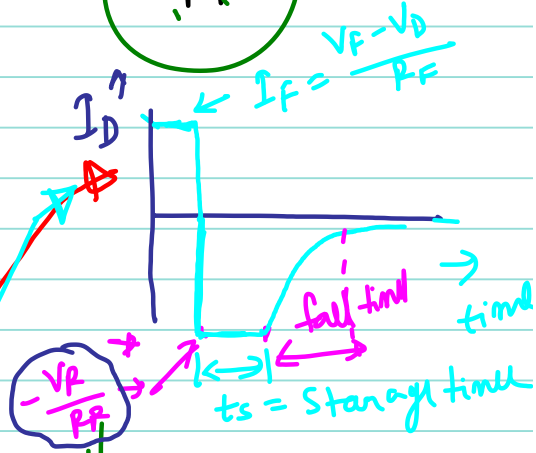
p-n junction diode — ckt. symbol.

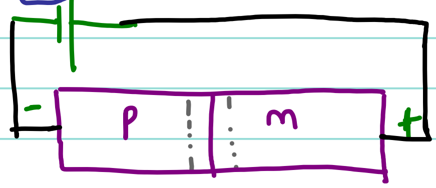


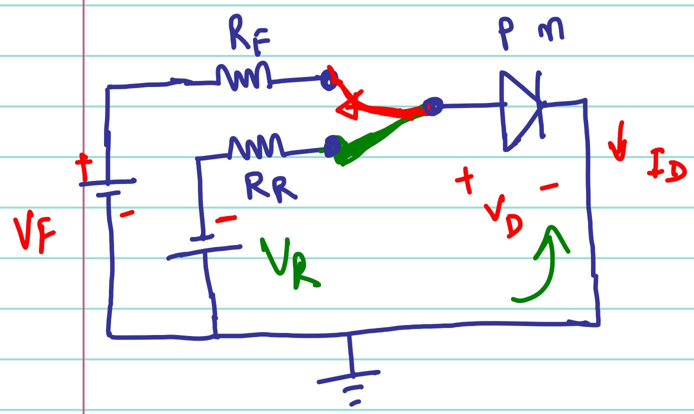


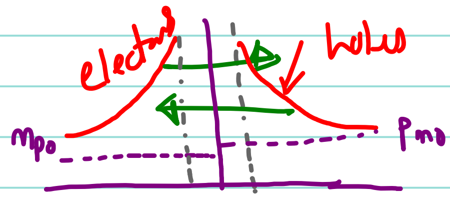










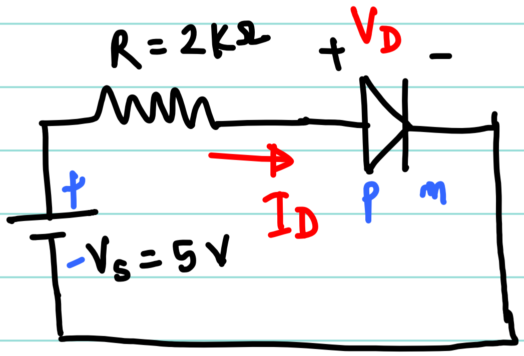


$$\rightarrow I_D = \frac{V_F - V_D}{R_F} \rightarrow I_D \simeq -\frac{V_R}{R_R}$$

Lec-6

Diode circuits: DC Analysis

(i) By Iteration



$V_s = I_D \cdot R + V_D$

$I_D = I_s\left[\exp\left(\frac{V_D}{V_T}\right) - 1\right]$

$V_s = I_s\left[\exp\left(\frac{V_D}{V_T}\right) - 1\right] R + V_D$

$I_s = 10^{-13}$ A (say)

$$5 = 10^{-13} \times 2\times10^{3} \times \left[\exp\left(\frac{V_D}{0.026}\right) - 1\right] + V_D$$

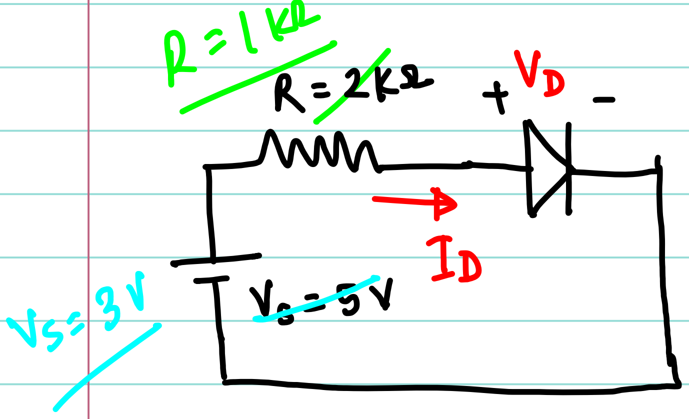
→ $V_D = 0.60\,V$ → $217\,V$

→ $V_D = 0.65\,V$ → $15.1\,V$

$V_D = 0.619\,V$

$I_D = \frac{5 - 0.619}{2\times10^{3}}$ A

(ii) Graphical Technique

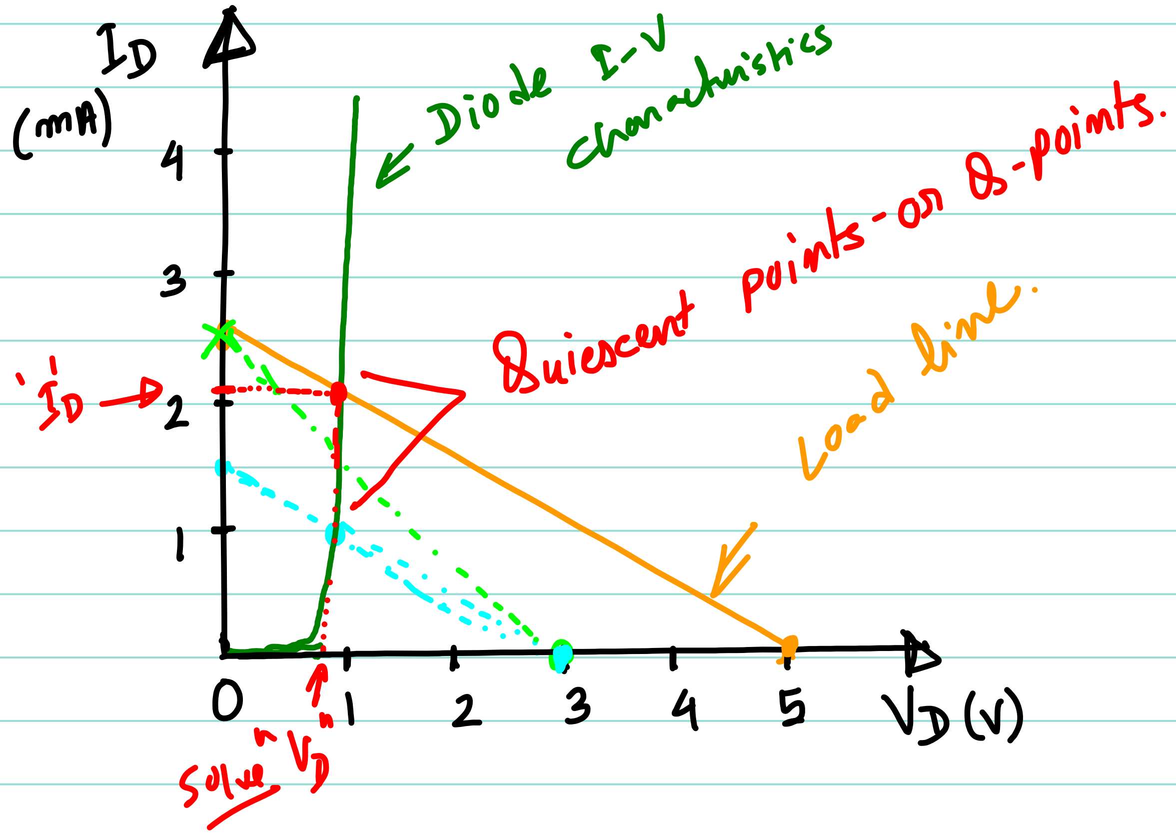


$$V_S = I_D R + V_D$$

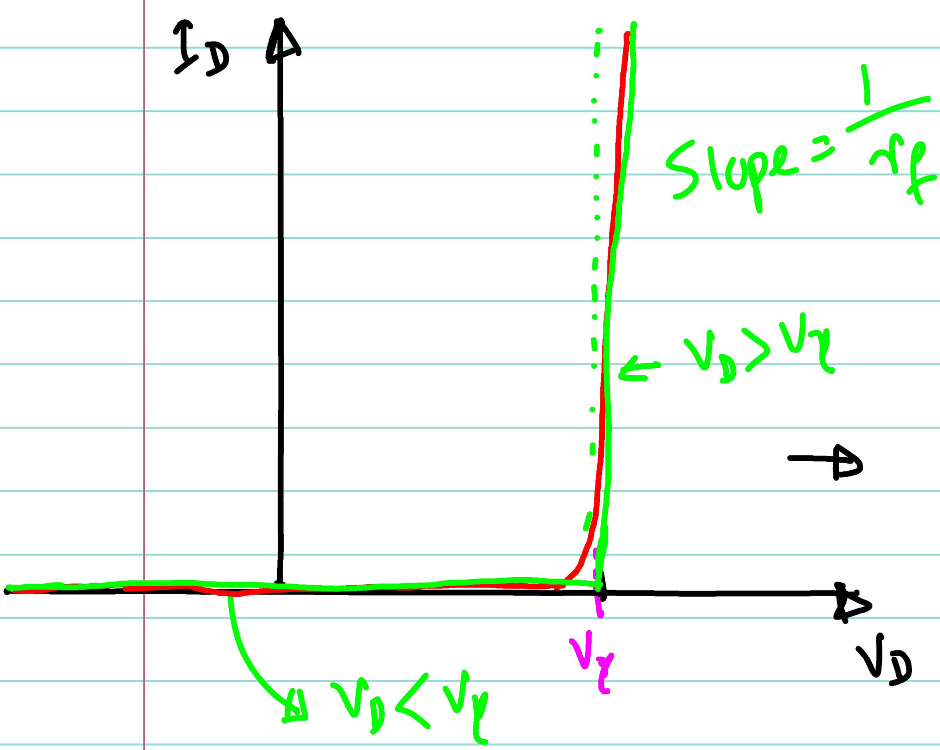
$$I_D = \frac{V_S}{R} - \frac{V_D}{R}$$

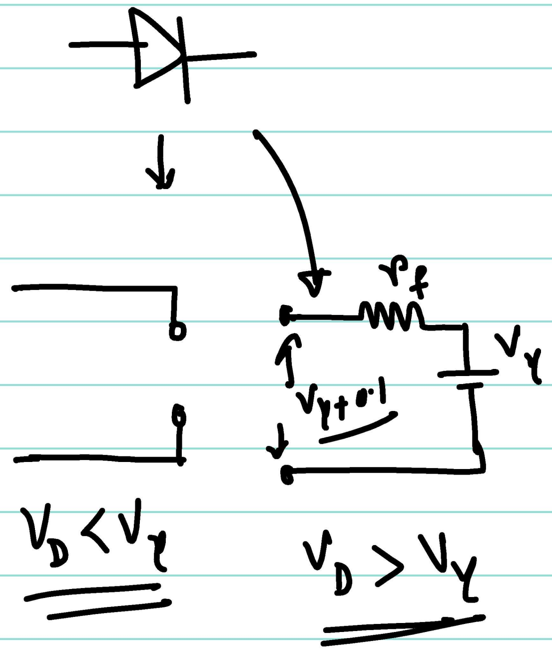
$I_D = 0$, $V_D = V_S = 5V.$

$V_D = 0$, $I_D = 2.5\ mA$

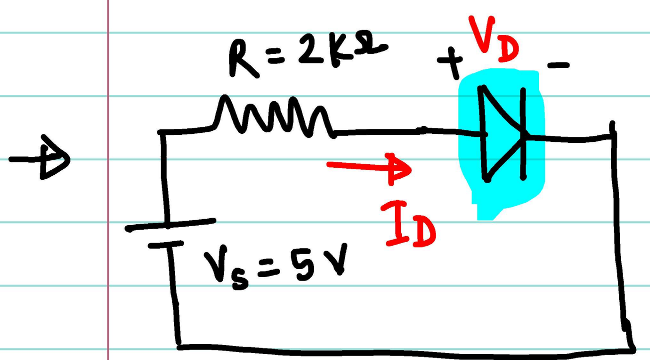


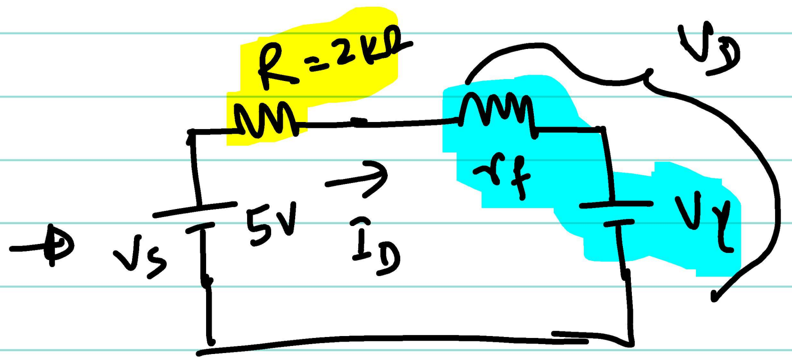
(iii) By using Piecewise Linear Model





Equivalent ckt.





$V_\gamma = 0.6V$, $r_f = 10\,\Omega$

$$I_D = \frac{5 - 0.6}{2K\Omega + 10\Omega}$$

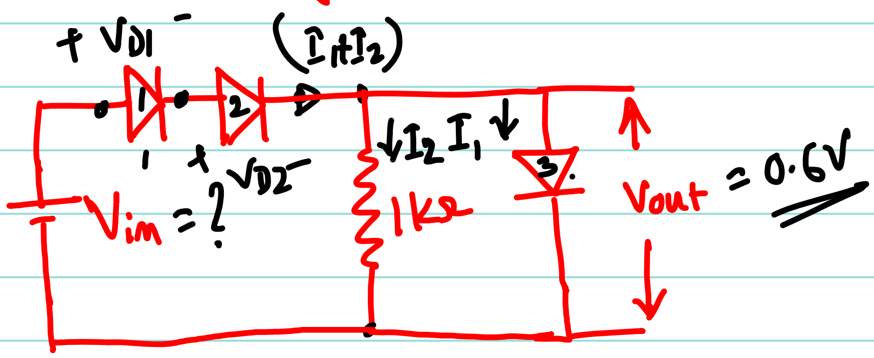
$$= 2.19 \text{ mA.}$$

$$V_D = 0.6 + I_D r_f = 0.6 + 2.19 \times 10^{-3} \times 10$$

$$= 0.622 \text{ V}$$

Diode circuit : Example-1

For each diode reverse-saturation current (I_S) is 2×10^{-13} A. Find out the input voltage (V_{in}) such that output voltage (V_{out}) becomes 0.6 V.



$V_D > 3V_T$

(-1) term can be neglected.

$I_s = 2\times10^{-13}$ A. ; $V_{out} = 0.6$ V

$$I_1 = I_s \exp\left(\frac{0.6}{0.026}\right) = 2.105 \text{ mA}$$

$$I_2 = \frac{0.6}{1\,k\Omega} = 0.6 \text{ mA}$$

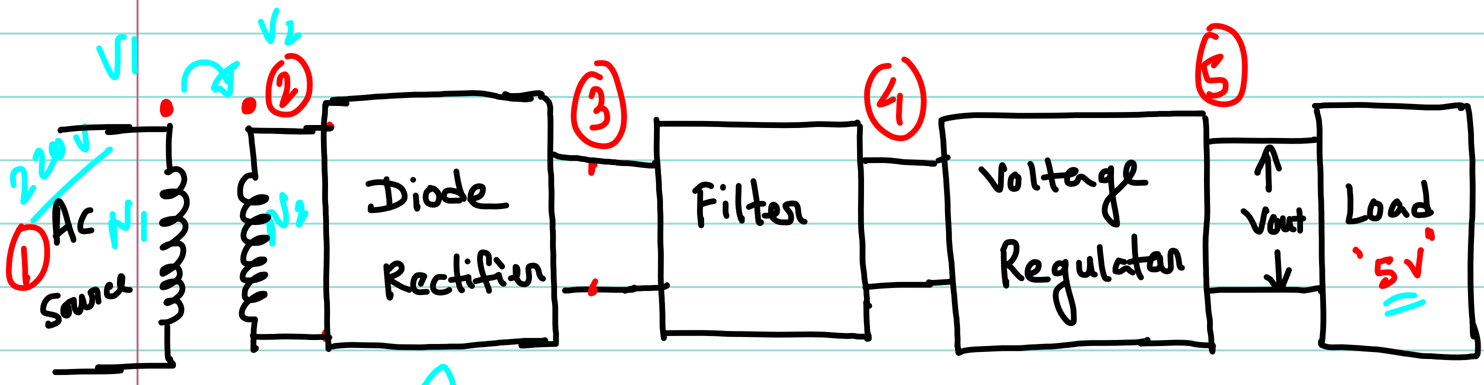
$(I_1 + I_2)$ is flowing through the diode 1 and 2

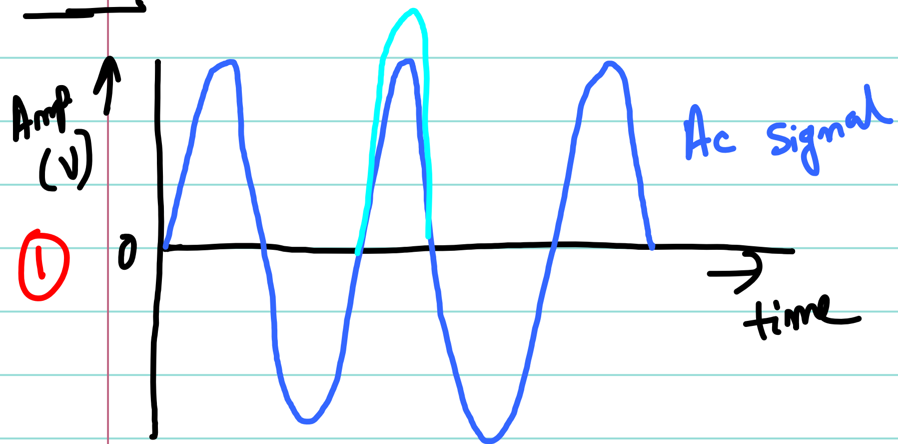
$= 2.705$ mA

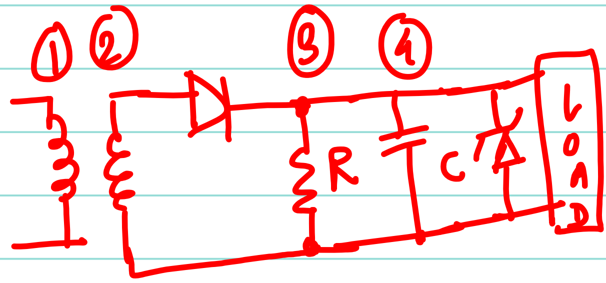
$$V_{D1} = V_{D2} = V_T \ln\left(\frac{I_1+I_2}{I_s}\right) = 0.6065 \text{ V.}$$

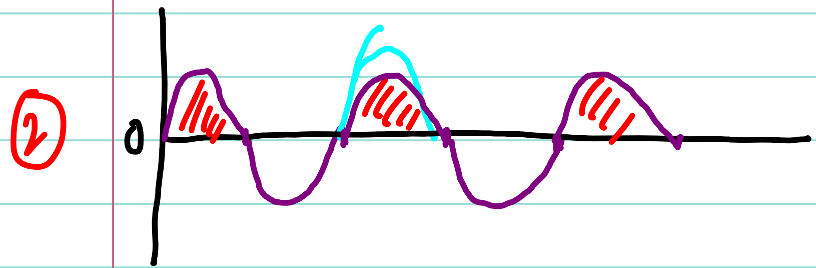
$$V_{in} = V_{D1} + V_{D2} + V_{out} = 1.81 \text{ V.}$$

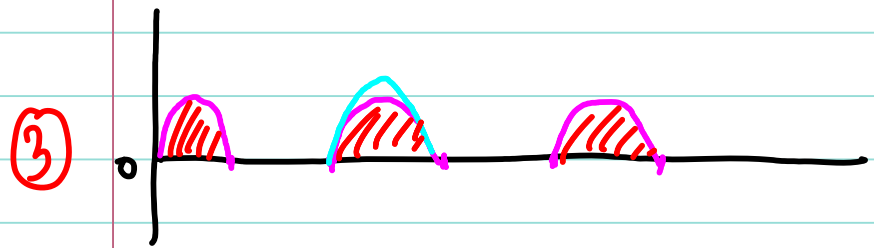
Rectifier circuits:

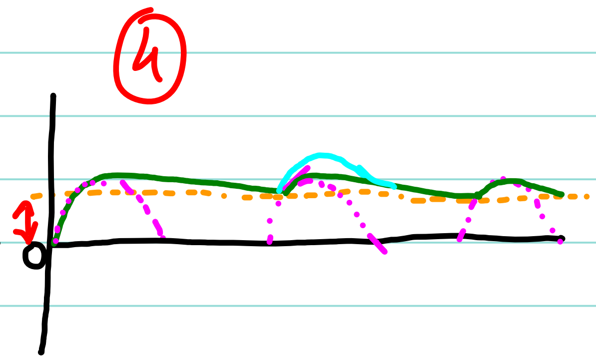




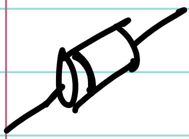


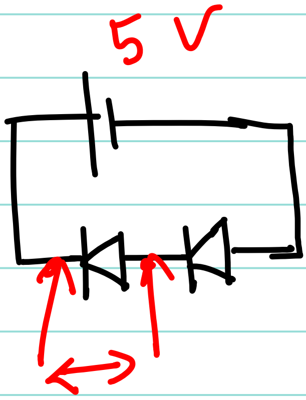


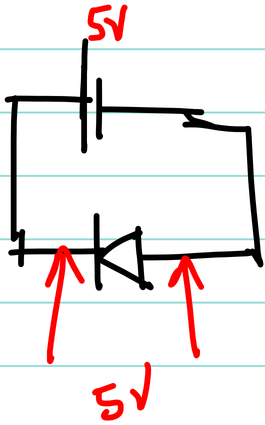




Question







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