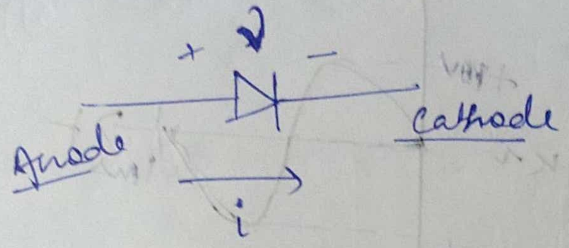
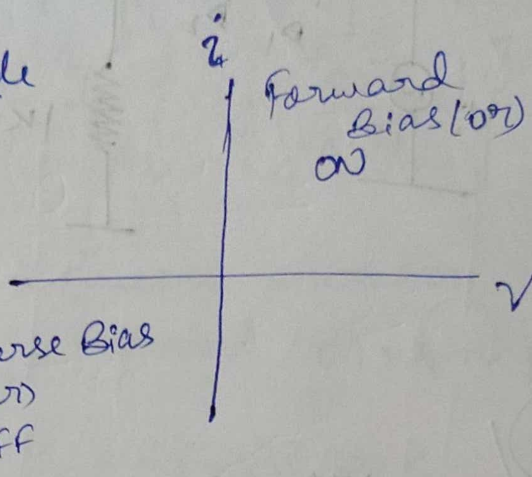
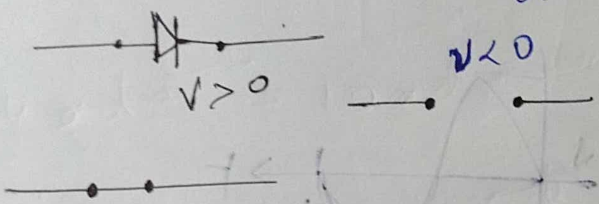
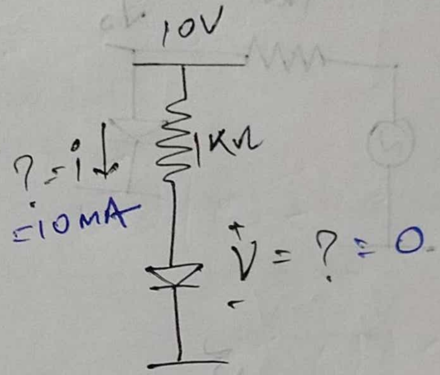
-: Diode circuit :-

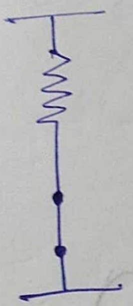


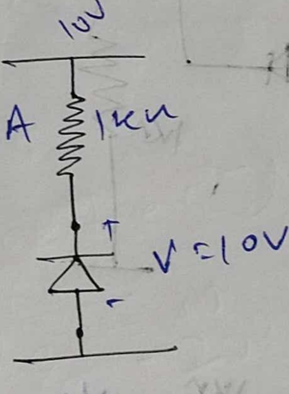
The concept of Ideal diode

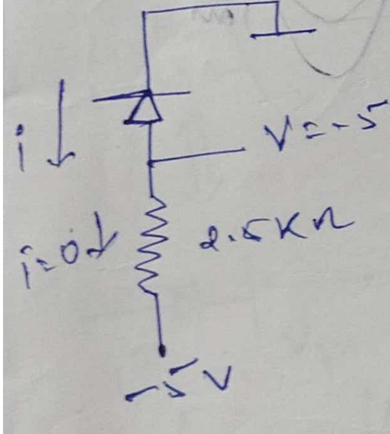


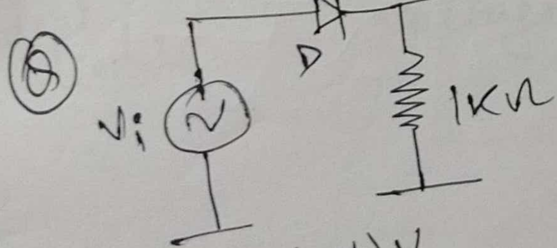


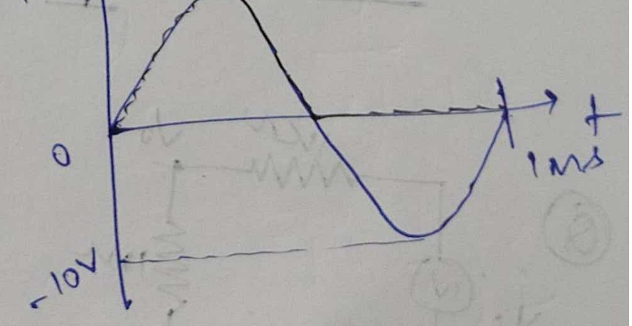










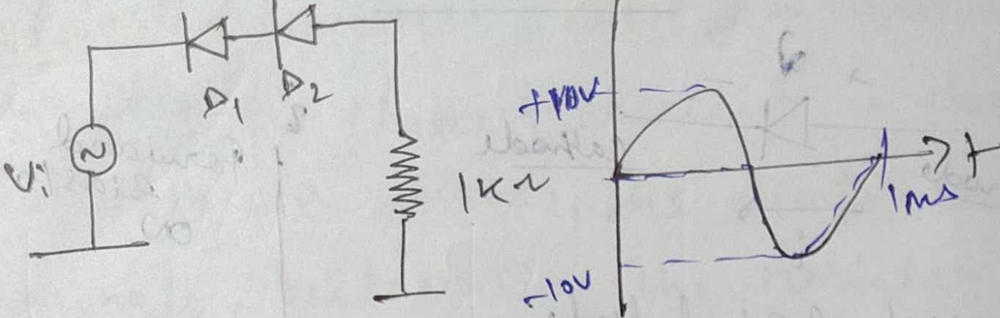


$V_i = 10\sin(\omega t)$ V

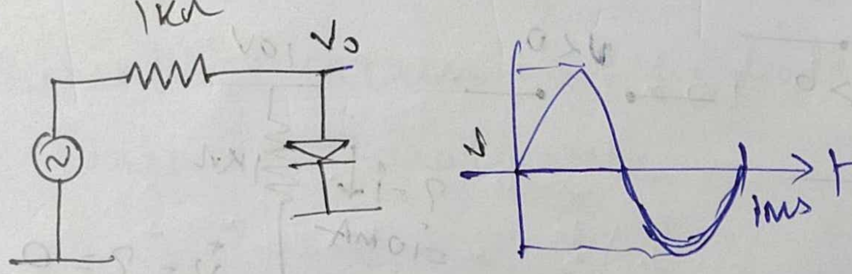
$f = 1$ kHz

$f = 2\pi\omega$

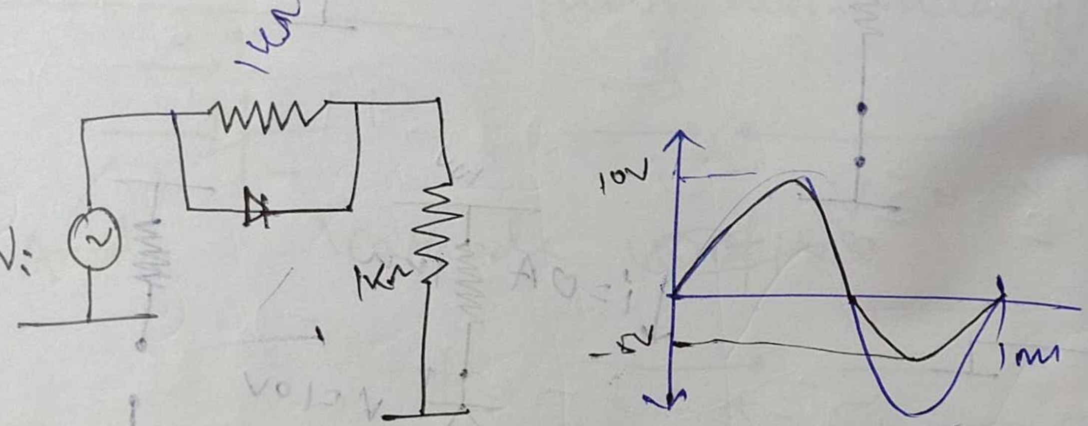
Q

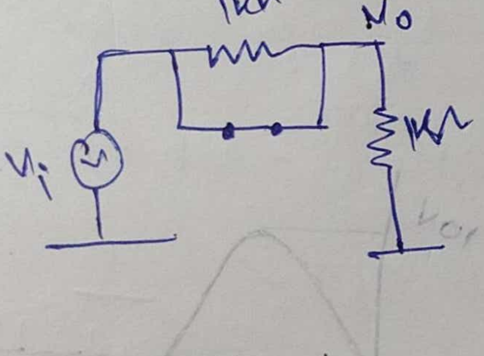

D1
D2
Vi
1kΩ
+10V
-10V
t
1ms

Q

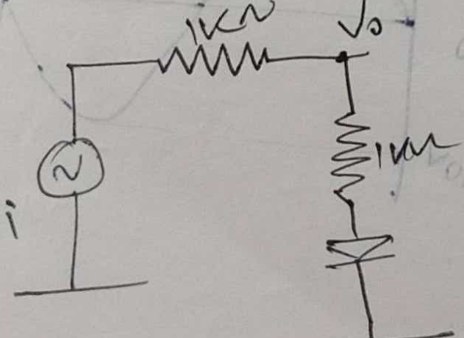

1kΩ
Vo
V
t
1ms

Q


1kΩ
Vi
1kΩ
10V
-5V
1ms


1kΩ
Vo
1kΩ
Vi

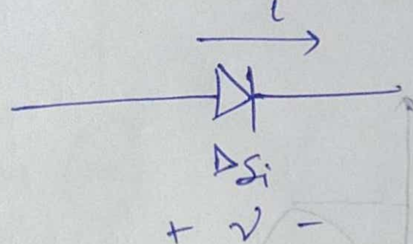
Q


1kΩ
Vo
1kΩ
Vi

Real diode is Extension of Ideal diode –

$$= I_s\left[e^{v/KT} - 1\right]$$

$$i = I_s\left[\exp\left(\frac{qv}{KT}\right) - 1\right]$$

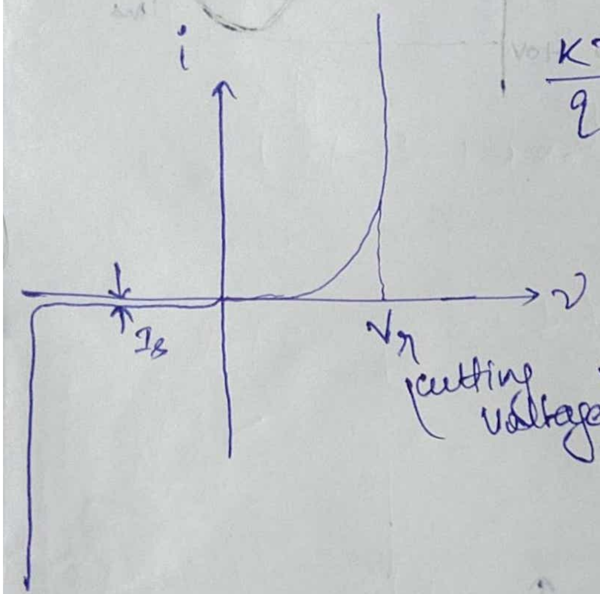


D_{Si} - Silicon Diode

$I_s \to$ Reverse saturation current 0.1 nA ~ pA

$$\frac{KT}{q} = V_T = 26\,mV @ 300^\circ K$$

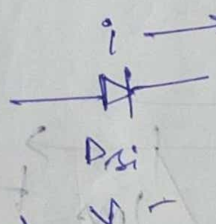
↑ thermal voltage



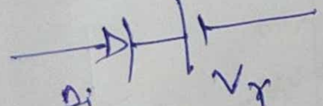
$$\boxed{i = I_s e^{v/V_T}} \quad v \geq V_T$$

$v < 0$

$$i = I_s\left[e^{v/V_T} - 1\right]$$



⇕

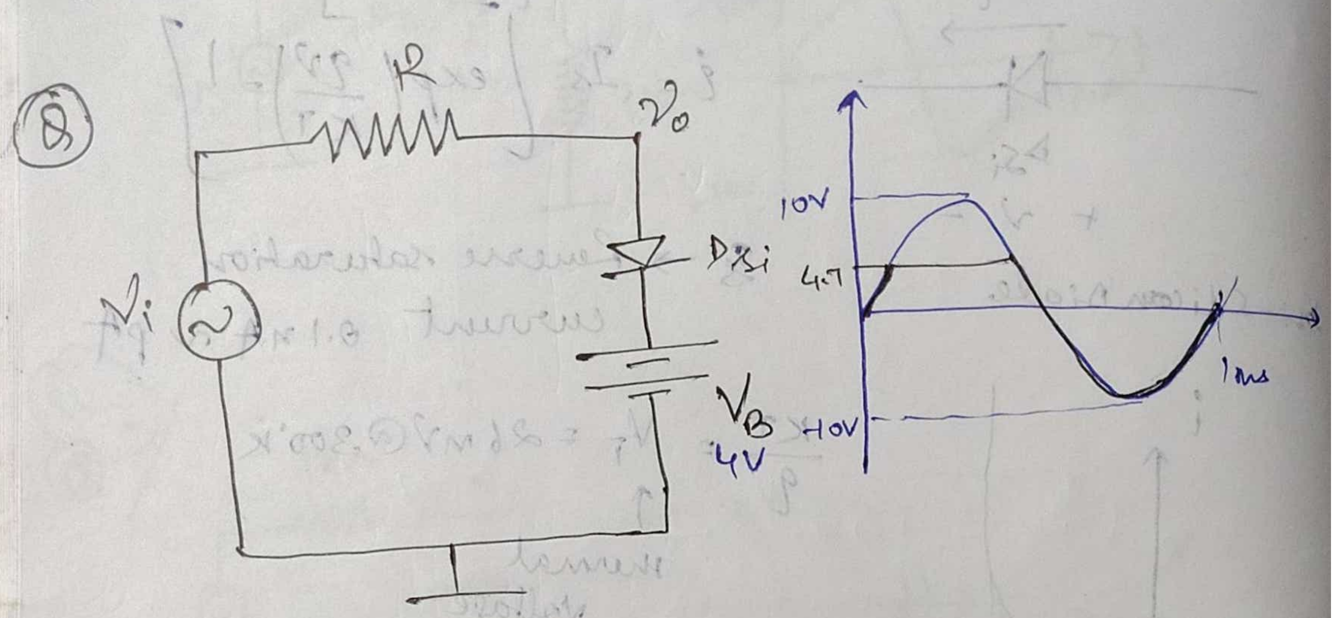


ideal diode

(with opposing voltage)

Clippers

Q

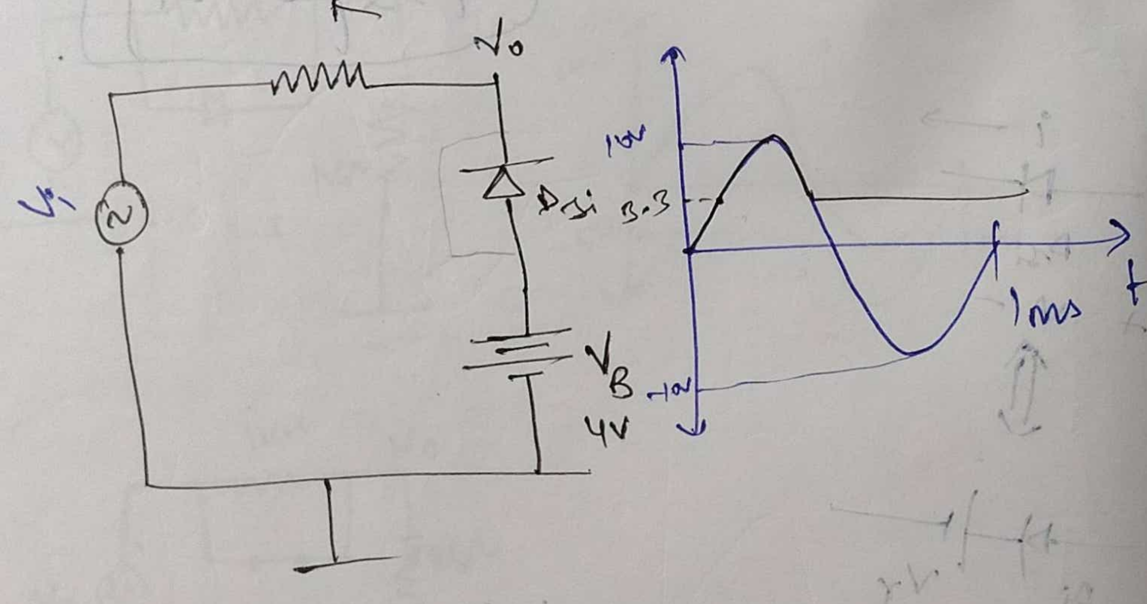


$V_A \sin(\omega t)$

$V_A > V_B$

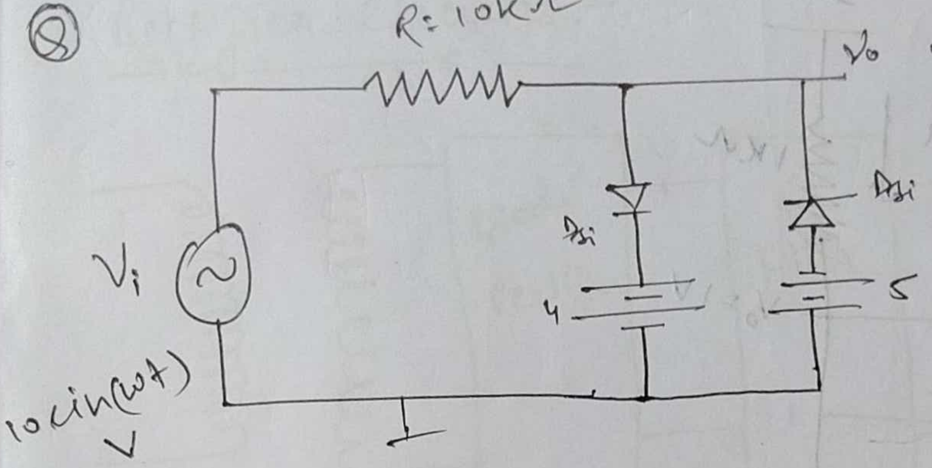
$10 > 4$

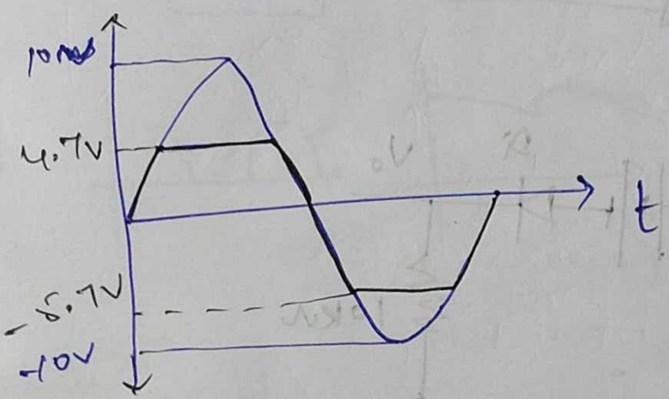
Q



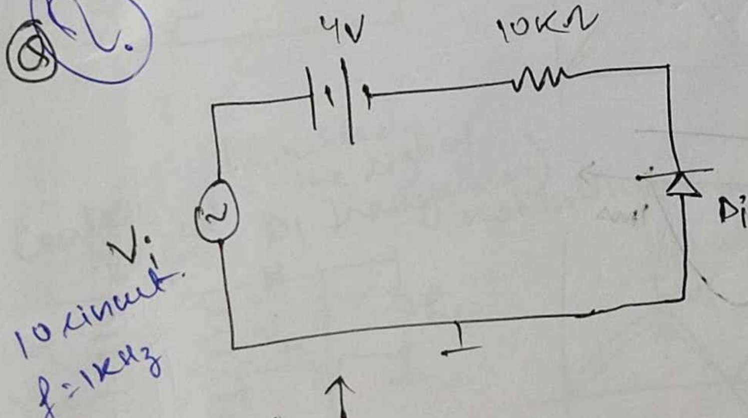
(Q)

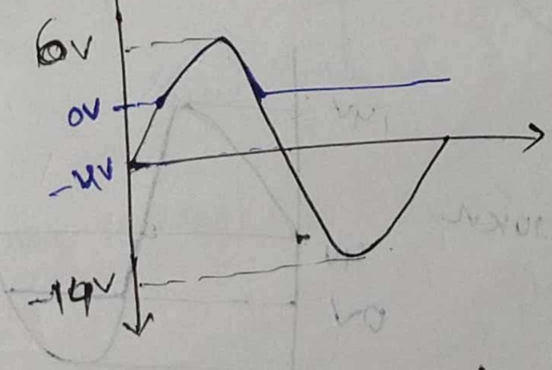
• Parallel Clipper



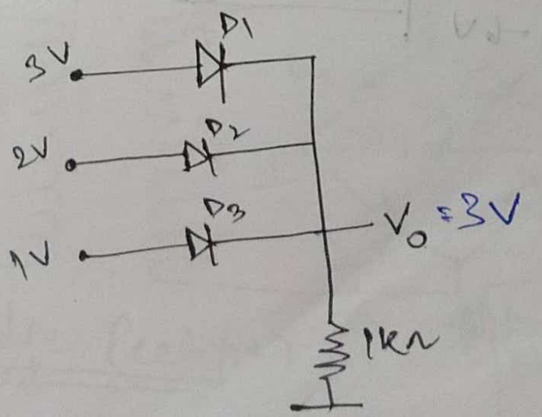


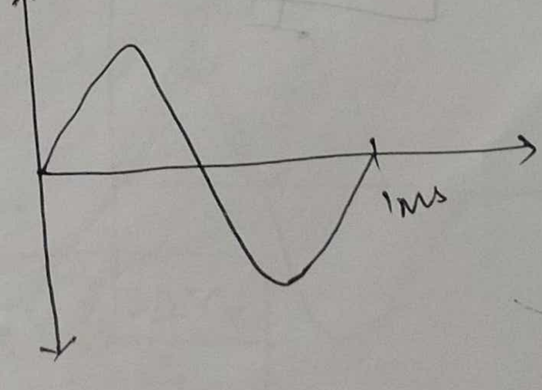
(Q) (2.)



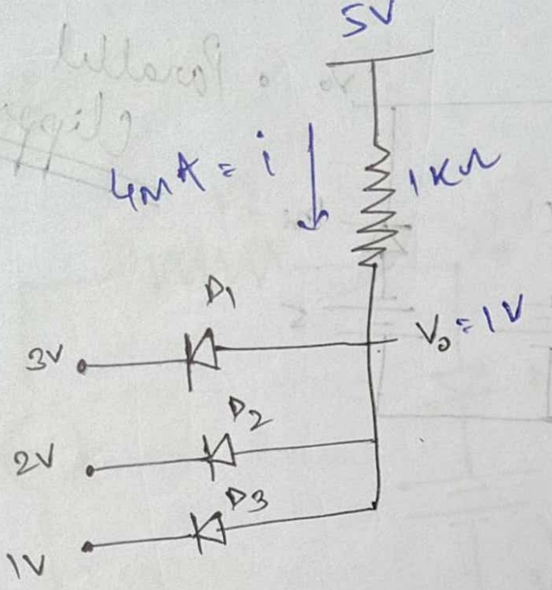


(Q)

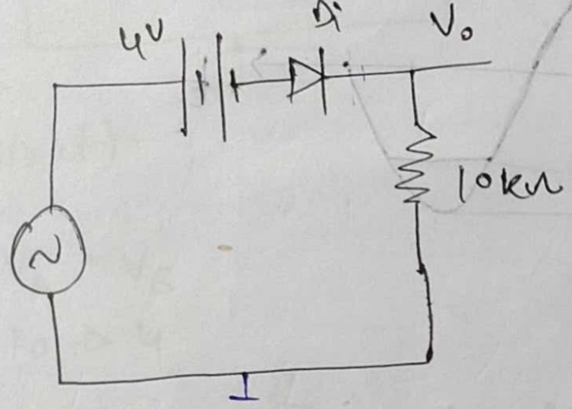


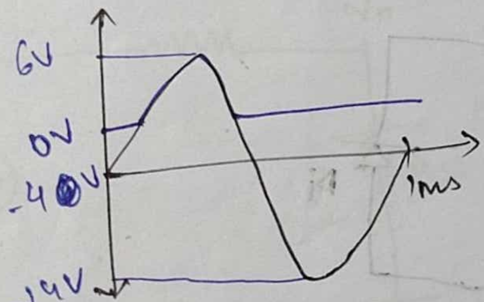


Q

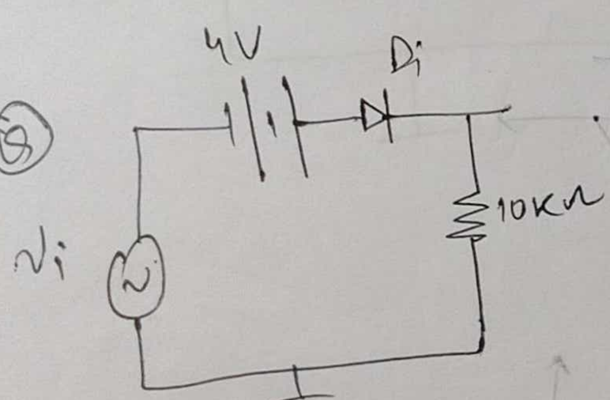

5V
4mA = i
1KΩ
D1
D2
D3
3V
2V
1V
Vo = 1V

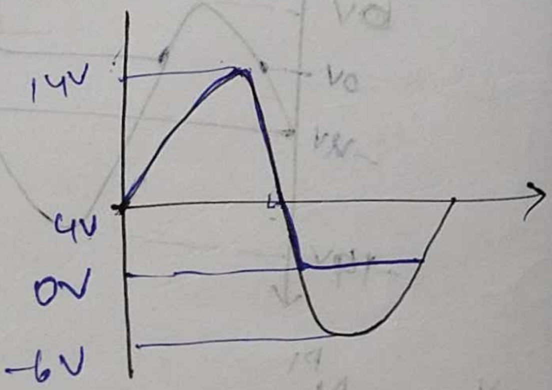
Q


4V
Di
Vo
10KΩ

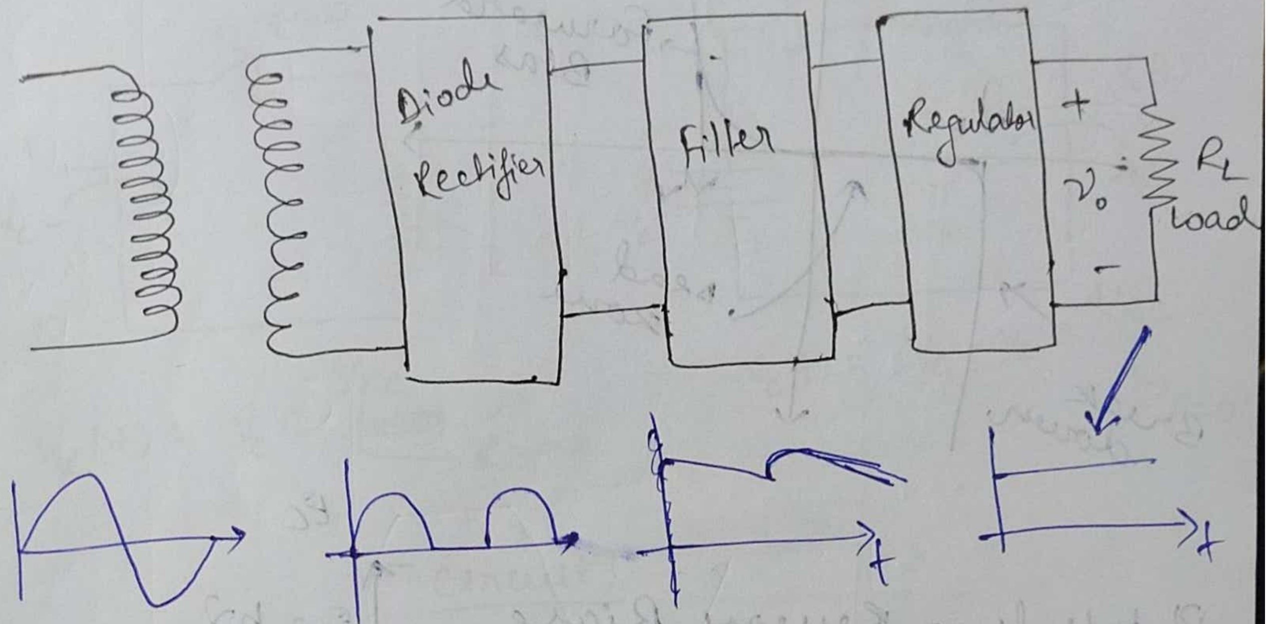

6V
0V
-4V
1ms
-14V

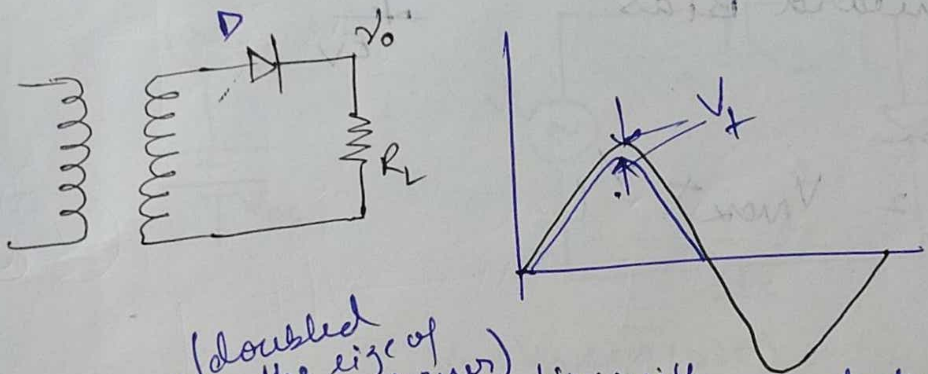
Q


4V
Di
10KΩ
vi

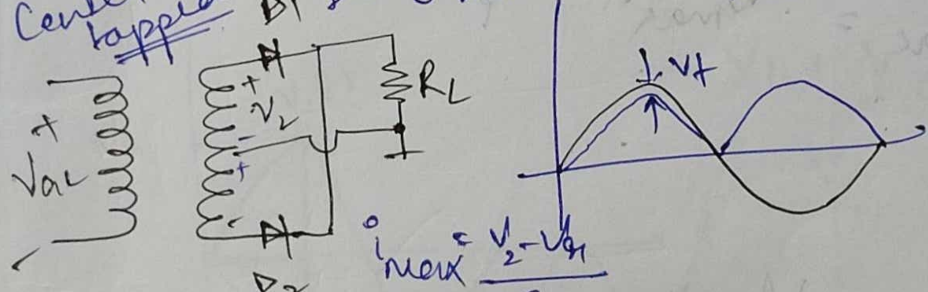

14V
4V
0V
-6V

Rectifier Circuits :-





Center tapped (doubled the size of the transformer) not in line with microelectronics.

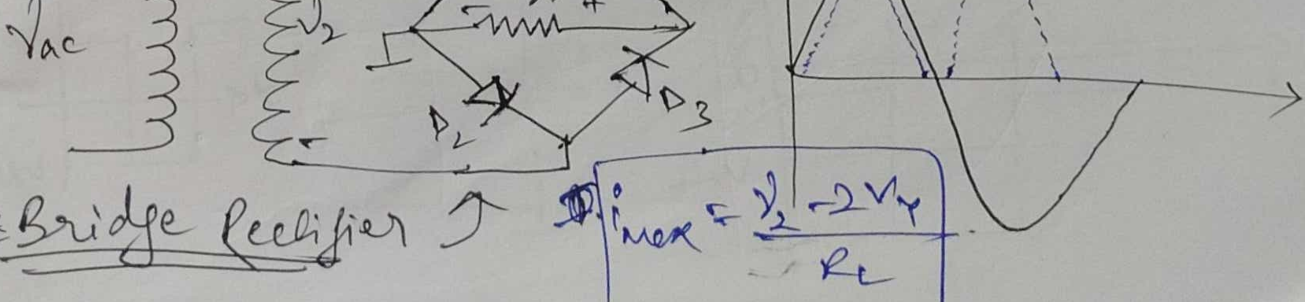


$i_{max} = \frac{V_2 - V_{\gamma}}{R}$

*Peak inverse voltage - PIV => $2V_2 - V_\gamma$

PIV = $V_{peak} - V_\gamma$

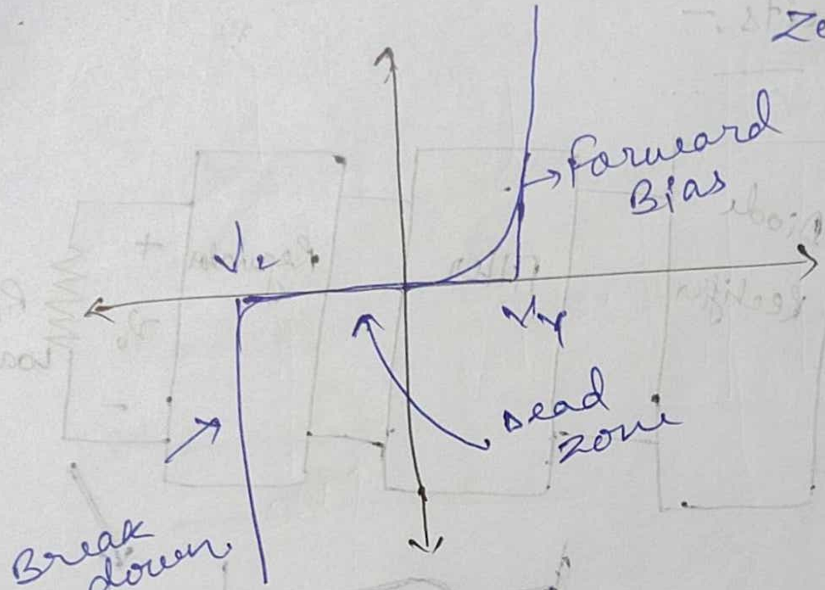
*

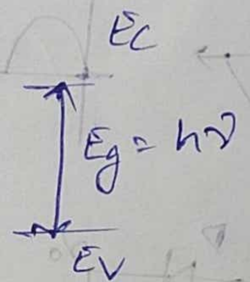


$\boxed{i_{max} = \frac{V_2 - 2V_\gamma}{R_L}}$

*Bridge Rectifier

Zener diode has - 3 ~~stage~~ states



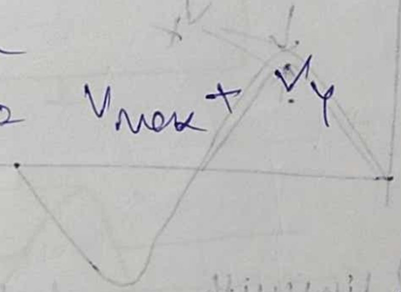


Photodiode - Reverse Biase

LED - Forward Bias

centertap

$V_{peak} = V_{max} + V_\gamma$

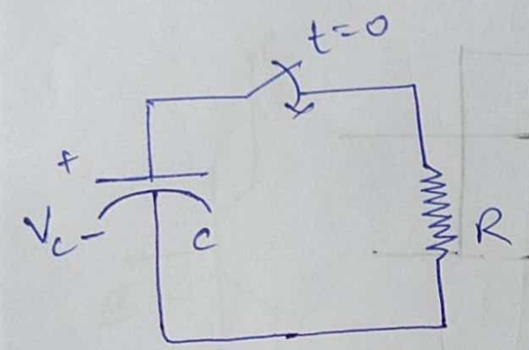


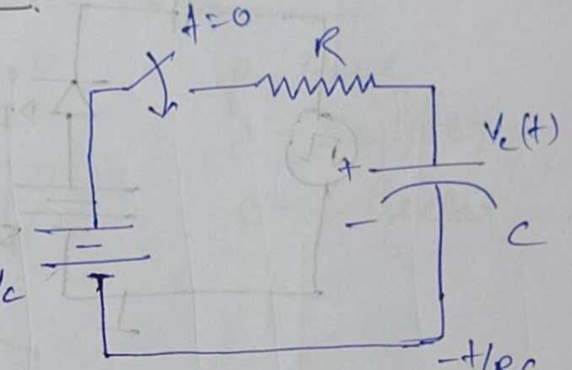
Bridged

$V_{peak} = V_{max} + 2V_\gamma$

$V_{R(max)} = V_S + V_B$

* Clampers *

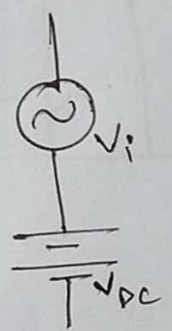


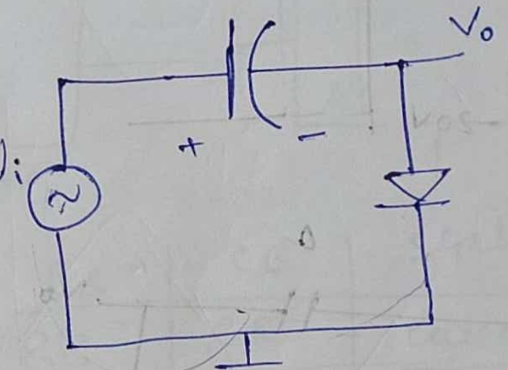


$V_R(t) = V_C e^{-t/RC}$ → $R = \infty$

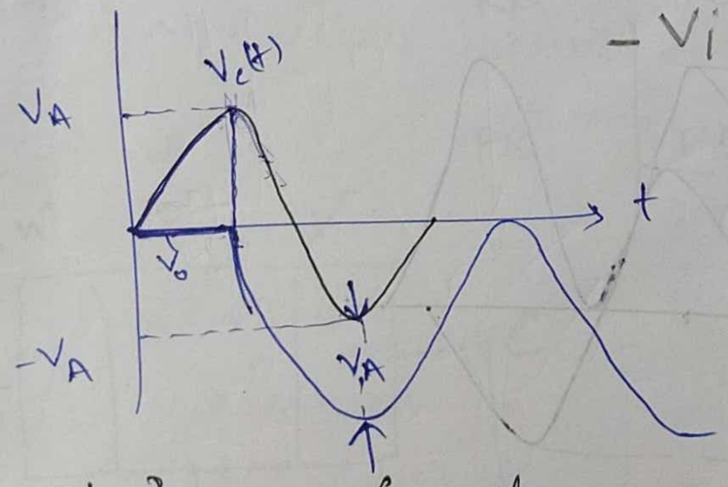
$V_C(t) = V_C - V_C e^{-t/RC}$ → $R = 0$

Circuit 1





$V_i = V_A \sin(\omega t)$

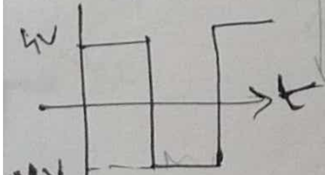


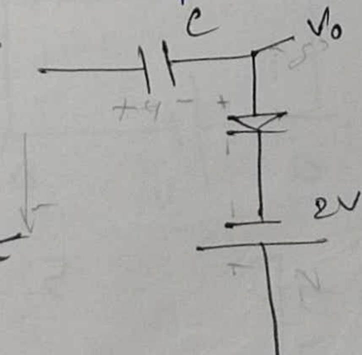
$-V_i + V_C$

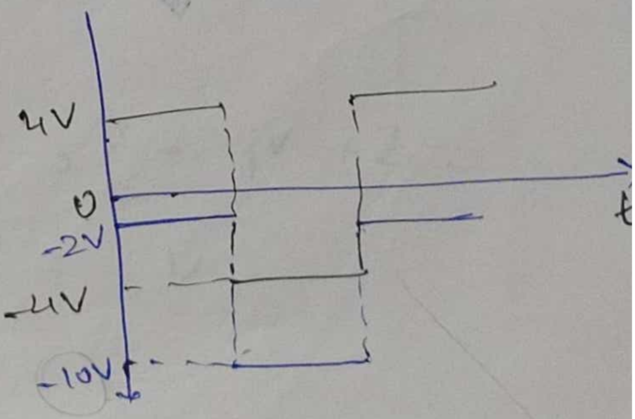
$V_{C_0} = V_i$

Circuit-2

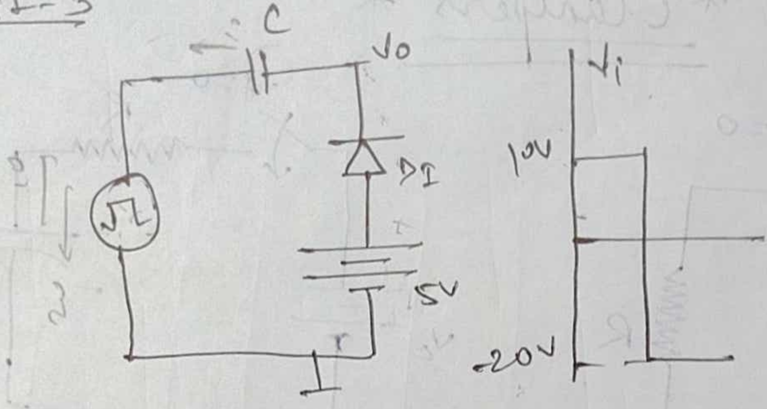
$V_{pp} = 8V$

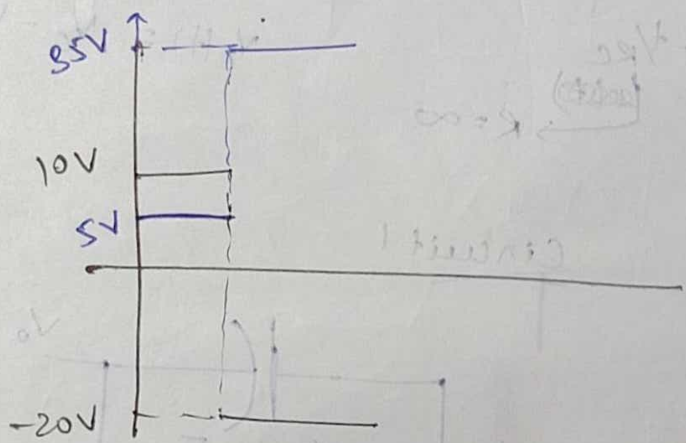




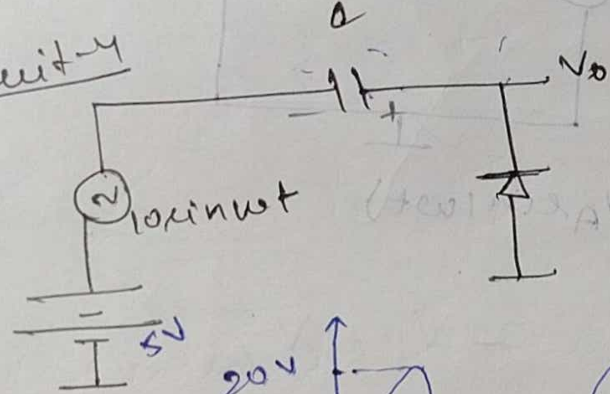


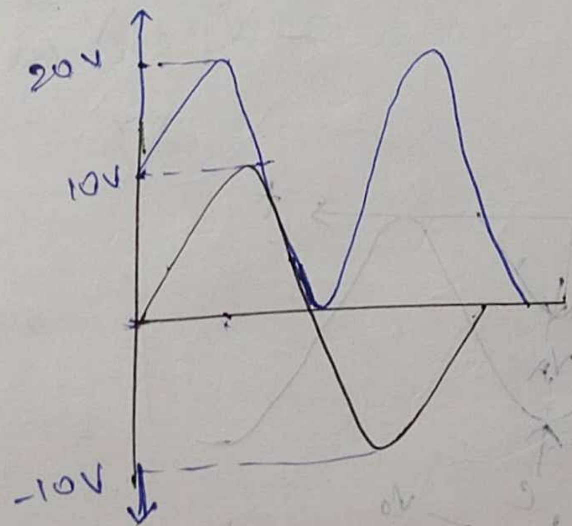
Circuit-3





Circuit-4

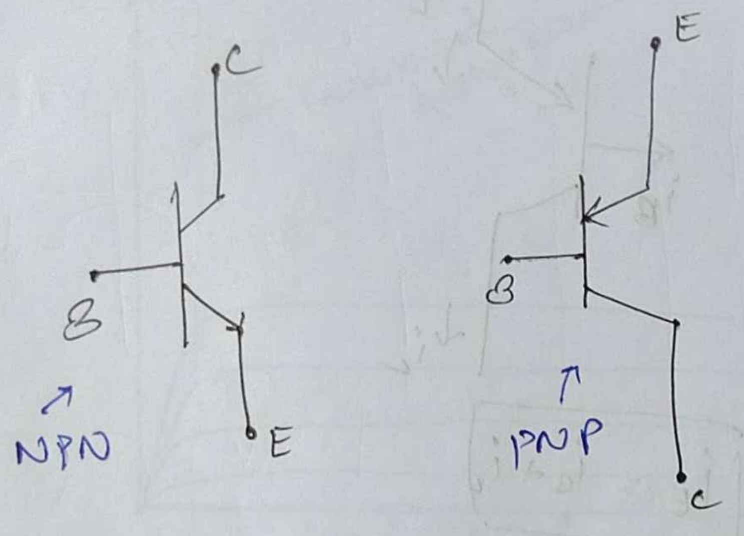




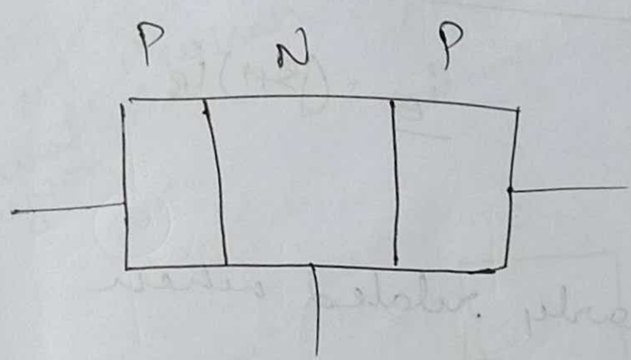
$$-5 + V_i - V_c = 0$$

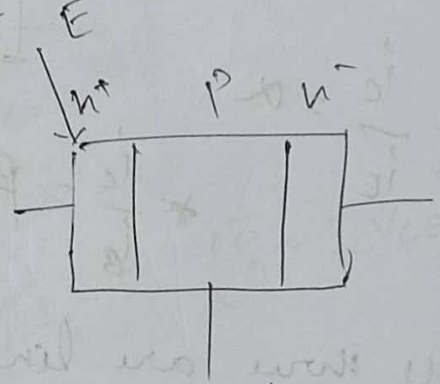
$$V_c = V_i - 5 = 5$$

* Bipolar Junction Transistors (BJTs)



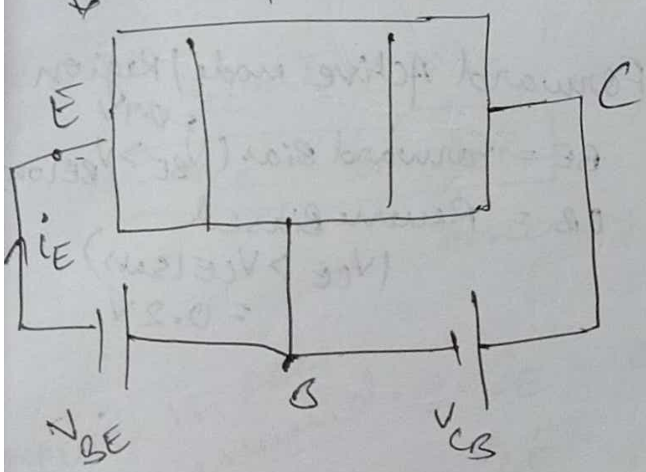
B - Base
E - Emitter
C - Collector.

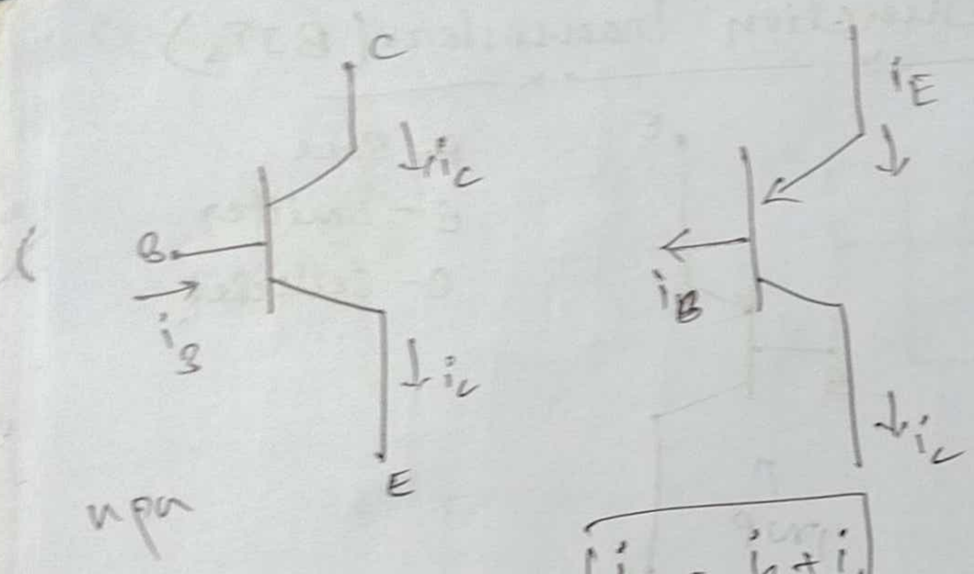




$$i_E = I_{EO} \exp\left(\frac{V_{BE}}{V_T}\right)$$

EB	CB	State
RB	RB	cuttoff
FB	RB	Forward active region / mode
RB	FB	Reverse active Region / mode
FB	FB	Saturation Region





$$\boxed{i_E = i_B + i_C}$$

* $\frac{i_C}{i_E} = \alpha$

* $\frac{i_C}{i_B} = \beta$

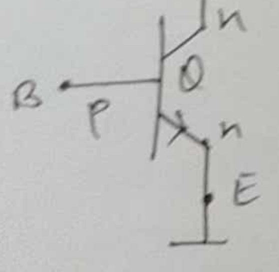
$i_E = (\beta+1)\, i_B$

All these are linearly related when device in FB.

$\alpha = \frac{\beta}{\beta+1}$, $\beta = \frac{\alpha}{1-\alpha}$

We can make faster device using npn BJT than pnp BJT

∴ BJT Characteristics :-



Grounded Emitter

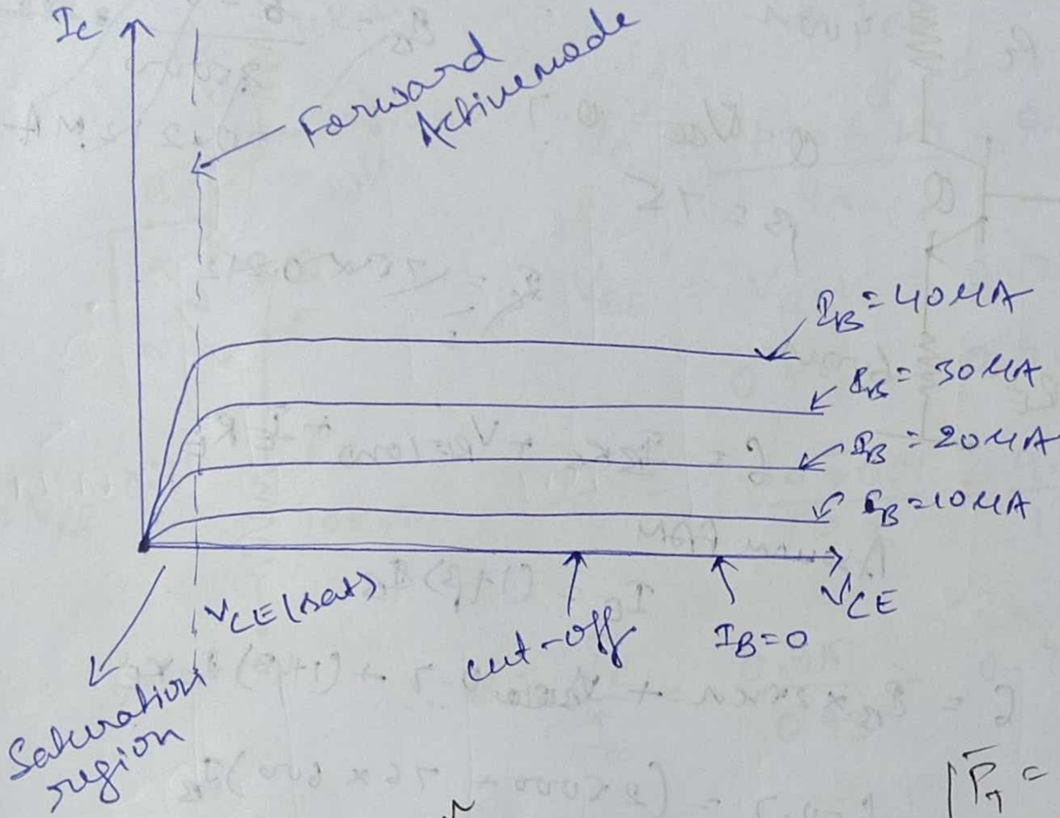
$V_{BE} > V_{BE(on)} = 0.7V$

Forward Active mode / Region

BE = Forward Bias ($V_{BE} > V_{BE(on)}$) $\approx 0.7V$

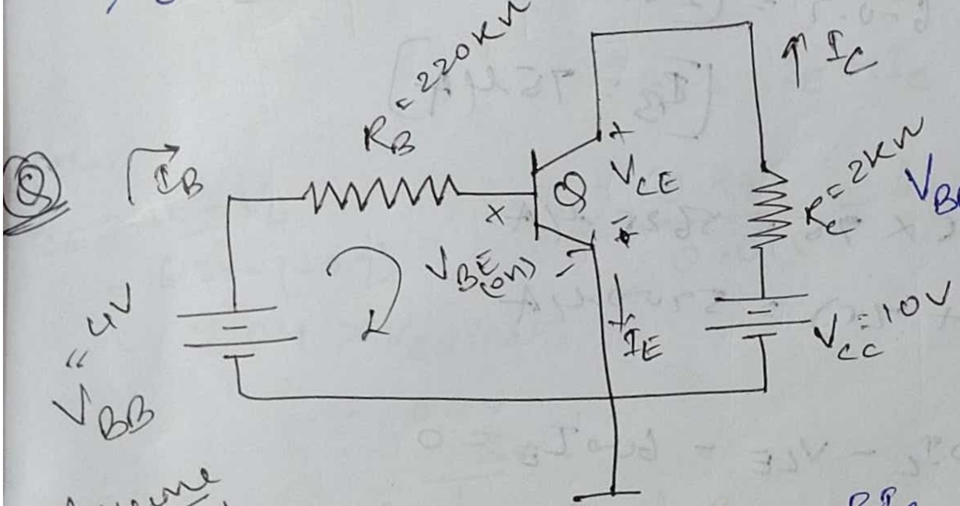
CB = Reverse Biased ($V_{CE} > V_{CE(sat)}$) $= 0.2V$

— : output characteristics :—



$$\left[P_T = I_C V_{CE}\right]$$

Q



$V_{BB} = I_B R_B + V_{BE(on)}$

Assume FAM

$$I_B = \frac{V_{BB} - V_{BE(on)}}{R_B} \qquad I_C = \beta I_B \qquad I_E = I_B + I_C$$

Now $V_{CC} = I_C R_C + V_{CE}$

$$\boxed{\therefore V_{CE} = V_{CC} - I_C R_C}$$

Sol^n

$$I_B = \frac{4 - 0.7}{220K} = 15\mu A$$

Assuming FAM

$I_C = 3mA$

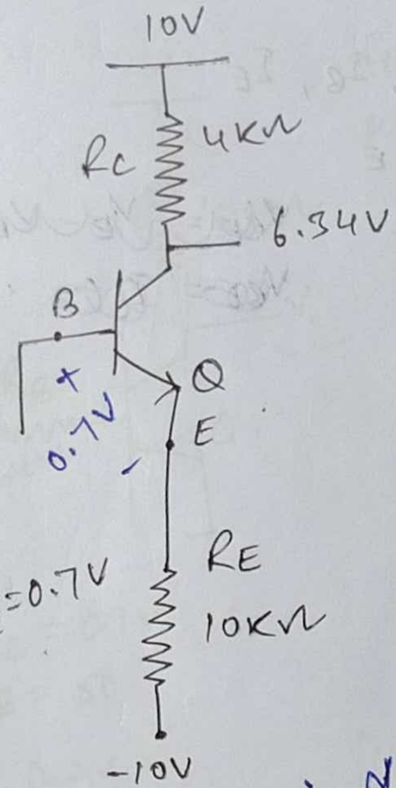
$I_E = 3.015 mA$

$V_{CE} = 10 - 3 \times 2000 \times 10^{-3} = 4V$

$P_T = 12mW$

Device in FAM as assumed.

(8)



Q = $V_{BE} = 0.7V$

Find I_S, I_C, I_E α, β & V_{CE}

$$I_C = \frac{10 - 6.34}{4k} = 0.915 mA$$

$$V_{BE} = V_B - V_E = 0.7V$$

$$0 + V_E = -0.7V$$

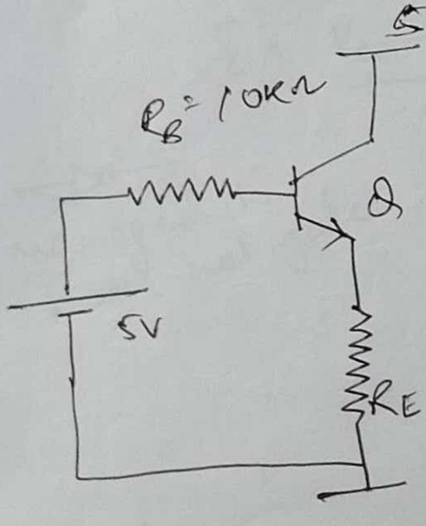
$$I_E = \frac{+10 - 0.7}{10K} = \frac{9.3}{10000} = 0.93 mA$$

$$\therefore \alpha = \frac{I_C}{I_E} = \frac{0.915}{0.93} = 0.98 \text{ Ans}$$

$$I_B = I_E - I_C = 0.93 - 0.915 = 0.015 mA$$

$$\therefore \beta = \frac{0.915}{0.015} = 61$$

Here
$V_{CE} = V_C - V_E$
$= 6.34 - (-0.7)$
$= 7.04 > V_{CE(sat)}$
$= 0.2V$



Find R_E
if $V_{CE} = 2.5V$

Q : $\beta = 100$
$V_{BE} = 0.7V$

$5 = V_{CE} + I_E R_E$
$2.5 = I_E R_E$

$5 = I_B \times 10 + 0.7 + 2.5$

$2.5 - 0.7 = I_B \times 10K$

$I_B = \frac{1.8}{10K}$

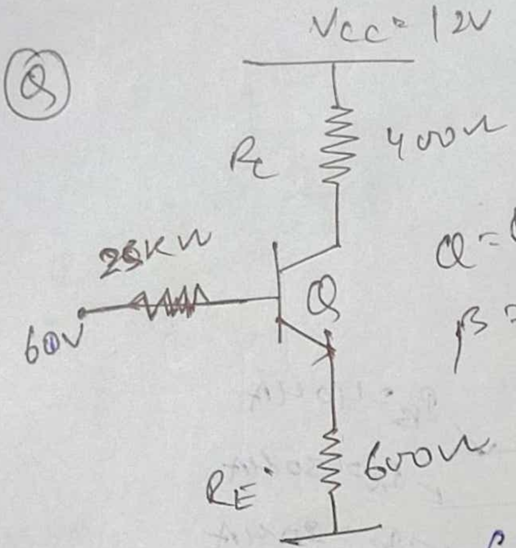
$I_B = 0.18 mA$

$I_E = 101 \times 0.18$
$= 18.18 mA$

$$\therefore \frac{2.5}{18.18} = R_E = 0.1375 = 137.5\Omega$$

Ans

(Q)



$Q = V_{BE} = 0.7$

$\beta = 75$

$\cancel{I_B = \frac{6-0.7}{25000\Omega} = 0.212M}$

$\cancel{I_C = 75 \times 0.212}$

$6 = I_B R_B + V_{BE(ON)} + I_E R_E$

Assume FAM

$I_E = (1+\beta) I_B$

$6 = I_B \times 25k\Omega + 0.7 + (1+\beta) I_B R_E$

$6 - 0.7 = (25000 + 76 \times 600) I_B$

$\boxed{I_B = 75\mu A}$

$I_C = \beta I_B = 75 \times 75 = 5625\ \mu A$

$I_E = (5625 + 75) = 5700\ \mu A$

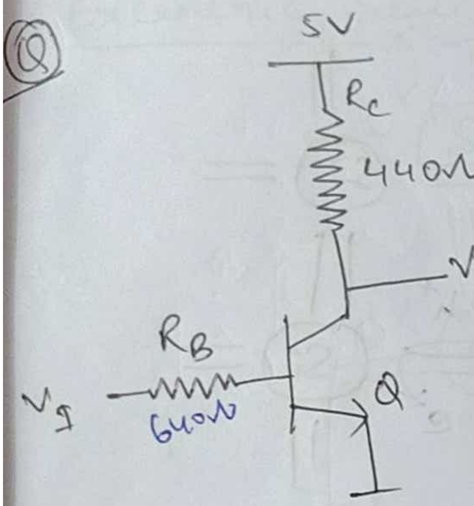
$V_{CC} - 400 I_C - V_{CE} - 600 I_E = 0$

$V_{CE} = (12 - 2.25 - 3.42)\ V$

$\boxed{V_{CE} = 6.33\ V}$

* Device in FAM as assumed

Q

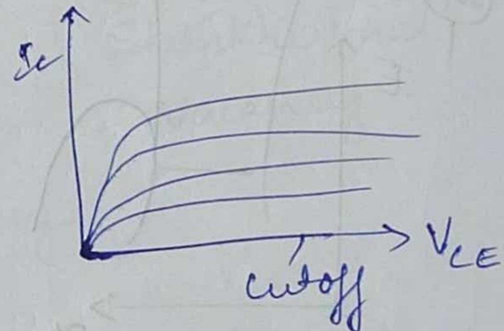


find I_B, I_C & V_o
when,
i) $V_I = 0.2V$ - logic 0
ii) $V_I = 3.6V$ = logic 1

Here, i) $V_I = 0.2V$

$I_B = 0$ $\quad I_C = 0$

$V_o = 5V$



Q: $V_{BE} = 0.7V$

$\beta = 50$

$V_{CE} = 0.2V$

EB	CB	Mode
FB	RB	FAM
RB	RB	cut-off ←
FB	FB	Saturation
RB	FB	Inverse Active

(ii) $V_I = 3.6V$

$I_B = \frac{3.6-0.7}{640} = 4.53mA$

$I_C = \beta I_B = 0.226A$

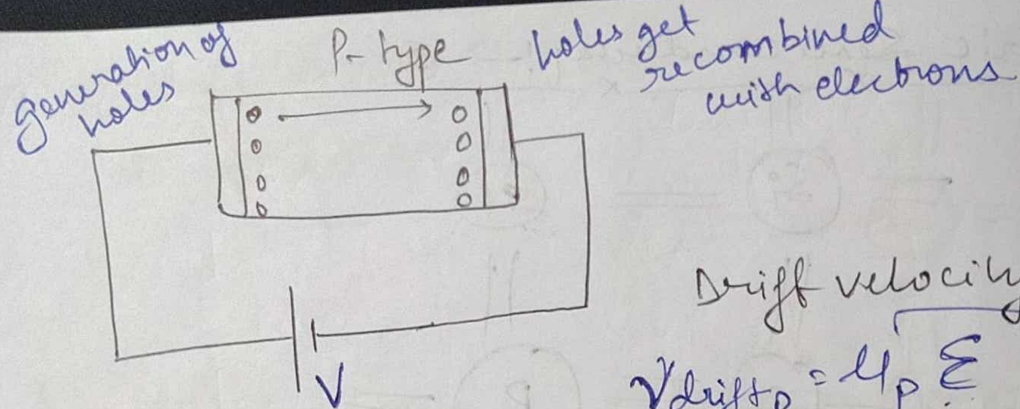
$V_o = V_{CC} - I_C R_C = \cancel{-94.687V}$
$= 0.2V$

Saturation

Force $V_{CE} = V_{CE(sat)}$

$I_C = \frac{V_{CC} - V_{CE(sat)}}{R_C} = 10.91 mA$

—▷○—
we managed to make not-gate



Drift velocity → 400 cm²/Vs

$$v_{drift_p} = \mu_p \mathcal{E}$$
mobility

$$\left[\frac{1}{\mu} = \frac{1}{\mu_1} + \frac{1}{\mu_2}\right]$$

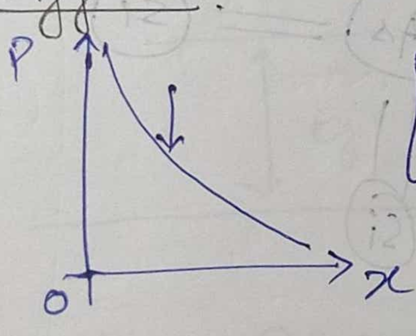
$$v_{drift_n} = \mu_n \mathcal{E}$$
→ 1350 cm²/Vs

$$\left[J_{n,drift} = q n v_{drift_n} = q n \mu_n \mathcal{E}\right]$$

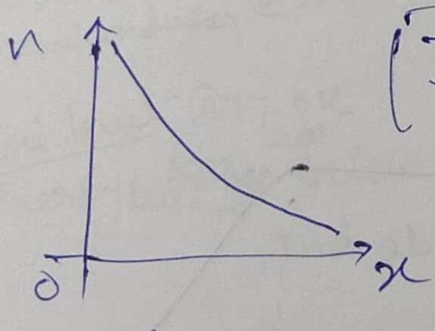
$$\left[J_{p,drift} = q p \mu_p \mathcal{E}\right]$$

$$J_{drift} = J_{n\,drift} + J_{p\,drift}$$
$$= q(n\mu_n + p\mu_p)\mathcal{E} \quad (A/cm^2)$$

Diffusion:-



$$\left[J_{diff_p} = -q D_p \frac{dp}{dx}\right]$$



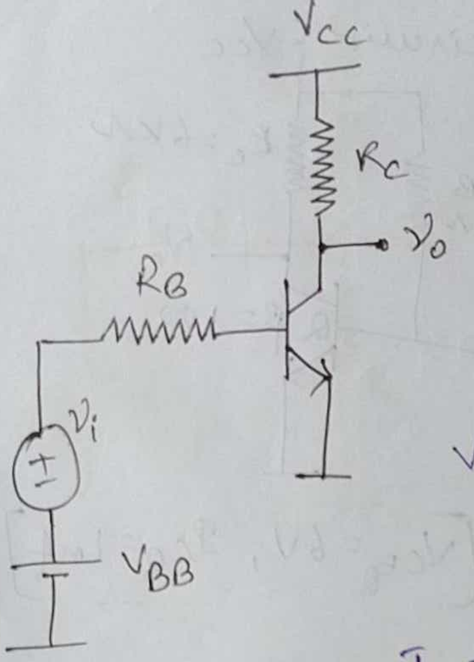
$$\left[J_{diff\,n} = q D_n \frac{dn}{dx}\right]$$

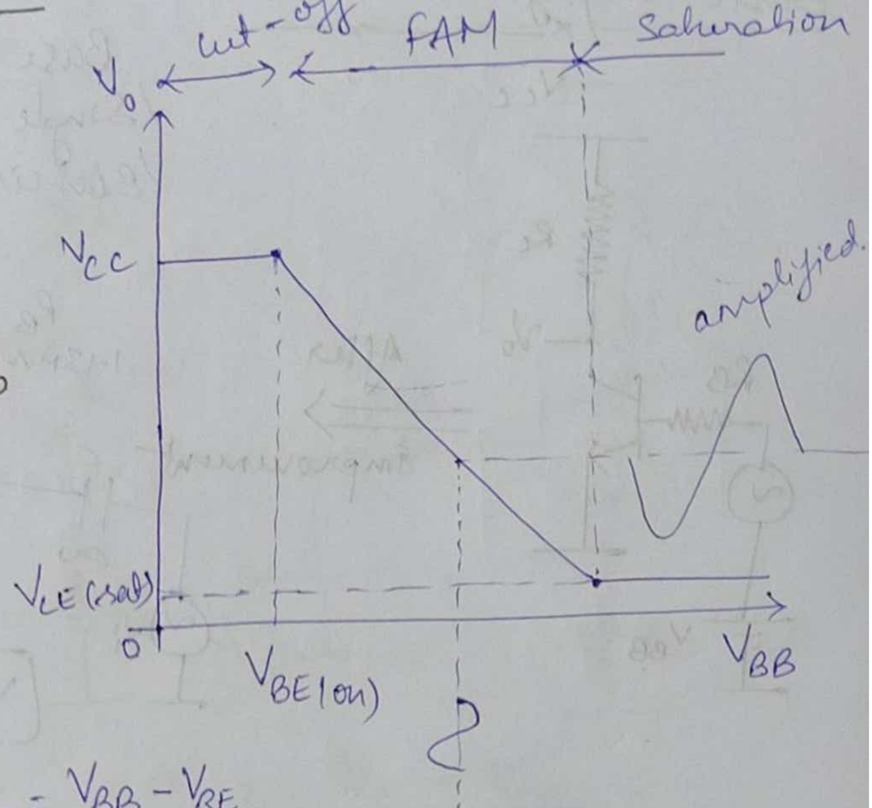
$$\left[J = J_{diff} + J_{drift}\right]$$

$$\left[\frac{D_n}{\mu_n} = \frac{KT}{q} = \frac{D_p}{\mu_p}\right]$$

Einstein's relation

(BJT - Biasing)





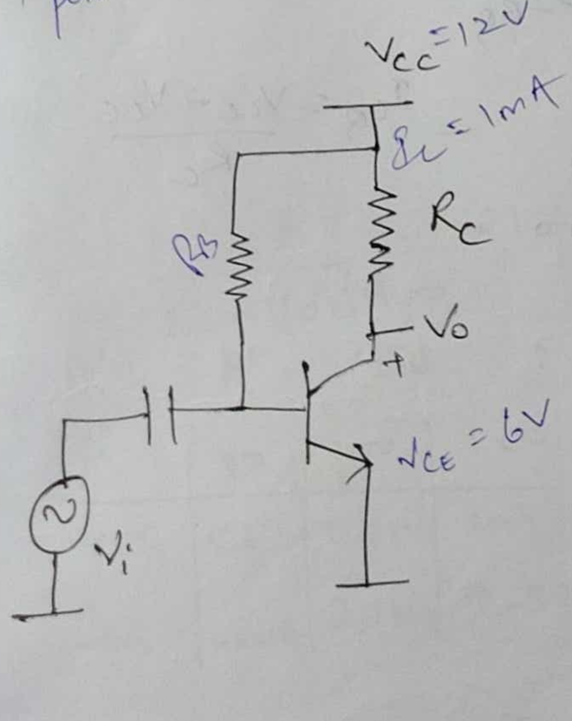
$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_C = \frac{\beta I_B}{\cancel{R_B}} = \beta\left(\frac{V_{BB} - V_{BE}}{R_B}\right)$$

(V_{CEQ}, I_{CQ}) operating point / Quiescent point

$V_o = V_{CC} - I_C R_C$

$\boxed{V_o \propto V_{BB}}$

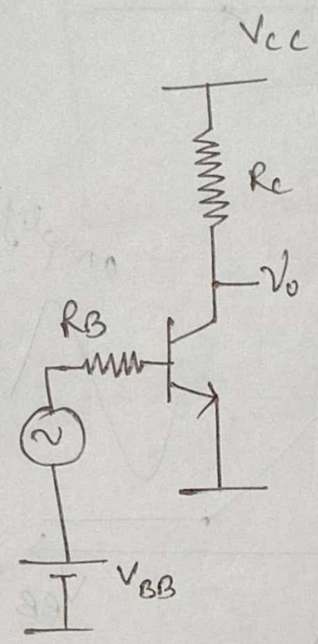


$$I_B = \frac{V_{CC} - V_{BE(on)}}{R_B}$$

$$I_C = \beta I_B$$

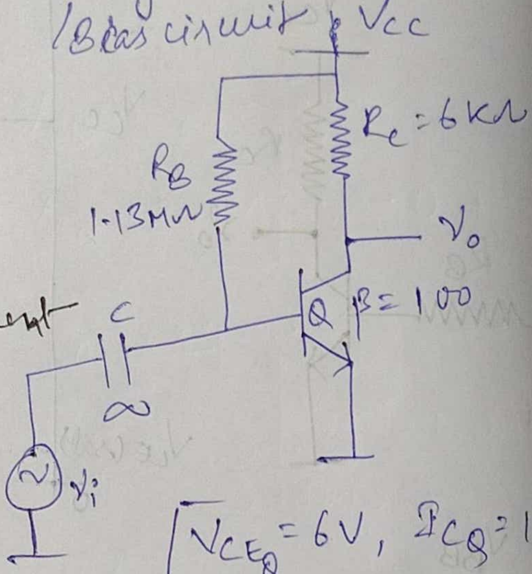
$$V_{CE} = V_{CC} - I_C R_C$$

Basic amplifier circuit:



After Improvement

Base Bias circuit / Single Base Resistor / Bias circuit



$[V_{CE_Q} = 6V, \; I_{CQ} = 1mA]$

β	50	100	150
V_{CEQ}	9V	6V	3V
I_{CQ}	0.5mA	1mA	1.5mA

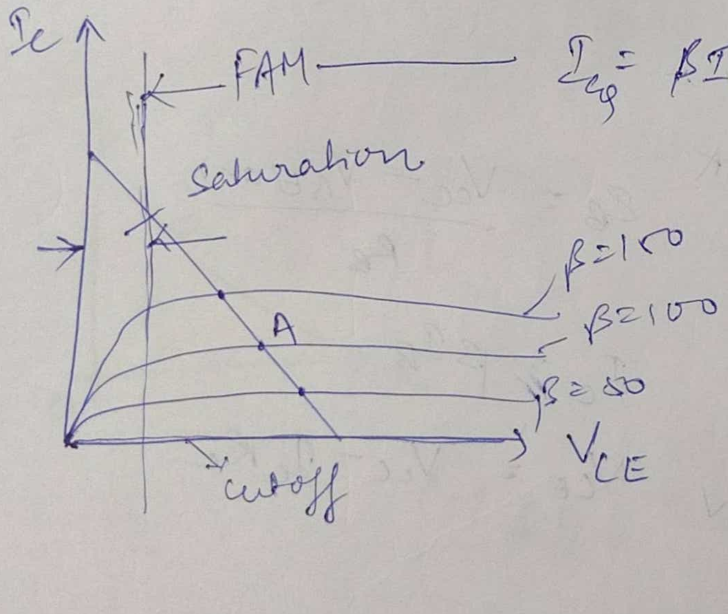
$$I_B = \frac{V_{CC} - V_{BE(on)}}{R_B}$$

$$V_{CE} = V_{CC} - I_{CQ} R_C$$

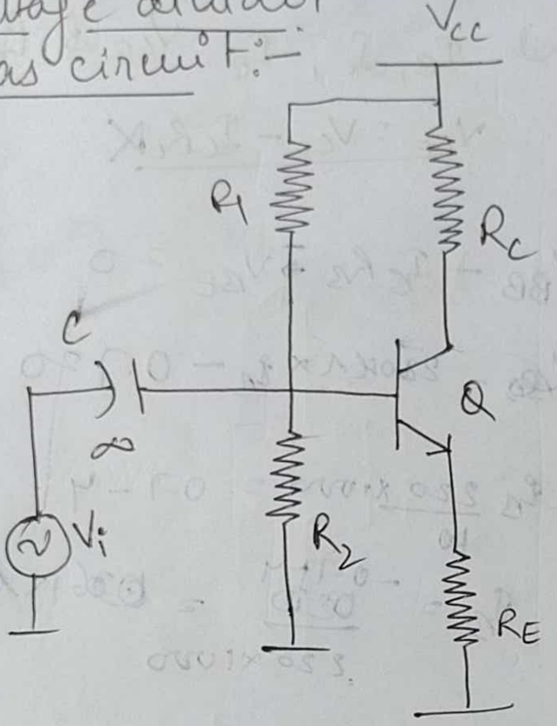
$$I_{BQ} = \frac{V_{CC} - V_{BE(on)}}{R_B} = 10\mu A$$

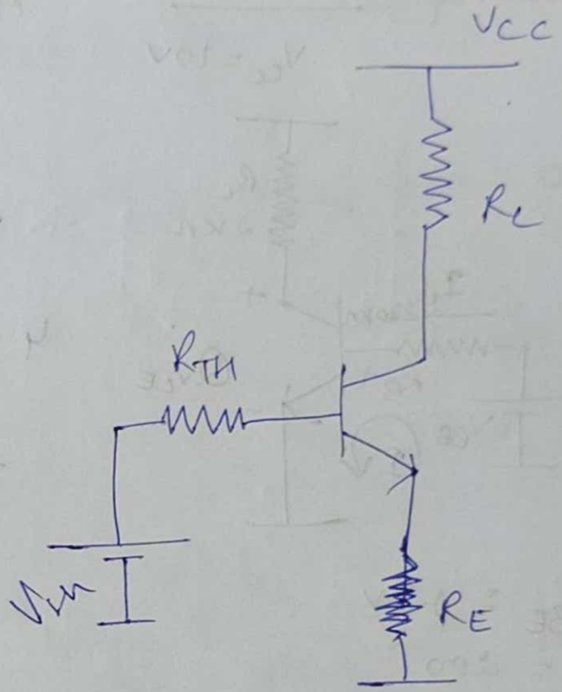
$$I_{CQ} = \beta I_{BQ}$$

$$I_{CQ} = \frac{V_{CC} - V_{CE}}{R_C}$$



Voltage divider Bias circuit :-





$R_{th} = R_1 || R_2$

$I_B = \dfrac{V_{TH} - V_{BE(on)}}{R_{TH} + (1+\beta)R_E}$

$V_{th} = \dfrac{V_{CC} R_2}{R_1 + R_2}$

$I_{CQ} = \beta I_{BQ}$

$V_{CEQ} = V_{CC} - I_C R_C - I_E R_E$

$\beta = 100$

$R_{th} = 10\,k\Omega$

$V_{CE} = 10 - I_C R_C - I_E R_E$

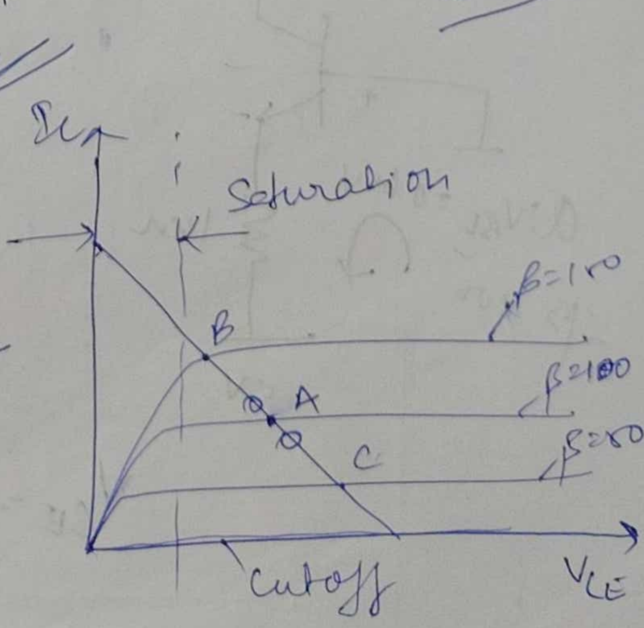
$= 10 - (100 \times 21.42\,\mu A \times 2\,k\Omega) - (1+\beta)\,21.42 \times 400$

$= 4.85\,V$

$V_{th} = 1.7\,V$

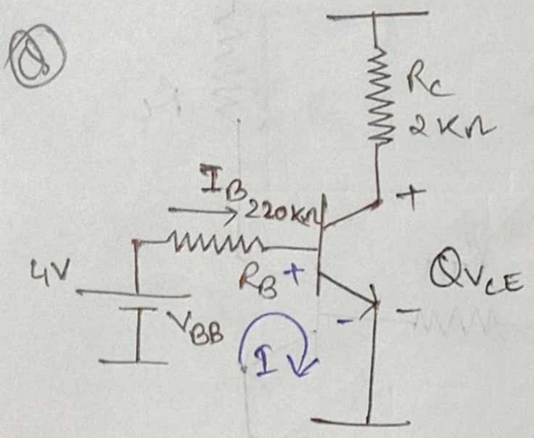
$I_B = \dfrac{1.7 - 0.7}{10 + (101)400} = 21.42\,\mu A$

β	80	100	150
V_{CEQ}	5.67	4.81V	4.4
I_{CQ}	1.8mA	2.16mA	2.32mA



Revision: BJT DC

Find I_B, I_C, I_E, V_{CE} & P_T



$V_{CE} = V_{CC} - I_C R_C$

$V_{BB} - I_B R_B - V_{BE} = 0$

$4 - 220K\Omega \times I_B - 0.7 = 0$

$-I_B \, 220 \times 1000 = 0.7 - 4$

$I_B = \frac{-0.7+4}{220 \times 1000} = 15 \mu A$

$Q_{BE} = 0.7V$

$\beta = 200$

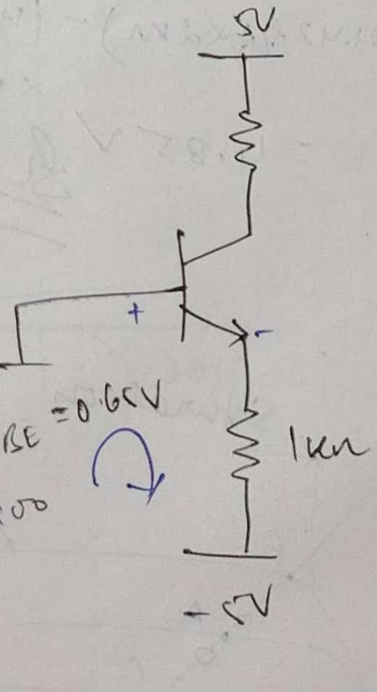
$I_C = \beta I_B$

$I_C = 200 \times 15 \mu A$

$= 3mA$

$V_{CE} = 10 - 3mA \times 2K\Omega$

$\boxed{V_{CE} = 4}$



$Q: V_{BE} = 0.65V$

$\beta = 100$

$- 0.65 - I_E 1K\Omega + 5 = 0$

$I_E = \frac{-5 + 0.65}{1000}$

$I_E = 4.35 mA$

$I_C = 4.31 mA$

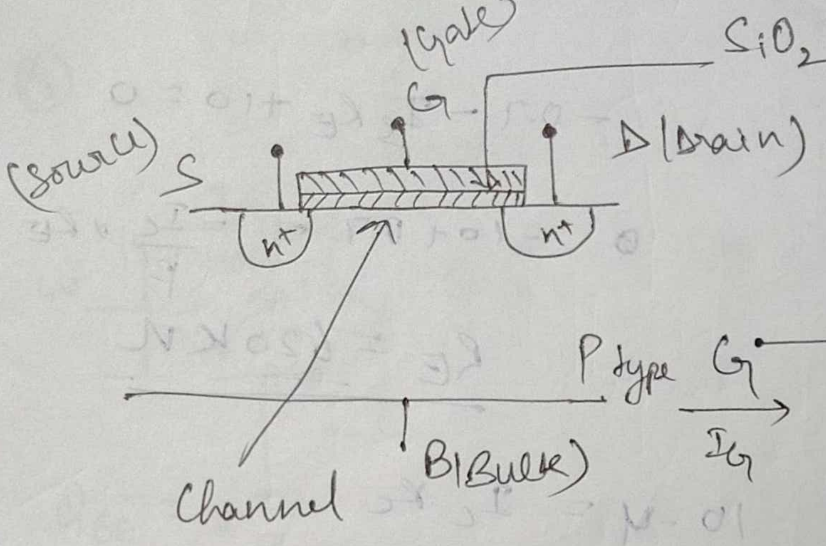
$I_B = 43.1 \mu A$

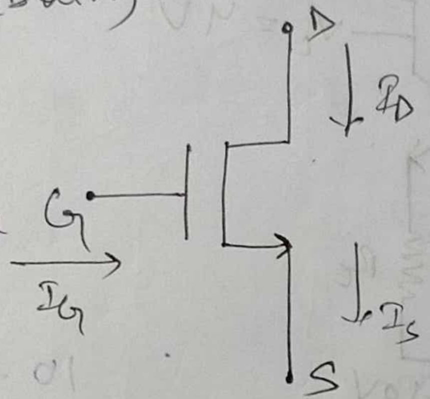
$V_{CE} = V_{CC} - I_C R_C - I_E R_E + 5$

$5 - 500 \times 4.31 mA - 4.35 + 5$

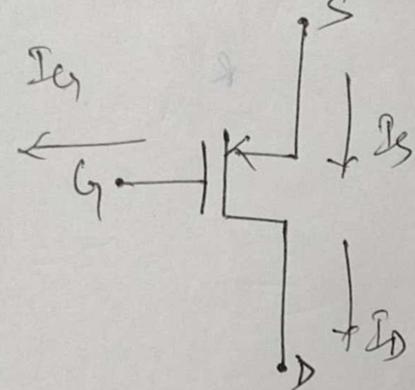
$= 3.495 V$

FET-DC





N-channel E-mode MOSFET



P-channel E-MOSFET

$\mu_n > \mu_p$

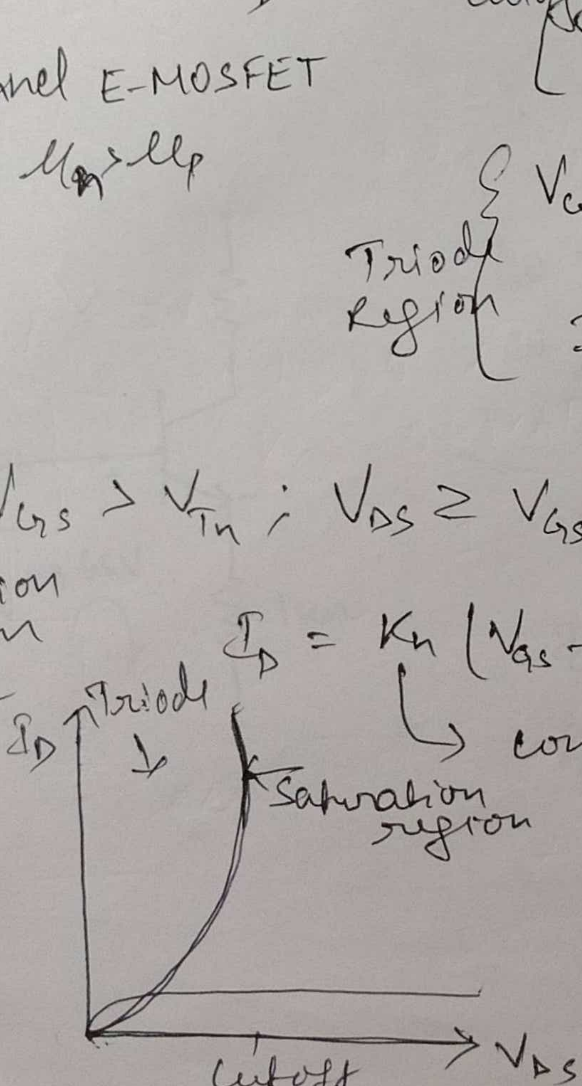
$I_D = I_S$ (any channel device)

Cutoff $\left\{ \begin{array}{l} V_{GS} > V_{Tn} \text{ (threshold voltage)} \\ I_D = 0 \leftarrow \text{cutoff} \end{array} \right.$

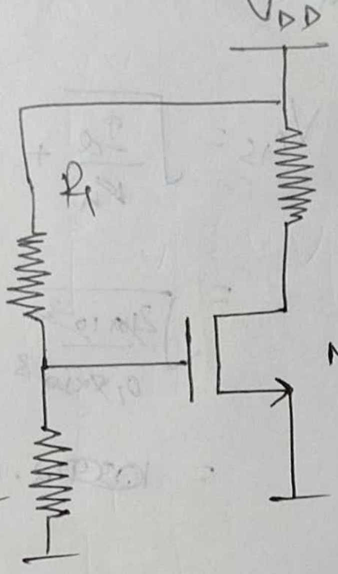
Triode Region $\left\{ \begin{array}{l} V_{GS} > V_{Tn} ;\ V_{DS} \leq V_{GS} - V_{Tn} \\ I_D = K_n \left[2(V_{GS} - V_{Tn}) V_{DS} - V_{DS}^2 \right] \end{array} \right.$

Saturation region $\left\{ \begin{array}{l} V_{GS} > V_{Tn} ;\ V_{DS} \geq V_{GS} - V_{Tn} \rightarrow \text{condition for saturation} \\ I_D = K_n (V_{GS} - V_{Tn})^2 \end{array} \right.$

$K_n \rightarrow$ conduction parameter



*



$* V_G = \frac{V_{DD} R_2}{R_1 + R_2} = V_{GS}$

$* I_D = K_n (V_{GS} - V_{TN})^2$

$* V_{DD} - I_D R_D = V_{DS}$

$* P_T = V_{DS} I_D$

Q) $V_{TN} = 1V$ $\quad V_{DD} = 5V$ $\quad R_D = 20k\Omega$

$K_n = 0.1 mA/V^2$ $\quad R_1 = 30k\Omega$ $\quad R_2 = 20k\Omega$