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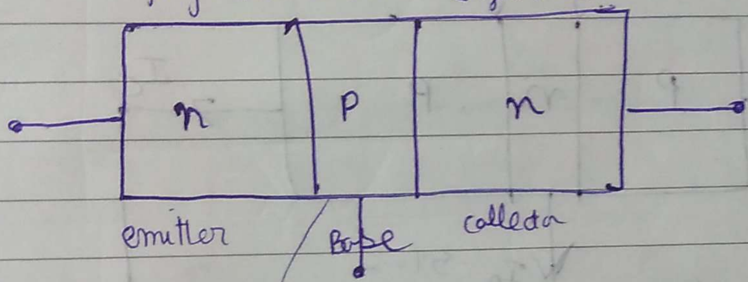
UNIT-3

TRANSISTORS

B J T

Bipolar (both holes & electrons) — Junction — Transfer (Resistance)

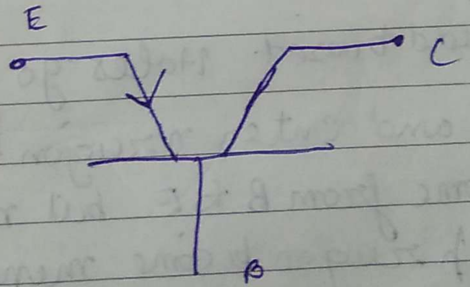
lightly ~~least~~ doped least area — highly doped — moderately doped longest area



least area & dope bcoz it offers high resistance.

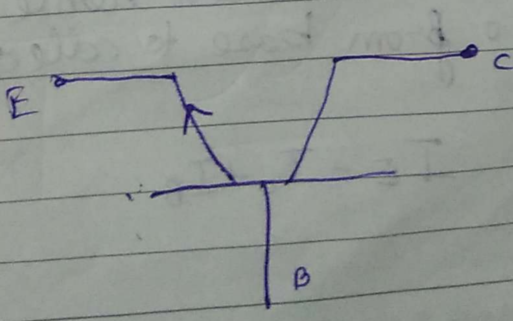
Collector - largest area for heat dissipation

Diagram



Pointing in

PnP

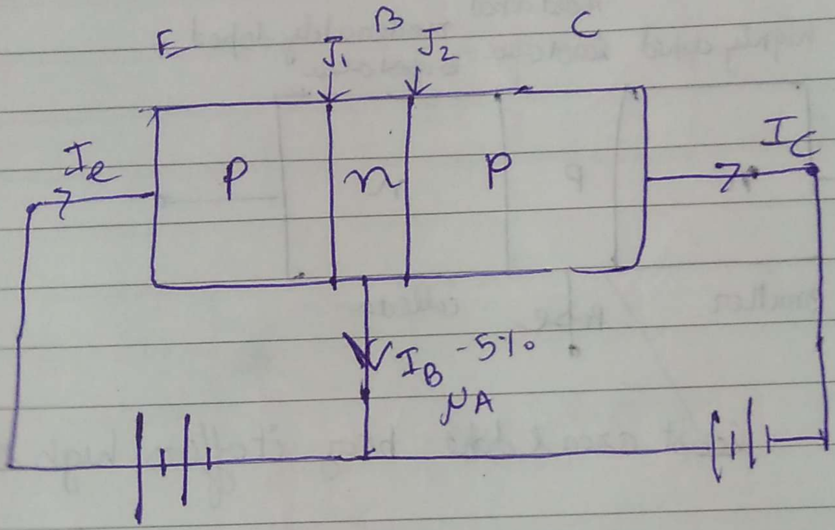


not pointing in

npn

Biasing is done to obtain the operating point of a device.

Always EB Junction (emitter base) is forward biased and CB (collector base) junction is reverse biased



V_{EB} or V_{EE}

$I_B = 5\%$

95% transfered

EB is forward biased. Holes go from P to n or E to B and enter n region by crossing J_1. e^- also come from B to E but negligible. Now holes of p region become minority of n region. So J_2 is reverse biased hence minority carriers (holes) go from base to collector

$I_E = I_C + I_B$

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Components of I_C (Orphaned)

when EB is not biased and CB is reversed biased minority current flows called I_{CO}.

$$\boxed{I_C = I_{C\,majority} + I_{CO}}$$

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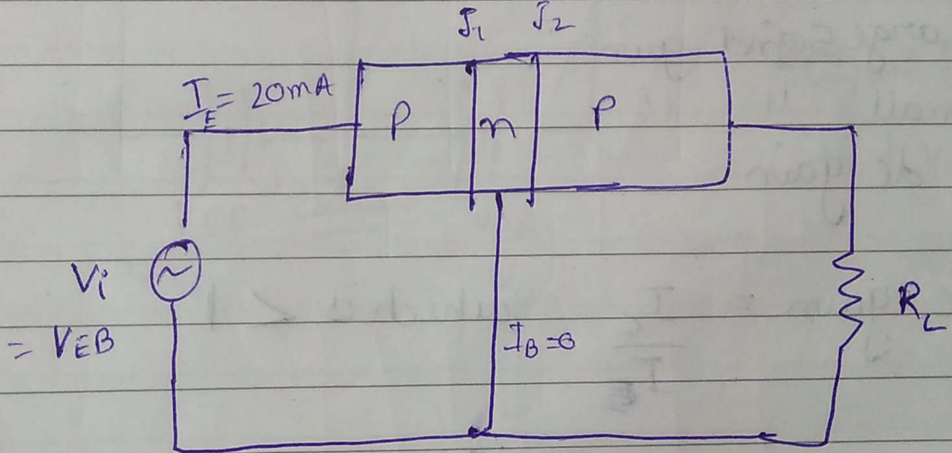

Eg

J_1 is FB, so $R_i = 10\Omega$ (small)

$R_{output} = 100\,k\Omega$ bcz RB

So $\cancel{I_B} = I_E = I_C = 20mA$

$V_0 = I_C \times 100\,k\Omega$

$= 2000V$

Amplifier

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Transistor current Equation

$$\boxed{I_C = \alpha I_E + I_{CO}}$$

in active region

α = current gain

↓

3 types

↓

1. Large signal gain
2. Small " "
3. dc gain

dc gain = $\frac{I_C}{I_E}$ which is < 1 (bcoz $I_E > I_C$ always)

Large signal gain - $\alpha = \frac{I_C - I_{CO}}{I_E - 0}$

~~..~~ ratio of gain in I_C when I_E is changed

α small or $\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E}$

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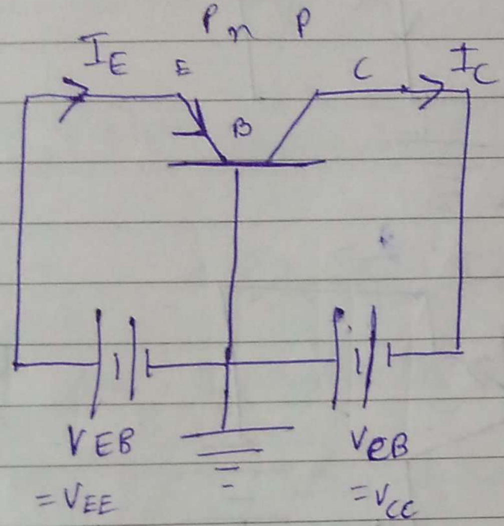
Configurations

The side which is common is grounded

CB - Common Base

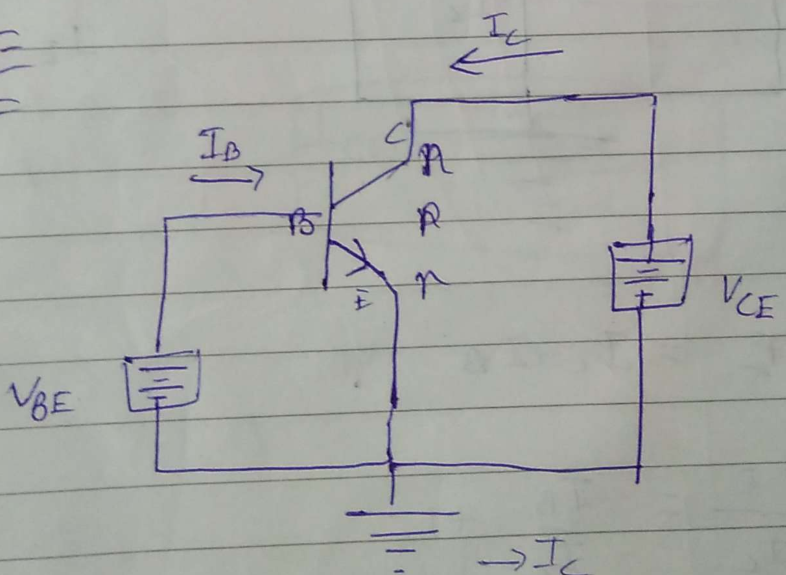


input charactristic
I_E & V_{EB}

output char
I_C & V_{CB}

$0.9 < \alpha < 0.99$

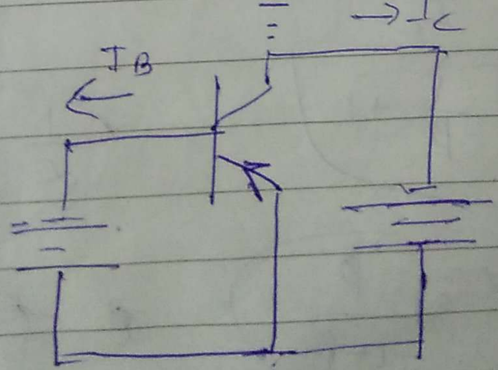
CE



β

CE current gain

$= \beta = \frac{I_C}{I_B} >> 1$



$50 < \beta < 100$

Preferred

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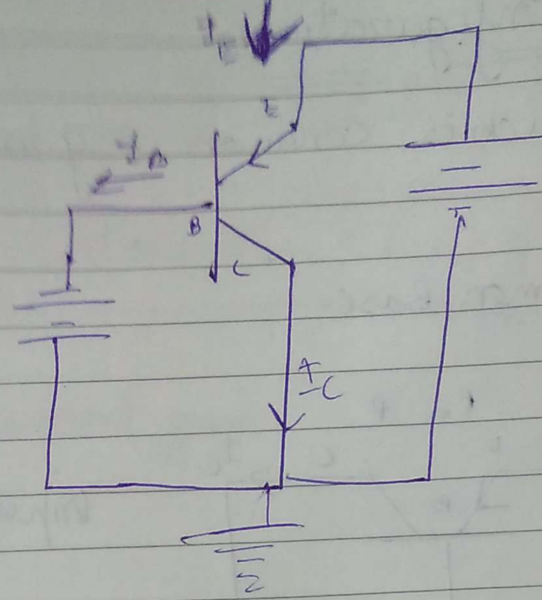

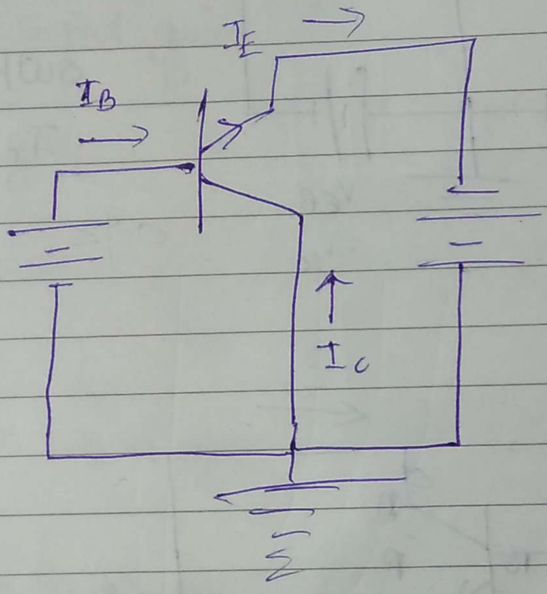

Input

I_B , V_{CB}

Output

I_E V_{CE}

$$I_E = I_C + I_B$$

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

$$\frac{1}{\alpha} = \frac{1}{\beta} + 1 \qquad \frac{1}{\alpha} = \frac{1+\beta}{\beta}$$

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

use this

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Current equation

CB $\quad I_C = \alpha I_E + I_{CBO}$ (1) — Common Base reverse saturation current when Emitter is open

CE $\quad I_C = \beta I_B + I_{CEO}$ (2) — Common emitter reverse saturation current when Base is open

putting value of I_E in (1)

$$I_C = \alpha (I_C + I_B) + I_{CBO}$$

$$(1-\alpha) I_C = \alpha I_B + I_{CBO}$$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

Comparing with (2)

$$\boxed{I_{CEO} = \frac{I_{CBO}}{1-\alpha}}$$

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Characteristics

1.) Input or Driving point char – x axis pe input voltage, y axis pe input current (when output voltage is constant)

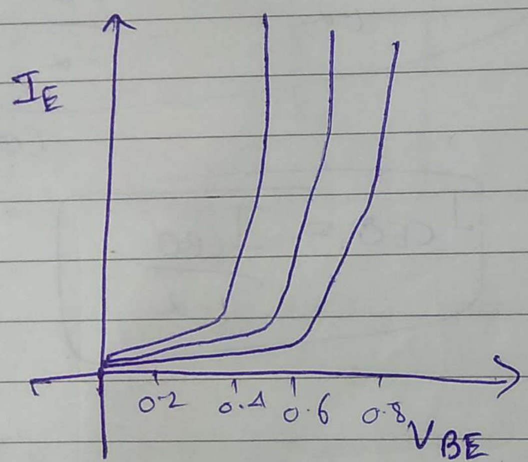
2.) output or collector char – output voltage on x axis, current on y axis (when input current is constant)

Common Base

As V_{CB} is increased, RB increases recombination less, resistance less I_E increases & becomes steeper as V_{BE} increases

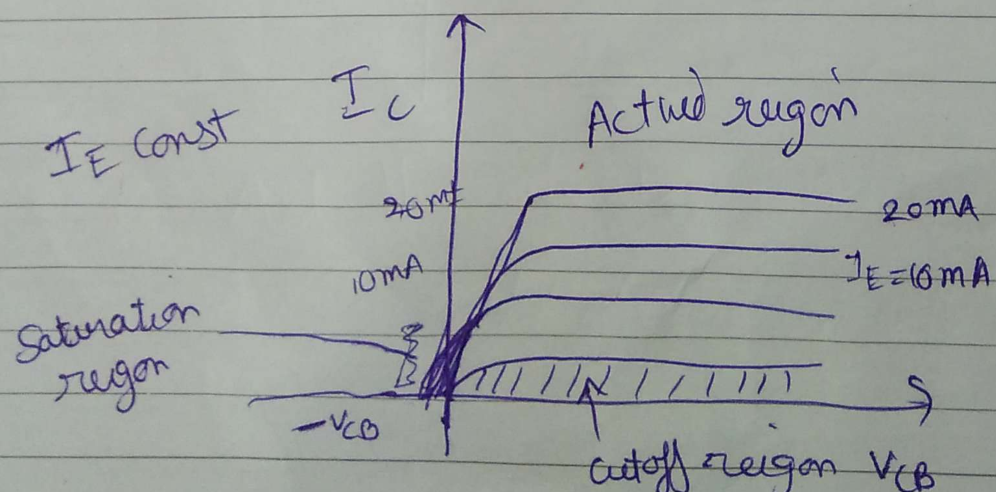
input

V_{CB} const



$$r_i = \frac{\Delta V_{BE}}{\Delta I_E}$$

output



As V_{CB} is increase reverse biased is increased, recombination decreases, $I_B \downarrow$

So $I_C \approx I_E$

imp

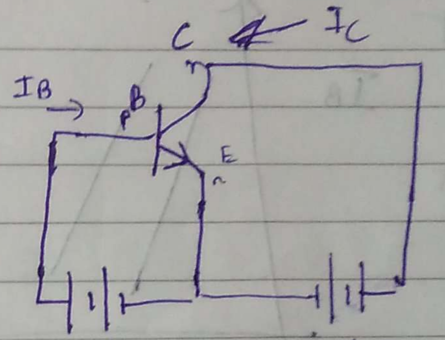
Active region - EB is FB
CB is RB

Cutoff EB & CB are RB

Saturation EB & CB both FB

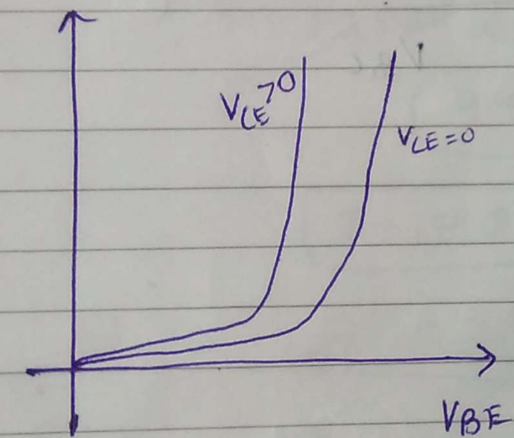
For ~~very small~~, sufficient FB in CB & EB, I_C changes fast & is independent of I_E.

Common emitter



I_B

V_{CE} const

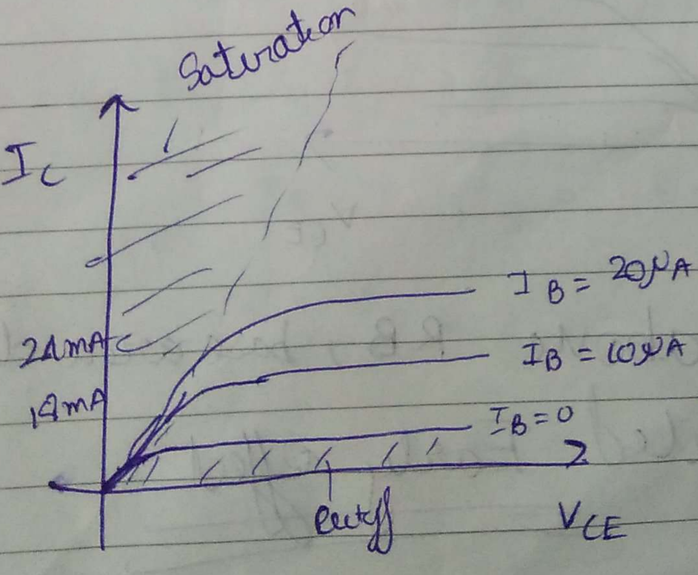


$V_{EB} = -ve$

so $V_{BE} = +ve$

$V_{CE} = +ve$

Same as Comm Base or FB diod



I_B const

As $I_B \uparrow$, RB $\uparrow$

depletion region $\uparrow$ so Recombination $\downarrow$

so $I_B \downarrow$

Hence $I_C \propto I_E$

Saturation region

At a very small value I_C will change fast & become independent of I_B.

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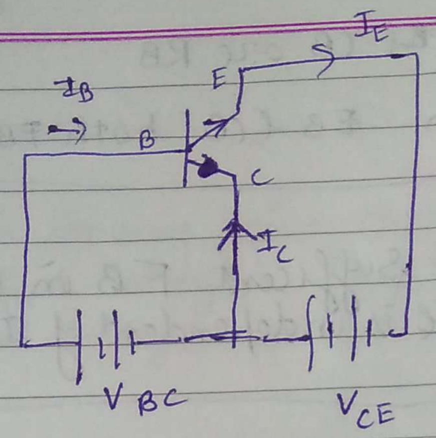
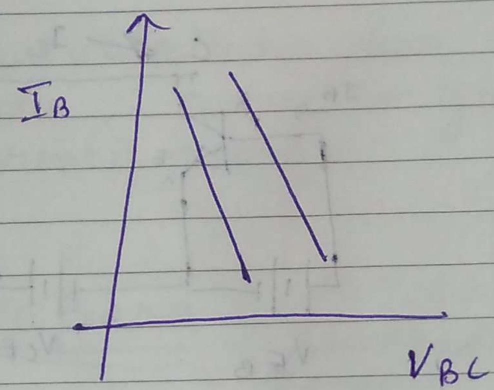
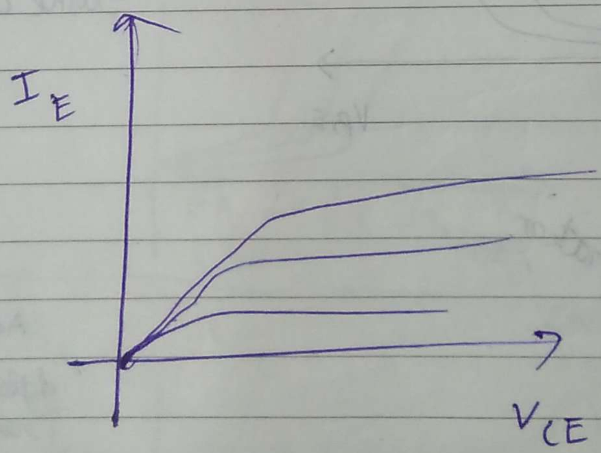


Input



Output



All the above RB, base area decreases shift is called <u>Early effect</u>

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$\beta = \frac{\alpha}{1-\alpha}$ $\quad I_E = I_C + I_B$ $\quad \alpha = \frac{I_C}{I_E}$ $\quad \beta = \frac{I_C}{I_B}$

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$I_C = \alpha I_E + I_{CBO}$ $\quad I_C = \beta I_B + I_{CEO}$ $\quad I_{CEO} = \frac{I_{CBO}}{1-\alpha}$

FORMULAS

Ques $I_E = 10mA$ $\quad \alpha = 0.98$

I_B & β

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

$$\beta = \frac{0.98}{1-0.98} = \boxed{49}$$

$$\alpha = \frac{I_C}{I_E}$$

$$\alpha I_E = I_C$$

$$10 \times 10^{-3} \times 0.98$$

$$9.8 mA = I_C$$

$$\boxed{I_B = 0.2 mA}$$

Q.2 PnP

$I_B = 45 \mu A$ $\quad I_C = 5.45 mA$

5.45
0.045
5.495

α, β, I_E

$$I_E = I_C + I_B = \cancel{50.45 \mu A}\ 5.45 + 0.045 mA$$

$$I_E = \boxed{5.495 mA}$$

$$\alpha = \frac{I_C}{I_E} = \frac{\cancel{5.45}}{\cancel{50.45}} = \frac{5.45}{5.495} = 0.991$$

$$\boxed{\beta = \frac{I_C}{I_B} = 121.11}$$

Q. Find I_B for $I_C = 10mA$

α & β will remain same for any device

$$\beta = \frac{I_C}{I_B} = 121.11$$

$$I_B = \frac{\cancel{10} \times 10^{-2}}{121.11} = \frac{1}{121.11}$$

$$\boxed{82.56\ \mu A}$$

Ques 3 npn transistor $\alpha = 0.98$, CB mode

$I_E = 3mA$ $I_{CBO} = 10\mu A$

Find I_B & I_C

$$I_C = \alpha I_E + I_{CBO}$$

$$I_C = 0.98 \times 3 + \frac{1}{100}$$

$$= 2.94 + 0.01$$

$$\boxed{I_C = 2.95mA}$$

$$I_B = I_E - I_C$$

$$= 3 - 2.95 = \boxed{0.05\ mA}$$

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Com B

Q-4 $I_{CBO} = 12.5 \mu A$ $I_E = 2mA$ $I_C = 1.97 mA$

α, β & I_B

$I_B = I_E - I_C = \boxed{0.03 mA}$

$\alpha = \frac{I_C}{I_C} =$

* 1) whenever Reverse saturation current is given you cannot use $\alpha = \frac{I_C}{I_E}$ & $\beta = \frac{I_C}{I_B}$ X
You can only use equation of revers satration

2) β_{dc} or α_{DC} is direct formula $\frac{I_C}{I_B}$ & $\frac{I_C}{I_E}$.
But β_{AC} is calculated using formul of reverse saturation

$I_C = \alpha I_E + I_{CBO}$

$$\frac{1.97 - \cancel{0.125}\ 0.0125}{2 mA} = \alpha$$

$\boxed{\alpha = 0.978}$

$$\beta = \frac{0.978}{1 - 0.978} = 44.45$$

resistance Com B

input output

$\frac{\cancel{V_{BE}}}{I_E}$ V

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Com B

$$R_{in} = \frac{in/p\ V}{in/p\ I} = \frac{\Delta V_{BE}}{\Delta I_E}$$

$$R_{out} = \frac{\Delta V_{CB}}{\Delta I_C}$$

Com E

$$R_{in} \quad \frac{\Delta V_{BE}}{\Delta I_B} \qquad R_{out} = \frac{\Delta V_{CE}}{\Delta I_C}$$

Q-5 Com B

$\Delta V_{BE} = 200\ mV$

$\Delta I_E = 5mA$

when ~~Base~~ V_{CB} is fixed

$$R_{in} = \frac{200}{5} = \boxed{40\Omega}$$

Q-6 Com E

$\Delta V_{BE} = 250\ mV$ $\quad$ $\Delta I_B = 1mA$

$R_{in} = 250\Omega$

Q-7

ΔV_{CE} from 5 to 10V

ΔI_C = 5mA to 5.8 mA

$$R_{out} = \frac{5}{0.8 \times 10^{-3}} = 6.25 \times 10^3 = 6250\ \Omega$$

Q-8

$I_E = 5mA$ $\quad$ $I_C = 4.95mA$

$I_B = 0.05mA$ $\quad$ $I_{CEO} = 200\mu A$

β_{dc}, & leakage current I_{CBO}

$$I_C = \beta I_B + I_{CEO}$$

$$\cancel{\frac{4.95 - 0.2}{0.05}}$$

β_{dc} = so direct formula

$$= \frac{I_C}{I_B} = \frac{4.95}{0.05} = 99$$

$$\alpha = \frac{\beta}{1+\beta} = 0.99$$

$$I_{CBO} = (1-\alpha) I_{CEO}$$

$$I_{CBO} = 0.01 \times 200\mu A$$

$$2\mu A$$

Q-9 Following OBS are data

I_E emitter open

$V_{CB} = 10V$

$I_{CBO} = 0.25 \mu A$

Base open

$V_{CE} = 10V$

$I_{CEO} = 25 \mu A$

I_E, I_B & α when $I_C = 1.2 mA$

$$I_{CEO} = \frac{I_{CBO}}{1-\alpha}$$

$$1-\alpha = \frac{0.25}{25}$$

$$1-\alpha = 0.01$$

$$\boxed{\alpha = 0.99}$$

$$I_C = \alpha I_E + I_{CBO}$$

$$-0.00025 + 1.2 = 0.99 I_E$$

$$\boxed{I_E = 1.211 mA}$$

$$I_B = I_E - I_C = 0.011 mA$$

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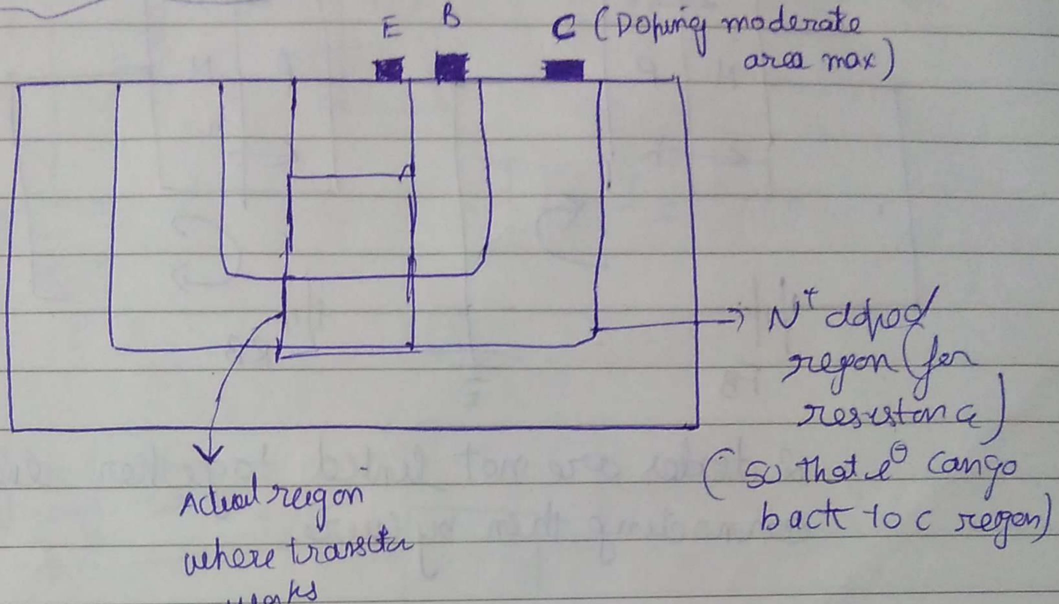
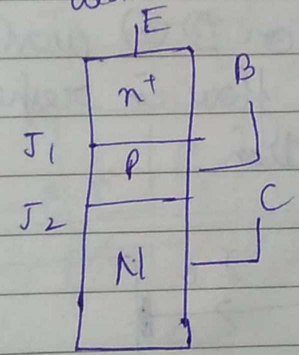
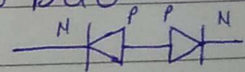
Imp topic missed

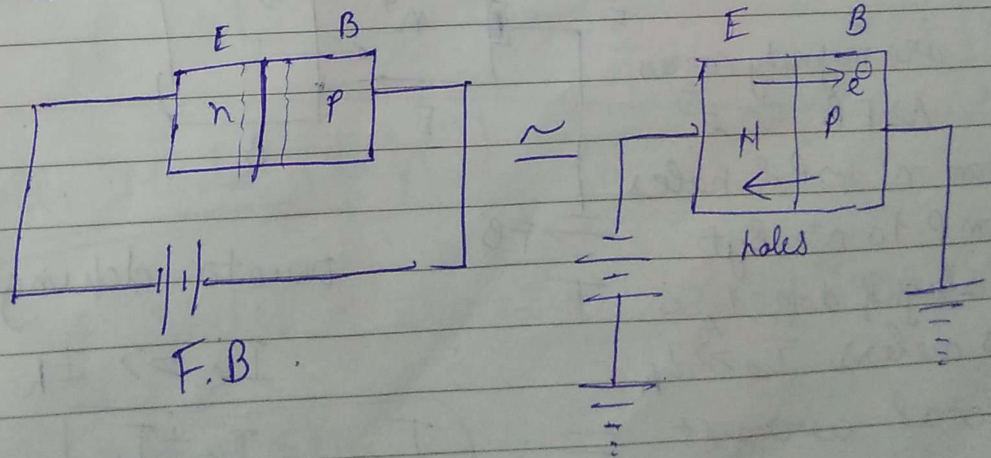




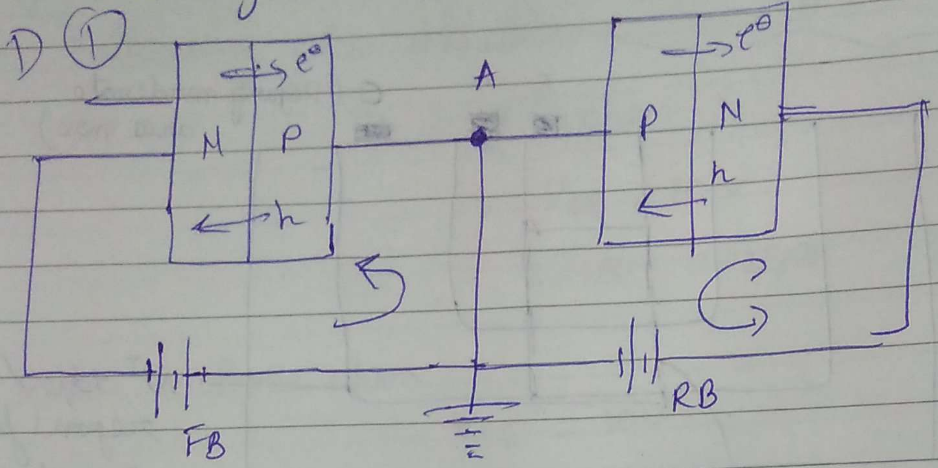
✱ If 2 diodes are connected back to back will it work as transistor??



Sol^n



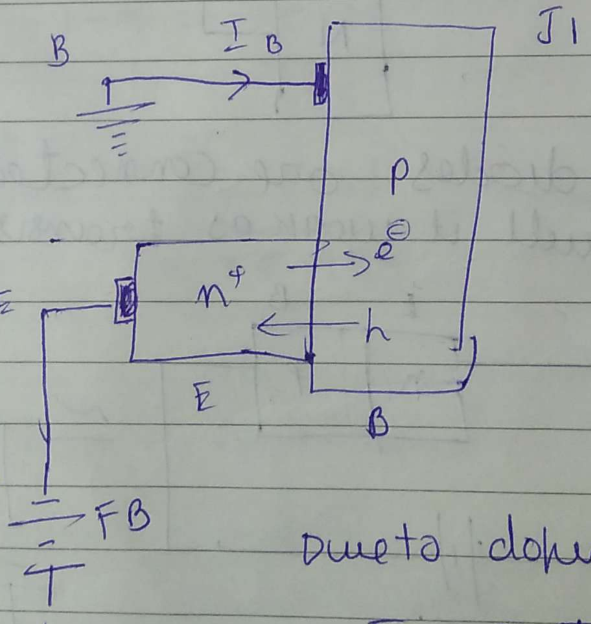
Joining 2 diodes



2 diodes are not linked together even by connecting them by wire.

Current from D① or D② won't cross the point A. Current will flow in respective loops only. So no transistor action.

Transistor

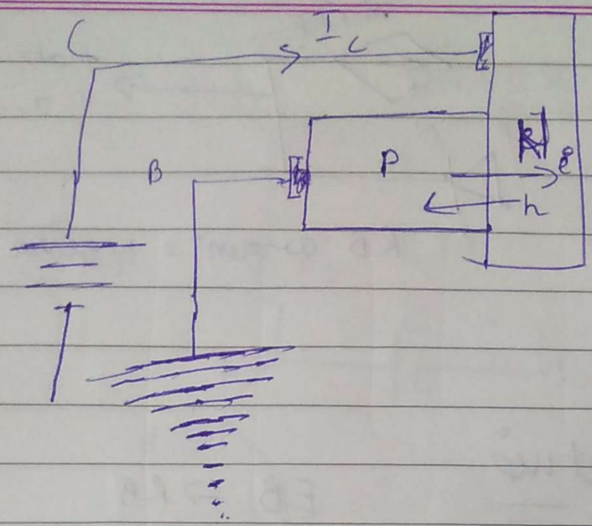


$e^{\ominus}$ are majority carriers in n^+. As FB, so $e^{\ominus}$ go from n^+ to P & holes from P to n^+. But Base is lightly doped, so holes are less, $I_e \gg I_h$

Due to doping (Base is lightly doped)

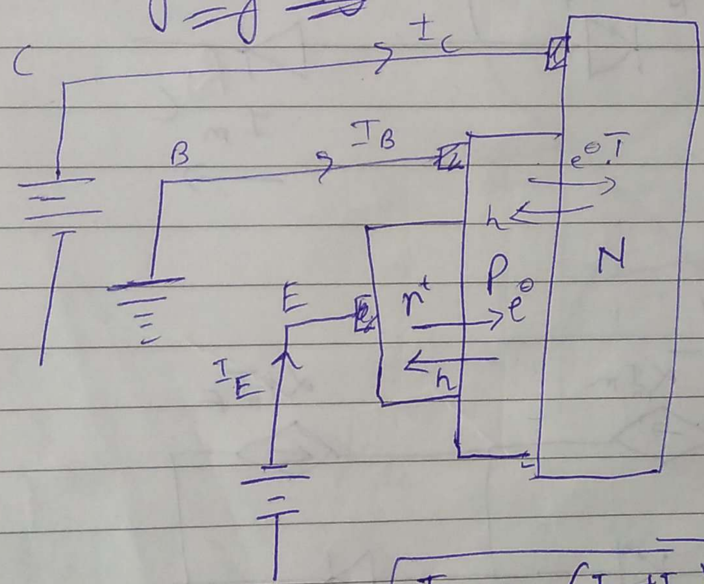
$I_e \gg I_h$

Total current = $\boxed{I_1 = I_e + I_h}$



$$I_2 = I_e + I_h$$

After fusing



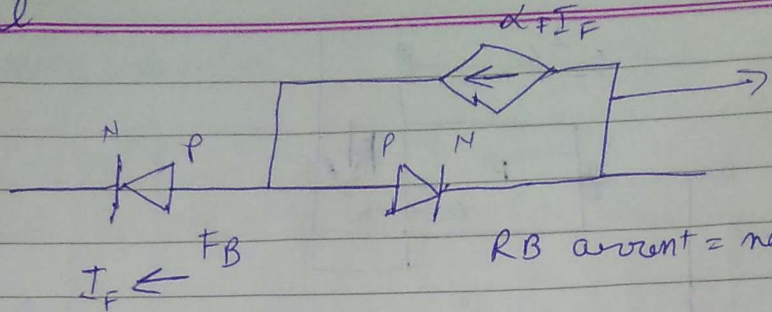
$$\boxed{I_E = -(I_B + I_C)}$$

Eber Molls Model (imp)

4 states of transistor using 1 model

Active
Inverse active
Saturation
cutoff

① Active

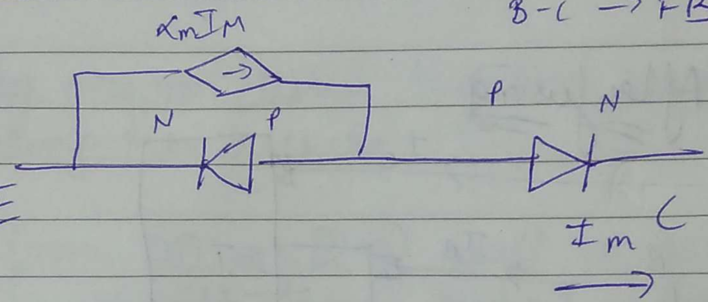


that's why $I_C = \alpha I_E$

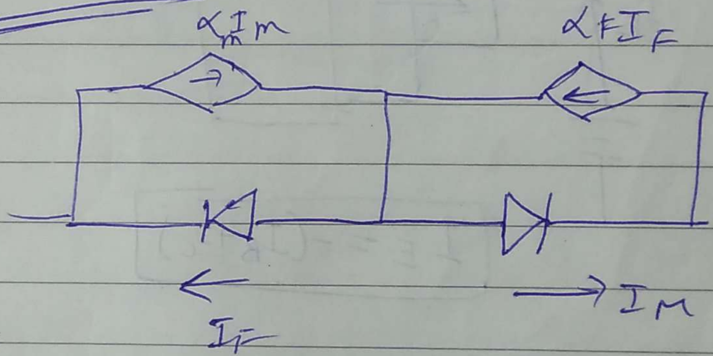
RB current = negligible

② Inverse Active

EB → RB
B-C → FB

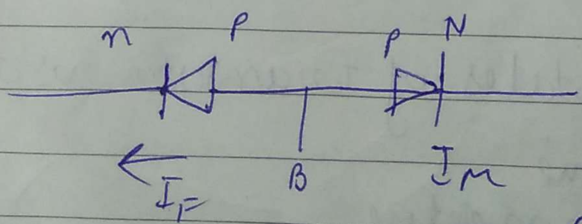


③ Saturated



Both FB

④ cutoff



Both R_B

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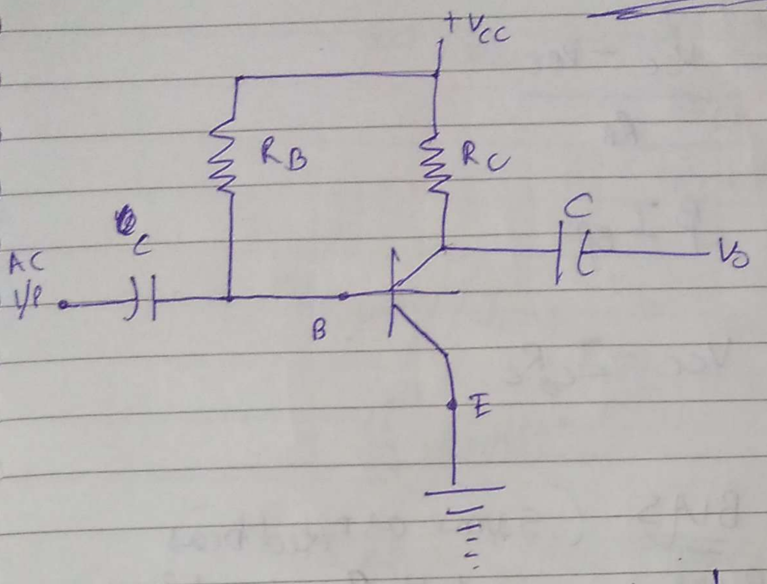
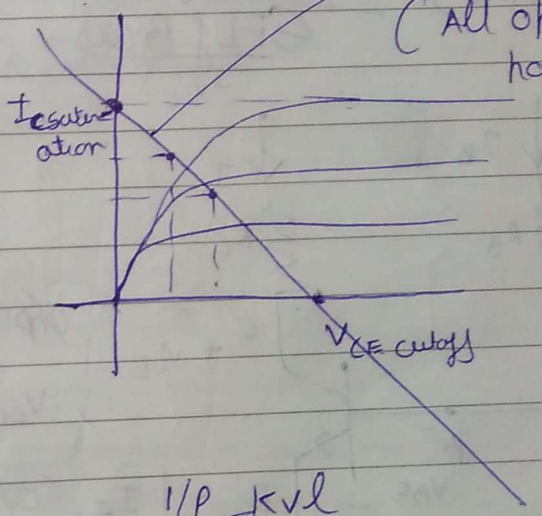
Common Emitter (emitter is grounded)

FIXED BIAS

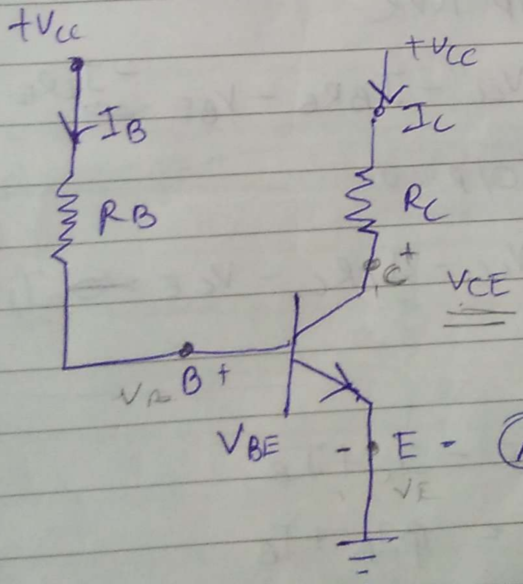
Resistance C (identify)
Resistance B



(Remove the unnecessary capacitors)



(All operating points lie on this Load line for dc & for AC it will move near load line)



I/P KVL

$+V_{CC} - I_B R_B - V_{BE} = 0$

O/P $+V_{CC} - I_C R_C - V_{CE} = 0$

(A) Load Line Points

$I_{C sat}$ can be found when $V_{CE} = 0$

$$\boxed{I_{C sat}\big|_{V_{CE}=0} = \frac{V_{CC}}{R_C} \Rightarrow \text{saturation pt}}$$

$$\boxed{V_{CE\,cutoff}\big|_{I_C=0} = V_{CC}}$$

$V_{BE} = V_B - V_E$

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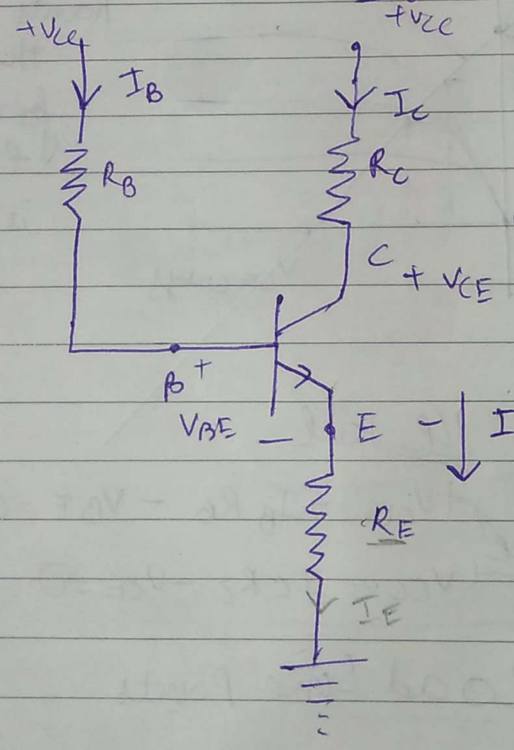
(B) Q pt (i) $I_{BQ} = \dfrac{V_{CC} - V_{BE}}{R_B}$

(ii) $I_{CQ} = \beta I_{BQ}$

(iii) $V_{CEQ} = V_{CC} - I_{CQ} R_C$

(better than Fixed) **EMITTER BIAS / SELF BIAS** (same as Fixed bias just R_E added)



Fixed bias was unstable
A ressistor is added to make stable

i/p KVL

$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$

O/P KVL

$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$

$I_E = I_C + I_B$

$= \beta I_B + I_B$

$\boxed{I_E = (1+\beta) I_B}$

Replace I_E in above equation (i/p only)

$V_{CC} - I_B R_B - V_{BE} - (1+\beta) R_E = 0$

~~$V_{CC} - I_C R_C - V_{CE} - (1+\beta) R_E = 0$~~

i/p walli mein $I_E = (1+\beta) I_B$

O/P walli eqn men $I_C \approx I_E$

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$$I_{C\,sat} / _{V_{CE}=0} = \frac{V_{CC} - \cancel{I_{CQ}R_E} - (1+\beta) R_E}{}$$

$$\frac{V_{CC}}{R_C + R_E}$$

$$V_{CE\,cutoff} / _{I_C = 0} = V_{CC}$$

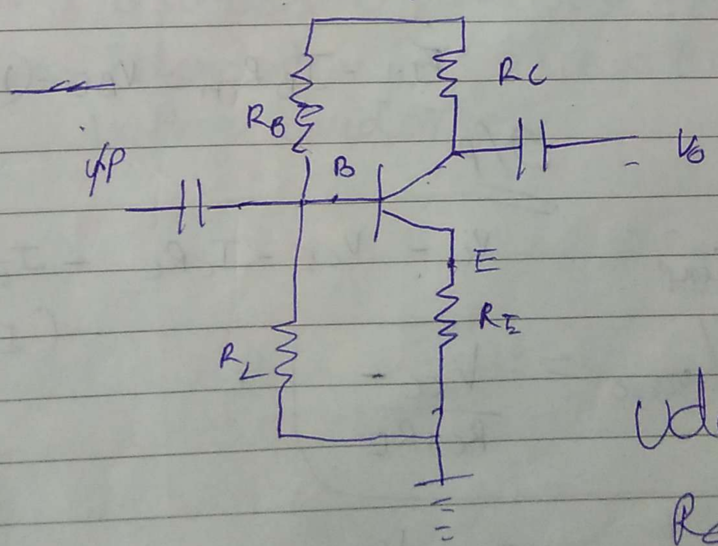
Q point

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B + R_E(1+\beta)}$$

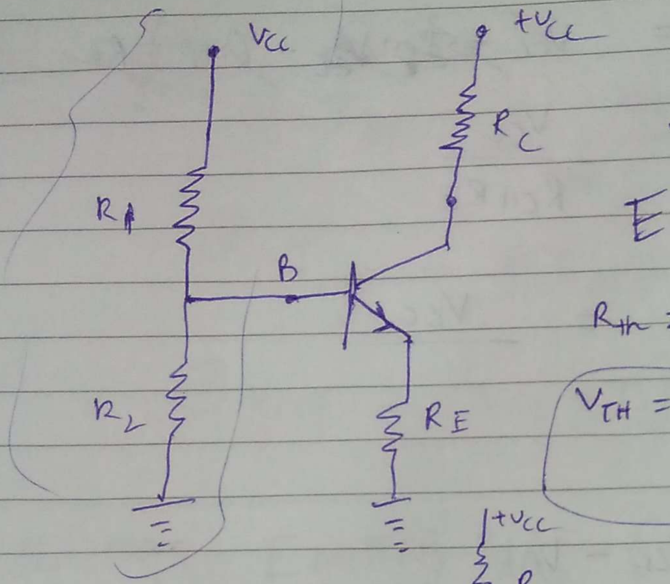
$$\boxed{I_{CQ} = \beta I_{BQ}}$$

$$V_{CEQ} = V_{CC} - I_C (R_C + R_E)$$

Voltage Divider

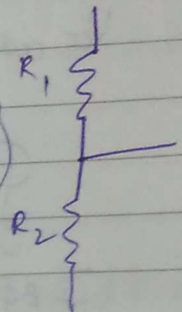


uda do
Raddi

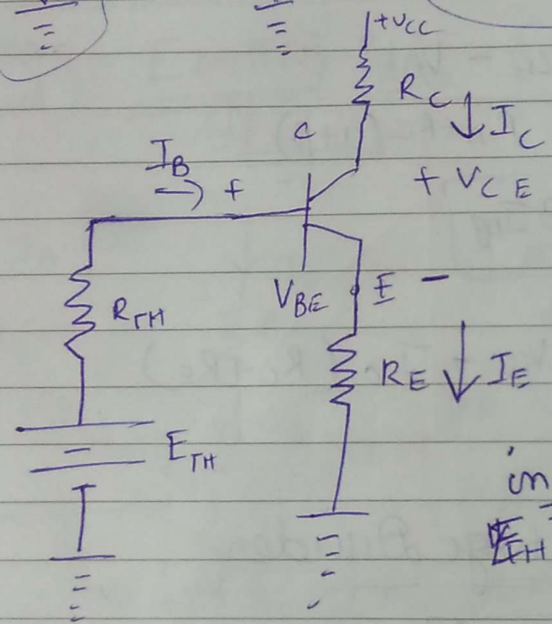


Eq circuit

$R_{th} = R_1 || R_2$



$$\boxed{V_{TH} = \frac{R_2 V_{CC}}{R_1 + R_2}}$$



in/p

$$E_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$$

$$E_{TH} - I_B R_{TH} - V_{BE} - \overbrace{(1+\beta)}^{I_B} R_E = 0$$

O/p

$$V_{CC} - V_{CE} - I_C R_C - I_E R_E = 0$$

$(I_C = I_E)$

Load Line

$$\boxed{I_{Csat}\Big|_{V_{CE}=0} = \frac{V_{CC}}{R_C + R_E}}$$

$$V_{CE\,cutoff}\Big|_{I_C=0} = V_{CC}$$

Q Points

$$I_{BQ} = \frac{E_{TH} - V_{BE}}{R_{TH} + R_E(1+\beta)}$$

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

$$V_{CEQ} = V_{CC} - I_C (R_C + R_E)$$

Stability Comparison

① Fixed Bias circuit is not properly stable.

② Emitter resistance is added to Fixed Bias to stabilize it. (called Emitter Bias or self Bias)

Problem with Emitter Bias

③ not stable bcoz values of I_{BQ} & I_{CQ} depend on β. β is highly sensitive to Temp specially for Si transistors.

④ It is desirable to develop a bias circuit which is less dependent on β. Such a Bias circuit is called voltage divider.

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Numericals - 2

Q-1 Fixed Bias

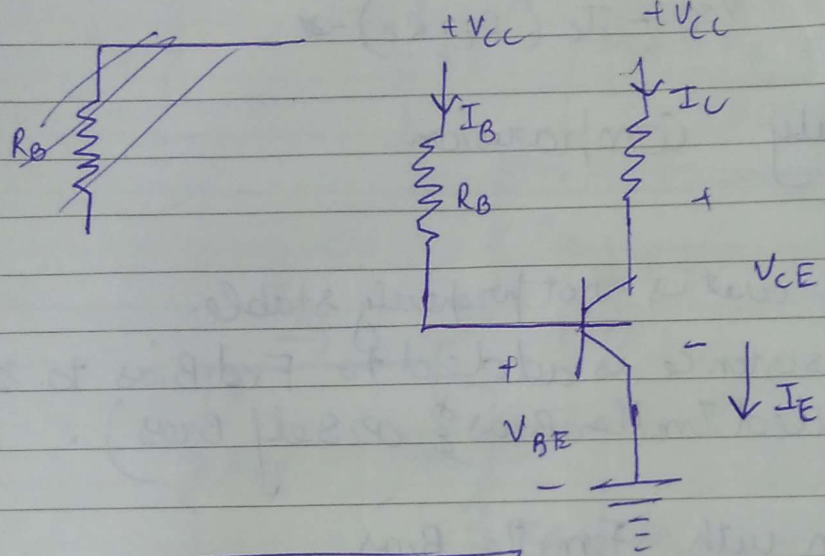
$R_B = 240k\Omega$ $V_{CC} = 12V$

$R_C =$ ~~200~~ $2.2k\Omega$

$\beta = 50$

Find I_{BQ}, I_{CQ}, V_{CEQ}

V_B, V_C, V_E, V_{BC}



$$\boxed{V_{BE} = 0.7}$$

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12 - 0.7}{240 \times 10^3}$$

$$= 0.47 \times 10^{-3}$$

$$\boxed{0.047\ mA}$$

$$I_{CQ} = \beta I_{BQ} = 50 \times 0.047 = 2.35\ mA$$

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

$$= 12 - 2.35 \times 2.2$$

$$V_{CEQ} = \boxed{6.83\ V}$$

we can consider V_{CEQ} for V_{CE}

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$V_{BE} = 0.7$

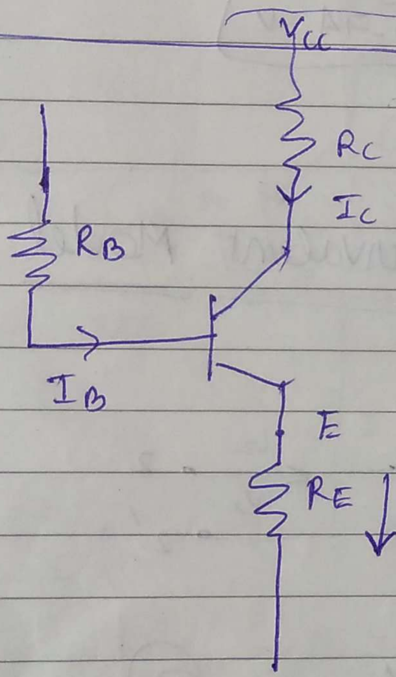
$V_B - V_E = 0.7$ $\qquad V_E = 0 =$ grounded

$\boxed{V_B = 0.7}$

$V_{CEQ} = V_C - V_E = 6.83$

$\boxed{V_C = 6.83}$

$V_{BC} = V_B - V_C = 0.7 - 6.83 = \boxed{-6.13}$



$V_{CC} = 20V$

$R_C = 2k\Omega \qquad R_B = 430k\Omega$

$R_E = 1k\Omega \qquad \beta = 50$

$I_{BQ}, I_{CQ}, V_{CE}, V_B; V_C, V_E$

$\boxed{V_{BE} = 0.7}$

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B + R_E(1+\beta)}$$

$$= \frac{20 - 0.7}{430 + 1(50+1)} \times 10^{-3}$$

$$= \boxed{0.0401 \, mA}$$

$I_{CQ} = \beta I_{BQ} = 50 \times 0.0401$

$= 2.00 \, mA$

$V_{CEQ} = V_{CC} - I_C (R_C + R_E)$

$= 20 - 2 \times 10^{-3} (\cancel{431}\ 3) \times 10^{3}$

$\boxed{V_{CEQ} = 14V}$

$\cancel{V_{CEQ} = V_C - V_E = 14 - 0 = 14 = V_C}$

$V_{BE} = 0.7 \qquad V_B = 0.7 \qquad V_E = 0$

$V_{BE} = 0.7$

$V_B - V_E = 0.7$

$V_B - I_E R_E = 0.7$

$V_B - (1+\beta) I_B R_E = 0.7$ $\quad I_E = (1+\beta) I_B$

$V_B - (51)\, 0.04 \times 1 = 0.7$

$V_B = 0.7 + 2.04$

$= \boxed{2.74 \text{ V}}$

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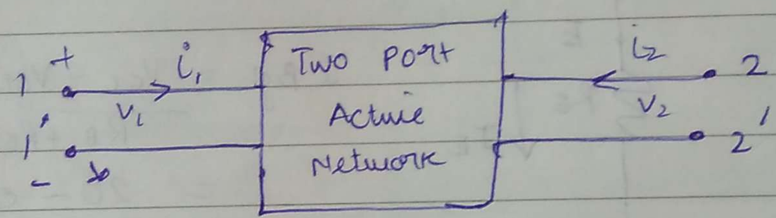
Hybrid Equivalent Model

Common Emitter



$V_1 = h_{11} i_1 + h_{12} V_2$ (1)

$i_2 = h_{21} i_1 + h_{22} V_2$ (2)

This means i_1 & V_2 are independent variables

Now
output short circuited $\quad V_2 = 0$

So $h_{11} = \dfrac{V_1}{i_1}$ = input impedance $= Z_i = h_i$

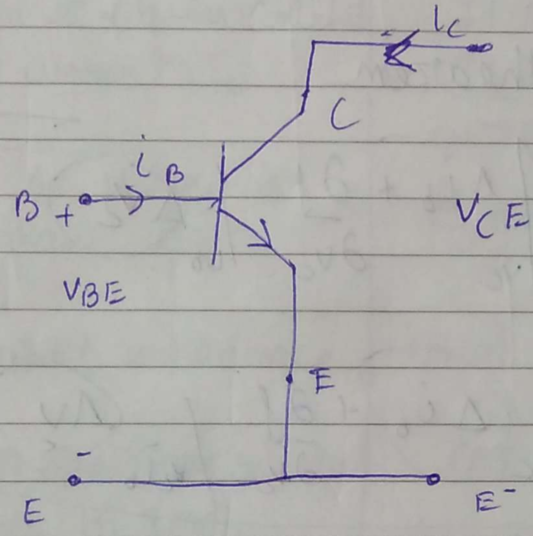
$h_{21} = \dfrac{i_2}{i_1} = h_f$, current gain forward

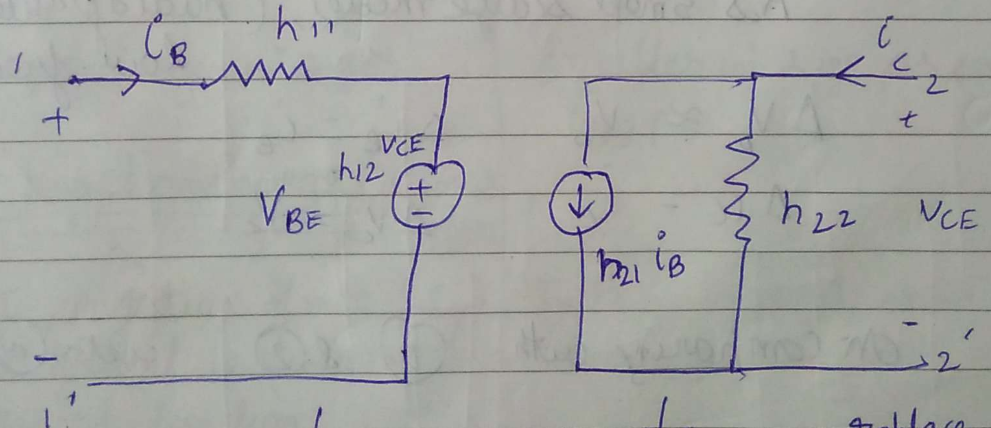
i/p
o c

So $i_1 = 0$

$h_{12} = \frac{V_1}{V_2}$ ⌀ h_r, reverse voltage gain

$h_{22} = \frac{i_2}{V_2}$ $1/r_o$ or h_o = Admittance





So this is a thevenin equivalent circuit

This is a norton equivalent circuit

replace i_2 with i_c
I_1 - i_B
V_1 - VBE
V_2 VCE

That's why hybrid

$50 \to 150$

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Derivation

$V_{BE} = V_B$

$V_b = f(i_b, V_c)$ (representing earlier equation in function form)

$i_c = f(i_b, V_c)$

using Taylor's theorem

$$\Delta V_b = \frac{\partial f}{\partial i_b}\Big|_{V_c} \Delta i_b + \frac{\partial f}{\partial V_c}\Big|_{i_b} \Delta V_c \quad (a)$$

$$\Delta i_c = \frac{\partial f}{\partial i_b}\Big|_{V_c} \Delta i_b + \frac{\partial f}{\partial V_c}\Big|_{i_b} \Delta V_c \quad (b)$$

As small scale model, (Audio frequency) low frequency

$\Delta V_b \approx V_b \qquad \Delta i_B = i_B$

$\Delta i_c = i_c \qquad \Delta V_c = V_c$

on comparing with (1) & (2) with (a) (b)

$h_{11} = \frac{\partial f}{\partial i_b}\Big|_{V_c} \qquad h_{12} = \frac{\partial f}{\partial V_c}\Big|_{i_b}$

$h_{21} = \frac{\partial f}{\partial i_B}\Big|_{V_c} \qquad \frac{\partial f}{\partial i_B}\Big|_{i_B}$

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JFET - Junction Field Effect Transistor

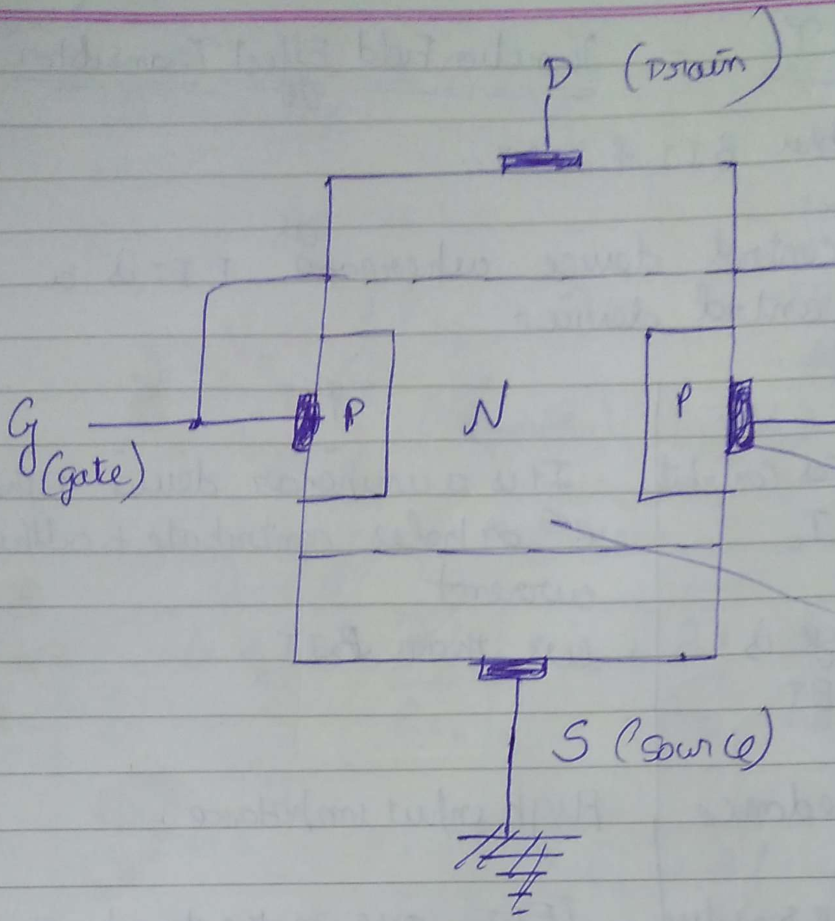
imp / sure

Differences b/w BJT & JFET

1.) BJT is a current control device whereas FET is a voltage control device.

BJT	JFET
2.) Both $e^{\ominus}$ & holes contribute to output current I_c	It is a unipolar device. Either $e^{\ominus}$ or holes contribute to output current
3.) BJT ka AC Voltage is higher than JFET	less than BJT
4.) Less input impedance BJT	High input impedance
5.) ~~Transistors~~ are more sensitive to changes in temp	JFET are more temp stable
6.) ~~Sma~~ larger in size	smaller in size as compared to BJT
7.) O/P based on charge carriers	
In BJT, injection of minority carriers takes place across Fwd Biased junction	In FET, majority charge carriers conduct

P infused in N substrate

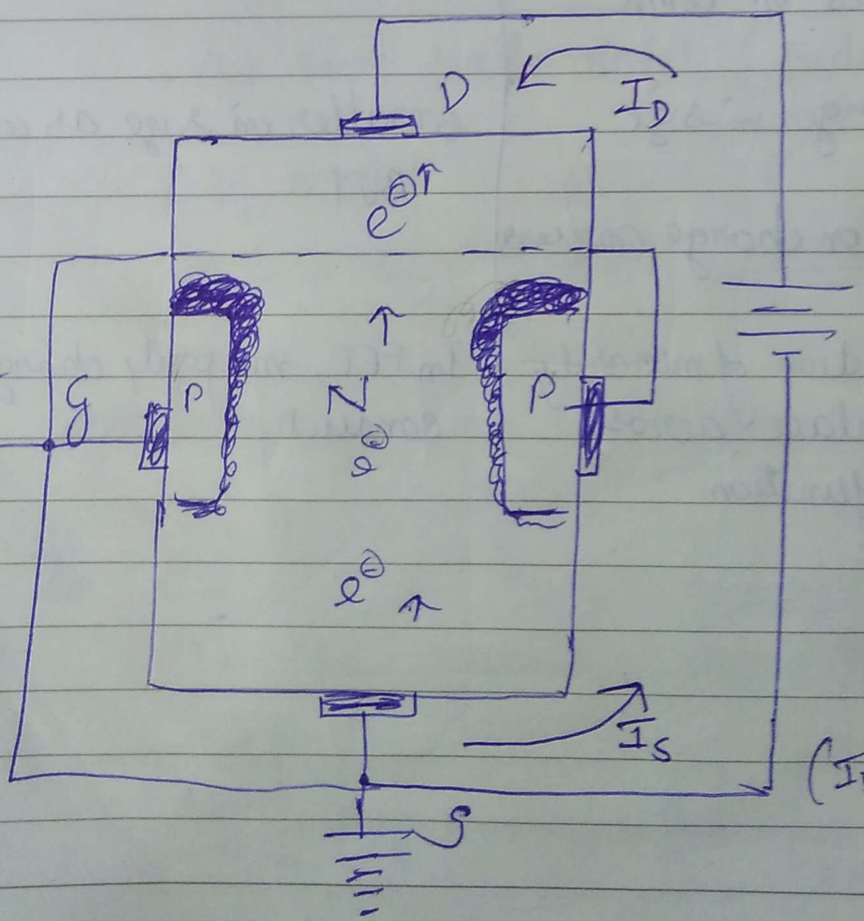


ohmic contacts

channel (provides resistance b/w D & S)

$V_{GS} = 0$

$V_{DS} = +ve$



D is +ve so $e^{\ominus}$ will go towards D. current is towards S

$(I_D = I_S)$

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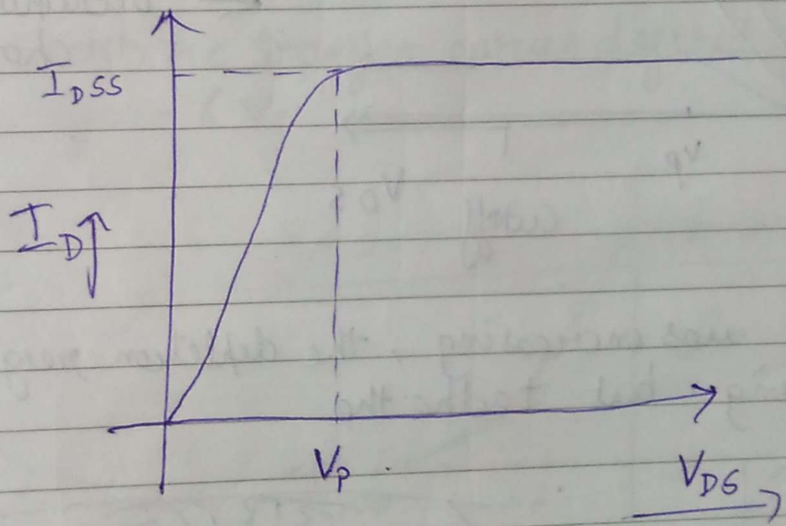
As we increase V_{DS}, more $e^{\ominus}$ will be attracted so current will go increasing. But also RB is increasing, so depletion is increasing. At some voltage, the depletion region will become so large that both depletion region will start touching eachother and no $e^{\ominus}$ will not be able to pass easily. This is the saturation level and current is called I_{DSS} (saturation Drain current) and the voltage is called pinchoff voltage



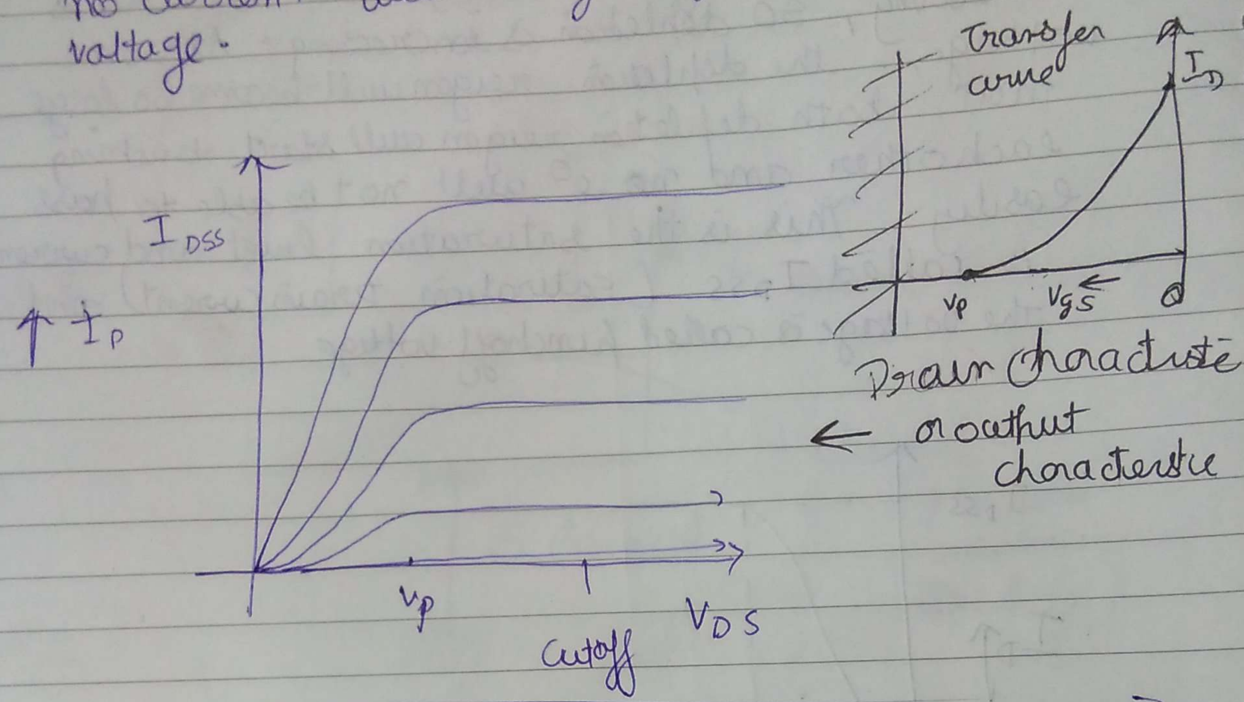
Now instead of taking $V_{GS} = 0$, V_{GS} is now equal to -2. So now the depletion region are already close to each other as RB is high.

That's why, V_P will be less, I_{DSS} will be less and saturation will come earlier. (common sense)

This means V_{GS} controls the current.

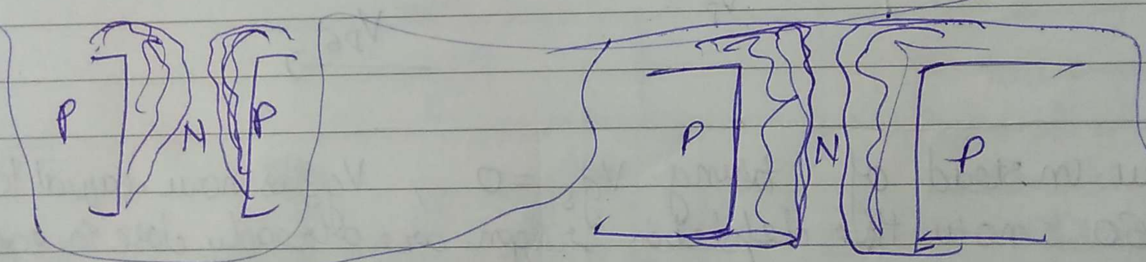
As V_{GS} becomes more $-ve$, saturation, V_P, I_{DSS} will start decreasing.

& so when $V_{GS} = -V_P$, at this voltage no current will start flowing. This is the cutoff voltage.



Drain characteristic ← or output characteristic

* when V_{DS} was increasing, the depletion region were closing but tedhe the



But when V_{gs} becomes $-V_P$, the channel closes properly

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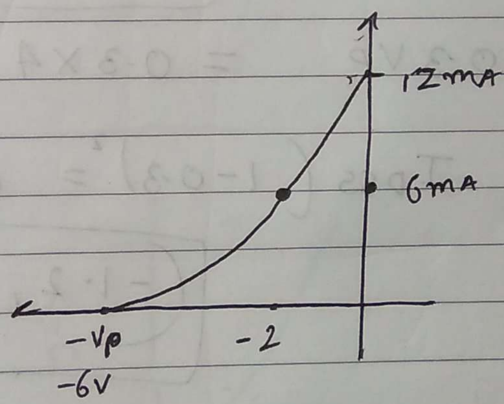
Analogous to BJT
Gate - Base
Drain - collector
Source - Emitter

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$ — Tells operation of JFET

For a particular value of V_{GS}, V_P and I_{DSS} are constant

Ques Sketch the transfer curve defined by $I_{DSS} = 12mA$
$V_P = -6V$.



Now finding ~~ID~~ points

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$ when $V_{GS} = 0.3V_P$

$$I_D = I_{DSS}\left(1 - \frac{0.3V_P}{V_P}\right)^2 = (0.7)^2 \times 12$$

$I_D = 0.5 \times 12 = 6$
& $V_{GS} = -0.3V_P = -0.3 \times 6 = -2$

Now when $V_{GS} = 0.5V_P$

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$\left(1 - \frac{0.3 \cancel{V_P}}{\cancel{V_P}}\right) \Rightarrow 0.49$

$I_{DSS} = 12mA \qquad V_P = -4$

$V_{gs} = 0.5 V_P \qquad V_{gs} = -2$

$I_D = I_{DSS}\left(1 - 0.5\right)^2 = 0.25 I_{DSS} = 3mA$

$\boxed{(-2, 3)}$

$V_{gs} = 0.\cancel{1} V_P = \cancel{0.4 \times} -0.4$

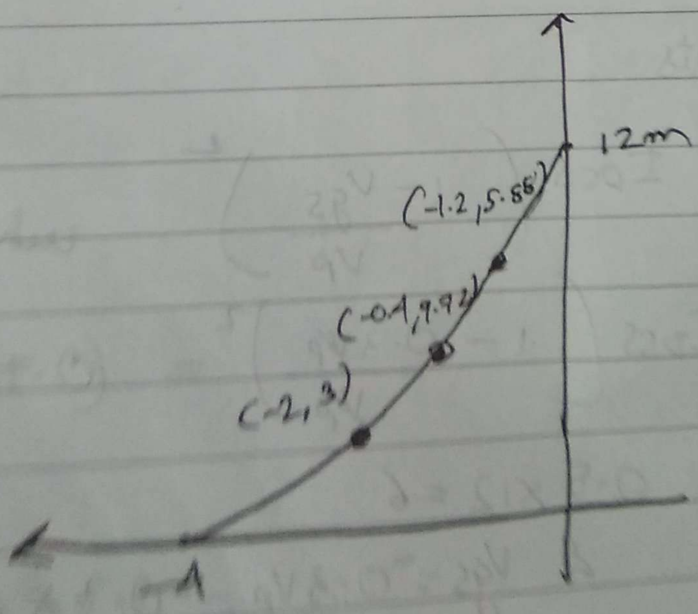
$I_D = I_{DSS}\left(1 - 0.1\right)^2 = 0.81 \times 12 = 9.72$

$\boxed{(-0.4, 9.72)}$

$V_{gs} = -0.3 V_P = 0.3 \times 4 = 1.2$

$I_{DSS}\left(1 - 0.3\right)^2 = 0.49 \times 12 = 5.88$

$\boxed{(-1.2, 5.88)}$



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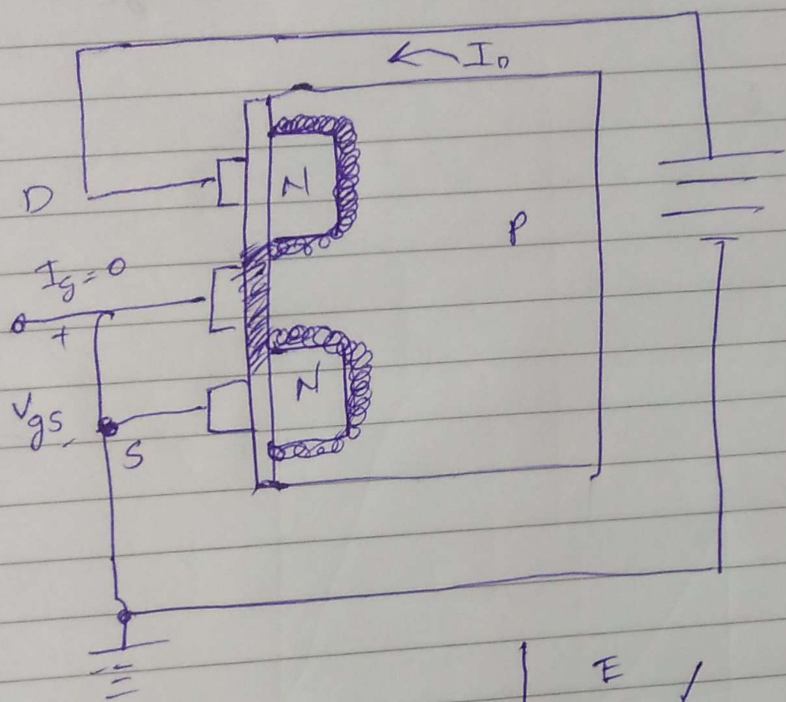
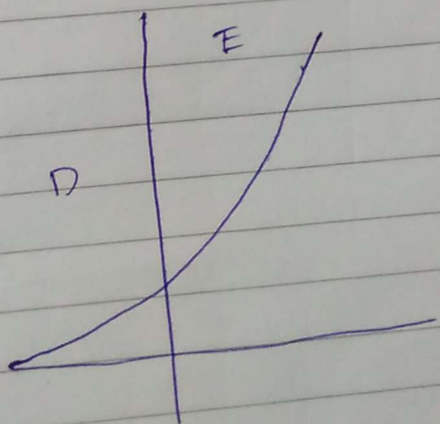
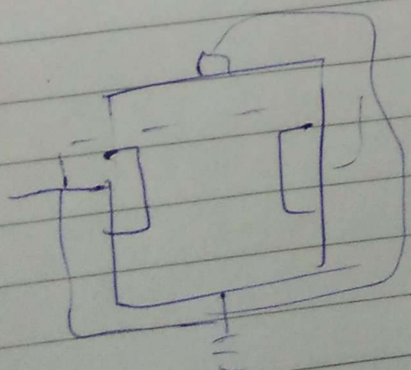
How to use Eber's equations.

Doubts Pg 183 - Eber's equation
Are they sufficient to explain?







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