03.07.19
Wednesday

Electronics Circuit Course

teacher:– Tanvir Sir

⊛ Basic knowledge:–

1. knowing voltage and current source
2. Dependent and independent source
3. Ohm's Law ⇝ (temp. mendatory), KVL, KCL.
4. Network Theorem:– Norton's, Thevenin's.
5. Nodal, Mesh
6. Impedence → resistance, inductance; capacitance

inductance → current lag করে কারণ current store করে।

capacitance → charge store করে।

⊛ Semi conductor Physics

- Diode
  - Diode Application/circuit
- BJT (Bipolar junction Transistor)
  - Application/circuit
- FET (Field Effect Transistor)
  - JFET
  - MOSFET
    - DMOS
    - EMOS

DMOS, EMOS → ckt.

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07.07.19

Sunday

Semi conductor materials:-

e^- এর flow যেদিকে current এর flow-ও সেদিকে
↳ natural current.

(*) Flow of charge (current):-

1. Conductor
2. Insulator
3. Semi conductor

(*) External field apply করলে huge amount এর চার্জ flow হবে → conductor. ex:- Cu, Al.

(*) 220V এ plastic গলে না।

(*) যার মধ্যে চার্জ এর flow হবে না → insulator.
ex:- Mica, wood, plastic.
external field বেশি দিলে পুড়ে যায়।

(*) বাইরে থেকে field দিলে charge এর generation হবে অর্থাৎ, e^- flow হবে। যখন field সরিয়ে ফেলা হবে তখন e^- ও hole এর সমতা তৈরি হবে। → semi conductor.
ex:- Si, Ge.

Temp. এর সাথে co-efficient change হয়।

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(*) Conductor এ → T বাড়ালে ~~resis~~ resistivity বাড়বে; conductivity কমবে। T↑ C↓ R↑ ((+)ve temp. co-efficient)

T বাড়ালে resistivity কমবে; conductivity বাড়বে। T↑ C↑ R↓ ((-)ve temp. co-efficient).

(*) Resistivity :- $\rho = \frac{1}{\sigma}$ → conductivity

(*) Conductor :- $10^{-6}\ \Omega\text{-cm}$ for copper's resistivity,

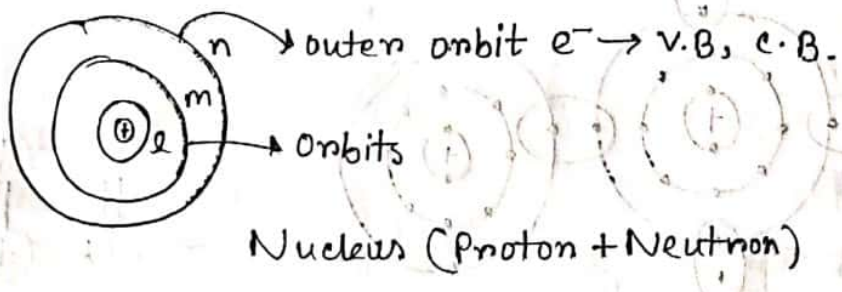
$$R = \rho \frac{L}{A}$$

$$\therefore \rho = \frac{RA}{L} = \frac{\Omega\text{-}m^2}{m} = \Omega\text{-}m$$

(*) Insulator :- $10^{12}\ \Omega\text{-cm}$ for Mica's resistivity.

(*) Semi conductor :- Resistivity of Si → $50 \times 10^3\ \Omega\text{-cm}$.

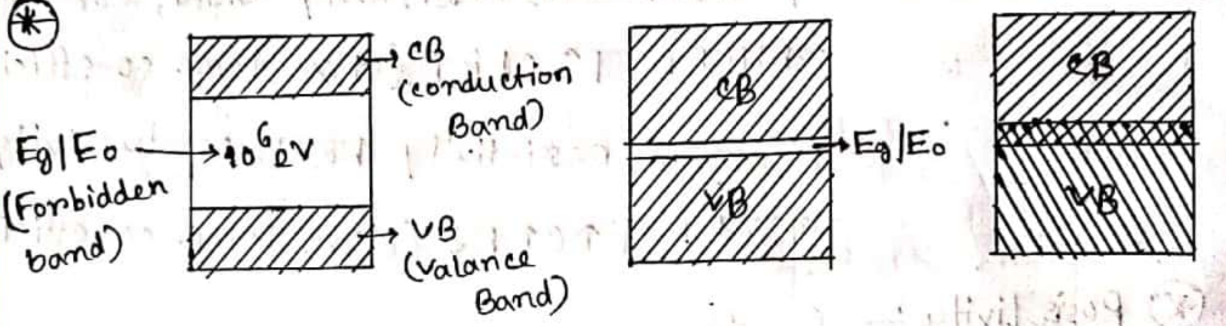
" " Ge → $50\ \Omega\text{-cm}$.



Nucleus (Proton + Neutron)

(*) outer shell nucleus থেকে যত দূরে তার উপর resistivity নির্ভর করে।

(*)



insulator semi conductor conductor

(*) $1.6\times10^{-19} J = 1 eV$

Si এর $E_g \rightarrow 1.16$ eV

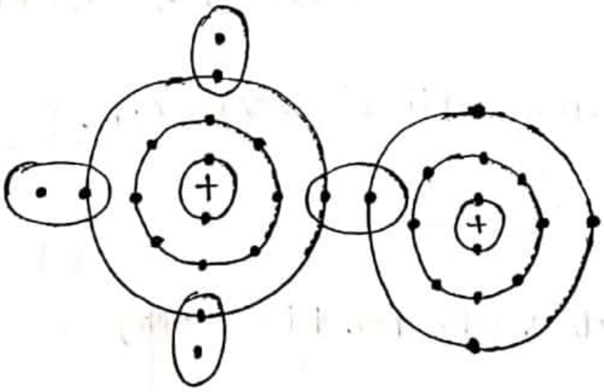
Ge এর $E_g \rightarrow 0.75$ eV

$Si_{14} \longrightarrow 2, 8, 4 \longrightarrow$ covalent bond

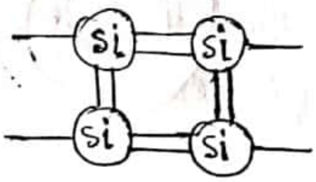
4টি e^- ~~নিয়ে~~ নিয়ে Ar_{18} এর e^- বিন্যাস লাভ করে। Si crystal/ lattice হিসাবে থাকে।

$Ge_{32} \longrightarrow 2, 8, 18, 4$

4টি e^- নিয়ে Kr_{36} এর e^- বিন্যাস লাভ করে।



Ge



silicon lattice or crystal.

⊛ Semi conductor:–

(1) Intrinsic :– (Pure)

i. They are the pure semi-conductor

ii. Free e^-s are due to natural causes. (Light, heat).

concentration of free e^- = concentration of holes.

(2) Extrinsic :– (Impure)

i. Impurity atoms are added

ii. Two types of impurity are there → trivalent impurity / → pentavalent "

iii. Added 1 part in 10 million

iv. Process of added impurity called doping

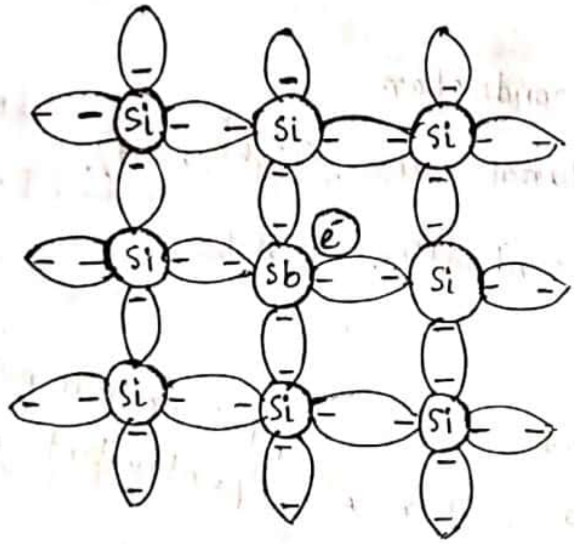
Group-3	Group-4	Group-5
B		Antimony, Sb, As.
Al		
Ga		
In		

→ যোজনী 3

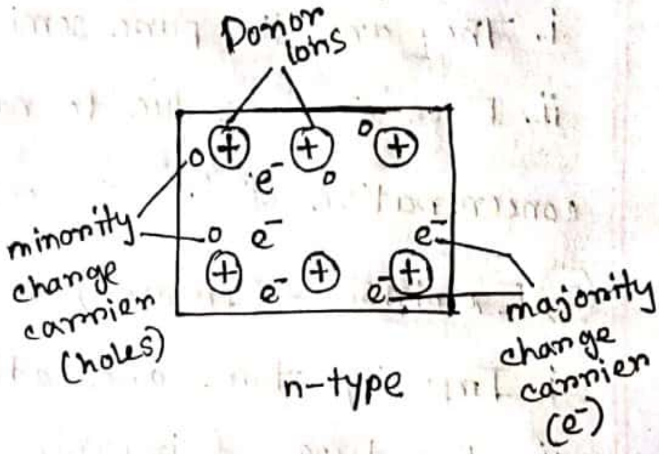
⊛ Extrinsic semi-conductor:–

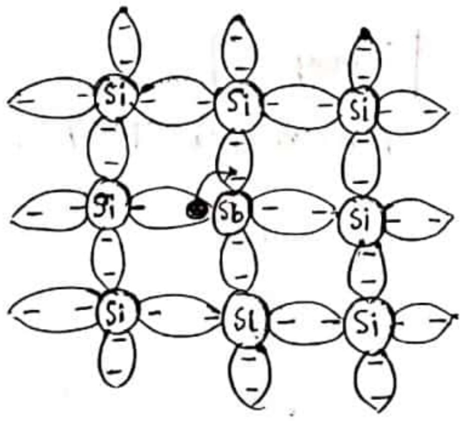
1. n-type ⟶ pentavalent

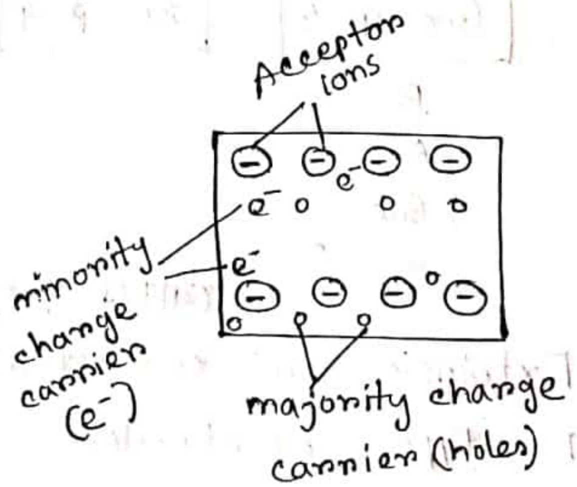
2. p-type ⟶ trivalent atom যখন extrinsic impure material এ add হয় তখন সেটা p-type.



n-type



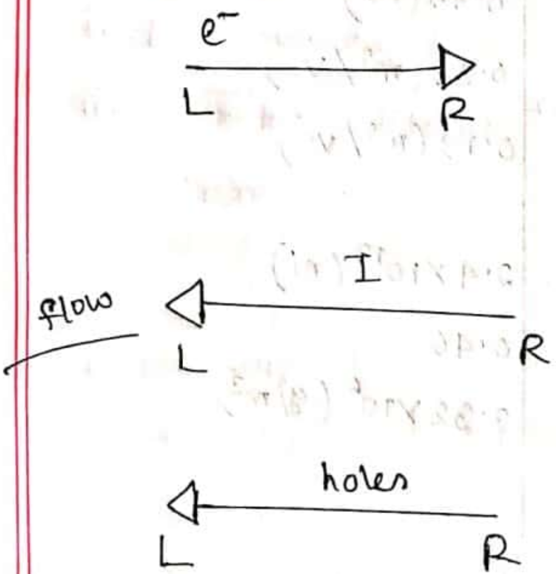




P-type

holes বেশি এবং
holes এর transportation
বেশি।

(*) Electron vs. hole float :-



[convention of Rule of current]

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08.07.19
Monday

Properties of Si and Ge at 30°K:—

	Si	Ge
• Energy gap	1·16	0·75 (eV)
• Electron Mobility	0·135	0·39 (m^2/Vs)
• Hole mobility	0·048	0·19 (m^2/Vs)
• Intrinsic carrier density	$1·5 \times 10^{16}$	$2·4 \times 10^{19}$ (n_i)
• Intrinsic resistivity	2300	0·46
• Density	$2·33 \times 10^6$	$3·32 \times 10^6$ (g/m^3)

Mass Action Law:—

Under thermal equilibrium product of free e^- concentration and free hole concentration is a constant and which is equal to square of ~~intris~~ intrinsic carrier concentration.

$\boxed{n = p = n_i}$ → hole con^c and e^- con^c same → Intrinsic semi conductor

After doping, $\boxed{np = n_i^2}$

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Proof:-

As giving thermal energy,

$\boxed{\text{Generation} = G}$

$\boxed{\text{Recombination} = R}$

$R \propto n$

$R \propto p$

$R \propto np$

$\Rightarrow R = r\,np$

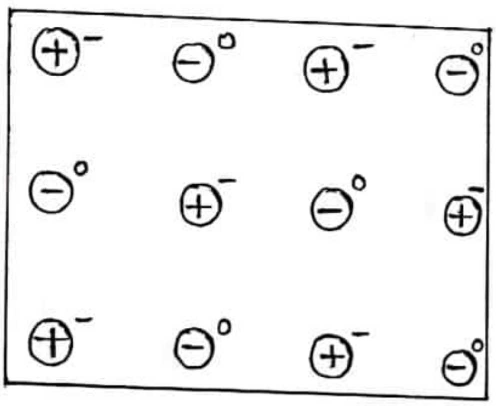
$r \rightarrow$ constant proportionality

$\boxed{G = r\,n_i^2}$

At thermal equalibrium, $G = R$

$\therefore \boxed{np = n_i^2}$

Charge carrier density:-



N_D = Concentration of Donor atom

N_A = Concentration of Acceptor ,,

n = Con^c of e^-

P = Con^c of hole

Total (+)ve charge in this piece of material $= N_D + P$

Total (-)ve charge $= N_A + n$

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at equalibrium / electrical neutral, $N_D + p = N_A + n$.

Case-1:— n type.

$\boxed{N_A = 0}$ cz সবাই ion, e^- accept করার কেউ নেই

$N_D + p = n$

$\boxed{N_D = n - p}$

Here, $n \gg p$

$\therefore N_D \approx n$

$\therefore n_n \approx N_D$

n-type

Again, according to MAL, Mass Action Law

$np = n_i^2$

$\Rightarrow n_n p_n = n_i^2$

$\Rightarrow \boxed{p_n = \frac{n_i^2}{N_D}}$ hole concentration বের করা যাবে।

Case-2:— p type

$\boxed{N_D = 0}$

$N_A + n = p$

$\Rightarrow N_A = p - n$

$p \gg n$

$\therefore \boxed{N_A \approx p}$

$\therefore p_p \approx N_A$

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according to MAL,

$np = n_i^2$

$\Rightarrow n_p p_p = n_i^2$

$\Rightarrow n_p = \dfrac{n_i^2}{p_p}$

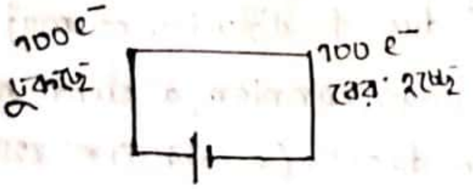
$\Rightarrow \boxed{n_p = \dfrac{n_i^2}{N_A}}$

extrinsic material,

$G \propto n_i^2$

$R \propto np$

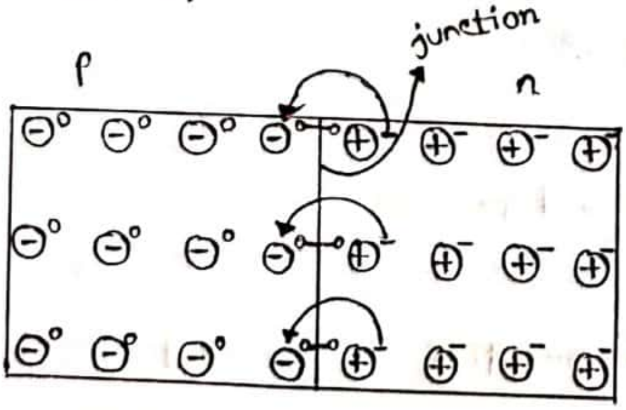
$\therefore np = n_i^2$

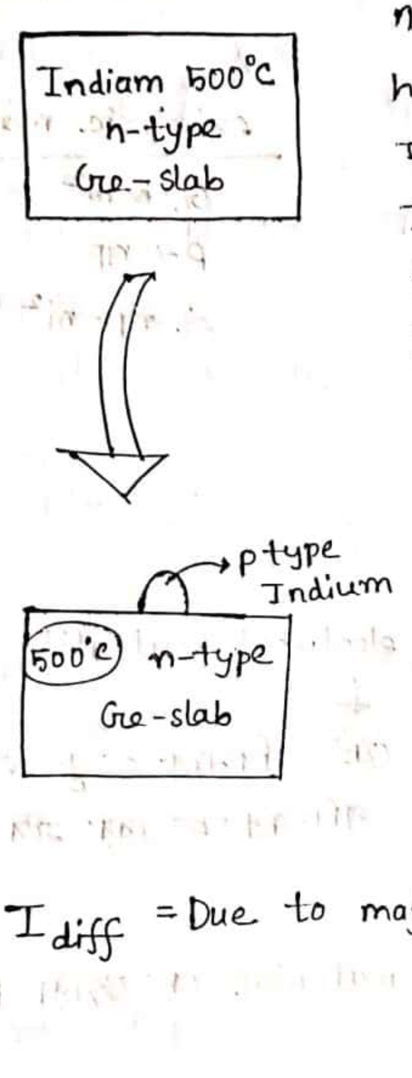


electrical neutrality

যেই পরিমাণ e^- ঢুকে, সেই পরিমাণ e^- বের হবে।

(*) P type material এবং n type material কে জোড়া দিলে p-n junction তৈরি হয়।



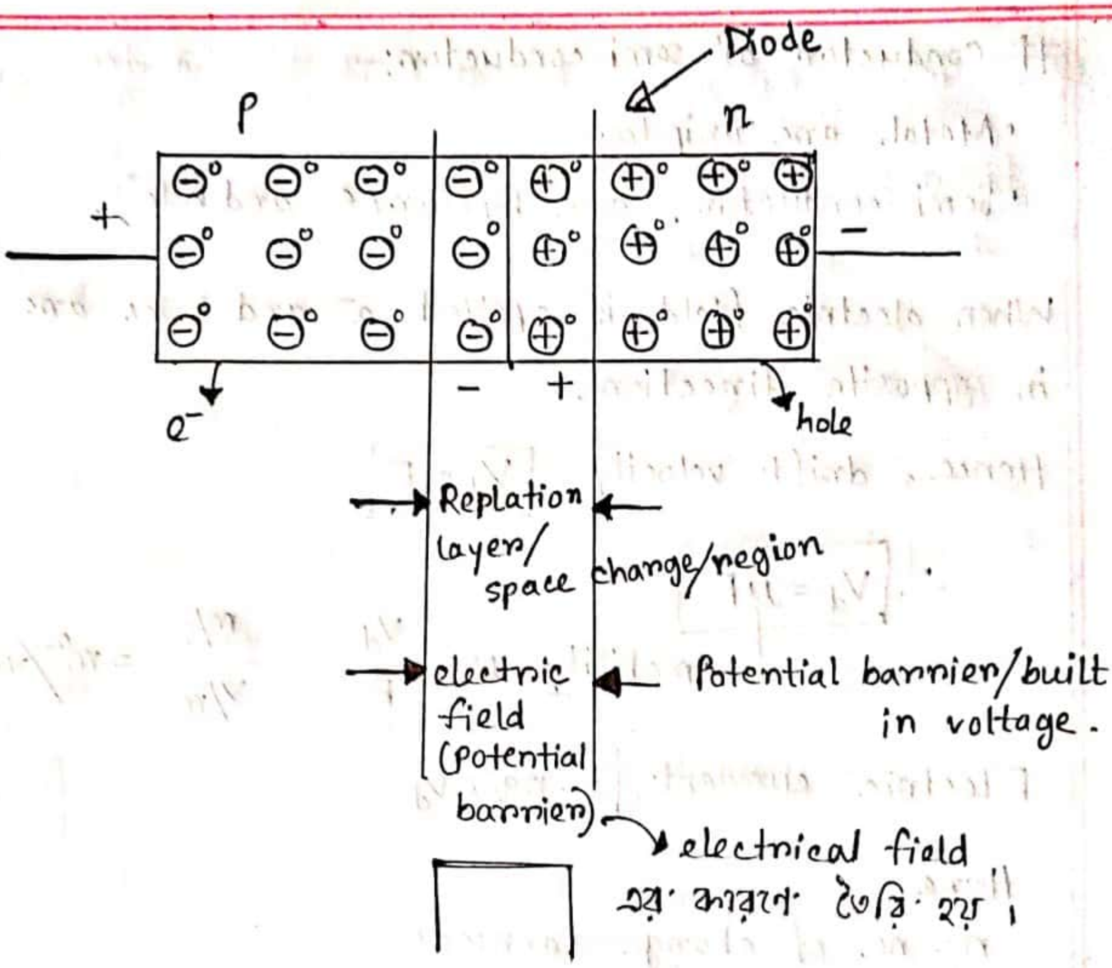


n-type Ge-slab কে 500°C এ heat করা হয়। ফলে liquify হয়। তখন trivalent material Indiam add করা হয়। Then ঠান্ডা করা হয়। ফলে p-type Indiam তৈরি হয়।

diffusion current:—

(*) due to diffusion of majority charge carrier, a current produces. (e^- এক পাশ থেকে আরেক পাশে গেলে)

I_{diff} = Due to majority charge carrier.



I_{drift} = Due to minority carrier.

⊛ at steady state condition,

$$I_{diff} = I_{drift}$$

∴ net current = 0.

⊛ (+)ve p এর সাথে, (−)ve n এর সাথে → সম্মুখ ঝোঁক (forward bias)

⊛ (−)ve p এর সাথে, (+)ve n এর সাথে দিলে barrier বড় হবে → reverse bias.

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10.07.19

Wednesday

Conductor of semi conductor:-

- Metals are unipolar
- Semi conductor's are bipolar (e^- and hole).

When electric field is applied, e^- and holes are drifted in opposite direction.

Hence, drift velocity, $\boxed{V_d \propto E}$.

$\therefore \boxed{V_d = \mu E}$

mobility, $\mu = \frac{V_d}{E} = \frac{m/s}{V/m} = m^2/V\text{-}s$.

Electric current, $\boxed{i = nqAV_d}$

Here,

n = no. of charge carriers

q = charge of e^-

A = Cross sectional Area

V_d = Drift velocity

Now, charge density, $J = \frac{i}{A}$

$$= \frac{nqAV_d}{A}$$

$$= nqV_d$$

$$= \underbrace{nq\mu}_{\sigma} E$$

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ohm's Law

$\therefore \boxed{J = \sigma E}$ — $V = IR$

conductivity

$$\boxed{\sigma = nq\mu}$$

Again, mobility $\propto \dfrac{1}{\text{effective mass}}$ $\qquad \mu \propto \dfrac{1}{EM}$

Effective mass of hole >> Effective mass of e^-

$\therefore \mu_n >> \mu_p$

$\therefore \boxed{J = (n\mu_n + p\mu_p) qE}$ → for intrinsic material

$\therefore \boxed{\sigma = (n\mu_n + p\mu_p) q}$

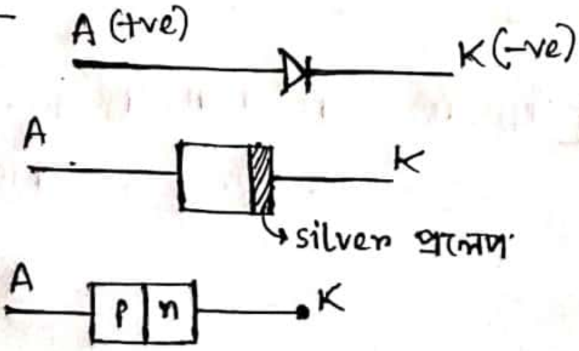
→ conductivity of semi conductor material

Diode:-

- a p-n junction
- bipolar device

bipolar → e^- ও hole দুইটাৰেই movement হয়।

Symbol:-



Ex:- LED, Photo diode etc.

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Biasing :- Applying external field to a device.

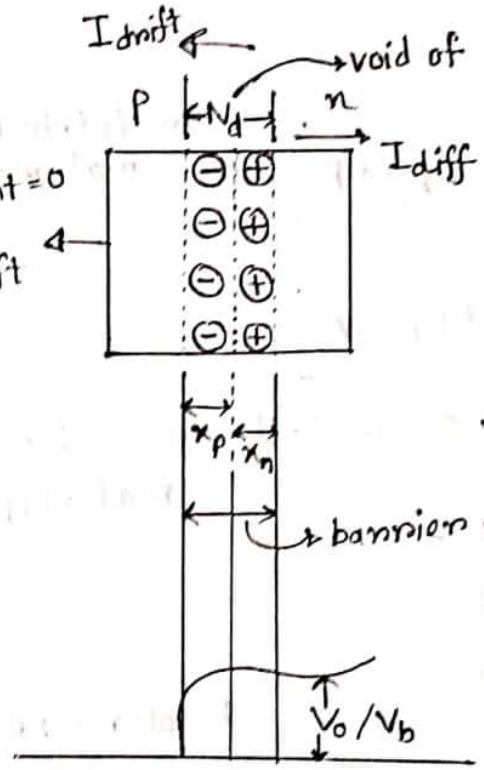
biasing conditions,

i. no applied bias

ii. reverse bias (RB)

iii. forward bias (FB)

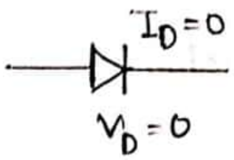
No applied bias :-



Net current = 0

$\therefore I_{diff} = I_{drift}$

$\therefore W_{dep} = x_p + x_n$



$V_0 = 0.7\,V\,(Si)$

$= 0.3\,V\,(Ge)$

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Built-in voltage:-

$$\boxed{V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)}$$

where;
V_0 = Built in voltage
V_T = Thermal voltage $= \frac{KT}{q}$

K = Boltzman constant $= 1.38 * 10^{-23}$ J/kelvin

T = Temperature at 300K.

q = e^- charge $= 1.6 * 10^{-19}$ C

$V_T \approx 26\,mV \approx 25\,mV$

N_A = con^c of acceptor atom

N_D = con^c of donor atom

n_i^2 = con^c of intrinsic Si (hole and e^-).

$\therefore\ q x_p A N_A = q x_n A N_D$

$$\Rightarrow \boxed{\frac{x_n}{x_p} = \frac{N_A}{N_D}}$$ normal temp. and at equilibrium.

$$\boxed{W_{dep} = x_n + x_p}$$

$$W_{dep} = \sqrt{\frac{2\epsilon_s}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)V_0}$$ built in voltage

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ϵ_s = permittivity of Si = $11 \cdot 76 \, \epsilon_o$

$\approx 1 \cdot 04 * 10^{-12}$ F/cm

$\epsilon_o = 8 \cdot 854 * 10^{-12}$ F/m.

$\therefore$ Typically, $W_{dep} = 0 \cdot 1$ to 1 um ; for Si.

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14.07.19

Sunday

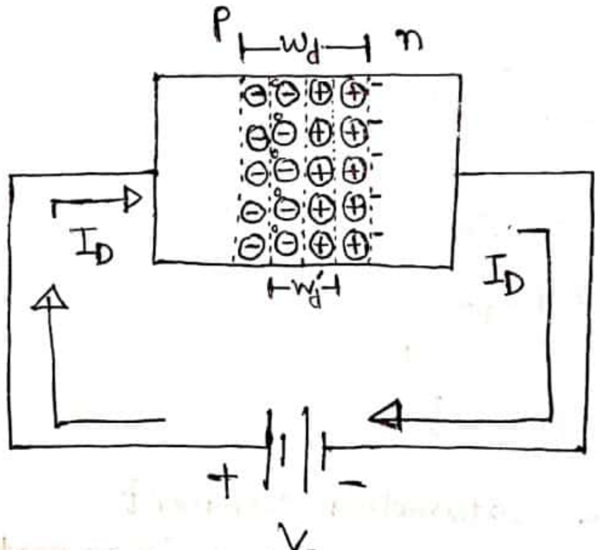
Diffusion Current:-

Drift current:-

Forward Bias:-

PN junction diode forward biased.

$\boxed{V_D = 0}$



$V_b = 0.7V$

$V_D = 0.7V$

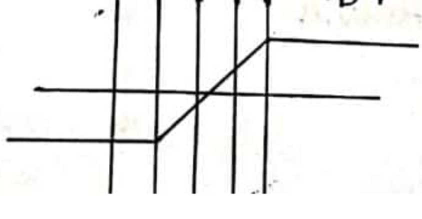
New built in voltage,

$= V_b - V_D$

$= 0$

$I_D = I_{maj} - I_s$ depend on temp.

$I_D \uparrow$ $I_{maj} \uparrow$



$V_D = 0$

$V_D > 0$

$w_d > w_d$ no applied.

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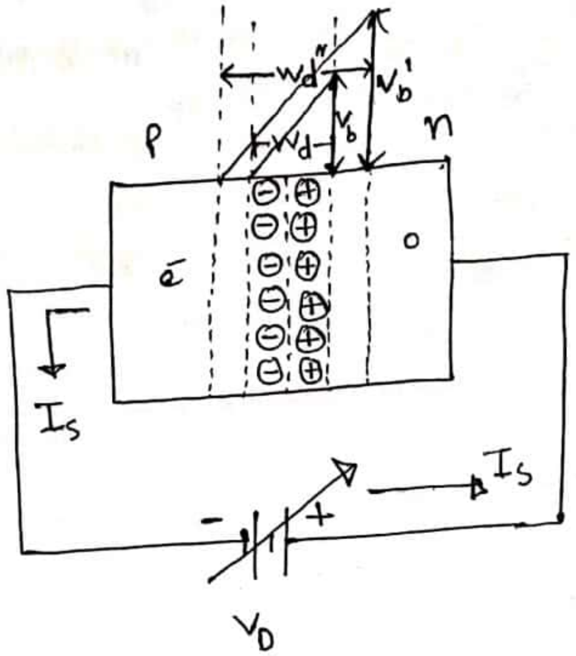
Reverse Bias:-



$I_D \approx 0$

$I_{maj} \approx 0$

$I_s (\mu A)$.

$W_{d_{rb}} > W_{d_{no\,bias}} > W_{d_{forward\,bias}}$

↓
reverse bias

$V_{b_{rf}} > V_{b_{no\,bias}} > V_{b_{fb}}$.

Diode current voltage relation:-

$$I_D = I_s \left(e^{KV_D/T_K} - 1 \right)$$

I_D = Diode current

I_s = Reverse saturated current

K = Boltzman constant $= \dfrac{11600}{\eta}$ → material এর con^c এর উপর depend করে।

V_D = voltage across diode

T_K = Temp. in Kelvin

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

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Here, $\eta = 1$ and 2

$= $ ideality factor

$$\left.\begin{aligned}\eta &= 1 \text{ for Ge} \\ &= 2 \text{ for Si}\end{aligned}\right] I_D \downarrow$$

$$\eta = 1 \text{ for Ge and Si} \Big] \; I_D \uparrow$$

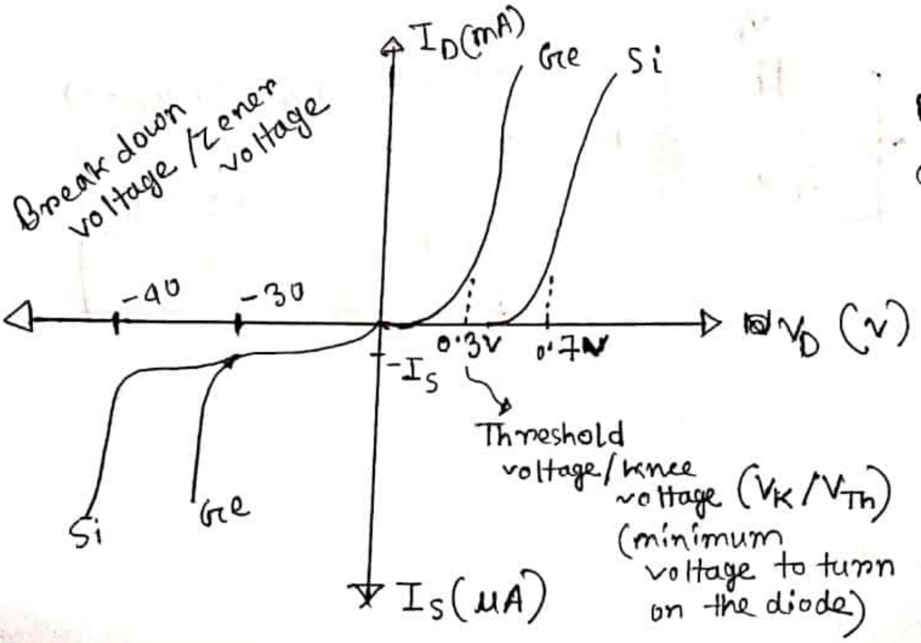
$$V_T = \frac{T_K}{11600}$$

$$= \frac{T_K}{K\eta}$$

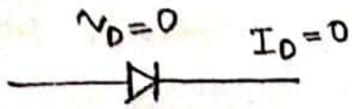
$$\therefore \frac{K}{V_T} = \frac{1}{V_T \eta}$$

$$\therefore \boxed{I_D = I_S \left(e^{V_D / \eta V_T} - 1 \right)} \; ***$$

Diode shockley equation

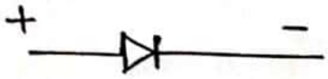


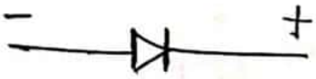
Diode I-V characteristics curve.



$V_D>0$

$I_D = I_s\left(e^{V_D/\eta V_T} - 1\right)$

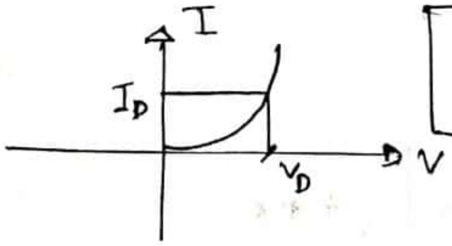




$V_D<0$

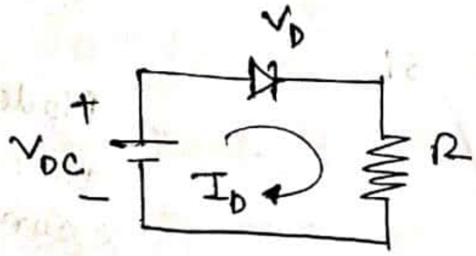
$I_D = -I_s$

DC or Static Resistance :-



$$\boxed{r_d = \frac{V_D}{I_D}}$$

Q-point :- Operating point / Quiescent point.



$-V_{DC} + I_D R + V_D = 0$

$$\therefore \boxed{I_D = \frac{V_{DC} - V_D}{R}}$$

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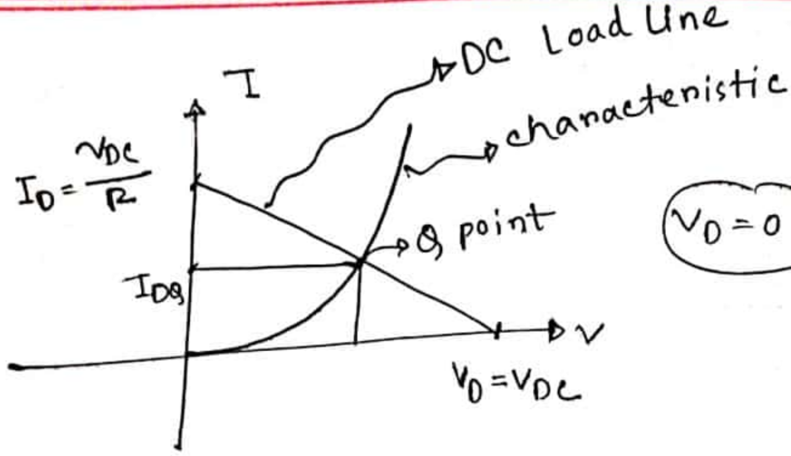

$V_D = 0$ assume

$V_D = 0$

$I_D = 0$

$V_D = V_{DC}$

rms value → equivalent effective value.

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15/07/2019
Monday

Breakdown voltage:-

Peak inverse voltage (PIV):- Maximum ~~allowab~~ reverse allowable voltage that a diode can resist without damaging.

AC or dynamic Resistance:-

The varying will change instantaneous operating point up and down and thus a change in voltage and current.

A straight line tangent is drawn to determine change in voltage and current and as well ac or dynamic resistance.

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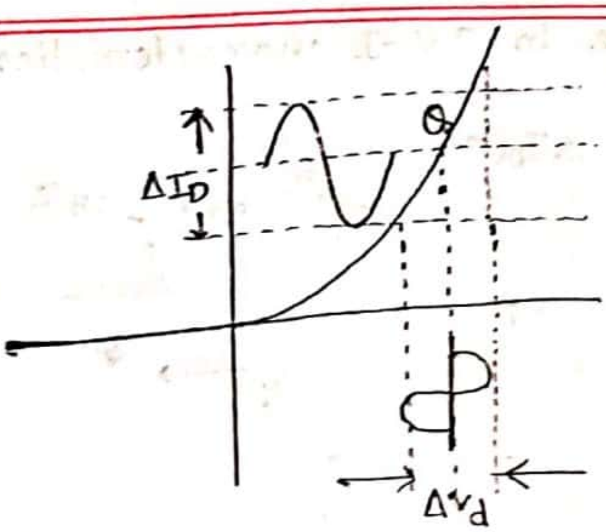

$$r_d = \frac{\Delta V_d}{\Delta I_d}$$

Alternative method:-

We know,

$$I_D = I_S\left(e^{V_D/\eta V_T} - 1\right)$$

$$\Rightarrow \frac{I_D + I_S}{I_S} = e^{V_D/\eta V_T}$$

Ignoring I_S,

$$\Rightarrow I_D + I_S = e^{V_D/\eta V_T}$$

$$\therefore \ln(I_D + I_S) = \frac{V_D}{\eta V_T}$$

$$\therefore \frac{d}{dV_D}\ln(I_D + I_S) = \frac{1}{\eta V_T}$$

$$\Rightarrow \frac{1}{I_D + I_S}\cdot\frac{dI_D}{dV_D} = \frac{1}{\eta V_T}$$

$$\Rightarrow \frac{dI_D}{dV_D} = \frac{I_D + I_S}{\eta V_T}$$

$\boxed{I_D \gg I_S}$

$$\therefore \frac{dV_D}{dI_D} = \frac{\eta V_T}{I_D}$$

KT/q

as $\boxed{\eta = 1}$

$$\therefore \frac{dV_D}{dI_D} = \frac{26\,mV}{I_D}$$

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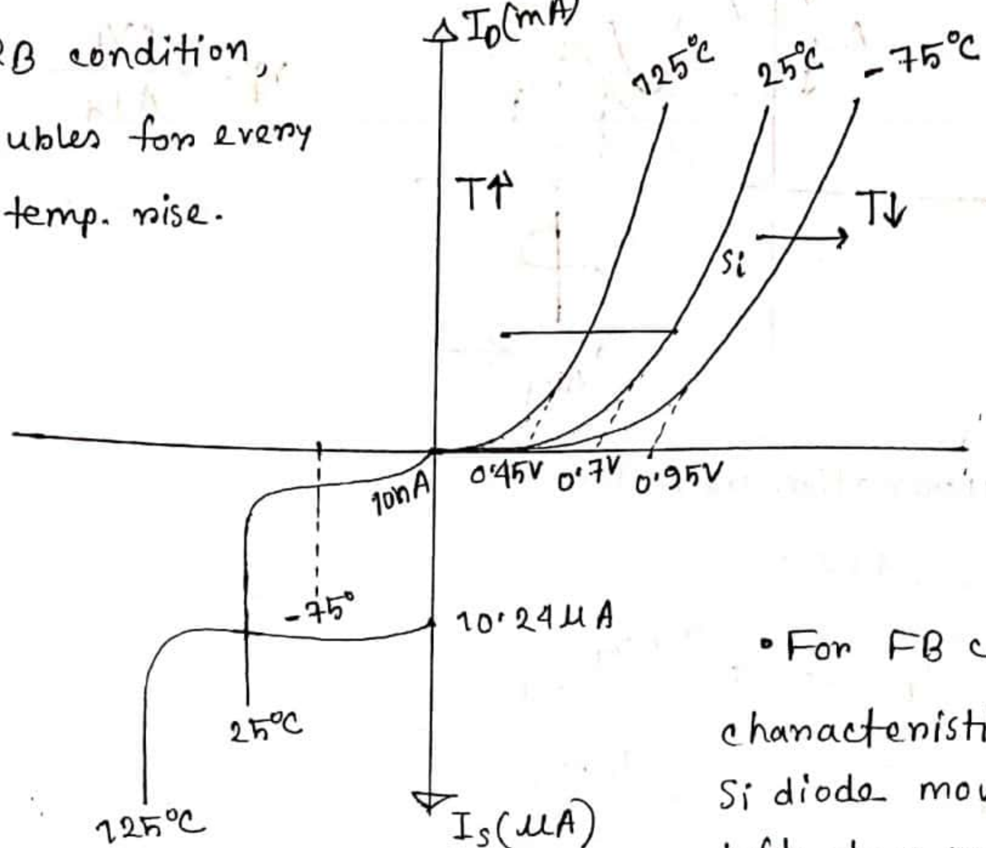
Effect of temp change in V–I characteristics:–

- For RB condition, I_s doubles for every $10^\circ c$ temp. rise.



- For FB condition, characteristics of Si diode moves left at a rate of 2.5 mV per degree centigrade temp. rise

* semi conductor এ temp. বাড়ালে resistance কমবে।

$\uparrow 100^\circ \times 2.5 = 0.25V$

$1^\circ C = \cancel{2E}\ 25\ mV$

$(0.7 - 0.25) = 0.45$

- T↑ device left shift হবে।
- T↓ device right shift হবে।

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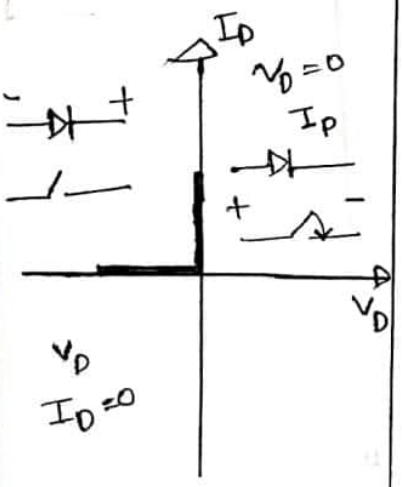
Diode equivalent ckt :—

Why equivalent ckt ?

• যাদের current বা voltage দেয়ার ক্ষমতা নাই, তারা passive element.
ex:- resistance.

~~Piecewise linear~~

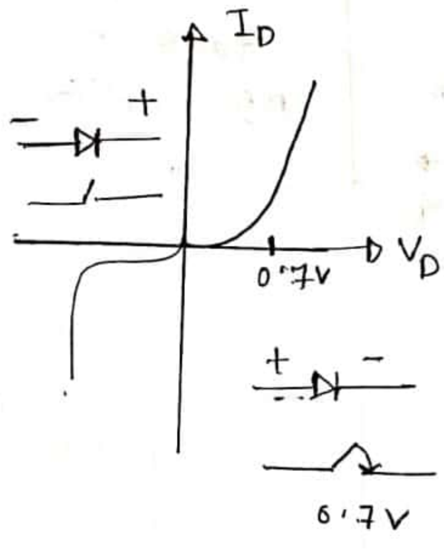
Ideal diode



↓

• conduct করে without any voltage drop.

Practical diode



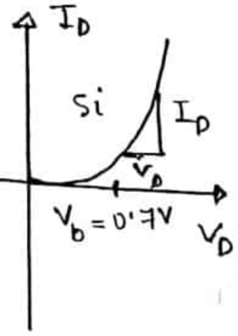
Piecewise Linear Model (PWL model)	Constant voltage drop model (extensively used)	Ideal diode model

Piecewise Linear Model (PWL model)

Representing a non-linear ckt in a linear way.

$\frac{1}{r_d} = \frac{I_D}{V_D}$

$\Rightarrow V_D = I_D r_d$

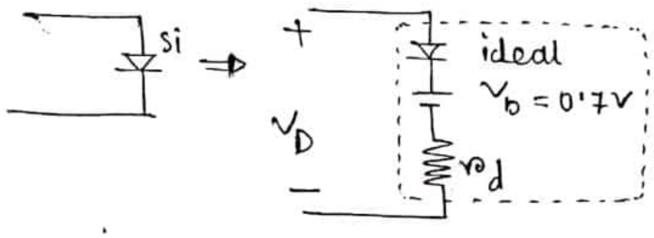


~~So~~ slope $= \tan\theta$

$= \frac{P}{B}$

$= \frac{1}{r_d}$

representation of a Si diode,



$\therefore V_D = V_b - I_D r_d$

Constant voltage drop model

$r_d = 0$

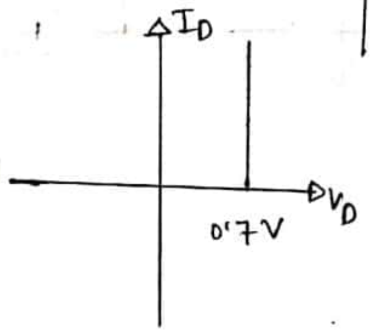
$\therefore$ slope $= \frac{1}{r_d}$

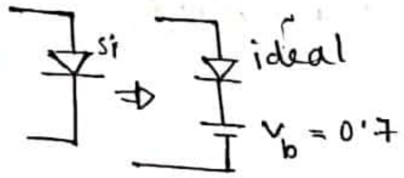
$= \frac{1}{0}$

$\tan\theta = \infty$

$\Rightarrow \theta = \tan^{-1}(\infty)$

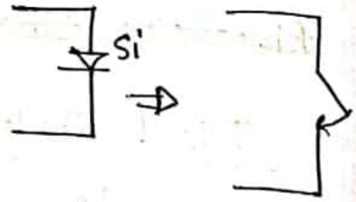
$= 90^\circ$





constant volt drop

Ideal diode model



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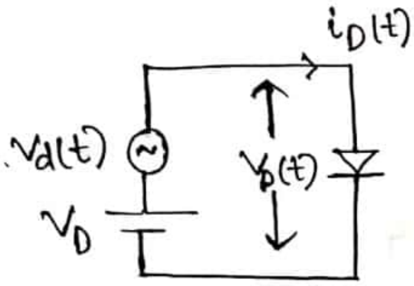
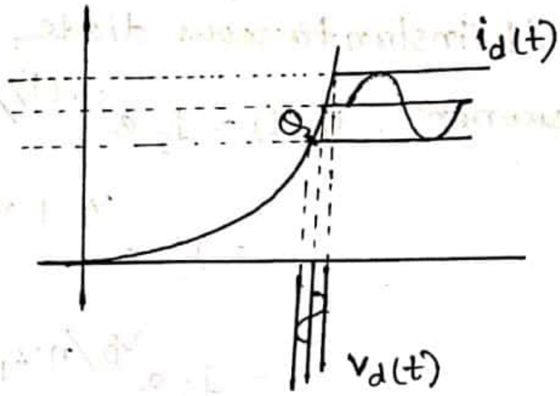
17/07/2019
Wednesday

The small signal model and its characteristics:—





Amplitude is small enough to be called linear portion.

The technique consists first biasing the Q point near the middle of the transfer characteristic. This is achieved by applying DC voltages V_D. The time varying quantity then superimposed.

ac & dc দুটোই আছে

Total instantaneous i/p , $\boxed{v_D(t) = V_D + v_d(t)}$ → dc

→ ac

Time varying quantity $v_d(t)$ having a sinusoid/ Triangular is supeimposed on V_D.

In the absence of $v_d(t)$.

$$I_D = I_S e^{V_D/\eta V_T}$$

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Now,

Total instantaneous diode current, $i_D(t) = I_S e^{v_D(t)/\eta V_T}$

$$= I_S e^{V_D + v_d(t)/\eta V_T}$$

$$= I_S e^{V_D/\eta V_T} \cdot e^{v_d(t)/\eta V_T}$$

$$= I_D \cdot e^{v_d(t)/\eta V_T}.$$

Now, if $\boxed{v_d(t)/\eta V_T \ll 1}$; $\left[\because e^x = \underbrace{1+x}_{} + \frac{x^3}{2!} + \cdots\right]$

less than 1 হলে 1st 2টো term রাখলে,

from exponential series,

we know that,

$$e^{v_d(t)/\eta V_T} = \left(1 + \frac{v_d(t)}{\eta V_T}\right)$$

$$\therefore i_D(t) = I_D\left(1 + \frac{v_d(t)}{\eta V_T}\right)$$

$$= I_D + I_D \frac{v_d(t)}{\eta V_T}$$

$$\therefore i_D(t) = DC + AC$$

$$= I_D + i_d(t)$$

$$\therefore i_d(t) = I_D \cdot \frac{v_d(t)}{\eta V_T}$$

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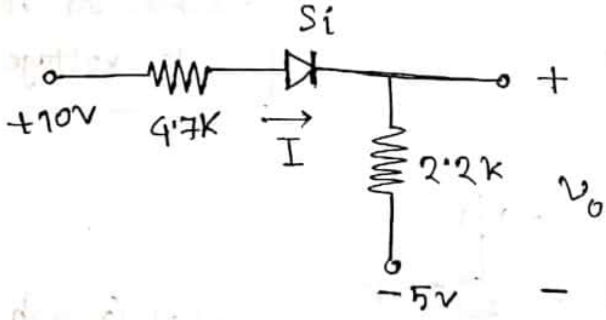
$$\therefore \frac{v_d(t)}{i_d(t)} = \frac{\eta V_T}{I_D}$$

$$\Rightarrow \boxed{r_d = \frac{\eta V_T}{I_D}}$$

r_d is called ac/dynamic/small signal resistance.

Germanium এ $\eta \to 1$

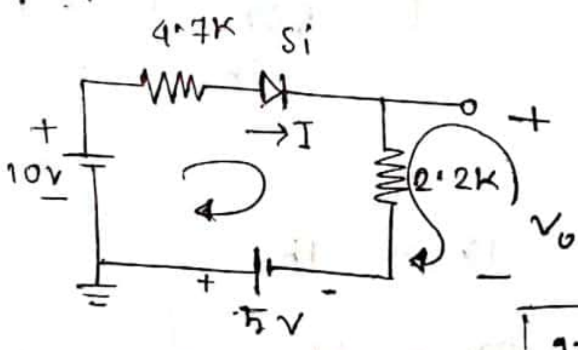
#



Find v_0 & I.

→ KVL,

$-10 + (4.7K * I) + (2.2K * I) - 5 + 0.7 = 0$



$-v_0 + I * 2.2K - 5 = 0$

$\Rightarrow V_0 = -5 + I * 2.2K$

ground এর সাপেক্ষে -5v দিলে তাই- outer loop এ KVL,

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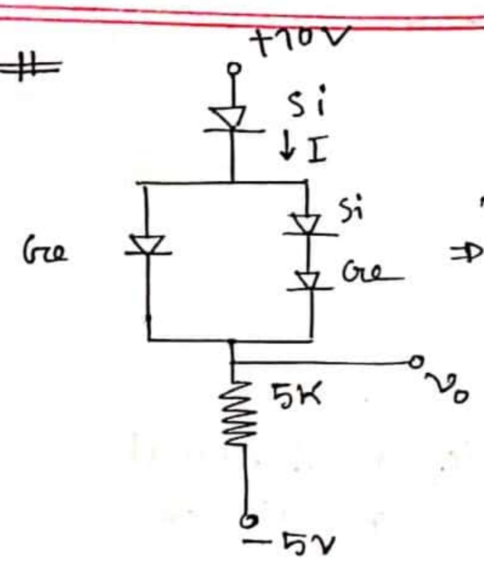
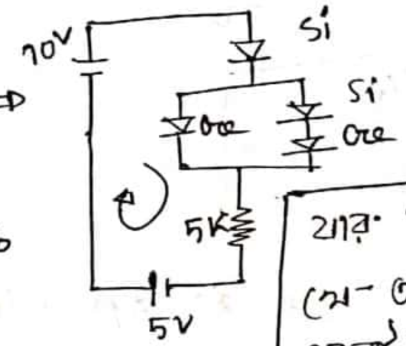


Find I & V_0.



যার voltage drop কম সে আগে on হবে, একই branch এ দুটো diode থাকলে। (parallel branch এ)

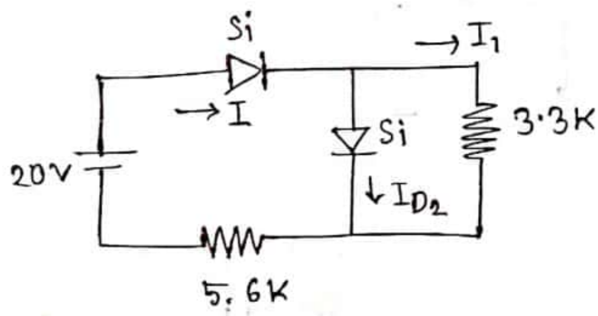
→

$$-10+0.7+0.3+(5K*I)-5=0$$

bubble এর voltage node voltage

$$-V_0+5K*I-5=0.$$

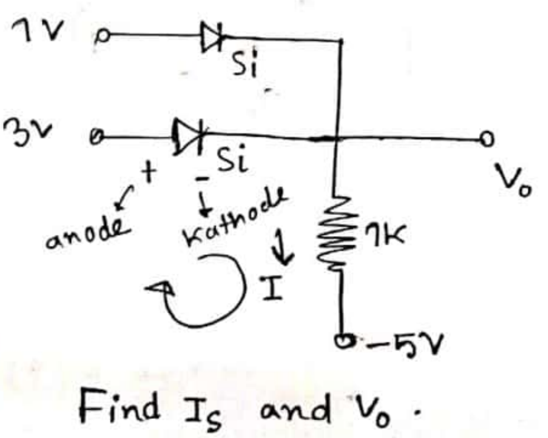
#



→ nodal / mesh

#

Sedra Smith book



* Anode (+) ও cathode (−), ~~হবে~~ So cathode (+) এ থাকলে current pass হবে না।

Find I_S and V_0.

* anode ও kathode এর মাঝে যে diode এর potential diff বেশি সে আগে on হবে।

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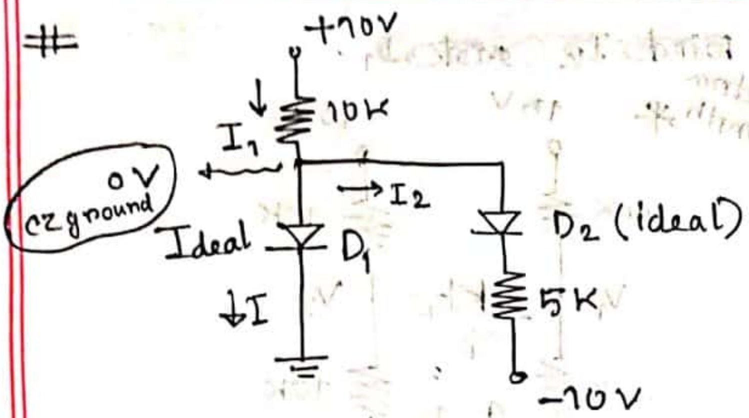

Find $I_1, I_2 = ?$

Diode D_1 is on ; (short)

$$I_1 = \frac{10-0}{10k} = 1mA.$$

$$I_2 = \frac{0-(-10)}{5k} = 2mA.$$

$$I_1 = I + I_2$$

$\Rightarrow I = I_1 - I_2 = 1mA - 2mA = -1mA$; reverse bias.

$$I_1 = I_2 = \frac{10-(-10)}{10k+5k} = \frac{20}{15K}$$

* reverse bias হলে diode off থাকে।
* যার potential difference বেশি সেই diode আগে on হবে।
* Anode kathode এর চেয়ে বড় হলে short হয়ে যাবে।
* voltage difference 0 হলে open হবে।

* short থাকলে current open দিয়ে যাবে না।

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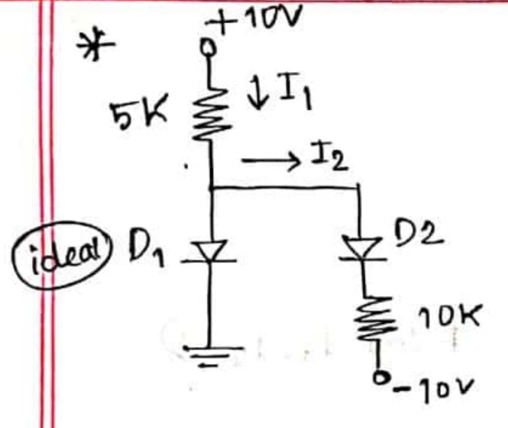
27.07.2019
Sunday

*



Find I_2 and I_1.

$\rightarrow$ $I_1 = \dfrac{10-0}{5K} = 2mA$

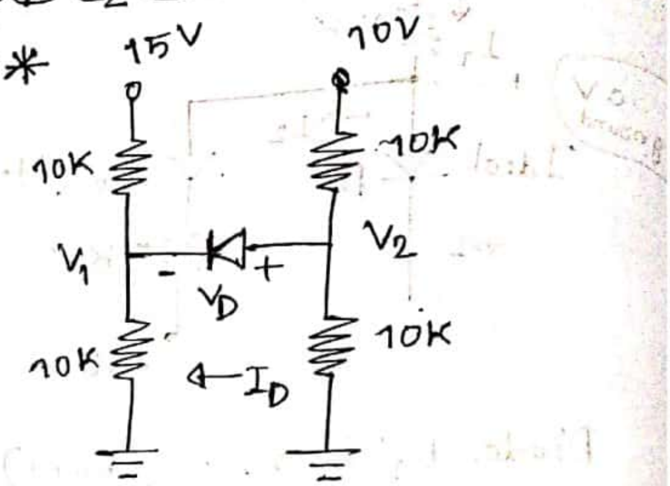
$I_2 = \dfrac{0-(-10)}{10K} = 1mA.$

$I_1 = I_{D_1} + I_2$

$\Rightarrow I_{D_1} = 1mA$. Ans.

~~Find I_2 and I_1.~~

sedra smith *



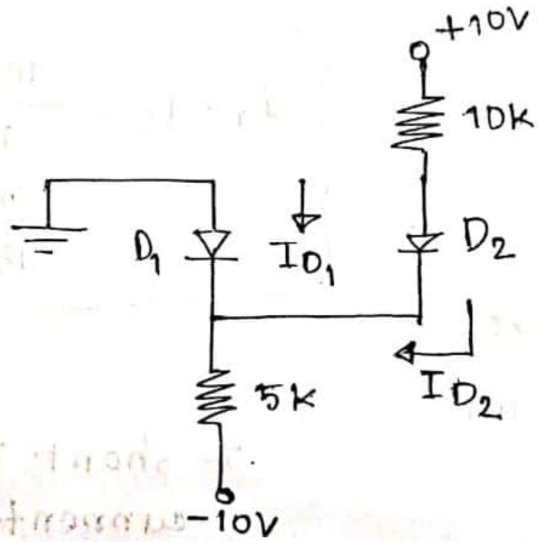
Find I_D.

$\rightarrow V_D = V_2 - V_1$

$= 5 - 7.5$

$= -2.5V$.

sedra smith *



Find I_{D_1} and I_{D_2}.

$\rightarrow I_1 = \dfrac{0-(-10)}{5K}$

$\Rightarrow I_1 = 2mA$

$I_{D_2} = 1mA$

$I_1 = I_{D_1} + I_{D_2}$

$I_{D_1} = 1mA$.

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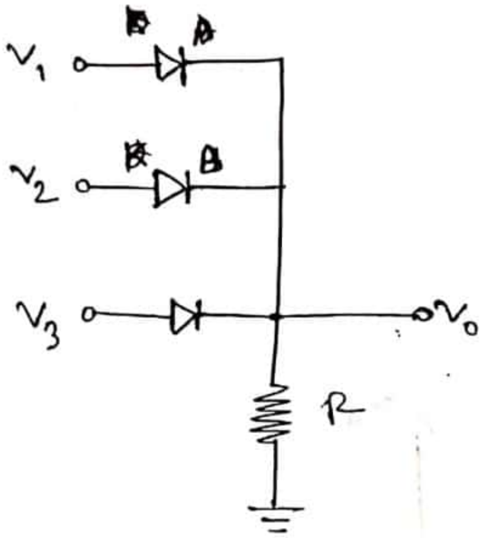
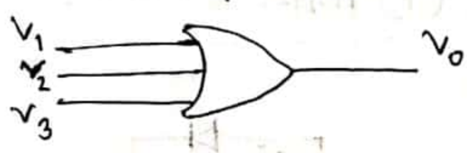
Logic Gate:-

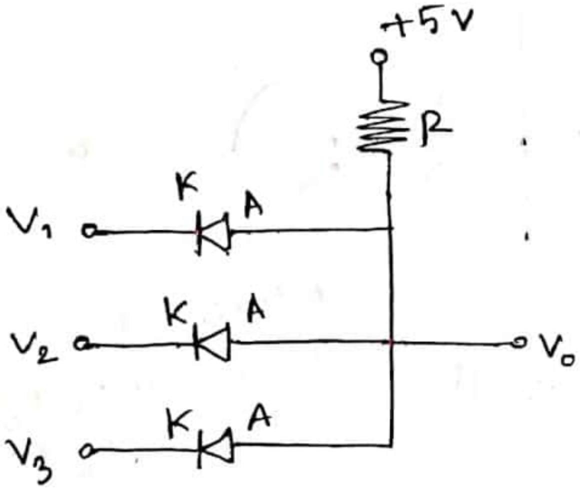
OR Gate



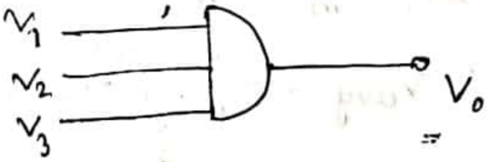
$$\boxed{V_0 = V_1 + V_2 + V_3}$$



AND Gate



$$\boxed{V_0 = V_1 \cdot V_2 \cdot V_3}$$



V_A	V_B	V_C	V_D
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1

V_A	V_B	V_C	V_D
0	0	0	0
0	0	1	0
0	1	1	0
1	1	1	1

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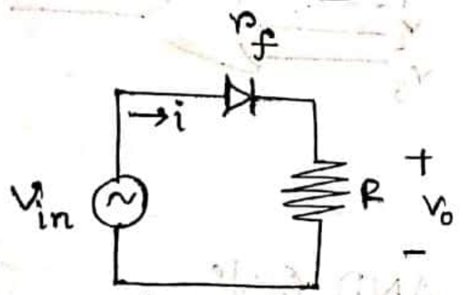
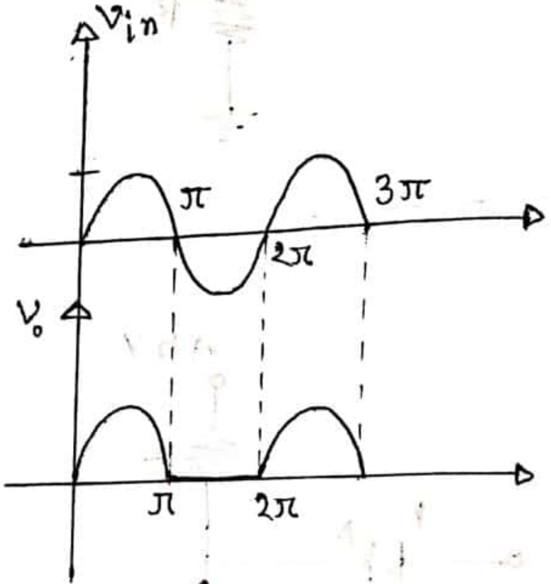
Rectifier:– is an electronic device that convert AC to DC.

2 types:– (i) Half wave
(ii) Full wave

(i) Half wave :–





$v_{in} = v_m \sin\theta$

$i = \frac{v_m}{r_f + R_L} \sin\theta = I_m \sin\theta$

$\therefore I_m = \frac{V_m}{r_f + R_L}$

time এর সাপেক্ষে changing → pulsating DC

- **Avg value :–**

$\theta = t$
$d\theta = dt$

Let, $v_{in} = V_m \sin\theta$

$$\therefore V_{avg} = \frac{1}{T}\int_0^T v_{in} \cdot dx$$

$$= \frac{1}{2\pi}\int_0^{\pi} v_m \sin\theta \cdot d\theta + \int_{\pi}^{2\pi} 0 \cdot d\theta$$

$$= \frac{v_m}{2\pi}\int_0^{\pi} \sin\theta \cdot d\theta.$$

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$$= \frac{V_m}{2\pi}\left[-\cos\theta\right]_0^{\pi}$$

• avg value এর আরেকটি নাম DC value.

$$= \frac{V_m}{2\pi}\left[-\cos\pi - (-\cos 0)\right]$$

$$\therefore \boxed{V_{avg} = \frac{V_m}{\pi}}, \quad \text{similarly, } I_{avg} = \frac{I_m}{\pi}$$

→ DC current

• **RMS value:—**

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V_{in}^2 \cdot dt}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi} \sin^2\theta \cdot d\theta}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\cdot\frac{1}{2}\cdot\int_0^{\pi} 2\sin^2\theta \cdot d\theta}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\int_0^{\pi}\left[1-\cos 2\theta\right]\cdot d\theta}$$

$$= \sqrt{\frac{V_m^2\cdot\pi}{4\pi}}$$

$$\therefore V_{r.ms} = \frac{V_m}{2}; \quad \therefore \text{similarly, } I_{rms} = \frac{I_m}{2}.$$

* $P_o = (I_{avg})^2 \times R_L$

$P_i = (I_{rms})^2 \times (r_f + R_L)$

$$\eta = \frac{P_o}{P_i} * 100\%$$

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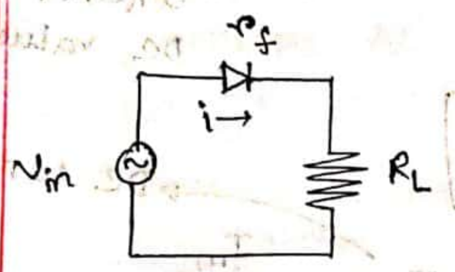
22/07/2019
Monday.

Efficiency :-



$$i = \frac{v_{in}}{r_f + R_L}$$

$$= \frac{v_m \sin\theta}{r_f + R_L}$$

$$= \frac{v_m}{r_f + R_L}$$

$$= I_m \sin\theta$$

$$I_m = \frac{v_m}{r_f + R_L}$$

$$P_{in} = (i_{rms})^2 (r_f + R_L)$$

$$= \left(\frac{I_m^2}{4}\right)(r_f + R_L)$$

r_f = Diode forward resistance

R_L = Diode Load resistance.

$$P_{out} = (i_{avg})^2 R_L$$

$$= \left(\frac{I_m^2}{\pi^2}\right) R_L$$

$$\eta = \frac{P_{out}}{P_{in}} * 100\%$$

$$= \frac{(I_m^2/\pi^2) * R_L}{(I_m^2/4) * (r_f + R_L)} * 100\%$$

r_f is negligible

$$\simeq \frac{4}{\pi^2} * 100\%$$

$$= 41\%$$

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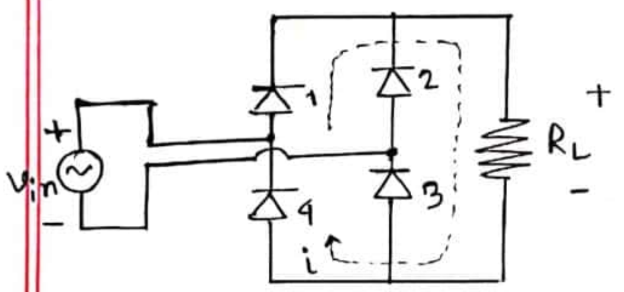
Full wave rectifier:-

1. Bridge rectifier
2. centre- tapped.

* যার anode এ (+) থাকিবে on.
* diode এর Anode দিয়ে ঢুকালে on and cathode দিয়ে ঢুকালে off.

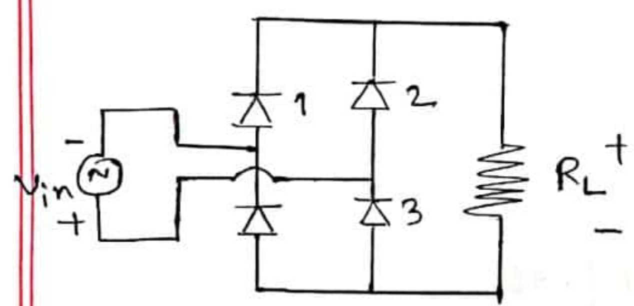
Bridge rectifier:-



at (+)ve cycle:-

D_1 and D_3 ON;

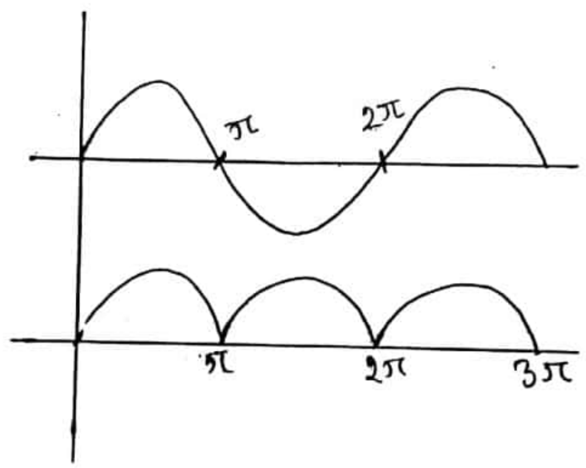
D_2 and D_4 OFF.



at (-)ve cycle:-

D_2 and D_4 ON;

D_1 and D_3 OFF.



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Avg value :-

$$V_{avg} = \frac{1}{T}\int_0^T v_{in} \cdot dt$$

$v_{in} = V_m \sin\theta$
$dt = d\theta \ , \ t = \theta$

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin\theta \cdot d\theta$$

$$= \frac{V_m}{\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$\therefore \boxed{V_{avg} = \frac{2V_m}{\pi}}$$

Similarly, $I_{avg} = \frac{2I_m}{\pi}$

RMS value :-

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v_{in}^2 \cdot dt}$$

$$= \sqrt{1/\pi \int_0^{\pi} V_m^2 \sin^2\theta \cdot d\theta}$$

$$= \sqrt{V_m^2/2\pi \left[\int_0^{\pi} [1-\cos 2\theta] \cdot d\theta\right.}$$

$$\therefore \boxed{V_{rms} = V_m/\sqrt{2}}$$

Similarly, $I_{rms} = \frac{I_m}{\sqrt{2}}$

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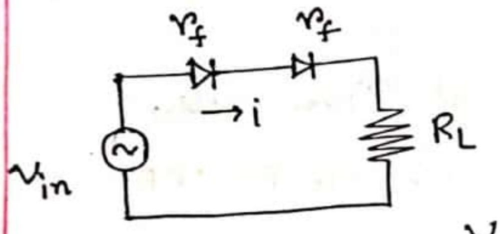
Efficiency:—



r_f = Diode forward resistance

R_L = Load resistance

$$i = \frac{v_{in}}{2r_f + R_L} = \frac{v_m}{2r_f + R_L}\sin\theta$$

$$= I_m \sin\theta$$

$$\therefore I_m = \frac{v_m}{2r_f + R_L}$$

* প্রতিটা (+)ve or (-)ve cycle এ ২টো করে diode on থাকে।

$$P_{out} = (i_{avg})^2 R_L$$

$$= \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$= \frac{4I_m^2}{\pi^2} R_L$$

$$P_{in} = (i_{rms})^2 (2r_f + R_L)$$

$$= \frac{I_m^2}{}(2r_f + R_L)$$

$$\eta = \frac{P_{out}}{P_{in}} * 100\%$$

$$= \frac{4I_m^2/\pi^2 * R_L}{I_m^2/2 * (2r_f + R_L)} * 100\%$$

r_f is negligible.

$$= \frac{8}{\pi^2} * 100\%$$

$= 81\%$

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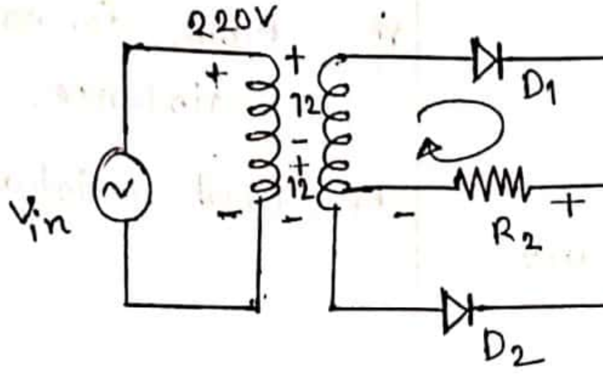
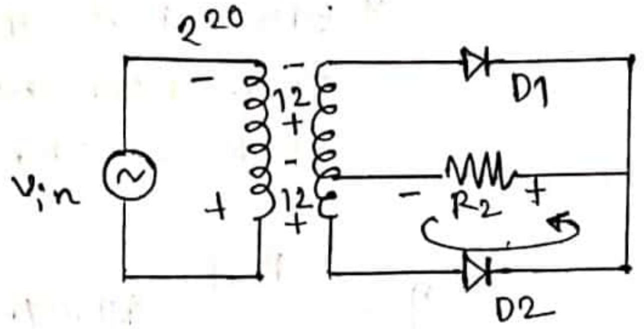
Centre - tapped Rectifier :-



at (+)ve cycle,
D1 ON, D2 OFF



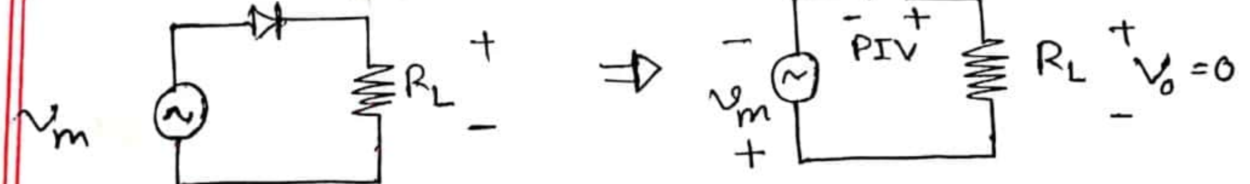
at (-)ve cycle,
D2 ON, D1 OFF.

PIV (Peak Inverse Voltage) :-

- maximum allowable reverse bias voltage that a diode ~~can't~~ can withstand without destroying its junction.

সহ্য করা

(1) Half wave rectifier :-



$PIV - V_m = 0 \Rightarrow \boxed{PIV = V_m}$ → maximum voltage V_m পর্যন্ত দেওয়া হয়।

$\boxed{PIV \geq V_m}$

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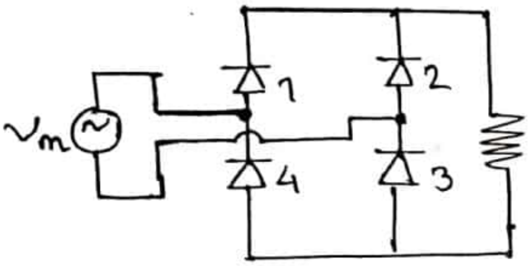
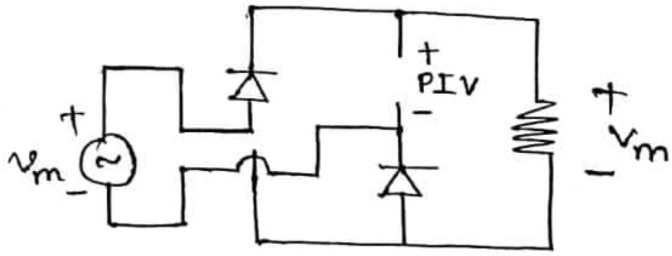
(2) Bridge Rectifier :- (Full wave)



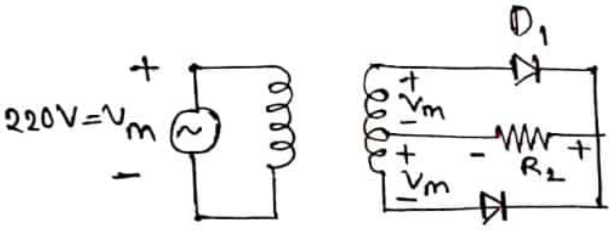
$\Rightarrow$



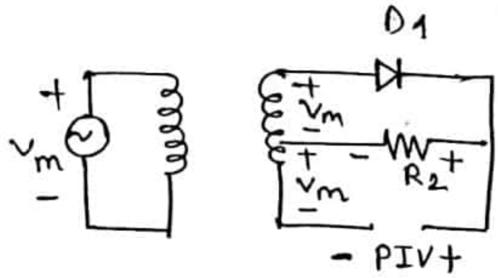
$$\boxed{PIV \geq V_m}$$

$$\boxed{PIV = V_m}$$

(3) Centre - tapped :-



$\Rightarrow$



$$\boxed{PIV \geq 2v_m}$$

$$\boxed{PIV = 2V_m}$$

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24.07.2019

Wednesday

Importance of PIV :-

1. If reverse bias voltage across a diode exceeds this value, the reverse current increases and breaks down the junction. So knowing PIV rating is important.

2. PIV rating is deciding factor to design a diode rectifier ckt.

• Advantage of Full wave rectifier :-

(i) Output is high

(ii) wastage of power is less, efficiency is 81%.

• Diadv. of Half wave :-

(i) Load receives approximately half of input power.

(ii) Avg. dc. voltage is low and efficiency is 41%.

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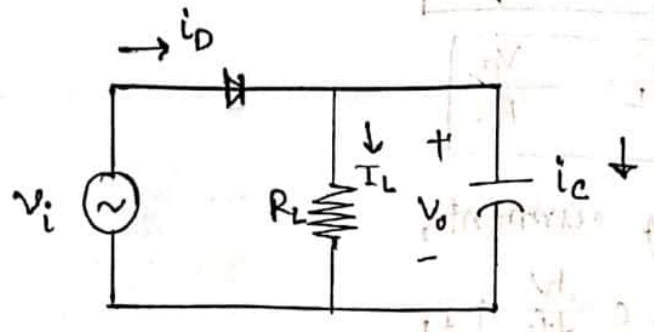
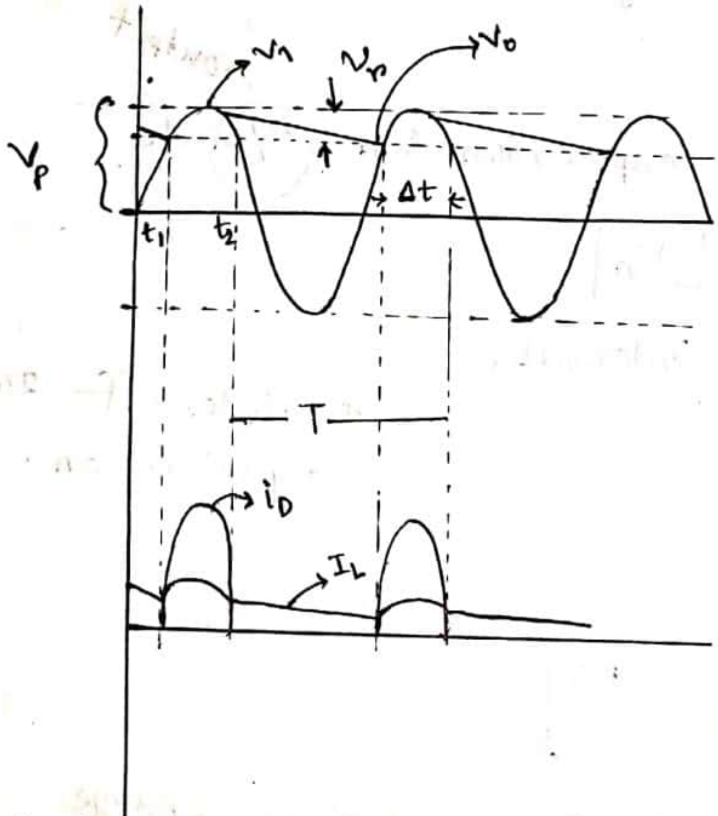
Rectifier with filter capacitor:—



$\Delta t \rightarrow$ diode এর conduction time.



Selecting diode for rectifier design two parameter should be matched:—

(i) Current handling capability:— the largest current the diode is expected to conduct

(ii) PIV.

* For sinusoidal input C is charged upto V_p.
* When the diode ~~acts~~ cuts off, C discharges through R_L.
* Next (+)ve cycle again diode turns 'on', and C is charged upto V_p and it repeats.

[C should be chosen a large value, $\tau = CR$ should be $\gg T$. ; $CR \gg T$ (Discharge interval).

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• Load current, $\boxed{I_L = V_o/R}$ when V_r is too small.

$$\boxed{I_L = \frac{V_p}{R}}$$

• Diode conducting current,

$$\boxed{i_D = i_c + I_L} = C\frac{dV}{dt} + I_L$$

at the end of discharge interval.

• $\boxed{V_o = V_p - V_r}$

• a more accurate expression for O/P dc voltage, $\boxed{V_o = V_p - \frac{1}{2}V_r}$ $\xrightarrow{\text{output}}$

• During diode off interval,

$$\boxed{V_o = V_p e^{-t/\tau}}$$

∗ diode off হলে capacitor on.

$$\therefore V_o = V_p e^{-T/RC}$$

Hence, $\boxed{V_p - V_r = V_p e^{-T/RC}}$

Again, we know,

$$\boxed{e^{-x} = 1 - x + \frac{x^2}{2!} - \dots}$$

∗ freq. change করলে ripple কমে যায়।

if $\boxed{x \ll 1}$ $e^{-x} = 1 - x$

so, $\boxed{e^{-T/RC} \cong 1 - \frac{T}{RC}}$

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since $CR \gg T$

$$\therefore V_p - V_r = V_p\left(1 - \frac{T}{RC}\right)$$

$$V_r = \frac{V_p T}{RC}$$

$$\Rightarrow \boxed{V_r = \frac{V_p}{fRC}}$$

if $V_r \ll V_p$.

$$\boxed{V_r = \frac{I_L}{fc}}$$

Assuming diode conduction ceases almost at the peak of v;

so conduction interval.

Δt;

$$\boxed{V_p \cos(\omega \Delta t) = V_p - V_r}$$

Again, $\cos(\omega\Delta t) = 1 - 2\left(\sin\left(\omega\Delta t/2\right)\right)^2$

since $\omega\Delta t$ is small angle,

$$\cos(\omega\Delta t) = 1 - 2 * \left(\frac{\omega\Delta t}{2}\right)^2$$

$$= 1 - \frac{1}{2}(\omega\Delta t)^2$$

$$\therefore V_p\left(1 - \frac{1}{2}(\omega\Delta t)^2\right)$$

$$= V_p - V_r$$

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$$\therefore \frac{V_p}{2}(\omega\Delta t)^2 = V_r$$

$$\Rightarrow (\omega\Delta t)^2 = \frac{2V_r}{V_p}$$

$$\therefore \boxed{\omega\Delta t = \sqrt{2V_r/V_p}}$$

- To determine avg. diode currents i_{Davg}.

Next Sunday
Quiz#1
এই পর্যন্ত
সব

$Q_{supplied} = i_{cav}\,\Delta t$

$$\boxed{i_{cav} = i_{Dav} - I_L}$$

Capacitor lost charge during discharge interval.

$$\boxed{Q_{lost} = cV_r}$$

$\therefore$ Now, $Q_{supplied} = Q_{lost}$

$$\Rightarrow \boxed{i_{cav}\,\Delta t = CV_r}$$

$$\Rightarrow i_{cav} = \frac{CV_r}{\Delta t}$$

$$= \frac{c * I_L}{fc\,\Delta t} = \frac{I_L}{f\Delta t}$$

$$\boxed{\Delta t = \frac{1}{2\pi f}\sqrt{2V_r/V_p}}$$

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$\therefore\ i_{Dav} = i_{cav} + I_L$

$\therefore\ \boxed{i_{Dav} = I_L \left[1 + \pi \sqrt{2V_p/V_r}\right]}$

$\boxed{i_{Dmax} = I_L \left[1 + 2\pi \sqrt{2V_p/V_r}\right]}$

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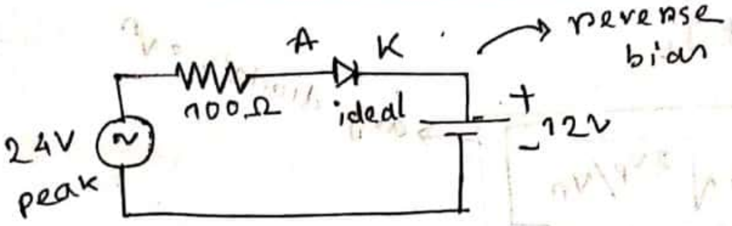
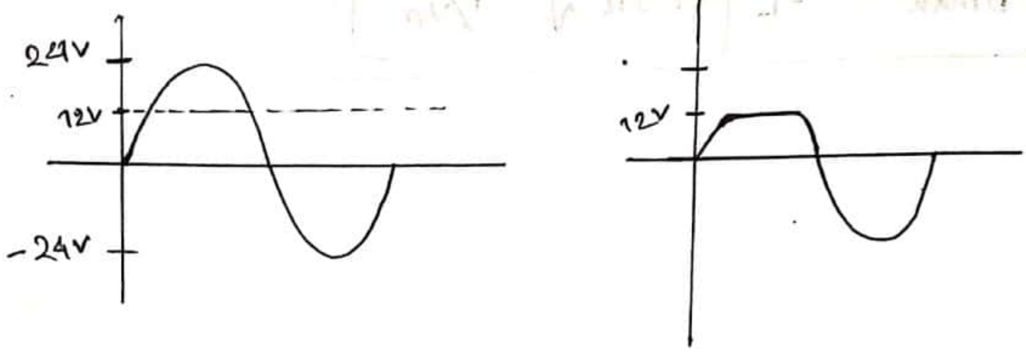
28.07.19

Sunday





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o/p → output

29.07.2019

Monday

Ripple factor:-

Ratio of rms value of ac component to the dc component in the rectified o/p is known as Ripple factor.

$$\therefore R_p = \frac{I_{ac}}{I_{dc}}$$

$$= \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$= \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$$

• $I_{rms} = \sqrt{I_{ac}^2 + I_{dc}^2}$

For half wave rectifier:-

$$R_p = \sqrt{\frac{(I_m/2)^2}{(I_m/\pi)^2} - 1} = 1.21$$

$(I_m/2)^2$ → r.m.s. value

$(I_m/\pi)^2$ → avg. value

For full wave rectifier:-

$$R_p = \sqrt{\frac{(I_m/\sqrt{2})^2}{(2I_m/\pi)^2} - 1} = 0.48.$$

$(I_m/\sqrt{2})^2$ → r.ms. value

$(2I_m/\pi)^2$ → avg. value

* freq. বাড়ালে time period কমে যায় ।

* যেই rectifier এর ripple বেশি তার efficiency কম ।

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Sedra

ex:- 4.8 Consider a peak rectifier ~~thread~~ fed by a 60 Hz sinusoid having a peak value $V_{peak} = 100$ volt, Let the load resistance $R = 10K\Omega$. Find the value of capacitance C, that will result in a peak-to-peak ripple of 2 volt. Also calculate diffraction of the cycle during which the diode is conducting and the average and the peak values of the diode currents.

→ Given,

$V_{peak} = 100$ volt

$V_{Ripple} = 2$ volt

$f = 60$ Hz

$R_L = 10K\Omega$

We know,

$$V_r = \frac{V_p}{fCR}$$

$$\Rightarrow C = \frac{V_p}{fV_r R}$$

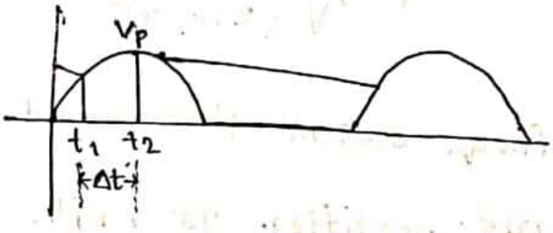
$$= \frac{100}{60 \times 2 \times 10 \times 10^3}$$

$$= 8.3 \times 10^{-5} F$$

Again, $\omega \Delta t = \sqrt{2V_r/V_p}$

$$= \sqrt{2 * 2/100}$$

$$= 0.2 \text{ rad}$$



fraction of cycle the diode is conducting,

$$= 0.2/2\pi * 100\%$$

$$= 3.18\%$$

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Now, $I_L = V_P/R = 100/10*10^3 = 0.01\,A$

the average diode current, $i_{dav} = I_L\left[1+\pi\sqrt{2V_P/V_r}\right]$

$= 0.01\left[1+\pi\sqrt{\frac{2*100}{2}}\right]$

$= 0.324\ A$

the peak value of the diode current, $i_{dmax} = I_L\left[1+2\pi\sqrt{2V_P/V_r}\right]$

$= 0.638\ A.$

Sedra

Ex: 4.68 | A half wave rectifier ckt. with a 1KΩ load operates from 120V rms and 60 Hz household supply through a 10 to 1 step down Tx. It uses a Si diode that can be modeled to have a 0.7V drop ~~from o~~ for any current.

1. What is the peak voltage of the rectified output?
2. For what fraction of ~~cy~~ the cycle ~~thus th~~ does the diode conduct?
3. What is the average output voltage?
4. What is the average current in the load?
5. Find the PIV of the diode.

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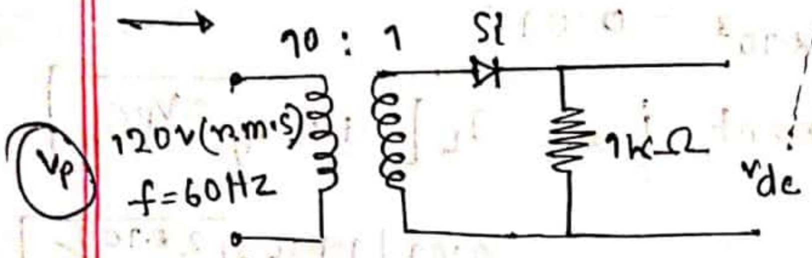
$V_{avg} = \frac{V_m}{\pi}$



$V_s = 12V$ (r.m.s.)

$V_2/V_1 = \frac{N_2}{N_1}$

$V_m = \sqrt{2} * 12V$

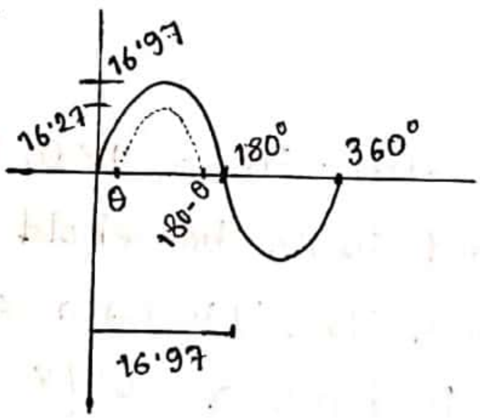
$= 16.97$ V

1. $V_m' = V_m - V_D$

$= 16.97 - 0.7$

$= 16.27$ V

2.



Diode conduction

$= 180 - \theta - \theta$

$= 180 - 2\theta$

$V_\Delta = V_m \sin\theta$

$\Rightarrow 0.7 = 16.97 \sin\theta$

$\Rightarrow \theta = 2.36°$

$\therefore$ Diode conduction $= 180 - 2 \times 2.36°$

$= 175.28$

$\therefore$ fraction of cycle the diode conducting,

$\frac{175.28}{2 * 180°} * 100\% = 48.69\%$

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3. the average output voltage, $V_{avg} = V_m/\pi$

$= 16.97/\pi$

$= 5.4\ V$

4. $\frac{V_m'}{R} = I_M$

$\Rightarrow I_M = 16.27/1K = 0.01697\ A$

$\therefore I_{avg} = I_M/\pi = 5.4 \times 10^{-3}\ A.$

5. $PIV \geqslant V_m$

$PIV = V_m = 16.97\ V$

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31 / 07 / 2019
Wednesday

crystal diode having an internal resistance of 5Ω is given in half wave rectifier. The turn ratio of Tx is 5 and load resistance is 800Ω. If the applied voltage of the Tx is 220V; 50Hz.

Calculate :– i. PIV

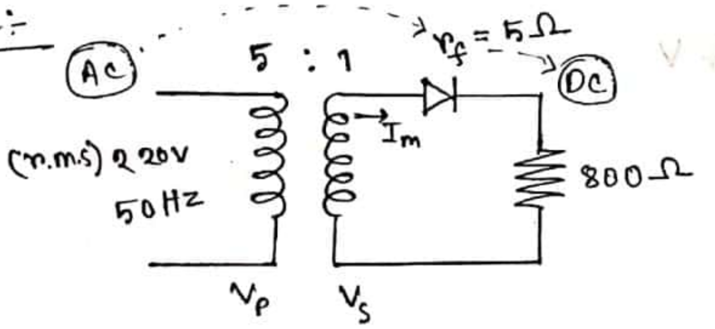
ii. DC o/p voltage

iii. o/p and i/p power

iv. Rectifier efficiency.

* diode normally 20 or 24V handle করতে পারে।

Sol:-



$V_s = \frac{220}{5} = 44V$

$V_m = \sqrt{2} * 44V$

(i) $PIV = V_m = \sqrt{2} * 44V = 62.23V$. (Ans)

$I_m = \frac{V_m}{r_f + R_L} = \frac{\sqrt{2}*44}{5+800} = 0.077 A$

$I_{avg} = \frac{I_m}{\pi} = \frac{0.077}{\pi} = 0.0246 A$ [load এর respect এ]

$I_{rms} = I_m/2 = 0.0385 A$. [input থেকে যা পাই]

(ii) $V_{avg} (V_{DC}) = V_m/\pi = \sqrt{2}*44/\pi = 19.81 V$

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(iii) $P_{in} = (i_{rms})^2 * (r_f + R_L) = 1.1932 \, W$

$P_{out} = (i_{avg})^2 * R_L = 0.484 \, W$

(iv) efficiency, $\eta = \frac{P_{out}}{P_{in}} * 100\% = 40.56\%$

Sedra

ex: 4.69 A full wave rectifier ckt with $1 k\Omega$ load operates from 120V rms and 60Hz household supply through a 5 to 1 Tx having a center tapped secondary winding Tx. It uses two Si diode that can be modeled to have a 0.7V drop for all currents.

i. What is the value of PIV?
ii. What is the peak voltage of the rectified output?
iii. For what fraction of a cycle does each diode conduct?
iv. What is the average output voltage?
v. What is the average current in the load?
vi. Determine the efficiency?

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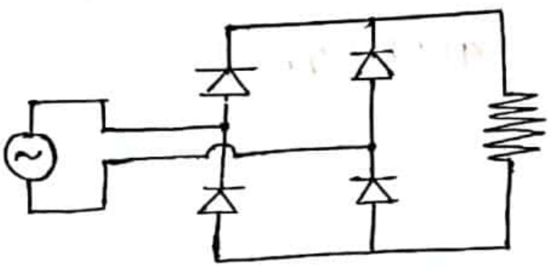
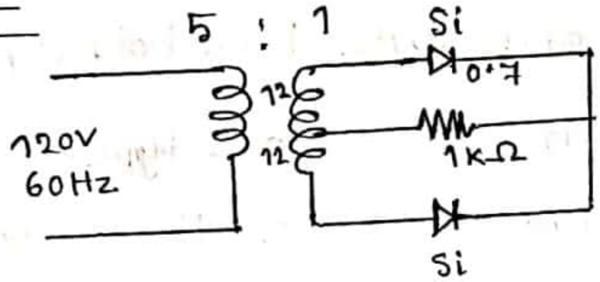
Bridge rectifier



Sol:-



(i) $V_s = \frac{120}{5} = 24V \text{ (r.m.s)}$

$V_m = \sqrt{2} * 24 V = 33.94 V$

$V_{rms} = 12V$

For center tapped,

$PIV \geq 2V_m$

$= 2V_m$

$= 2*(12*\sqrt{2})$

$= 33.94$

$V_m = 12 * \sqrt{2} = 16.9 V$

(ii) peak rectified o/p $= V_m - V_D = 16.9 - 0.7 = 16.2V$

V_m'

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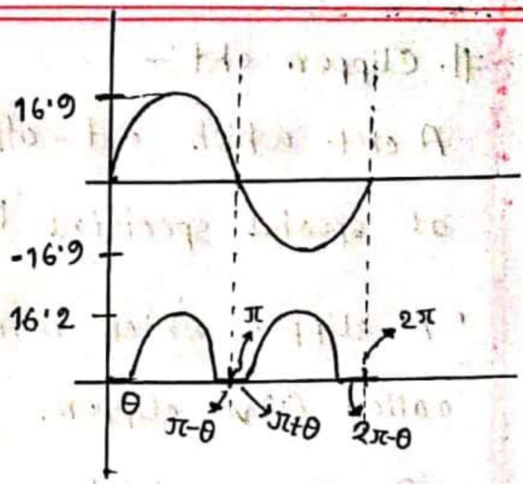
(iii) $v(t) = v_m \sin\theta$.



$v_D = V_m \sin\theta$

$\Rightarrow 0.7 = 16.2 \sin\theta$

$\Rightarrow \theta = \sin^{-1} \frac{0.7}{16.2}$

$= 2.48°$

Diode conduction $= 2(\pi - \theta - \theta) \rightsquigarrow$ (two diodes)

$= 2(\pi - 2\theta)$

$= 2(180 - 2 * 2.48°)$

$= 350.08$.

$\therefore$ fraction of cycle

$= \frac{350.08}{2\pi} * 100\%$

$= \frac{350.08}{2 \times 180} * 100\%$

$= 97.24\%$

(iv) avg. voltage, $V_{avg} = 2V_m'$ (rectified) $/\pi$

$= \frac{2 * 16.2}{\pi}$

$= 10.31\ V$

(v) avg. current, $I_{avg} = V_{avg}/R_L = 10.31 mA$.

$I_m = V_m/R_L = 16.2/1K = 16.2 mA$

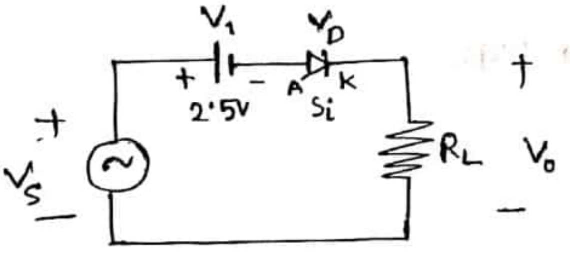
$I_{avg} = V_{avg}/R_L = 10.31/1K = 10.31 mA$

i/p → input

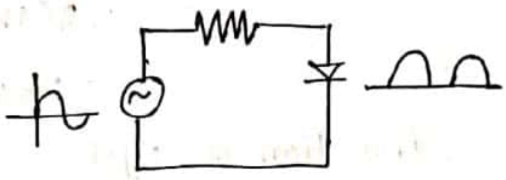
Clipper ckt :-

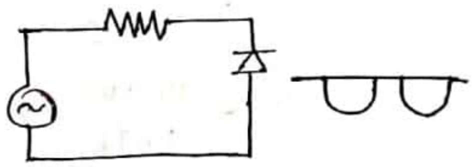
A ckt which cut-off voltage above or below are both at ~~special~~ specified level is called clipper.

- A clipper which removes (+)ve half cycle of i/p is called (+)ve clipper.
- A clipper which removes (−)ve half cycle of i/p is called (−)ve clipper.



forward



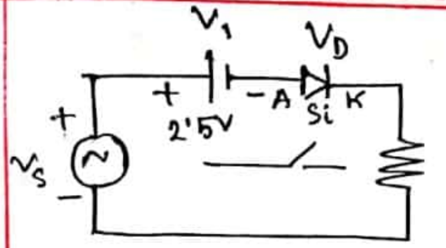


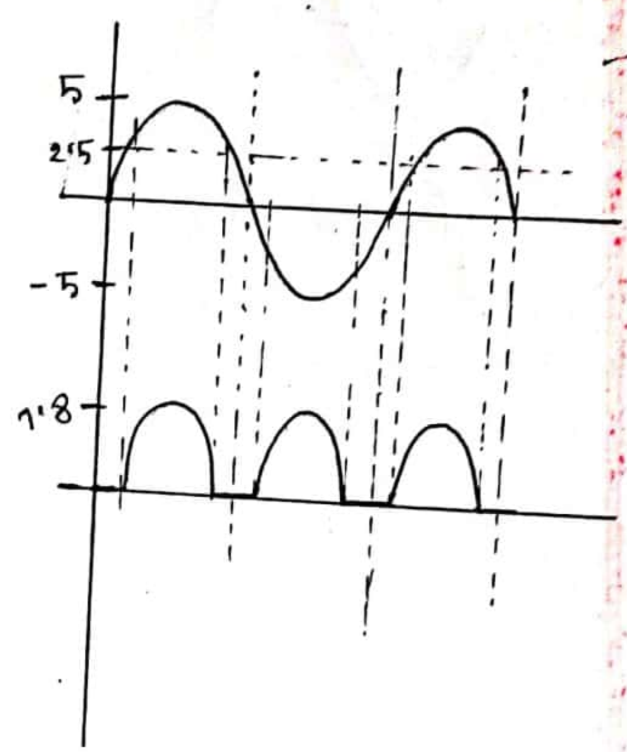
2 types :-

(i) Series clipper → Load এর across এ o/p.

(ii) Parallel clipper → wave form এর দুয়ের অংশকে বাদ দেয় না।

* DC থাকলে biased clipper.
* DC আগে 'on' হবে।





For (+)ve cycle:-

$$-V_S + V_1 + V_D + V_o = 0$$

$$\therefore V_o = V_S - V_1 - V_D$$

$$= 5 - 2'5 - 0'7$$

$$= 1'8V$$

For (−)ve cycle:-

$$V_o = 0$$

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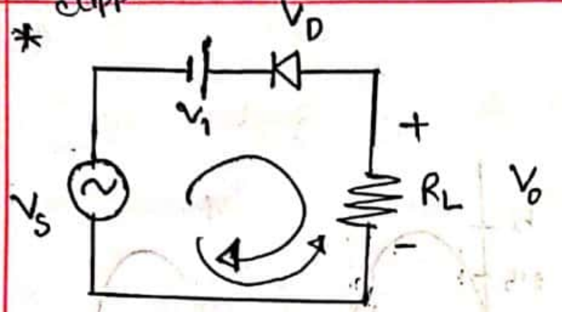
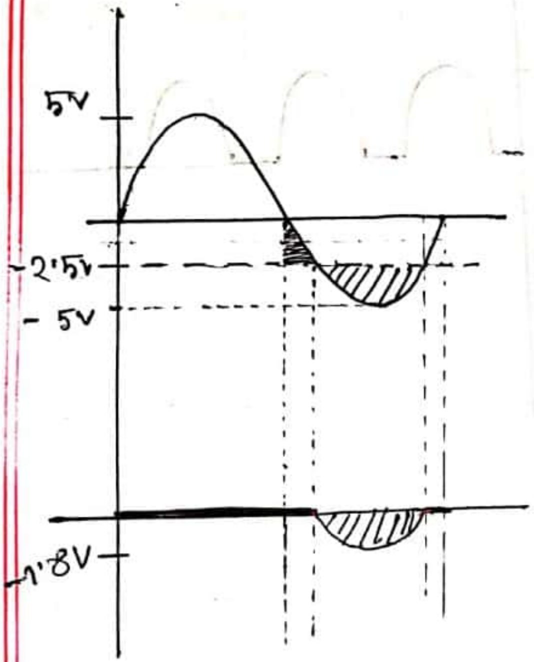
1N4001, 1N4009 > Diode

04/08/2019
Sunday

* series clipper



$(+)$ve cycle, $V_S > 0$
(reverse bias)



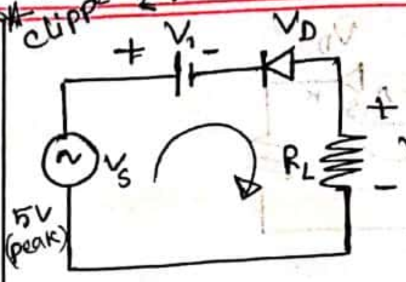
$(-)$ve cycle, $-V_S - V_0 + V_D + V_1 = 0$

$\therefore V_0 = -V_S + V_D + V_1$

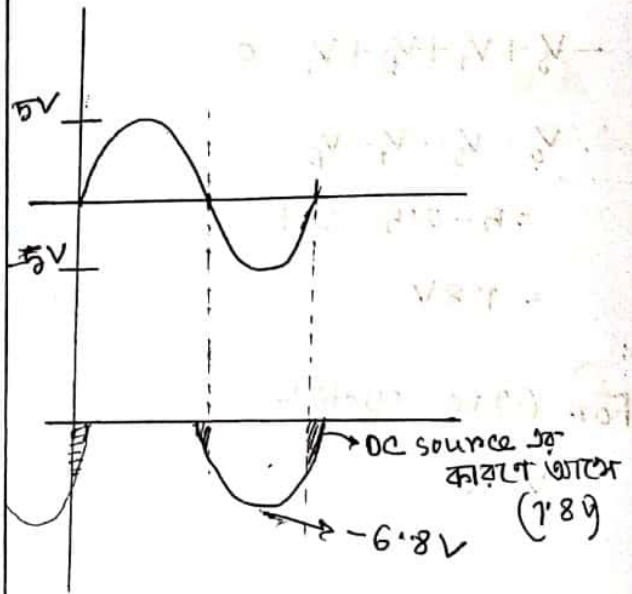
$= -5V + 0.7V + 2.5V$

$= -1.8V$

* series clipper 2.5V



$2.5V - 0.7V = 1.8V$



$(-)$ve cycle, $-V_S - V_0 + V_D - V_1 = 0$

$\Rightarrow V_0 = -V_S + V_D - V_1$

$= -5 + 0.7 - 2.5$

$= -6.8V$

* series clipper এর output এর একটা portion বাদ চলে যায়।

* Diode off থাকলে DC র effect count করার দরকার নাই।

Diode on " " " " " করতে হবে।

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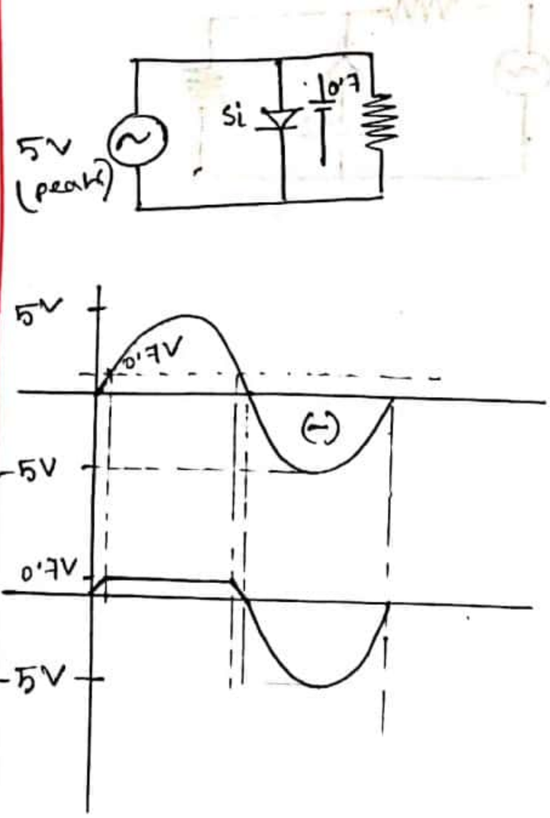
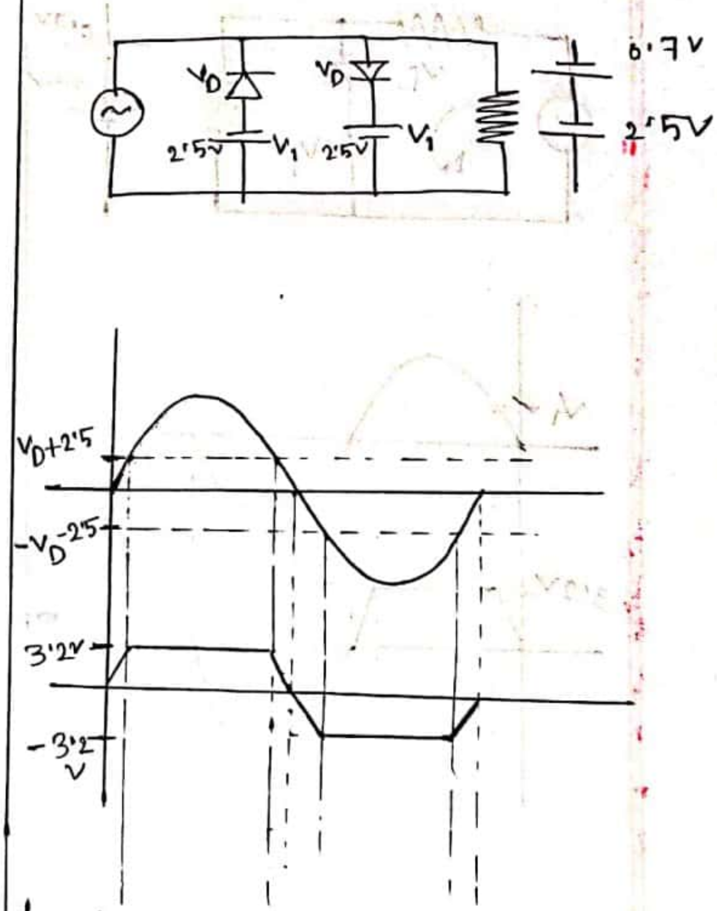
* Parallel clipper





* parallel clipper output এর একটি ~~on~~ portion এর অংশবিশেষ কাটে, পুরোটা বাদ পড়ে না।

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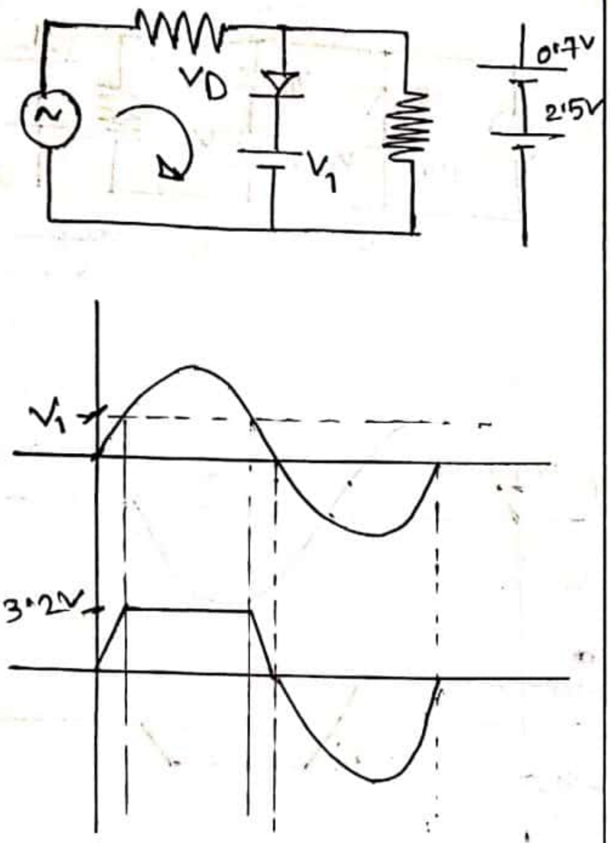

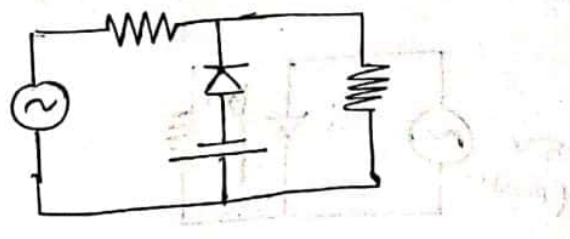

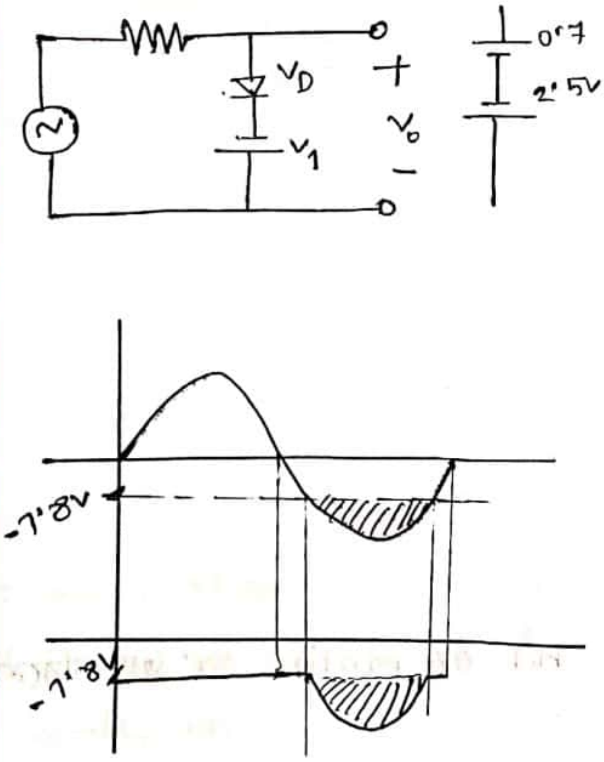

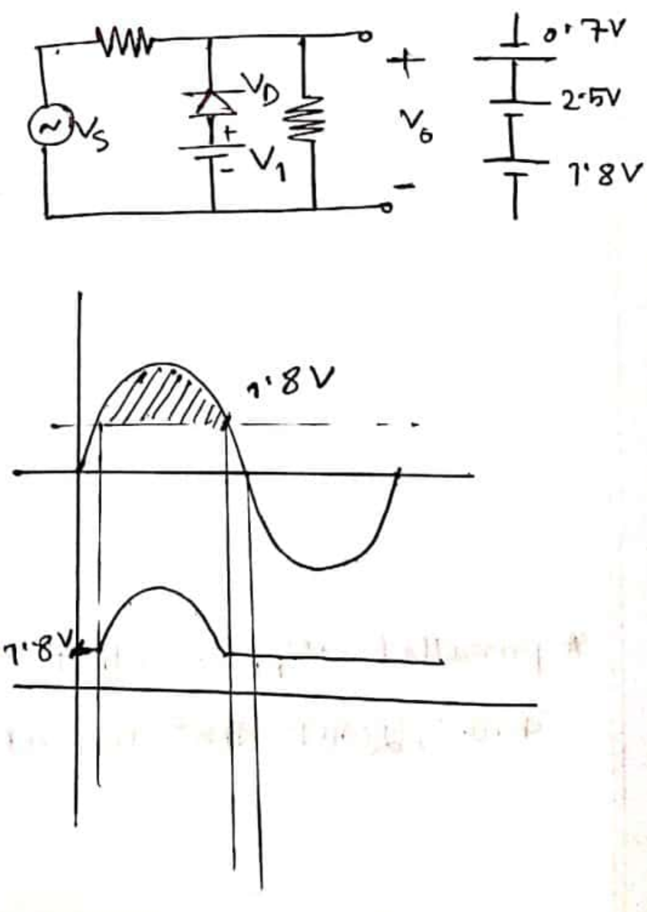

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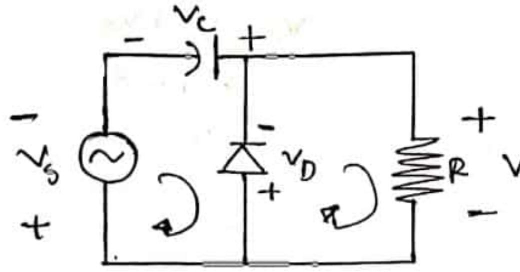
05/08/2019
Monday

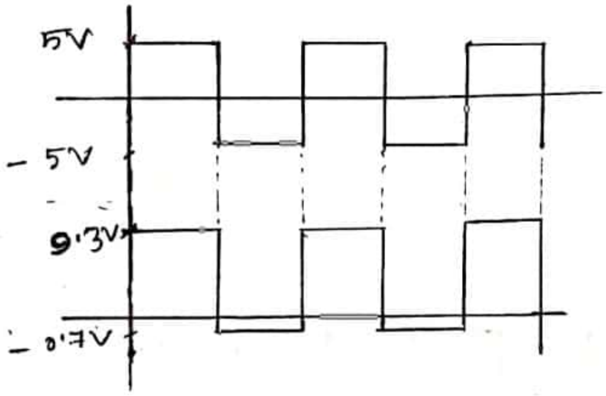
Clamper:– A ckt that clamps the (+)ve or (−)ve peak of a signal at a desired dc level is known as clamping.

- A clamping adds a dc component to the signal and does not change the amp./shape of the input signal.

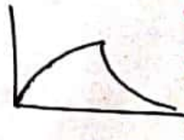


* diode on → capacitor charging
  diode off → capacitor discharging.

(i) charging cycle
(Diode will be on).



* capacitor যে পাশে charge হচ্ছে তার উল্টা পাশে discharge হবে। যে এখন এটা battery হয়ে গেছে।



(−)ve cycle, $-V_s + V_D + V_c = 0$
(Diode on)
$$\therefore V_c = V_s - V_D$$
$$= 5 - 0.7$$
$$= 4.3V$$

$$-V_D - V_0 = 0$$
$$\Rightarrow V_0 = -V_D$$
$$= -0.7V$$

(+)ve cycle, $-V_s - V_c + V_0 = 0$
(Diode off)
$$\therefore V_0 = +V_s + V_c$$
$$= 5 + 4.3$$
$$= 9.3V$$

* capacitor একবার fixed হলে ঐ polarity ই থাকবে।

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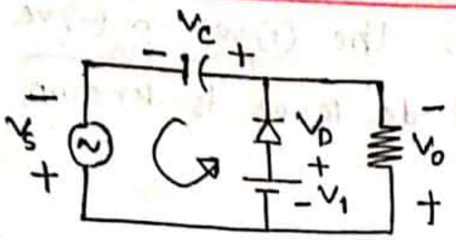
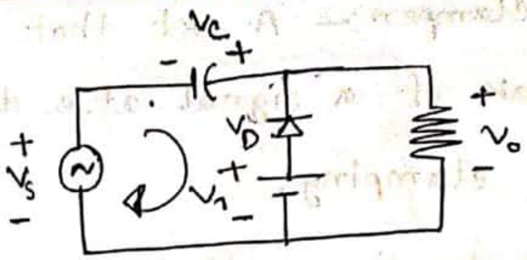




(-)ve cycle,

$-V_S - V_1 + V_D + V_C = 0$

$\therefore V_C = +V_S + V_1 - V_D$

$= 5 + 2.5 - 0.7$

$= 7.5 - 0.7$

$= 6.8V$

$-V_0 - V_D + V_1 = 0$

$\therefore V_0 = -V_D + V_1$

$= -0.7 + 2.5$

$= 1.8V$

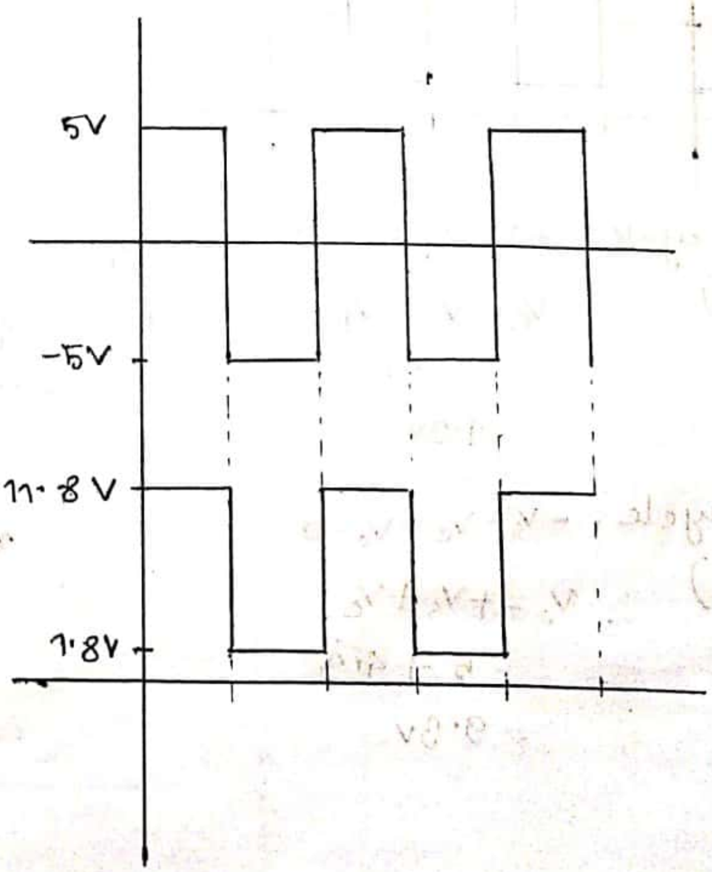
(+)ve cycle,

$-V_s - V_C + V_0 = 0$

$\therefore V_0 = V_s + V_C$

$= 5 + 6.8$

$= 11.8V$



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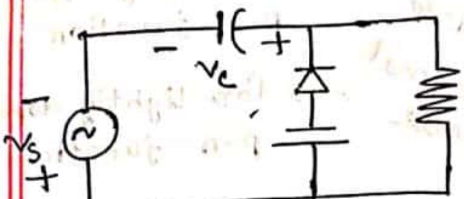


AC তে capacitor এর polarity নাই।

(−) ve cycle,

$$-V_s + V_1 + V_D + V_c = 0$$

$$\therefore V_c = V_s - V_1 - V_D$$

$$= 5 - 2.5 - 0.7$$

$$= 1.8\,V$$

$$-V_0 - V_D - V_1 = 0$$

$$\Rightarrow V_0 = -V_D - V_1$$

$$= -3.2\,V$$

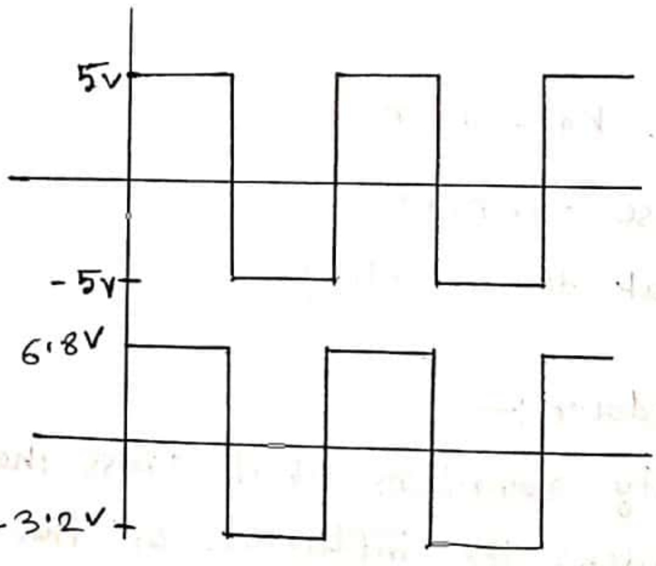
(+) ve cycle,

$$-V_s - V_c + V_0 = 0$$

$$\therefore V_0 = V_s + V_c$$

$$= 5 + 1.8$$

$$= 6.8\,V$$



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07/08/2019
wednesday

Breakdown mechanism :-

(i) Zener Breakdown → for only Zener diode.

(ii) Avalanche Breakdown → for normal diode

* Zener breakdown occurs when electric field in the depletion layer increases in a point where it can break covalent bonds and generate electron hole pairs.

usually, $\boxed{V_Z < 5V}$.

- Reverse bias voltage
- Rise of intensity of E.f.
- Breakdown covalent bonds in narrow depletion region
- Create electron hole pairs
- increase reverse current
- sustain at Break down voltage

Avalanche Breakdown :-

When the minority carriers that cross the depletion layer under the influence of the electric field, gain sufficient K.E. to be able to break covalent bonds in atom with which they collide.

Usually $\boxed{V_Z > 7V}$

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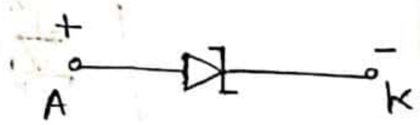
Zener diode :—

A properly droped crystal diode which has a sharp breakdown voltage, is known as Zener diode.

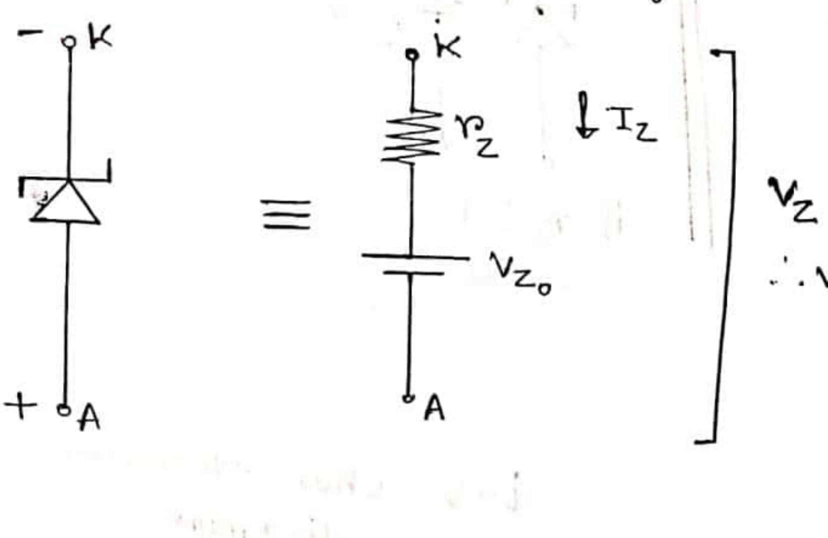


• The bar is turned into Z-shape. Following points to be remember :—

i. Zener diode is designed to operate in the Zener breakdown region to zener voltage.

ii. Forward bias characteristics is like an ordinary diode.

iii. It is used to make voltage regular ckt.



$\therefore V_Z = V_{Z_0} + I_Z r_Z$.

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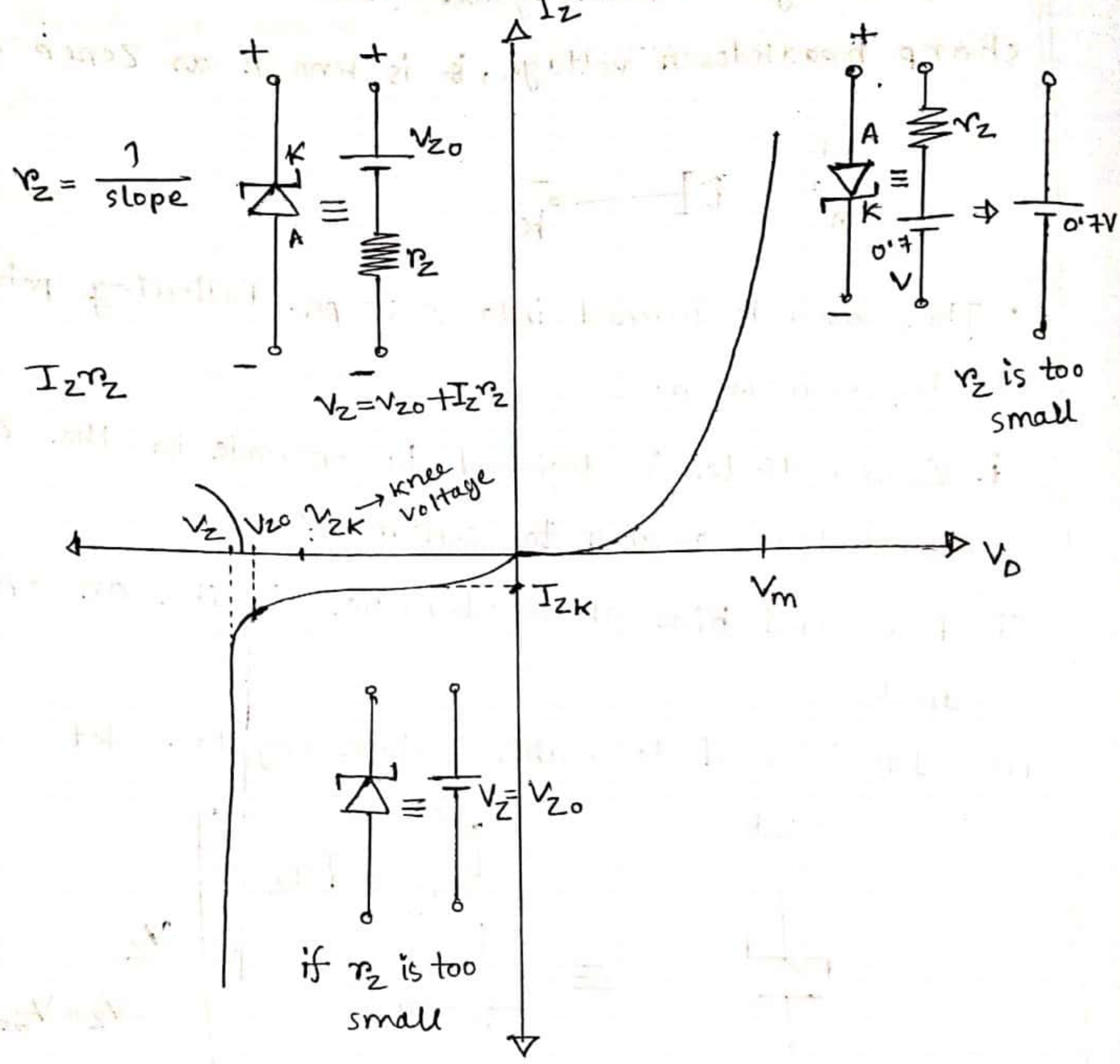

i-V characteristics diagram

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* reverse bias এ Zener diode voltage ঠিক fixed করে দেয়। এটা হচ্ছে Zener breakdown voltage.

* forward bias এ Zener diode normal diode এর মতো কাজ করে।

* line regulation → the ability to change the specified output voltage.

* • Line regulation $= \frac{\Delta V_o}{\Delta V_s} \times 100\%$

• load regulation $= \frac{\Delta V_o}{\Delta I_L} \times 100\%$

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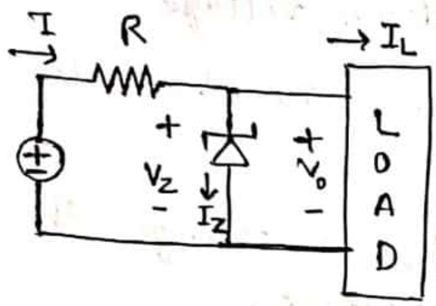
28/08/2019
Wednesday

Use of zener diode as Shunt Regulator:—



- V_o is constant once the diode starts to conduct at RB condition.
- Used for over-voltage protection.

Desire, $V_o \neq f(V_s, I_L)$

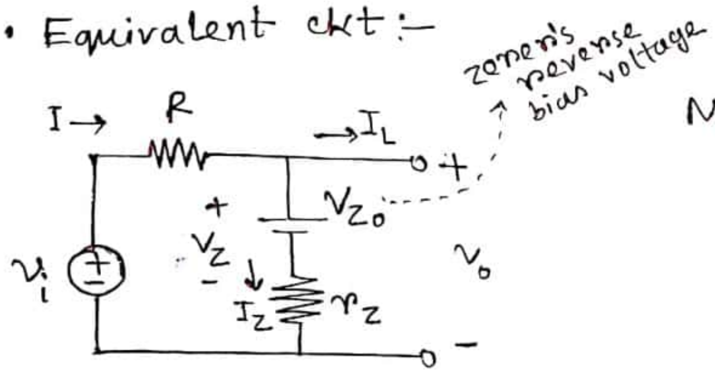
- Line regulation $= \dfrac{\Delta V_o}{\Delta V_s}$ (mV/V)
- load regulation $= \dfrac{\Delta V_o}{\Delta I_L}$ (mV/mA)

The line regulation is the ability to change in V_o corresponding to 1V change in V_s.

load regulation:—

is the ability to change in ~~at~~ V_o corresponding to 1mA change in I_L.

- Equivalent ckt:—



Now, $I = I_Z + I_L$

$$V_Z = V_{Zo} + I_Z r_Z = V_o$$

$$V_S = IR + V_{Zo} + I_Z r_Z$$

$$= R(I_L + I_Z) + V_{Zo} + I_Z r_Z$$

$$= I_Z(R + r_Z) + I_L R + V_{Zo}$$

$$\therefore I_Z = \frac{V_S - I_L R - V_{Zo}}{R + r_Z}$$

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Now,

$$V_0 = V_{Z0} + r_Z \left(\frac{V_S - I_L R - V_{Z0}}{R + r_Z} \right)$$

$$\therefore V_0 = V_{Z0} \cdot \frac{R}{R + r_Z} - I_L \frac{R \cdot r_Z}{R + r_Z} + V_S \frac{r_Z}{R + r_Z}$$

From here,

Line regulation, $\frac{\Delta V_0}{\Delta V_S} = \frac{r_Z}{R + r_Z}$

load regulation, $\frac{\Delta V_0}{\Delta I_L} = -(R \parallel r_Z)$

current emitting resistance $R = \frac{V_{S\,min} - V_{Z0} - r_Z I_{Z\,min}}{I_{Z\,min} + I_{L\,max}}$

Temperature effect in Zener diode:–

Zener diode whose $V_Z \leq 5V$ exhibit (–)ve temperature co-efficient. (normal diode এর মতো কাজ করে)

- $V_Z > 5V \rightarrow$ (+)ve temp. co-eff. ($T\uparrow R\uparrow$)
- Normal diode $\rightarrow$ (–)ve temp co-eff ($-2.5\ mV/^\circ C$)

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Q:– It is required to design a Zener shunt regulator to provide an output voltage approximately $\underline{7.5\,V} \rightarrow V_Z$. And the The raw supply varies between 15 and 25 V. load current varies over the range of 0 to 15 mA. and its Zener diode has V_Z at a current of $\underbrace{20\,mA}_{I_Z}$ $r_Z = 10\,\Omega$. $I_{Z\,min} = \frac{1}{3} I_{L\,max}$.

Find the required value of R and determine the line and load regulation. Also determine the percentage change in V_0 corresponding to full changing V_S and full changing I_L.

→ $V_{Z_0} = 7.5\,V$ $\qquad R = ?$ $\qquad \% \Delta V_0 = ?$

$I_Z = 20\,mA$ $\qquad \frac{\Delta V_0}{\Delta V_S} = ?$

$r_Z = 10\,\Omega$

$V_S = \underbrace{15\,V}_{V_{S\,min}} \sim 25\,V$ $\qquad \frac{\Delta V_0}{\Delta I_L} = ?$

$I_L = 0\,mA \sim 15\,mA$.

$\therefore I_{Z\,min} = \frac{1}{3} \times 15 = 5\,mA$.

$$\therefore R = \frac{V_{S\,min} - V_{Z_0} - r_Z I_{Z\,min}}{I_{Z\,min} + I_{L\,max}}$$

$$= \frac{15 - 7.5 - 10 * 5}{5 + 15}$$

$$\doteq 372\,\Omega$$

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$$\frac{\Delta V_o}{\Delta V_s} = \frac{r_z}{R+r_z} = \frac{10}{R+10} = \frac{10}{372+10} = 0.026$$

$$\frac{\Delta V_o}{\Delta I_L} = -\frac{R \cdot r_z}{R+r_z} = -\frac{372 * 10}{372+10} = -9.74$$

$$\% \frac{\Delta V_o}{\Delta V_s} = 0.026$$

$$\% \Delta V_o = 0.026 * \Delta V_s$$

$$= 0.026 * 10$$

$$\% \Delta V_o = \frac{0.026}{7.5} * 100\%$$

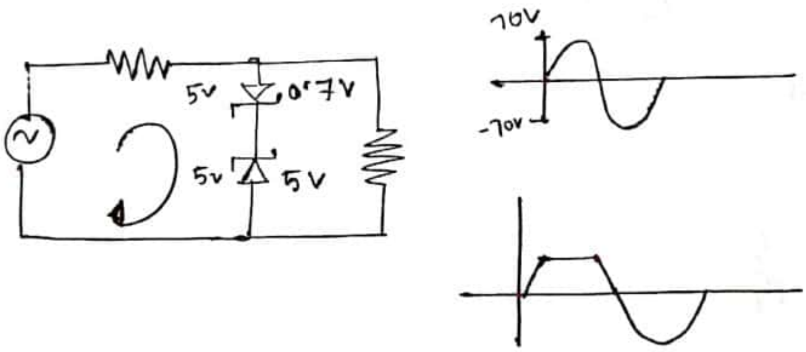
$$= 0.35\%$$

$$\frac{\Delta V_o}{\Delta I_L} = -9.74$$

$$\Rightarrow \Delta V_o = \left(\frac{-9.74 * 15}{7.5}\right) * 100\%$$

$$= -1948\%$$

(*)



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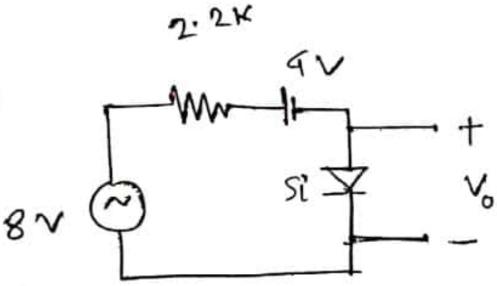

draw the output wave form.

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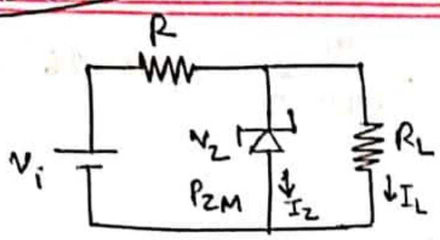

(i) V_i and R_L fixed

(ii) V_i fixed and R_L variable

(iii) V_i variable and R_L fixed.

(i) case-1:- $V_Z > V_i$ (zener on হবে না, normally কাজ করবে)

case-2:- $V_Z < V_i$ (Zener on হবে)

$$V_{Th} = V_L = \frac{R_L}{R+R_L} * V_i > V_Z$$

$$V_L = \frac{R_L}{R+R_L} * V_i < V_Z$$

• V_Z যদি V_{Th} এর চেয়ে বড় হয় তাহলে Zener off হবে।

$I_Z = 0$

$I_L = \frac{V_L}{R_L}$

$P_Z = I_Z V_Z = 0$

$V_Z = 0$

• $I = \frac{V_i - V_L}{R} = I_L$

• $I_S = I_Z + I_L$

$I_L = \frac{V_o}{R_L} = \frac{V_Z}{R_L}$

• $I_S = \frac{V_i - V_Z}{R}$

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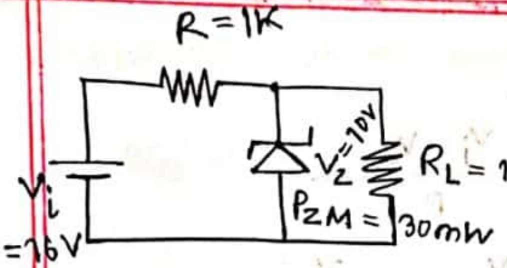
01/09/2019
Sunday



v_i and R fixed.

First we have to determine whether zener is 'on' or 'off'.

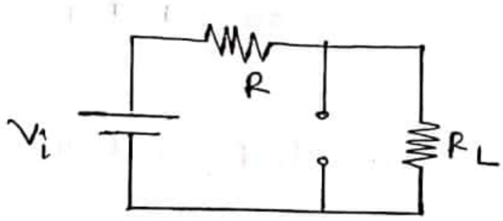
For that, we have to apply thevenin's,

$$\boxed{V_{th} = V_Z = \frac{R_L}{R+R_L} * V_i}$$

Two cases :- $V_{th} \geq V_Z$ (ON)

$V_{th} < V_Z$ (OFF)

$\boxed{\text{First if OFF ; } V_{th} < V_Z}$



Here,

$I_R = I_L = \frac{V_i}{R+R_L}$

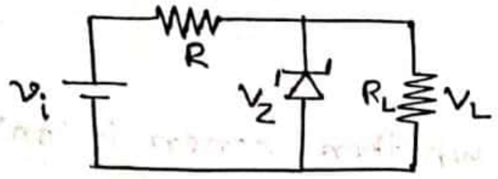
$P_Z = 0 = I_Z V_Z$ (zener off)

$V_Z = 0$

$V_R = I_R R$

$V_L = I_L * R_L$

case 2:- $V_{th} \geq V_Z$: ON



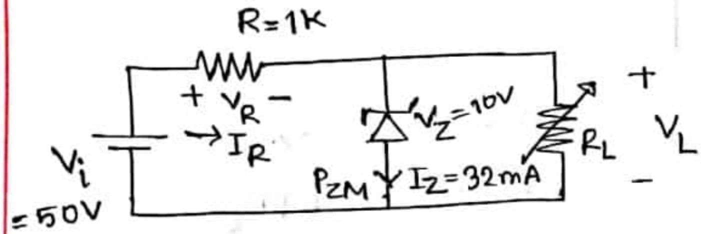
$$I_R = \frac{V_i - V_Z}{R}$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}$$

Again, $I_R = I_Z + I_L$

$$P_Z = I_Z V_Z$$
$$= (I_R - I_L) * V_Z$$
$$= \left(\frac{V_i - V_Z}{R} - \frac{V_Z}{R_L}\right) V_Z$$

(2) V_i fixed and R_L variable:-



- load = 0 ; short ckt
- load resistance কম থাকলে zener on হবে না ।

We have to find out minimum value of R_L and maximum of R_L for which zener is ON.

P_{ZM} = Maximum power dissipation capability of zener

R = current Limiting resistor

R_L = varying Load

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* condition for minimum R_L :-

$$V_{th} = \frac{R_L}{R+R_L} v_i = V_Z$$

$$\therefore v_i R_L = V_Z (R+R_L)$$

$$\Rightarrow R_L (v_i - V_Z) = V_Z R$$

current emitting resistance

$$\therefore \boxed{R_{L\,min} = \frac{V_Z R}{V_i - V_Z}}$$

* when load is minimum and I_L is maximum :-

$$\therefore \boxed{I_{L\,max} = \frac{V_L}{R_{L\,min}}}$$

$$= \frac{V_Z}{R_{L\,min}}$$

$I_Z \downarrow \; I_L \uparrow$

Now, KCL,

$IR = I_Z + I_L$; when I_L max; I_Z will be minimum.

$$\therefore I_R = I_{Z\,min} + I_{L\,max}$$

$$\therefore I_{Z\,min} = I_R - I_{L\,max}$$

$$= \frac{V_i - V_Z}{R} - \frac{V_Z}{R_{L\,min}}$$

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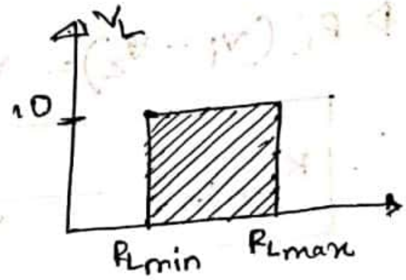
* For maximum R_L :-

$P_{ZM} = V_Z I_{ZM}$

$\therefore \boxed{I_{Z\,max} = \frac{P_{ZM}}{V_Z}}$; when $I_{Z\,max}$; I_L is minimum.

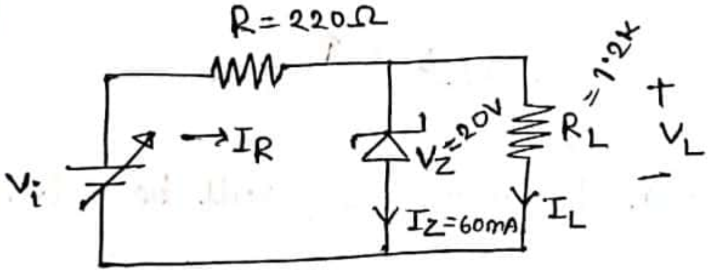


$I_{L\,min} = I_R - I_{Z\,max}$

$= \frac{V_i - V_Z}{R} - \frac{P_{ZM}}{V_Z}$

$$\boxed{R_{L\,max} = \frac{V_L}{I_{L\,min}} = \frac{V_Z}{I_{L\,min}}}$$

(3) V_i variable, R_L fixed :-



condition for minimum i/p

$V_{th} \geq V_Z \longrightarrow$ ON

$V_{th} < V_Z \longrightarrow$ OFF

$\therefore V_{th} = \frac{R_L}{R+R_L} * V_i = V_Z$

$$\therefore \boxed{V_{i\,min} = \frac{V_Z(R+R_L)}{R_L}}$$

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* Condition for maximum v_i :—

v_{imax} is limited by I_{Zmax}.

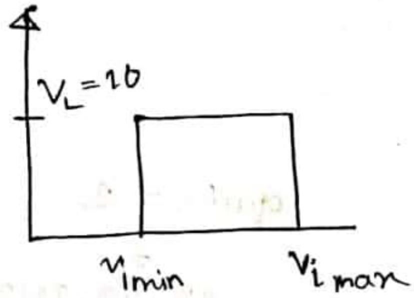
$$\boxed{I_R = I_Z + I_L}$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}$$

$$I_{Rmax} = I_{Zmax} + I_L$$

$$\therefore v_{imax} = V_{Rmax} + V_Z$$

$$= I_{Rmax} * R + V_Z$$



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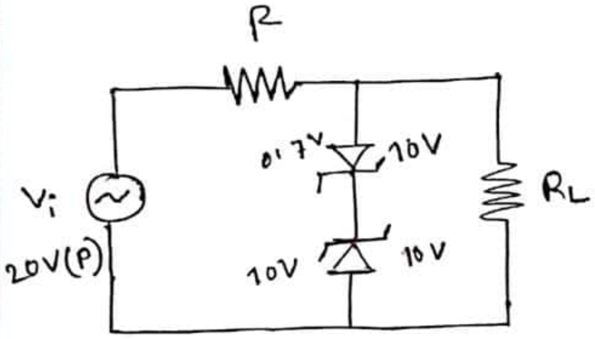
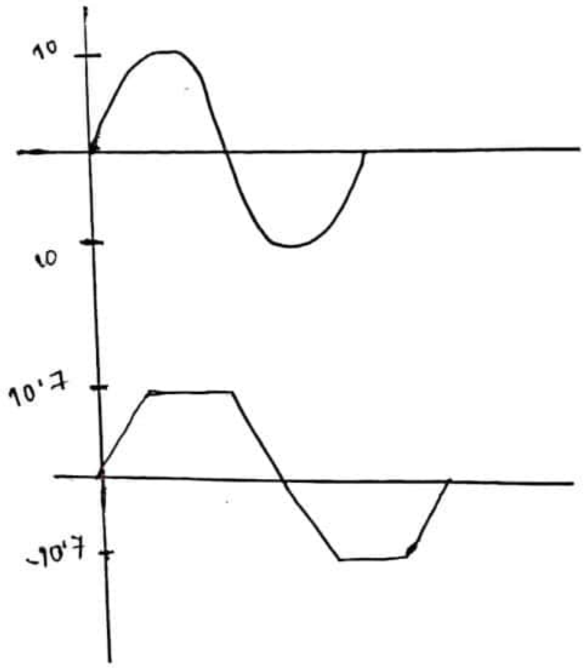
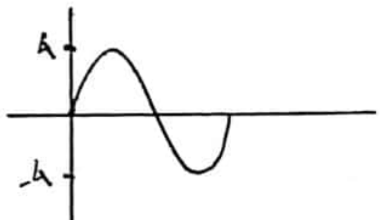
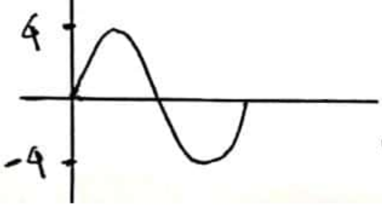




$v_i = 4V$ হলে,





diode won't work. cz $4+4 = 8V$ যা $10V$ এর চেয়ে কম।

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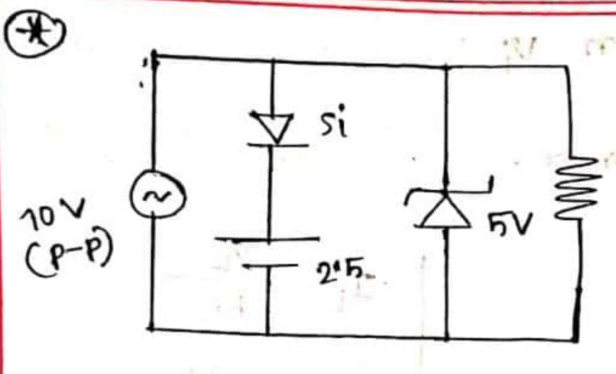

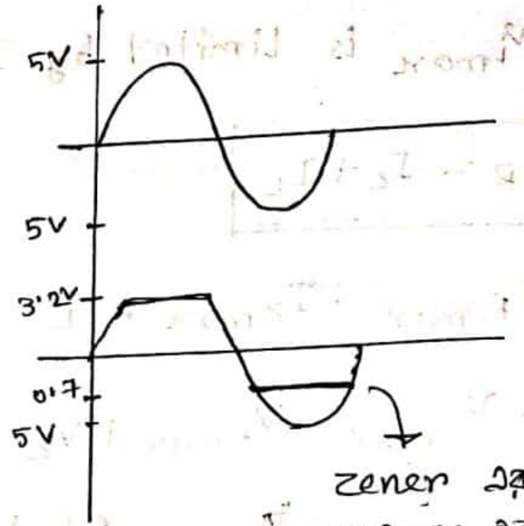

zener এর ক্ষেত্রে এরকম হবে।

quiz #2
↓
09.09.2019

29.07-2019 থেকে আজকে পর্যন্ত

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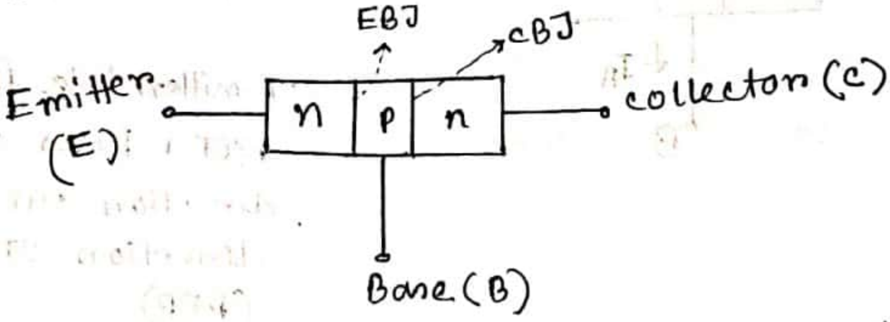
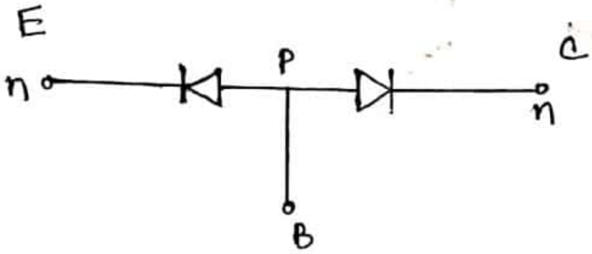
02.09.2019
Monday

Bipolar Junction Transistor (BJT):—

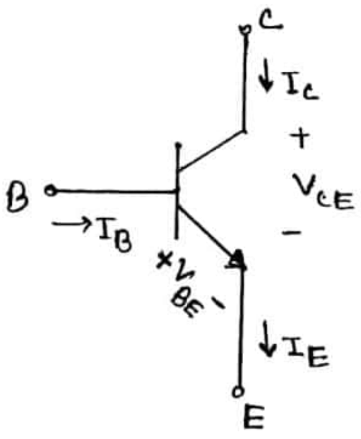
2 types :— (i) npn (ii) pnp





100% 5% 95%
• E → B → C
mA μA mA

• Transistor → amplification করা হইটা signal এর কাজ ।



• Bipolar → e^- and hole

• Transistor → Transfer through resistor

• Emitter এ doping process বেশি, " constant বেশি তাই e^- নিঃসরণ হয় বেশি (npn) ।

• biasing → operating point set করা

• $I_E = I_B + I_C$; $I_E \approx I_C$
↓
maximum current

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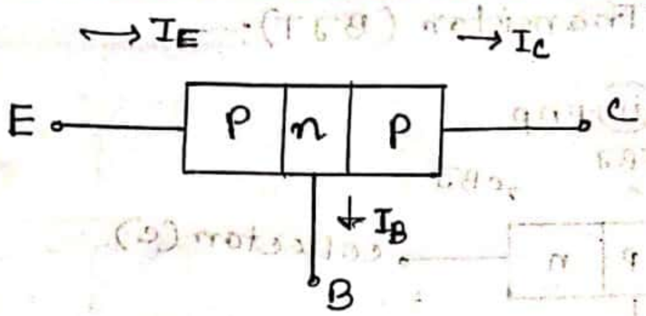
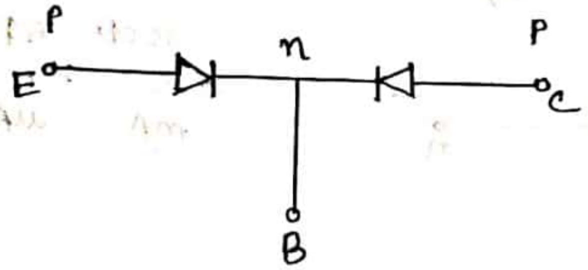
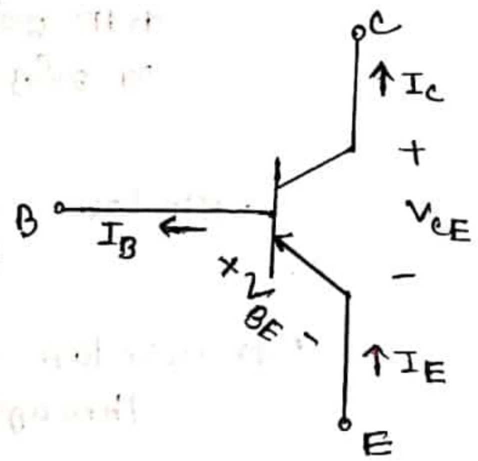


- Emitter hole নিঃসরণ করে। holes এর direction current এর direction এর দিকে। (pnp)





3 doped regions creates 2 junctions:–

i. Emitter (E)

ii. Collector (C)

iii. Base (B)

$\boxed{E > C > B}$

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Doping junction:-

E → • Heavily doped
• Injects majority carriers
(e⁻ for npn and holes for pnp)

C → Medium doped
B → Lightly doped

• C collects 95% of e⁻
B collects 5% of e⁻ emits by emitter.

2 junctions:- (i) EBJ (ii) CBJ

• Modes of operation:-

EBJ	CBJ	Modes	Use
FB	RB	Active	Works as amplifier (analog ckt)
FB	FB	Saturation	Works as switch-on (digital ckt)
RB	RB	cut-off	Works as switch-off (digital ckt)

• Origin of name:-

Transfer + Resistor = Transistor.

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• Some facts:—

i. 3 regions

ii. Doping

iii. Diodes (2)

iv. Emitter diode ; collector diode

v. Resistance

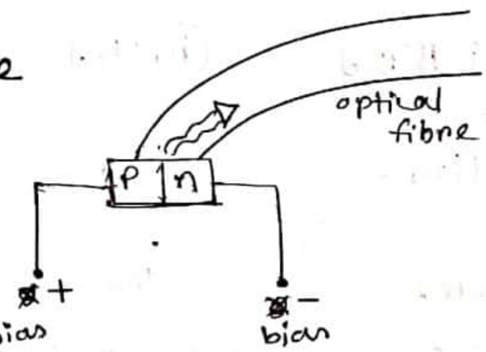
• Special Diodes:—

(i) Schottky diode

(ii) Varactor diode

(iii) Photo diode

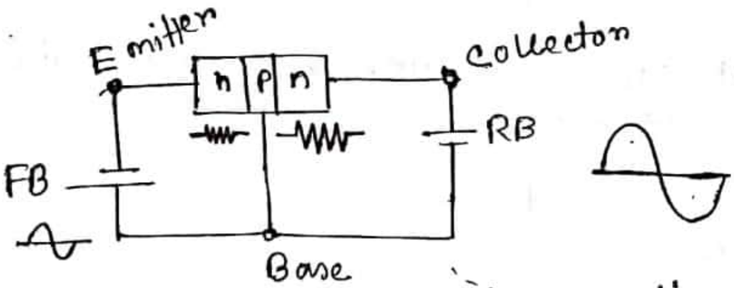
(iv) LED:—



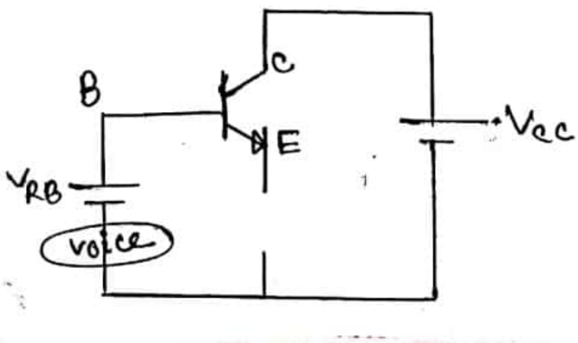
→ interference

খুব: একটা হবে না।

#



→ active



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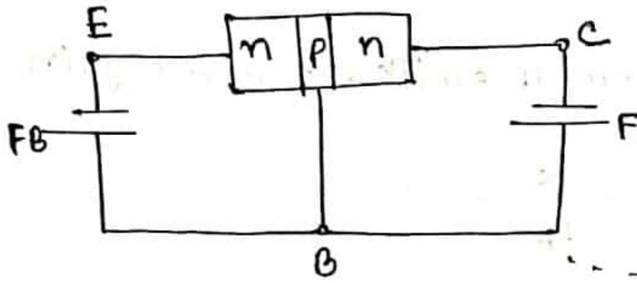
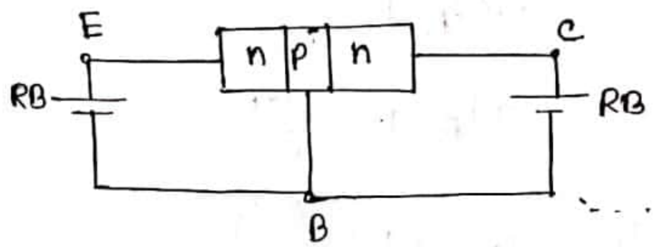
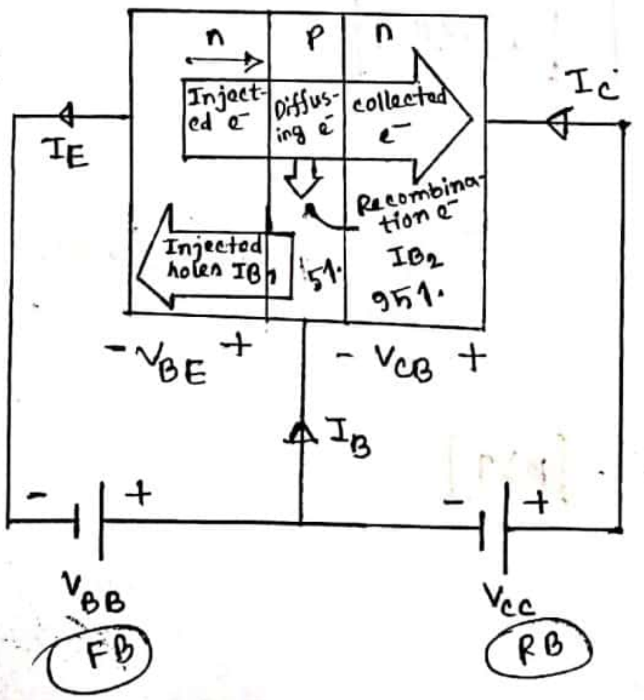


→ saturation



→ cut-off

- Emitter diode → FB এ ব্যবহৃত হবে → (Emitter base ও collector এর মধ্যে থাকে)
- collector " → RB এ " " → (collector base ও Emitter এর মধ্যে থাকে)



- e^- flow ও current direction → opposite
- gain $= \frac{o/p}{i/p}$

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$I_C = \alpha I_E$; $\alpha \to$ common base current gain

$I_C = \beta I_B$; $\beta \to$ common emitter current gain

$$\alpha = \frac{I_C}{I_E} \quad ; \quad \beta = \frac{I_C}{I_B}$$

- Emitter current, $I_E = I_C + I_B$

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

$$= \alpha I_E + \frac{\alpha I_E}{\beta}$$

$$\therefore I_E = I_E \left(\alpha + \frac{\alpha}{\beta}\right)$$

$$\Rightarrow 1 = \alpha \left(1 + \frac{1}{\beta}\right)$$

$$\therefore 1 = \alpha \left(\frac{\beta+1}{\beta}\right)$$

$\alpha \approx 0.99$

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

$$\therefore \boxed{\alpha = \frac{\beta}{\beta+1}}$$

$\boxed{\text{so, } \alpha < 1}$

Again,

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

$\beta \to 100 \sim 200$

$$\Rightarrow \alpha\beta + \alpha = \beta$$

$$\Rightarrow \beta(1-\alpha) = \alpha$$

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

$\therefore \boxed{\beta > 1}$

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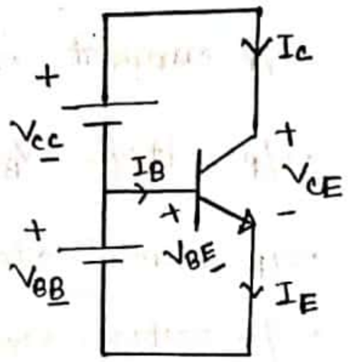
04.09.2019

Wednesday

npn:-



diode এর Forward voltage

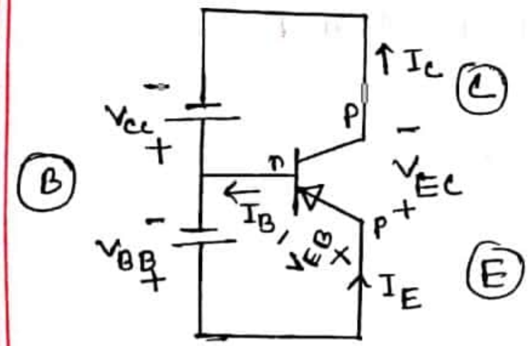
$$I_c = I_s e^{V_{BE}/V_T}$$

emitter → lower potential

$$I_B = \frac{I_c}{\beta} = \frac{I_s e^{V_{BE}/V_T}}{\beta}$$

$$I_E = \frac{I_c}{\alpha} = \frac{I_s e^{V_{BE}/V_T}}{\alpha}$$

pnp:-



emitter → higher potential

$$I_c = I_s e^{V_{EB}/V_T}$$

$$I_B = \frac{I_c}{\beta} = \frac{I_s e^{V_{EB}/V_T}}{\beta}$$

$$I_E = \frac{I_c}{\alpha} = \frac{I_s e^{V_{EB}/V_T}}{\alpha}$$

V_T = Thermal voltage = $\dfrac{KT}{q}$

≈ 25mV at room temp. and pressure.

3 configurations:-

1. Common Base (CB)
2. Common Emitter (CE)
3. Common Collector (CC)

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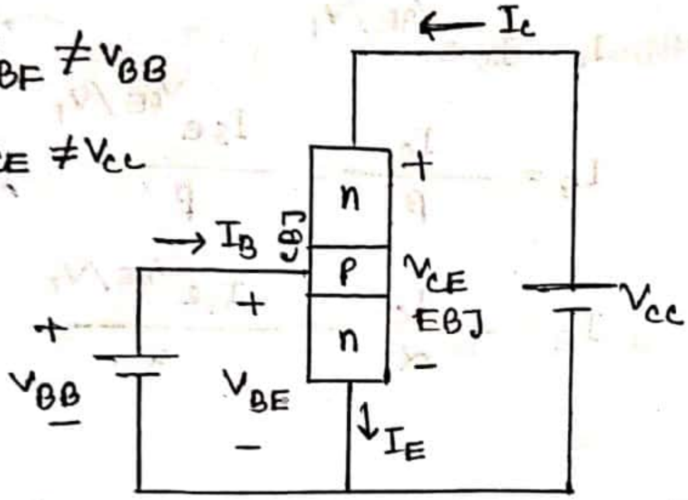
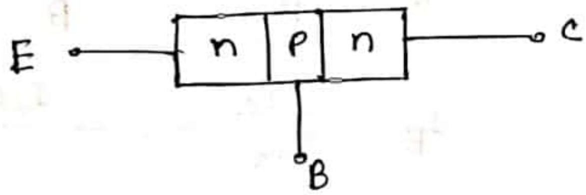
Common Emitter:-

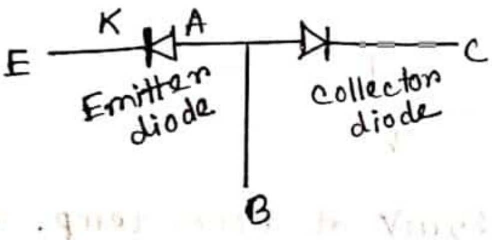
- $V_{BE} \neq V_{BB}$
- $V_{CE} \neq V_{CC}$

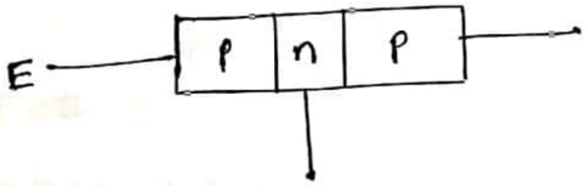


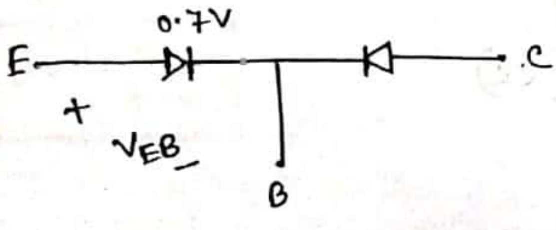
- i/p current → I_B
- i/p voltage → V_{BE}
- o/p current → I_C
- o/p voltage → V_{CE}

- gain → input এর চেয়ে output বেশি আসা।









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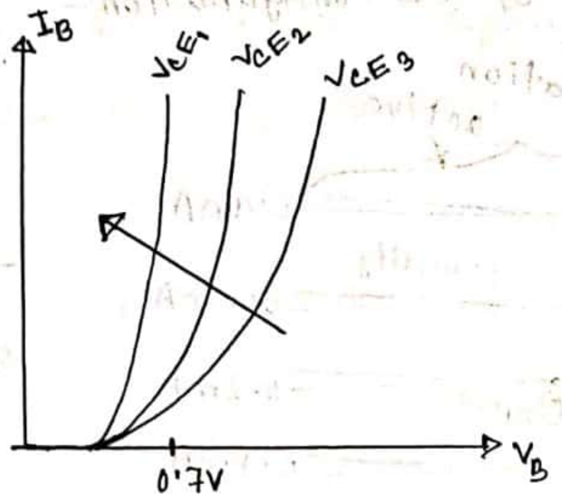
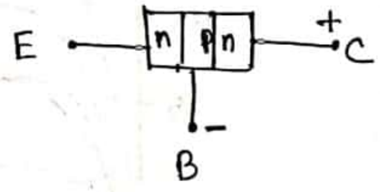
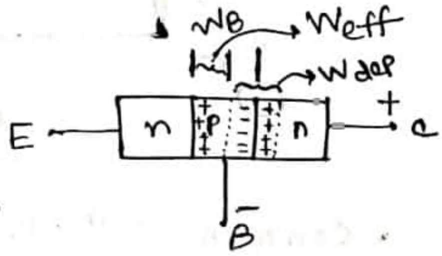


$V_{CE_3} > V_{CE_2} > V_{CE_1}$

$\uparrow V_{CE} = \uparrow V_{CB} + V_{BE} \rightarrow 0'7$



* $V_{CE} \downarrow$ curve left এ shift করবে



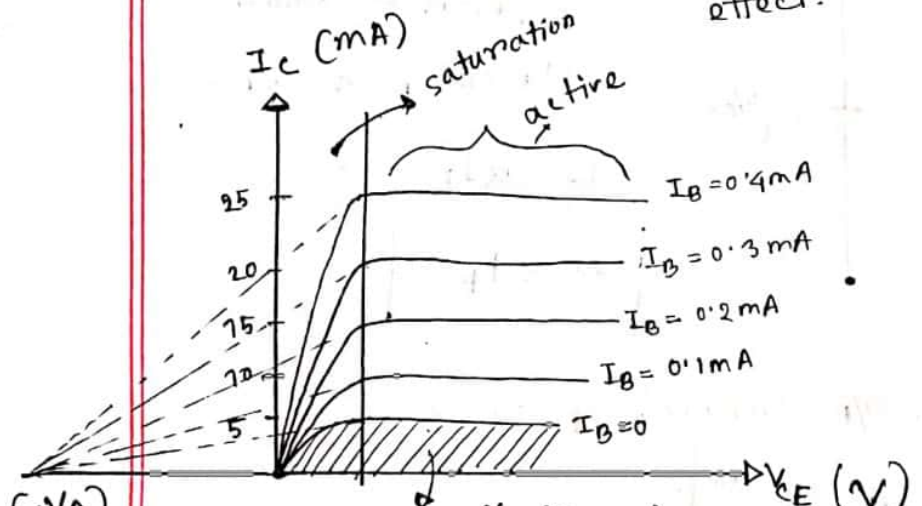
Base width Modulation

it is called Early effect.

• $W_B = W_{eff}\downarrow + W_{dep}\uparrow$

fixed

• $I_B \downarrow$ $I_C \uparrow$



• depletion layer বাড়লে চার্জের শূন্যতা বাড়বে। charge carrier কমে যাবে। ~~?~~ forward reverse

• $I_C = \beta I_B + (\beta+1) I_{CBO}$ → base open (minority current এর কারণে)

• $I_C = \beta I_B$ → gain

• active mode → amplification হবে।

• $\beta = \dfrac{\Delta I_C}{\Delta I_B} = \dfrac{15-10}{0'2-0'1} = \dfrac{5mA}{0'1mA} = 50$

$\approx 100 \sim 200$

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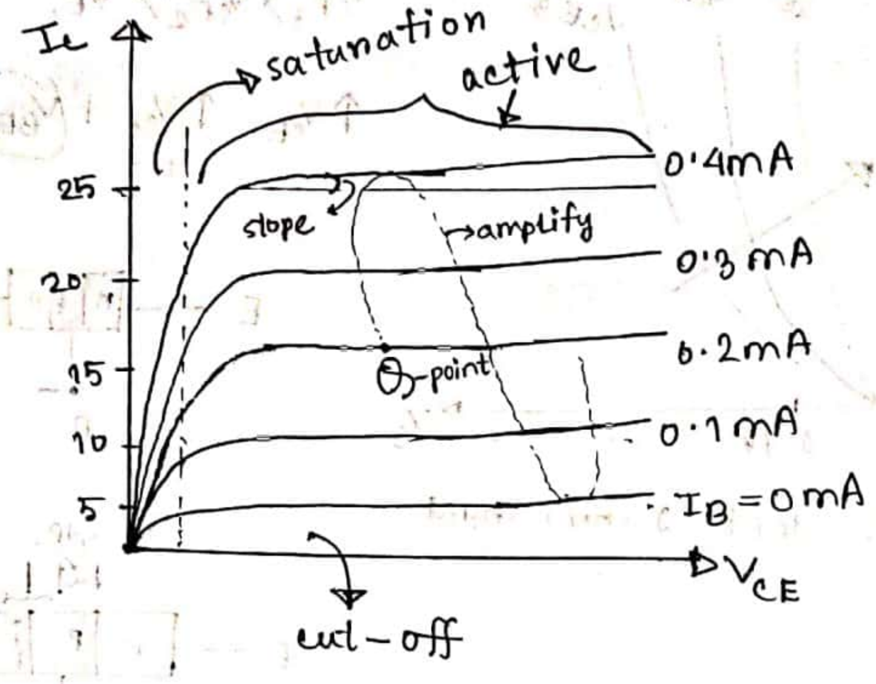
08.09.2019

Sunday

- O/P characteristic of CE configuration:-

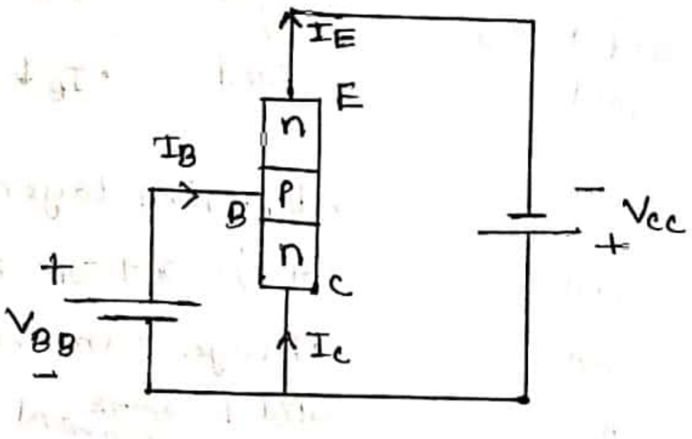


$-V_{CE} = V_{CB} + V_{BE}$

$V_{CB} = -V_{CE}$

$= -V_{BE}$

- Common collector configuration :-



$V_{CE} = V_{BE} + V_{BC}$

Graphical Relation between I_E vs. V_{CE}.

$I_c = \alpha I_E$

$\boxed{I_c \approx I_E}$

So, we can replace O/P current I_E to I_c.

So; $\boxed{\text{O/P of CE} \equiv \text{O/P of CC}}$.

for all practical purposes.

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- The common collector configuration is used for impedance matching. Because of high i/p impedance and low i/p impedance.

- current Amp factor, $\boxed{\gamma = \frac{\Delta I_E}{\Delta I_B}}$

We know, $I_E = I_C + I_B$

gain = $\frac{o/p}{i/p}$

CB → α

CE → β

CC → γ

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

$$\Rightarrow \gamma = \beta + 1$$

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

$$\Rightarrow \gamma = \frac{\alpha + \cancel{\alpha}\, 1 - \alpha}{1-\alpha}$$

$$\therefore \boxed{\gamma = \frac{1}{1-\alpha}}$$

$I_E = I_C + I_B$ ——— (1)

$I_C = \alpha I_E + I_{CBO}$ ——— (11)

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

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

$$\therefore \boxed{I_E = \gamma I_B + \gamma I_{CBO}}$$

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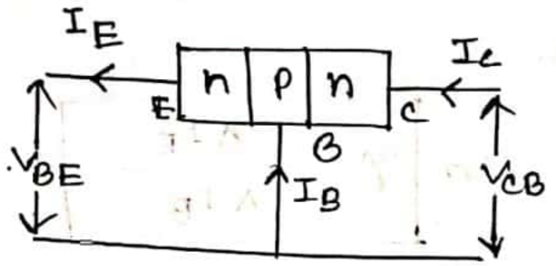
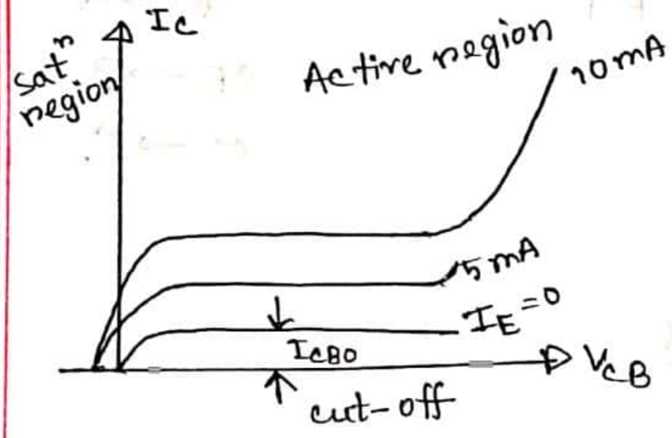
Common Base configuration :-



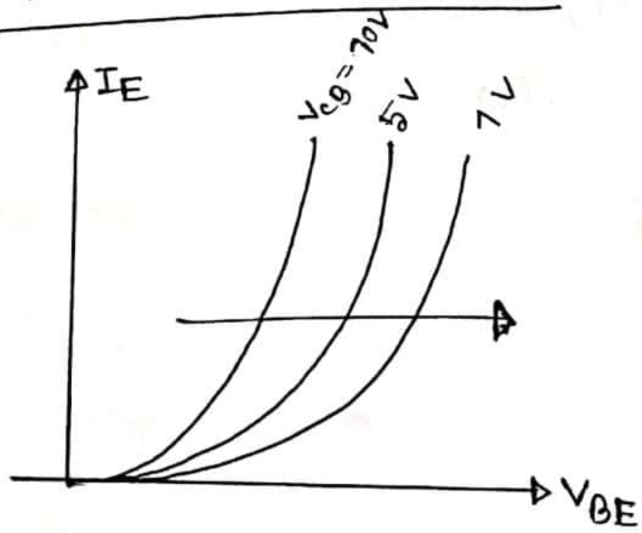
i/p current = I_B
i/p voltage = V_{BE}
o/p current = I_c
o/p voltage = V_{CB}

o/p characteristics



$$\boxed{I_c = \alpha I_E + I_{CBO}}$$

i/p characteristics :-



I_E vs V_{BE}

$V_{CB} \uparrow$ $I_B \downarrow$

$I_c \uparrow$

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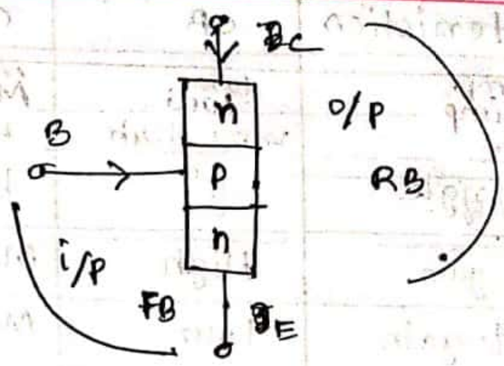
*

$$\beta = \frac{\Delta I_C \rightarrow o/p}{\Delta I_B \rightarrow i/p}$$

$$= \frac{5mA}{0.1\,mA}$$

$$= 50$$



09.09.2019
Monday

Characteristics	CB	CE	CC
Input imp.	low	Medium	High
o/p imp.	Very High	High	low
Phase angle	0°	180°	0°
Voltage gain	High	Medium	low
Current gain	Low.	Medium	High
Power gain	low	Very High	Medium

* একটা diode forward bias এ থাকলে তার resistance ছোট।

Practically,

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

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

$I_{CBO} \rightarrow$ Collector current with collector junction is RB and base open circuited.

$I_{CEO} \rightarrow$ Collector current with collector junction is RB and emitter open.

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

$$= \alpha (I_C + I_B)$$

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

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

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

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

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

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$\therefore (1-\alpha) = \frac{1}{\beta+1}$

$\therefore I_c = \beta I_B + \frac{I_{CBO}}{1-\alpha}$

$I_c = \beta I_B + I_{CEO}$ —— (ii)

Comparing equation (i) and (ii),

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

$= (\beta+1) I_{CBO}$

$\therefore \boxed{I_c = \beta I_B + (\beta+1) I_{CBO}}$

* biasing ছাড়া কোনো transistor চালানো যায় না।

DC Biasing of transistor :-

is the process of applying external dc voltages to select the appropriate operating points.

Three operating points :-

1. Active region
2. Saturation region
3. Cut-off region

For these we need an npn.

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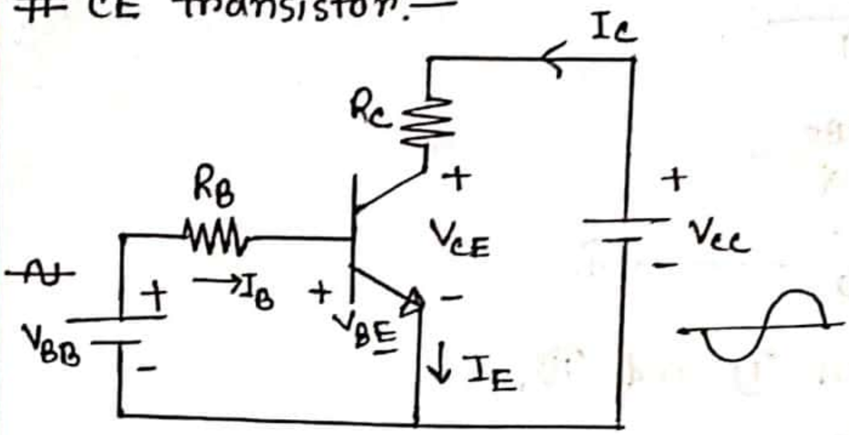
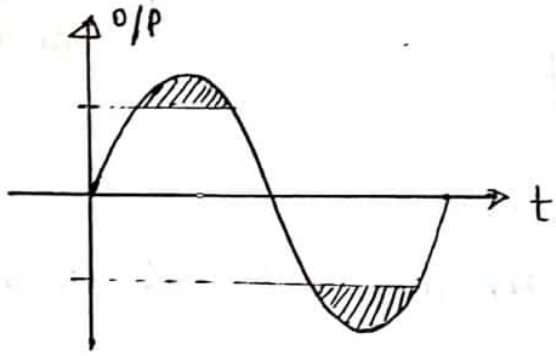
CE transistor:—



If we apply an i/p small ac signal with DC then we desire to achieve an o/p amplified signal.



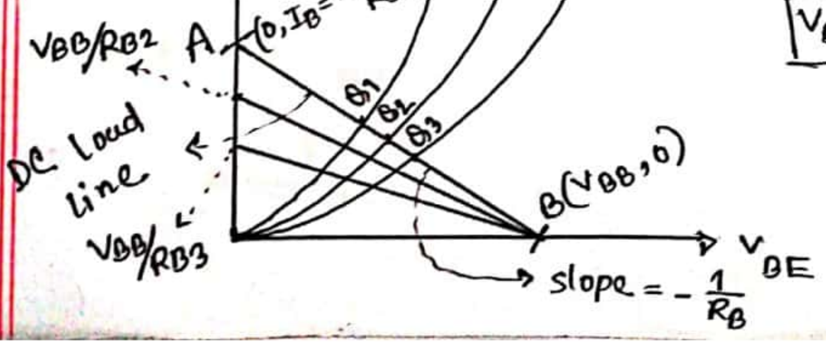
It is not desired that to get an o/p which one is clipped, it is called faithful amplification.

Operating point :—

Transistors ~~an~~ are two port devices.

RB↑ slope↓
RB↓ slope↑

• i/p operating point :—



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

$$\boxed{V_{BB} = V_{BE} + I_B R_B}$$

$V_{CE3} > V_{CE2} > V_{CE1}$

at point A, $V_{BE} = 0$; $I_B = \frac{V_{BB}}{R_B}$

at point B, $I_B = 0$; $V_{BE} = V_{BB}$

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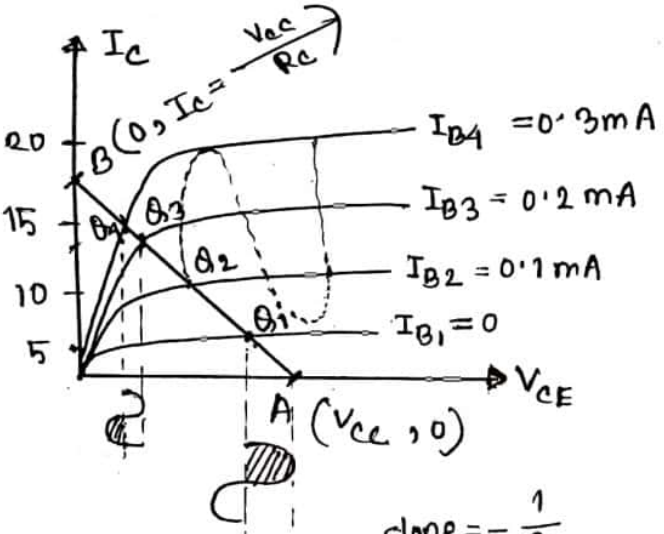
• o/p operating point :—



$$\text{slope} = -\frac{1}{R_C}$$

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

$$\boxed{V_{CC} = V_{CE} + I_C R_C}$$

o/p characteristic equation

at point A, $I_C = 0$;

$V_{CC} = V_{CE}$

at point B, $V_{CE} = 0$;

$$I_C = \frac{V_{CC}}{R_C}$$

Q_2 → best কারণ মাঝামাঝি আছে।

o/p ভালো আসবে।

15/09/2019
Sunday

* I_C can change due to two reasons:–

(i) Change in β value:– β of two different transformers will never be same. So change in β will result in change of operating point. On Q-point co-ordinates are (V_{CEQ}, I_{CQ}) ; $\boxed{I_C = \beta I_B}$

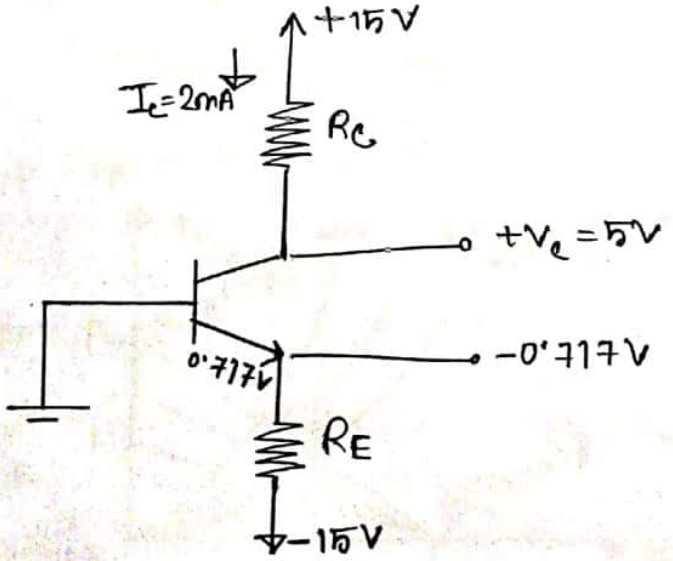
(ii) Change in temperature:– If temperature changes minority carrier also change. So, I_C also changes as,

$$\boxed{I_C = \beta I_B + (\beta+1) I_{CBO}}$$

Temp. ↑ I_{CBO} ↑ I_C ↑.

Sedra

Ex:– 6·2 The transistor in the ckt has $\beta = 100$; exhibits $V_{BE} = 0{\cdot}7V$ at $I_C = 1mA$. Design the ckt that a current of 2mA flows through the collector. and a voltage +5V ~~appeares~~ appears at collector.

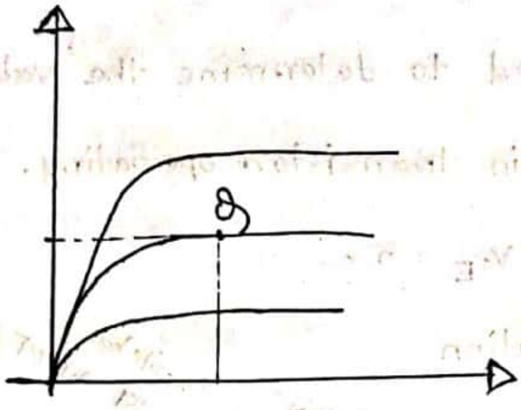


$$R_C = \frac{15-5}{2mA} = 5k\Omega$$

$$I_{C_1} = I_S e^{V_{BE_1}/V_T} \quad \text{——— (I)}$$

$$I_{C_2} = I_S e^{V_{BE_2}/V_T} \quad \text{——— (II)}$$

P.T.O.



$$\frac{I_{c_2}}{I_{c_1}} = e^{V_{BE_2}/V_T - V_{BE_1}/V_T}$$

$$\Rightarrow \frac{V_{BE_2} - V_{BE_1}}{V_T} = \ln\left(\frac{I_{c_2}}{I_{c_1}}\right)$$

$$\Rightarrow V_{BE_2} = V_{BE_1} + V_T \ln\left(\frac{I_{c_2}}{I_{c_1}}\right)$$

$$= 0.7\,V + 2\,mV * \ln\left(\frac{2mA}{1mA}\right)$$

$$\therefore V_{BE_2} = 0.717\ V$$

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

$$\Rightarrow 0.717 = 0 - V_E$$

$$\therefore V_E = -0.717\,V$$

$$I_c = \alpha I_E$$

$$= \left(\frac{\beta}{\beta+1}\right) * I_E$$

$$I_E = I_c\,(\beta+1)/\beta$$

$$\therefore R_E = \frac{V_E - (-15)}{I_E}$$

$$= \frac{-0.717 + 15}{I_E}$$

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Sedra

Ex-6.3

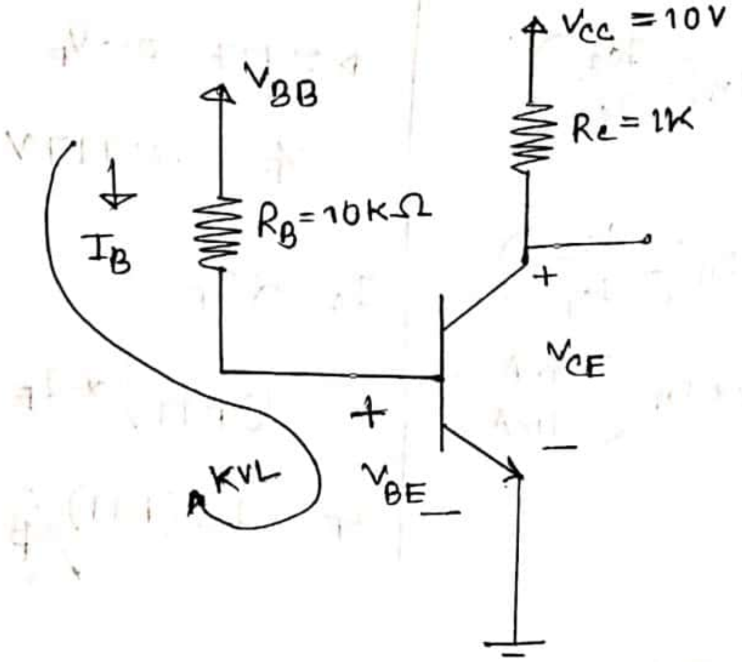
For the ckt, it is required to determine the value of voltage, V_{BB} that results in transistor operating.

(a) in the active mode, $V_{CE} = 5V$.

(b) at the edge of saturation

(c) deep in saturation, $\beta_{forced} = 10$ → switching এর ক্ষেত্রে

For simplicity, assume $V_{BE} = 0.7V$, $\beta = 50$.



(a) $V_{CE} = 5V = V_C - V_E$ ∴ $V_C = 5V$

$V_E \to 0$

$$I_C = \frac{V_{CC} - V_C}{R_C} = \frac{10-5}{1K} = 5mA$$

$$I_C = \beta I_B$$

$$I_B = I_C/\beta = 5mA/50 = 0.1mA.$$

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

$= 0.1mA * 10K + 0.7V$

$= 1.7V$

(b) at the edge of saturation, → sat^n হওয়ার আগ মুহূর্ত

$V_{BB} =$

$V_{CE\ edge\ of\ sat^n} = 0.3V = V_C - \cancel{V_E}^{0} = V_C$

$\beta = 50$

$I_C =$

$I_B =$

$V_{BB} =$

(c) $V_{CE\ sat^n} = 0.2V$

$\beta_{forced} = 10$

$V_{BB} =$

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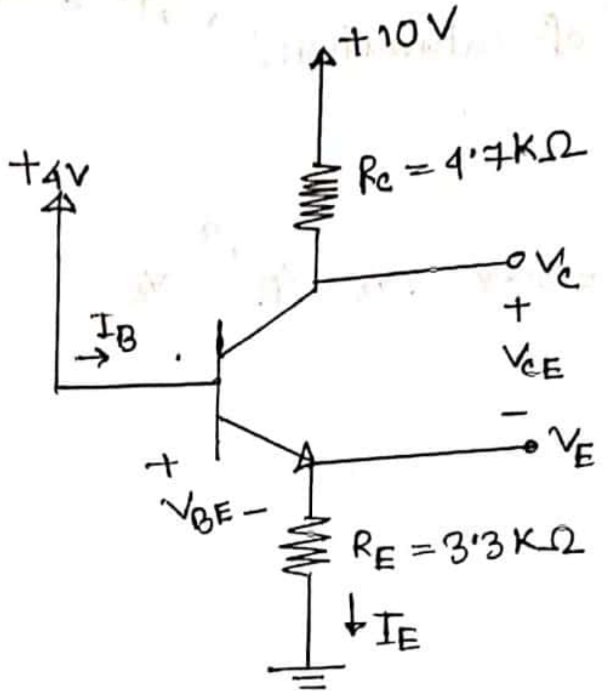
Sedra

Ex – 6'4 Consider the ckt in the following figure to determine all node voltages and branch currents. ~~b/e~~ ~~with~~ $\beta = 100$. Also determine whether the BJT is on active or saturation or cut-off mode.



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

$V_B = 4V$

$V_E = V_B - 0.7V = 3.3V$

$$I_E = \frac{3.3V}{3.3K\Omega} = 1mA.$$

$I_E = (\beta+1)I_B$

$$\boxed{\begin{aligned} \Rightarrow I_E &= I_C + I_B \\ &= \beta I_B + I_B \\ &= I_B(\beta+1) \end{aligned}}$$

$$\therefore I_B = \frac{I_E}{\beta+1} = \frac{1mA}{101} = 9.9\mu A$$

$I_C = \beta I_B$
$= 100 \times 9.9\mu A$
$= 0.99 mA$

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$$I_C = \frac{10 - V_C}{R_C}$$

$\Rightarrow 10 - V_C = I_C R_C$

$\Rightarrow V_C = 10 - I_C R_C$

$= 10 - 0.99mA * 4.7K$

$= 10 - 4.65V$

$= 5.35 V$

$V_{CB} = V_C - V_B$

$= 5.34V - 4$

$= 1.34 V$

$= (+) ve$

$= RB$

EBJ in forward bias and CBJ in reverse bias.

so, the device is running on active mode.

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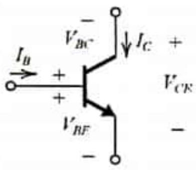
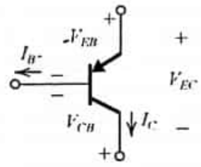
Table 6.3 Conditions and Models for the Operation of the BJT in Various Modes

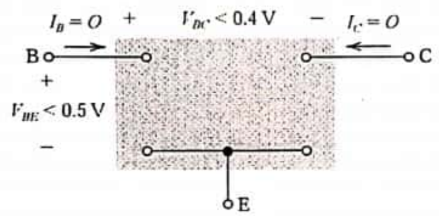
npn

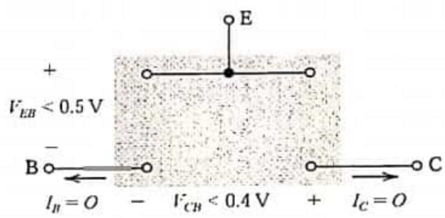


pnp

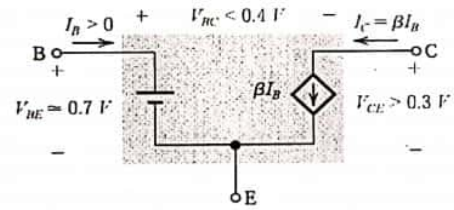


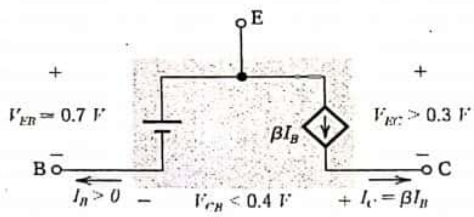
Cutoff
EJB: Reverse Biased
CBJ: Reverse Biased



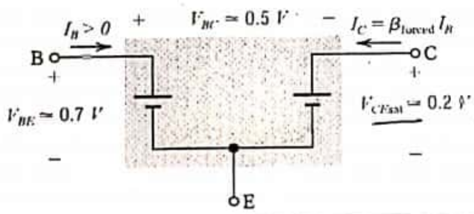


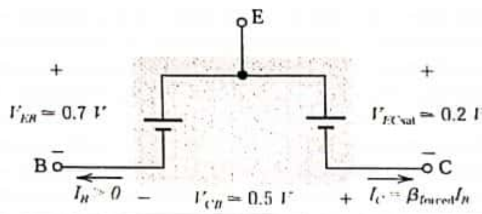
Active
EBJ: Forward Biased
CBJ: Reverse Biased





Saturation
EBJ: Forward Biased
CBJ: Forward Biased





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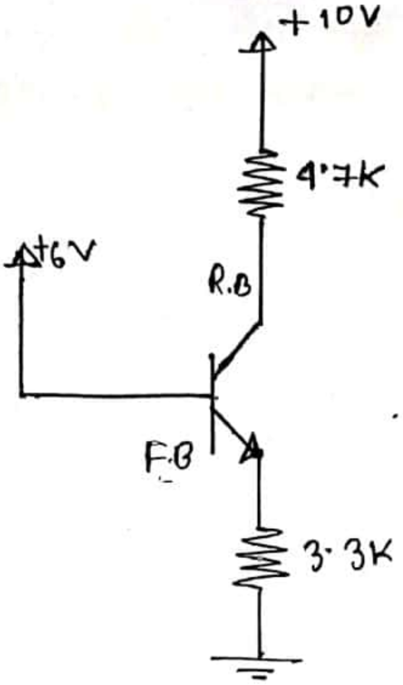
16.09.2019
Monday

Ex-6.5 Determine all the node voltages and branch currents. if $\beta = 50$.



$V_B = 6V$

$V_{BE} = 0.7V$

$V_E = V_B - 0.7$
$= 6 - 0.7$
$= 5.3V$

$I_E = \frac{V_E}{R_E} = \frac{5.3}{3.3K}$
$= 1.6 mA$

$I_c = \frac{\beta}{\beta+1} * I_E = \frac{50}{51} * 1.6mA$
$= 1.57 mA$

$\therefore V_c = 10 - I_c * R_c = 10 - (1.57 * 4.7K)$
$= 2.67V$

The device is not on active mode. It runs on sat^n mode.

$V_{CB} = V_c - V_B = (2.67 - 6)V = -3.33V$;

$\hookrightarrow$ FB sat^n mode

$V_{CE\,sat} = 0.2V = V_c - V_E$

$\therefore V_c = V_E + 0.2V$
$= 5.3 + 0.2V$
$= 5.5V$

$I_c = \frac{10 - 5.5}{4.7K}$
$= 0.95mA$

$I_B = I_E - I_c$
$= 1.6mA - 0.95mA$
$= 0.65mA$

$\beta_{forced} = \frac{I_c}{I_B}$
$= \frac{0.95}{0.65}$
$= 1.46$

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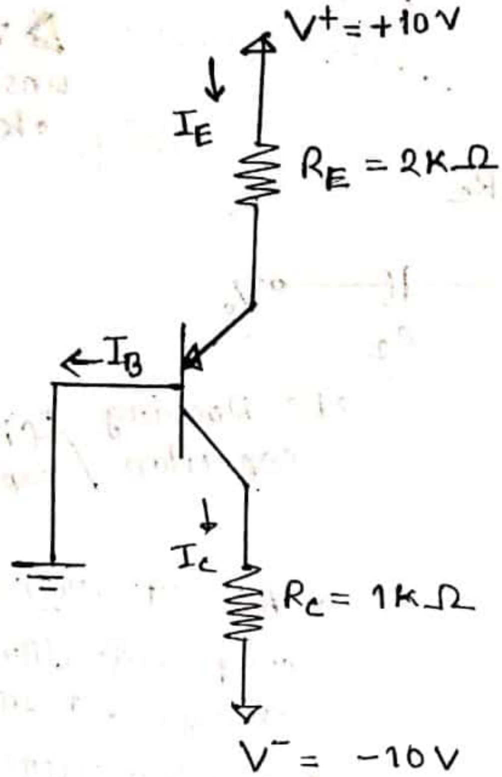
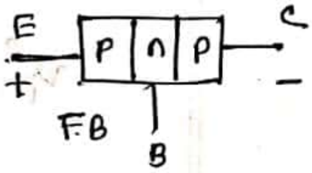
sedra practice
Ex – 6.6, 6.8 – 6.10

Ex-6.7 :- Determine all the node voltages and currents.



* npn ; $V_{BE} = 0.7V$
V_{CB}

* pnp ; $V_{EB} = 0.7V$
V_{BC}



* β এর value না থাকলে 100 ধরে নিতে হবে।

$V_E - V_B = V_{EB} = 0.7V$; $V_B = 0V$; $V_E = 0.7V$

$I_E = \frac{10 - 0.7}{2k} = 4.65 mA$

let, $\beta = 100$; $I_C = \frac{\beta}{\beta+1} * I_E = 4.60 mA$; $I_B = \frac{I_C}{\beta} = 4.6 * 10^{-3}$
$= 46 * 10^{-6}$
$= 46 \mu A$.

$I_C = \frac{V_C + 10}{1K}$

$\Rightarrow V_C = -5.4V$

$V_{BC} = V_B - V_C = 0 + 5.4V = 5.4V$

* mode change এর math → important.
* voltage divider bias ckt → very stable ckt.

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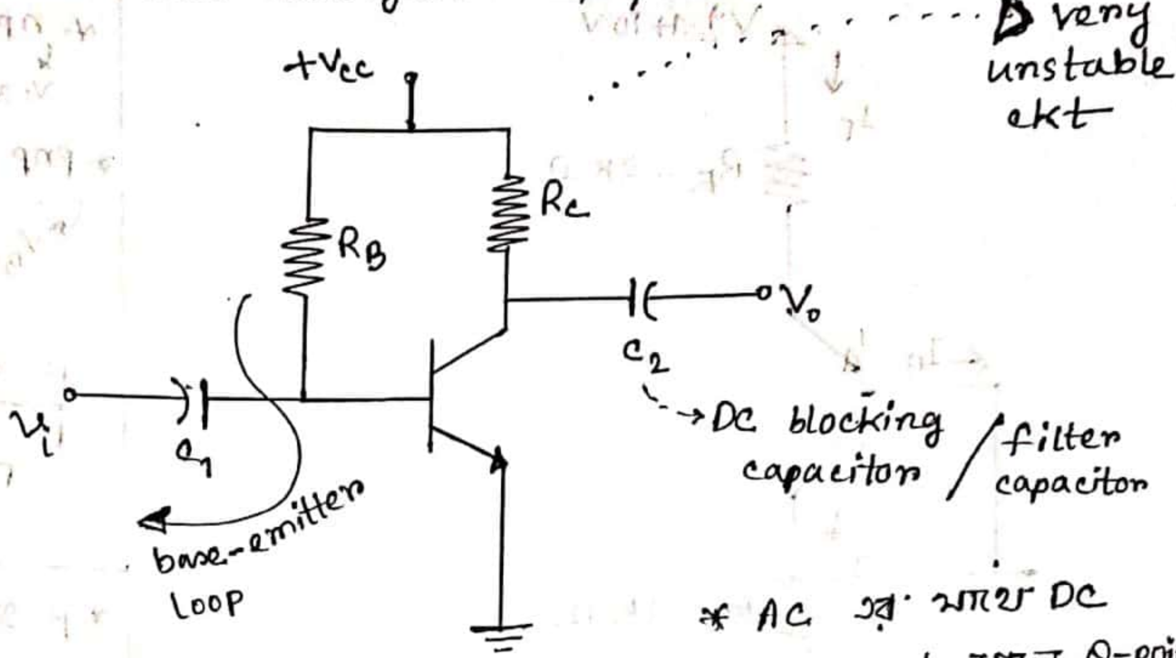
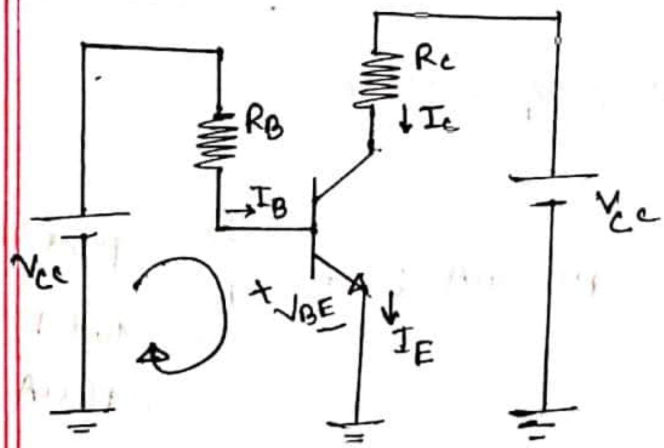
Biasing configuration:–

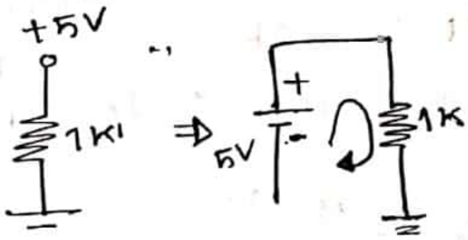
Boylestad

1. Fixed Bias configuration:– / Base bias / Base-resistor Method



* AC এর সাথে DC component থাকলে Q-point change হয়ে যাবে।
* Q-point যাতে move না করে তাই capacitor use করা হয়।





Base-emitter loop,

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

$$-5 + 1 * I = 0$$

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

$$I_C = \beta I_B = \beta * \left(\frac{V_{CC} - V_{BE}}{R_B}\right).$$

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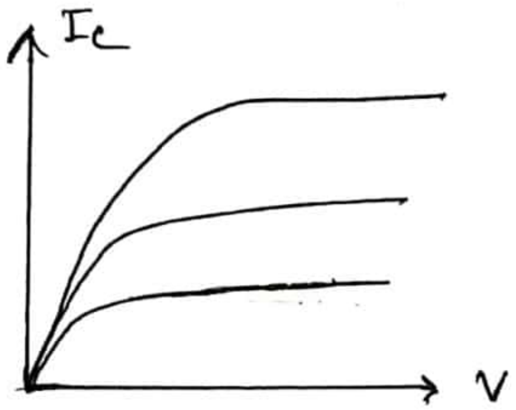
Collector-emitter loop,

$$\boxed{V_{CE} = V_{CC} - I_C R_C}$$ → output equation (characteristics eqn)



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18.09.19

Wednesday

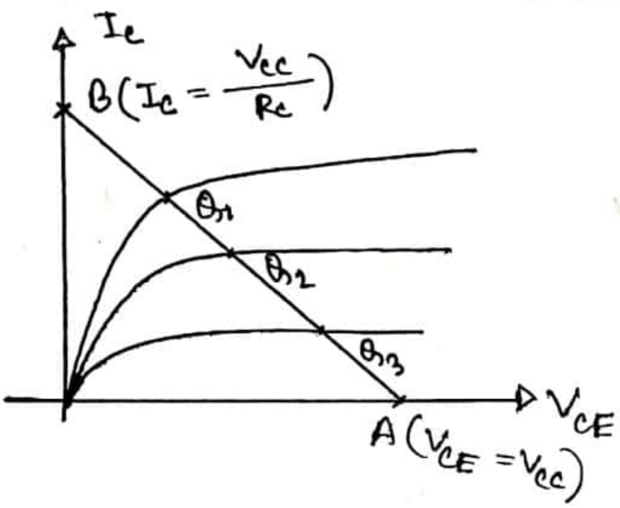
Fixed Bias configuration:-

$*V_{cc} \uparrow$ slope $\uparrow$

$$V_{CE} = V_C - V_E$$

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

Characteristics equation $\boxed{V_{CE} = V_{cc} - I_c R_c}$



at point (A), $I_c = 0$

$$V_{CE} = V_{cc}$$

at point (B), $V_{CE} = 0$

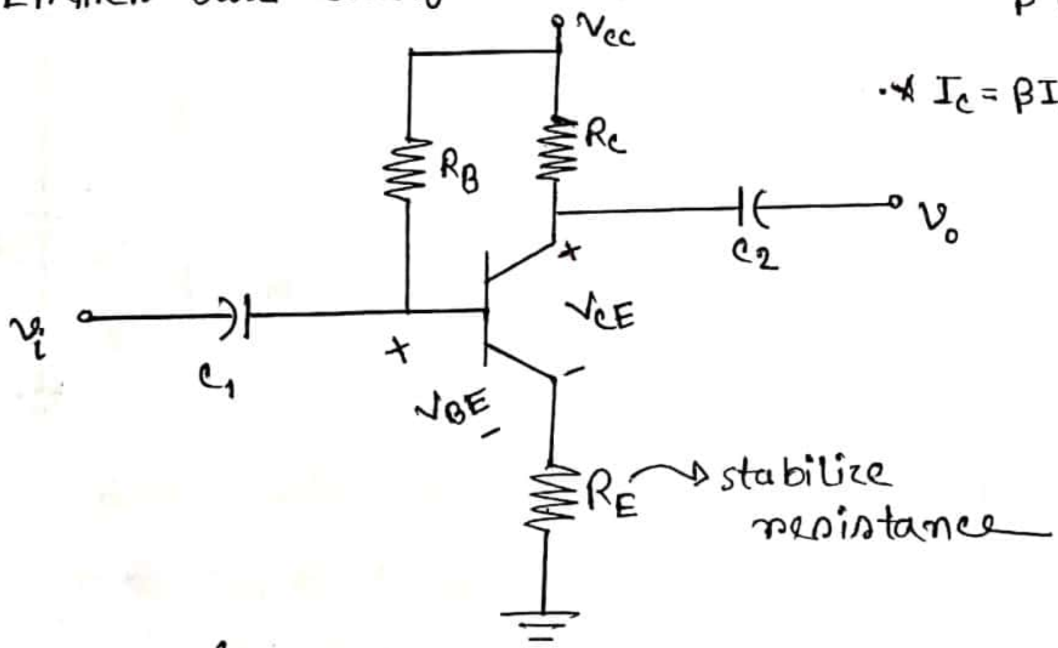
$$I_c = \frac{V_{cc}}{R_c}$$

$$* I_c = \beta I_c$$

$$= \beta\left(\frac{V_{cc} - V_{BE}}{R_B}\right)$$

$$* I_c = \beta I_B + (\beta + 1) I_{CBO}$$

Emitter Base configuration:-



good ckt

For BE loop:-

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

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

$$\therefore \boxed{I_B = \frac{V_{cc} - V_{BE}}{R_B + (\beta+1) R_E}}$$

$$I_c = \beta I_B$$

$$= \beta \left(\frac{V_{cc} - V_{BE}}{R_B + (\beta+1) R_E} \right)$$

For CE loop:-

$$-V_{cc} + I_c R_c + V_{CE} + I_E R_E = 0$$

$$\boxed{I_c \approx I_E}$$

$$\therefore -V_{cc} + I_c R_c + V_{CE} + I_c R_E = 0$$

$$\Rightarrow V_{CE} = V_{cc} - I_c (R_c + R_E).$$

$$V_E = I_E R_E$$

$$V_{CE} = V_c - V_E$$

$$V_c = V_{CE} + V_E$$

$$V_c = V_{cc} - I_c R_c$$

$$V_B = V_{cc} - I_B R_B$$

$$V_B = V_{BE} + V_E$$

$$V_{CE} = V_{cc} - I_c R_c - I_E R_E$$

$$= V_{cc} - I_c R_c - V_E$$

$$\Rightarrow V_{CE} + V_E = V_{cc} - I_c R_c$$

$$\Rightarrow \boxed{V_c = V_{cc} - I_c R_c}$$

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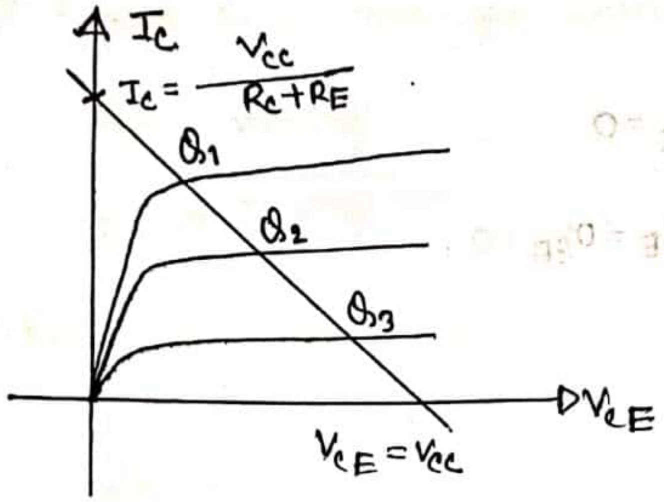

Advantage of Emitter Bias:—

(i) I_C is changed so Q changed

Temp↑ I_C↑ $\left(I_C = \beta I_B + (\beta+1) \overset{\uparrow}{I_{CBO}}\right)$

$I_C \approx I_E$
so, I_E↑

$\underset{\text{drop}}{\underline{I_E R_E}}$ ↑ as $I_C \approx I_E \Rightarrow I_B \downarrow \Rightarrow I_C \downarrow$

$$I_B \downarrow = \frac{V_{CC} - V_{BE} - I_E R_E}{R_B}$$

(ii) β is also unchanged.

$$I_C = \beta \left(\frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} \right)$$

suppose,
$R_B = 220\,\Omega$
$R_E = 470\,\Omega$
$\beta = 200$
so, $R_E \times \beta$ = (...) $K\Omega$
R_B টা বেশি ছোট হয়ে যায়।

so, β nullify হয়ে যায়।

$$I_C = \beta \left(\frac{V_{CC} - V_{BE}}{(\beta+1) R_E} \right)$$

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disadvantage of that ckt :—

- $R_B << \beta R_E$; β এর value না জানা থাকতে পারে। R_B এর value বাড়ানো না কমানো সেটা β এর উপর depended.
- R_B এর value বাড়াতে হলে, V_{cc} এর value ও বাড়ানো লাগে। ফলে cost বেড়ে যায়।

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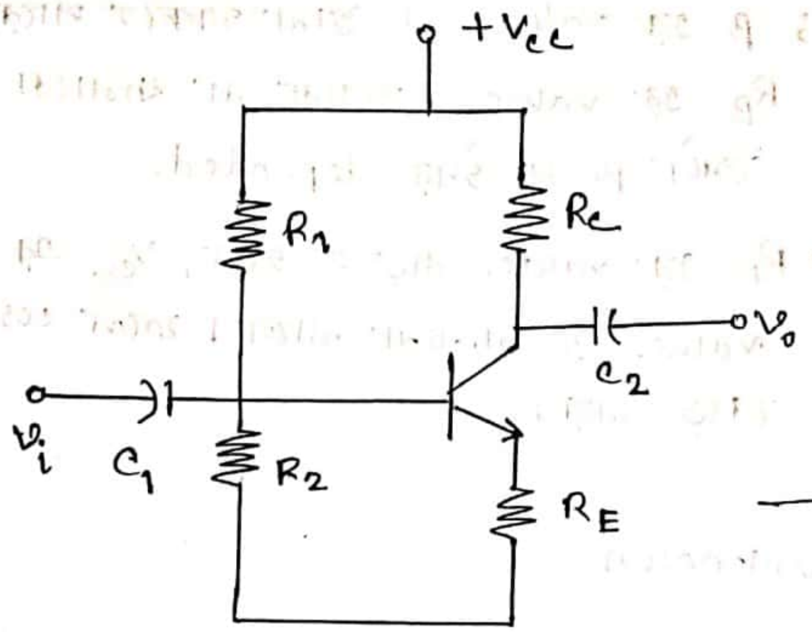
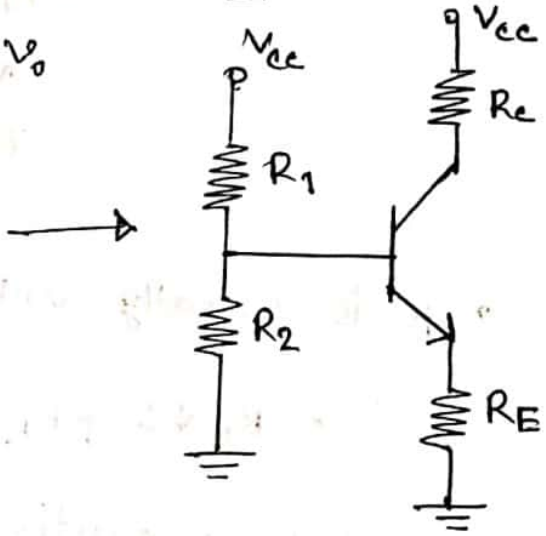
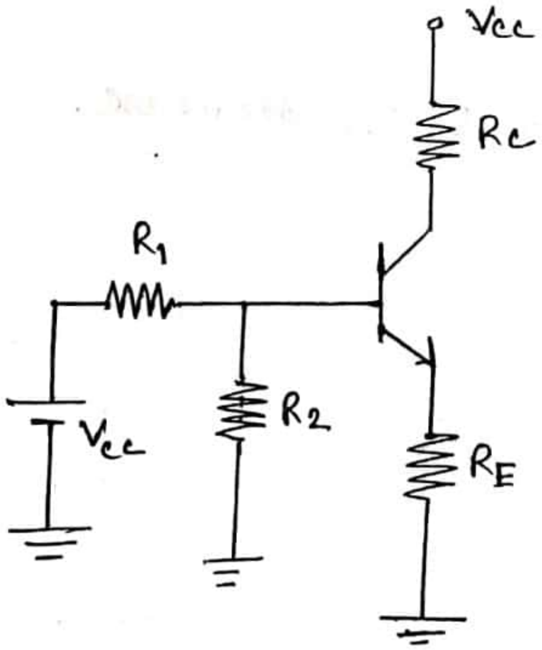
22.09.2019
Sunday

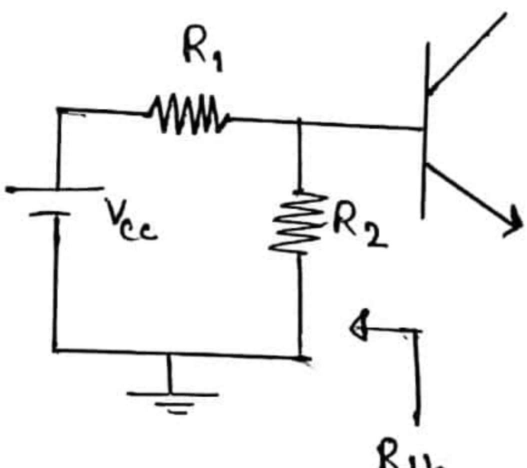
Voltage Divider Biasing :-



Exact analysis :-







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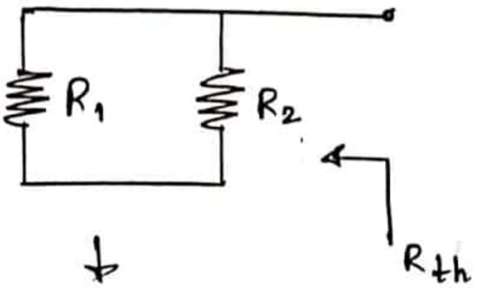
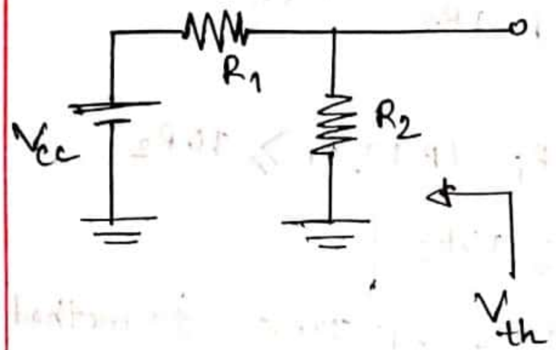
R_{th} , V_{th}

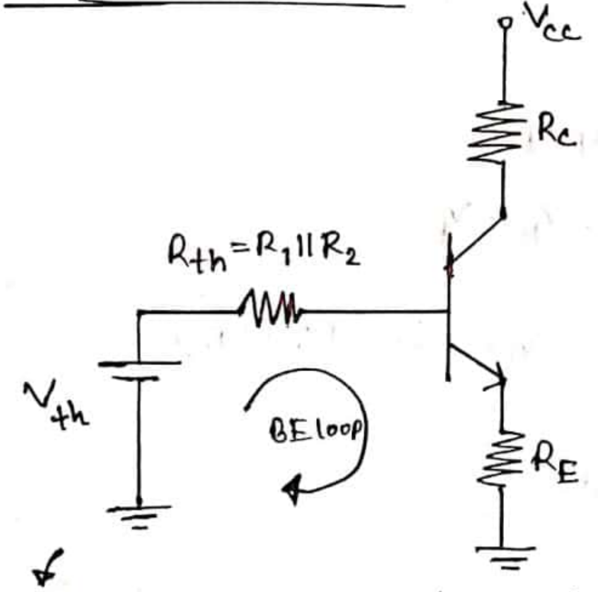


$$\boxed{R_{th} = R_1 \parallel R_2}$$



$$\boxed{V_{th} = \frac{R_2}{R_1+R_2} * V_{cc}}$$

simplified ckt :—



এই ckt কে ২ ভাবে solve করা যায় — 1. exact method,
2. approximate method.

for BE loop

$$-V_{th} + I_B R_{th} + I_E R_E + V_{BE} = 0$$

$$I_B = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1) R_E}$$

↓
input current

$$I_C = \beta * I_B$$

$$R_{input} = (\beta+1) R_E$$

কারণ R_{th} এ $R_1 \parallel R_2$ এর resistance parallel করলে value কমে যায়। তাই neglegible.

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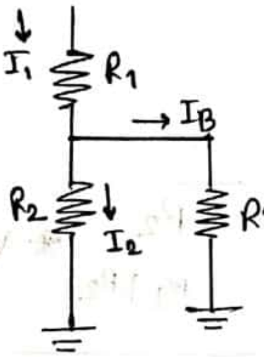
for CE loop

$$V_{CE} = V_{CC} - I_C (R_C + R_E) \qquad \boxed{I_C \approx I_E}$$

Approximate method:-



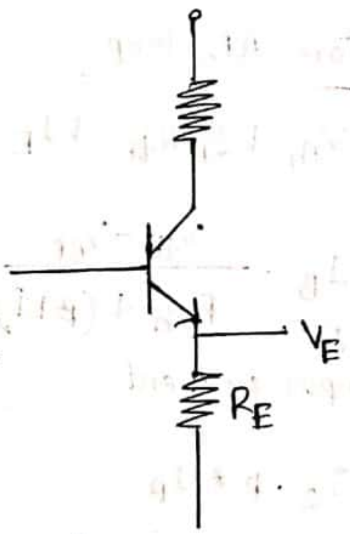
$$I_1 = I_2$$

$$V_B = \frac{R_2}{R_1 + R_2} * V_{CC}$$

when $R_i = (\beta + 1) R_E \geqslant 10 R_2$

$$\boxed{\beta R_E \geqslant 10 R_2}$$

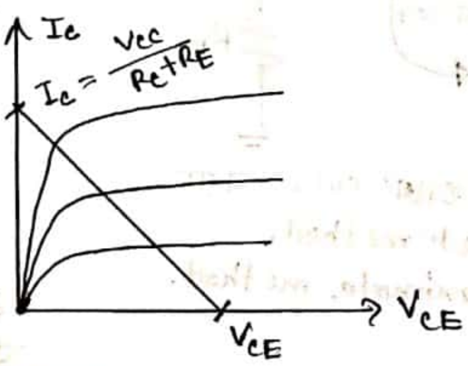
এটা fulfill না হলে এই method apply করা যাবে না। তাই exact method apply করতে হবে।



$$V_E = I_E R_E$$

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

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



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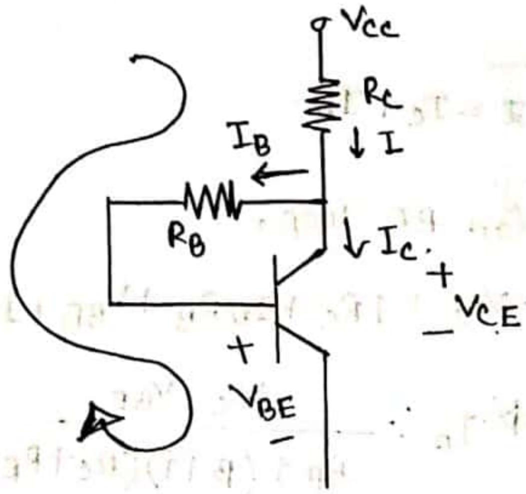
collector Feed back (F/B) biasing:—



$$I = I_c + I_B = \beta I_B + I_B = (\beta+1) I_B$$

for BE loop,

$$-V_{cc} + IR_c + I_B R_B + V_{BE} = 0$$

$$\Rightarrow I_B = \frac{V_{cc} - V_{BE}}{R_B + (\beta+1) R_c}$$

$$I_c = \beta I_B$$

$$I_c = \beta * \frac{V_{cc} - V_{BE}}{R_B + (\beta+1) R_c}$$

$$-V_{cc} + I * R_c + V_{CE} = 0$$

$$\therefore (I_c + I_B) * R_c - V_{cc} + V_{CE} = 0$$

$$\Rightarrow I_E * R_c - V_{cc} + V_{CE} = 0$$

$$\therefore V_{CE} = V_{cc} - I_c R_c \qquad [\because I_c \approx I_E]$$

- Advantages:—
  1. β will not effect Q point
  2. Temp. will not effect
- disadvantages:—
  1. $R_B \downarrow\downarrow \quad (\beta+1) R_c \uparrow\uparrow$
  2. $V_{cc} \uparrow\uparrow \; R_B \downarrow\downarrow$ so that R_B will decrease.

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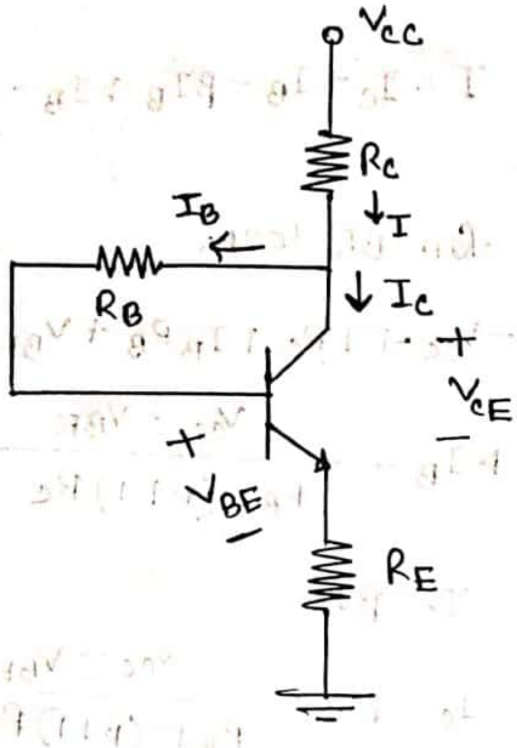
Collector F/B Biasing with emitter resistance:-



$I = I_C + I_B$

for BE loop,

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

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

$R_B \ll (\beta+1)(R_C + R_E)$

$-V_{CC} + I * R_C + V_{CE} + I_E R_E = 0$

$\Rightarrow -V_{CC} + \underbrace{(I_C + I_B)}_{I_E \approx I_C} R_C + V_{CE} + I_C R_E = 0$

সমান না ধরলেও চলবে

$\Rightarrow V_{CE} = V_{CC} - I_C (R_C + R_E)$

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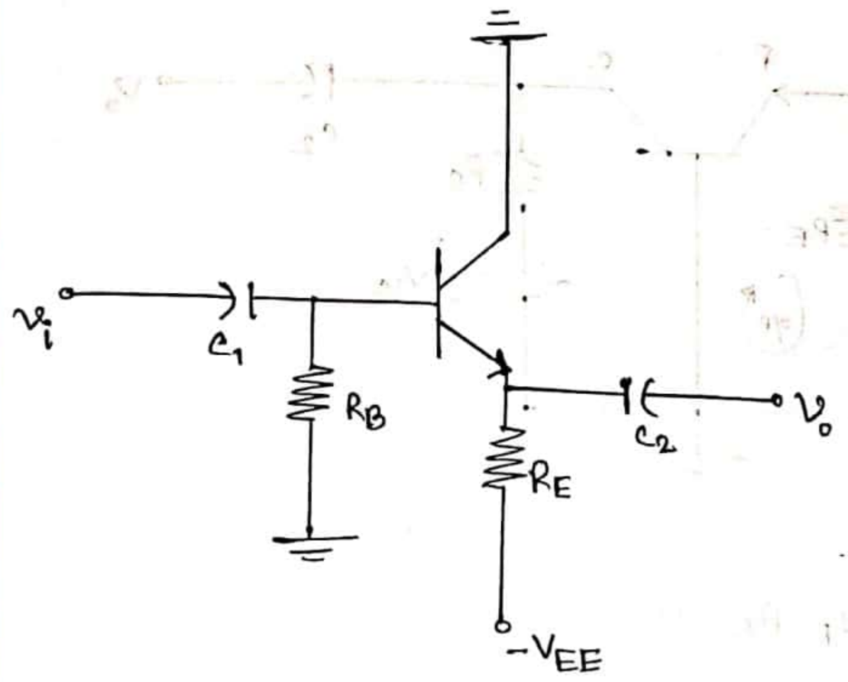
Emitter follower configuration :-



BE loop,

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

$$\Rightarrow I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta+1) R_E}$$

$$V_{CE} + I_E R_E - V_{EE} = 0$$

$$\therefore V_{CE} = V_{EE} - I_E R_E$$

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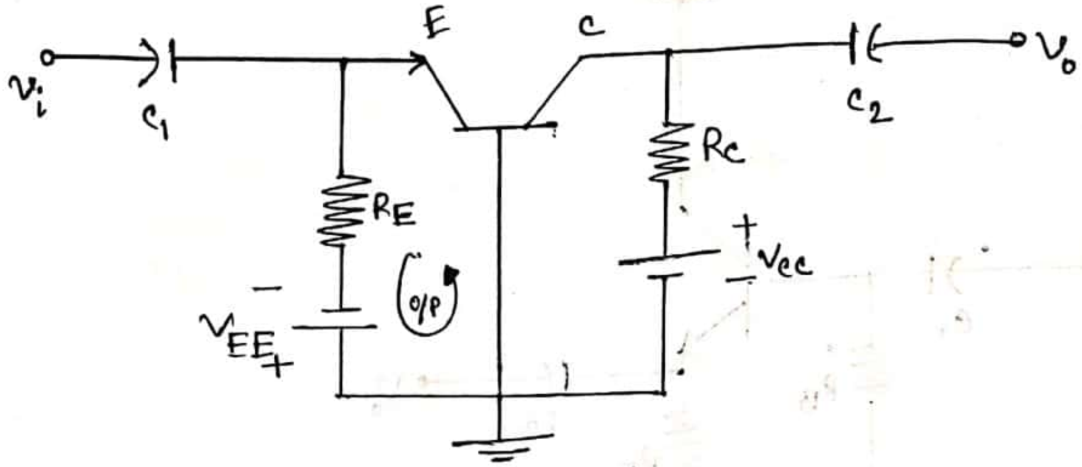
common base

CB configuration :-



BE loop,

$$-V_{EE} + V_{BE} + I_E R_E = 0$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}$$

o/p loop,

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

$$\Rightarrow V_{CE} = V_{CC} + V_{EE} - I_C R_C - I_E R_E$$

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

$$\boxed{I_C \approx I_E}$$

CB loop,

$$-V_{CC} + I_C R_C + V_{CB} = 0$$

$$\therefore V_{CB} = V_{CC} - I_C R_C .$$

wednesday
1 pm extra cls.

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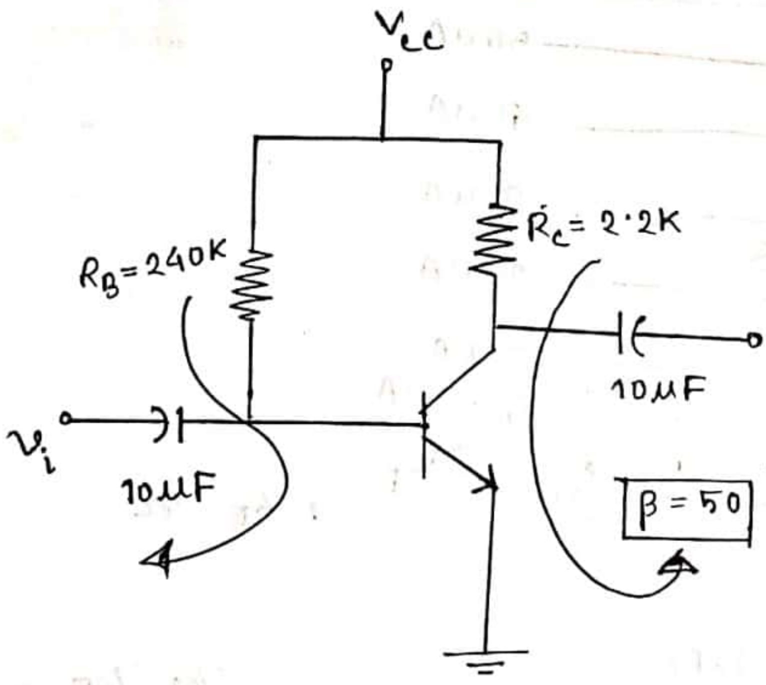
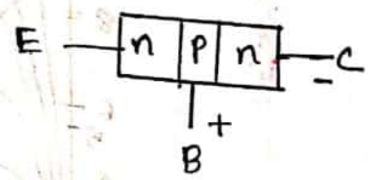
23.09.2019
Monday.

Ex-4.1

Determine the following for the network.

I_{BQ}, I_{CQ}, V_{CEQ}, V_B, V_C, V_{BC}.





$$I_{BQ} = \frac{V_{cc} - V_{BE}}{R_B}$$

$$= \frac{12 - 0.7}{240K}$$

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

$$V_{CEQ} = V_{cc} - I_c R_c$$

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

$$V_{CE} = V_C - \cancel{V_E}$$

$$V_{BC} = V_B - V_C = (-)\text{ve} \quad \text{RB}$$

This BJT is running on linear mode.

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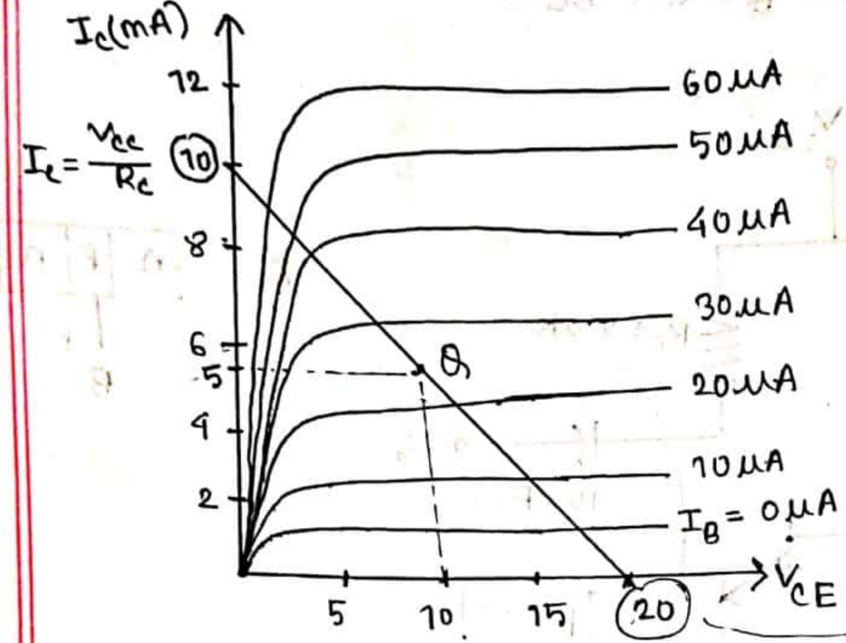
Ex-4.3

Given the load line and the defined Q point. Determine the required value of V_{CC}, R_C, R_B for fixed Bias ckt.



$\rightarrow V_{CE} = V_{CC}$

for fixed bias,

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

$$R_C = \frac{V_{CC}}{I_C} = \frac{20V}{10mA} = 2K\Omega$$

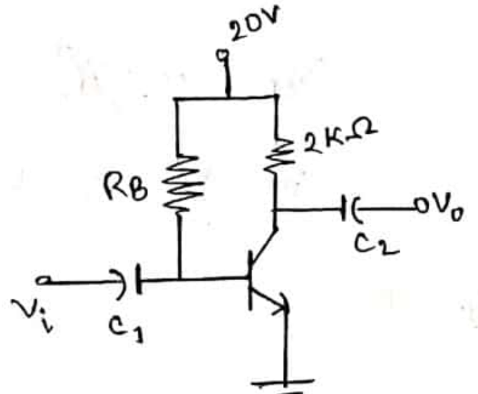
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$\Rightarrow R_B = \frac{20 - 0.7}{25 \mu A}$$

$I_{BQ} = 25 \mu A$

$I_{CQ} = 5 mA$

$V_{CEQ} = 10 V$



fixed bias ckt

$$\beta = \frac{I_C}{I_B} = \frac{5 mA}{25 \mu A}$$

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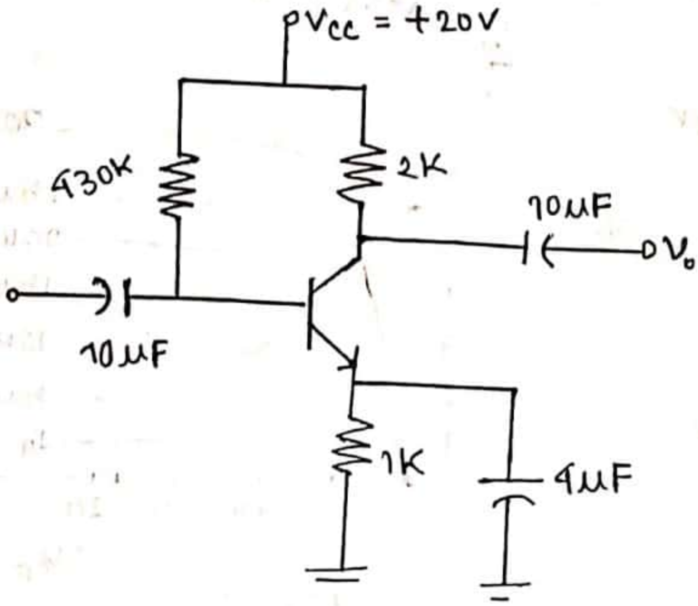
4.4 For the following network determine I_B, I_C, V_{CE}, V_B, V_C, V_E, V_{BC}.



$\beta = 50$

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

$I_C = \beta I_B$

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

$V_E = I_E R_E$; $I_E = I_C + I_B$

$V_{BE} = V_B - V_E$

$V_{CE} = V_C - V_E$

$V_{BC} = V_B - V_C$

- $V_{BC} \rightarrow (-)$ve হলে, Linear mode, RB.
- $V_{BC} \rightarrow (+)$ ve হলে, saturation mode, FB.

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Ex-4.7

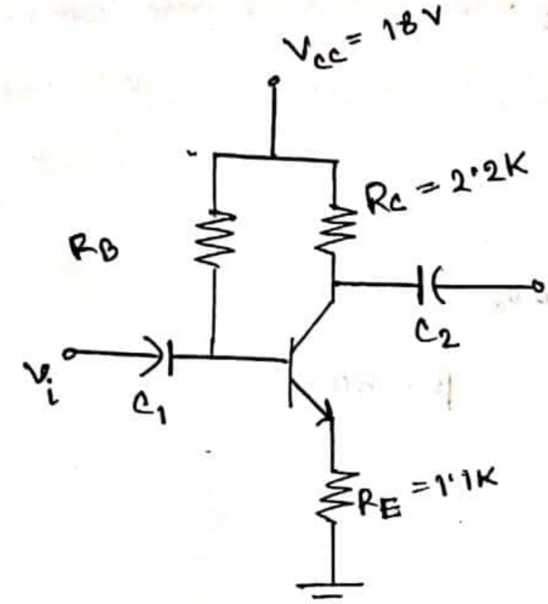

Fig:-1

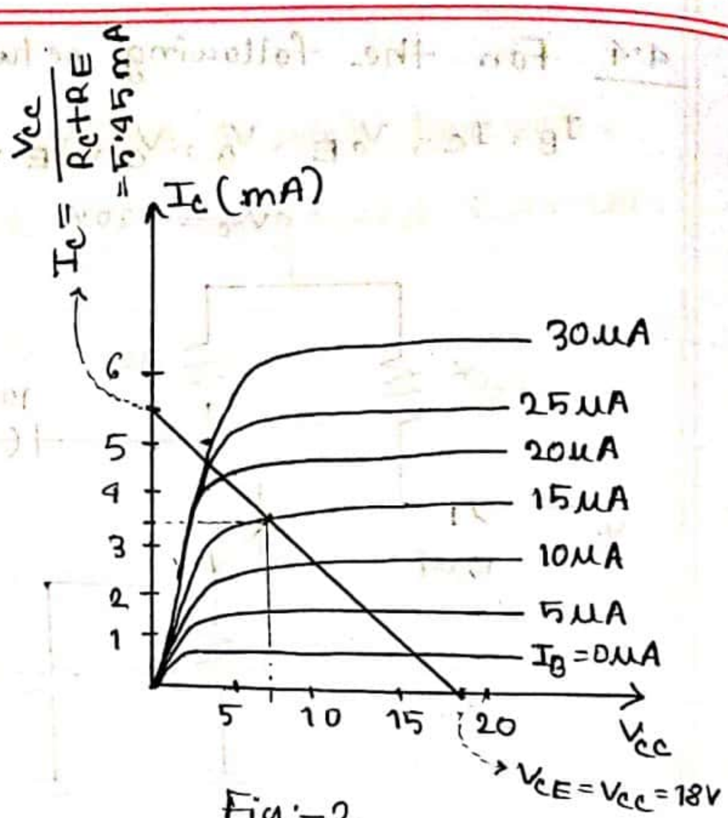

Fig:-2

a. Draw the load line for the network of fig:-1 of the characteristics curve of fig:-2.

b. For a Q-point at the intersection of the load line with a base current of 15μA. Find the values of I_{CQ} and V_{CEQ}.

c. Determine the DC β at the Q-point.

d. Using the β determine ~~impedance~~ in previous part, calculate the required value of R_B and suggest the possible standard value.

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Sol:-

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

$I_C = 0$

$V_{CE} = V_{CC} = 18\,V$

$V_{CE} = 0\,V$

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

$$= \frac{18}{2.2K + 1.1K}$$

$= 5.45\ mA$

(b)

$I_{CQ} = 3.5\,mA$

$V_{CEQ} = 8V$

(c) $$\beta = \frac{I_C}{I_B}$$

$$= \frac{3.5mA}{15\mu A}$$

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

$\Rightarrow R_B =$

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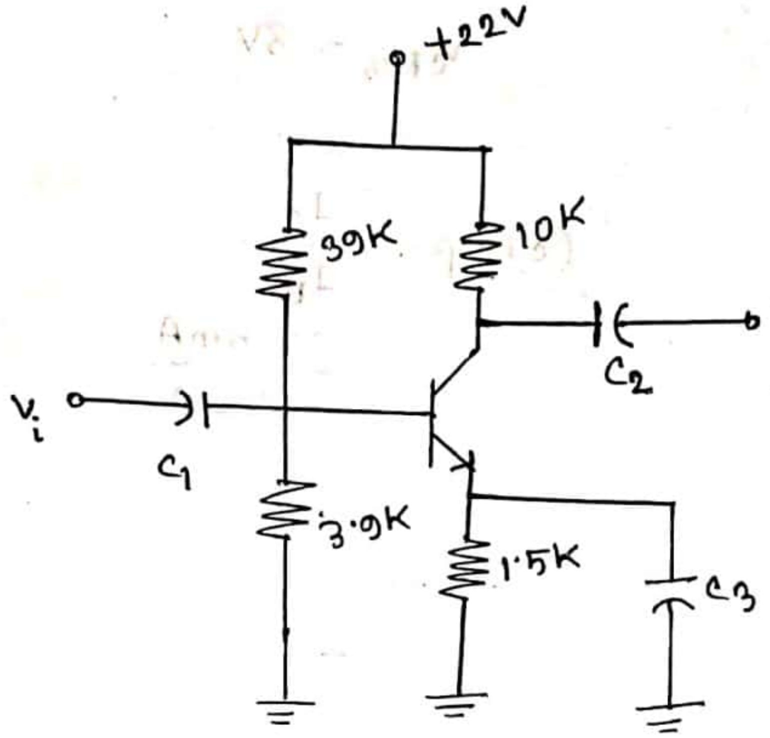
Ex-4.8

Determine V_{CE}, I_C.



$\boxed{\beta=100}$

$\beta R_E \geqslant 10 R_2$

$100 * 1.5K \geqslant 10 * 3.9K$

$150K \geqslant 39K$; condition fulfilled.

$$V_B = \frac{3.9K}{3.9K + 39K} * 22V$$

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25.09.2019
Wednesday

Small signal Analysis:-

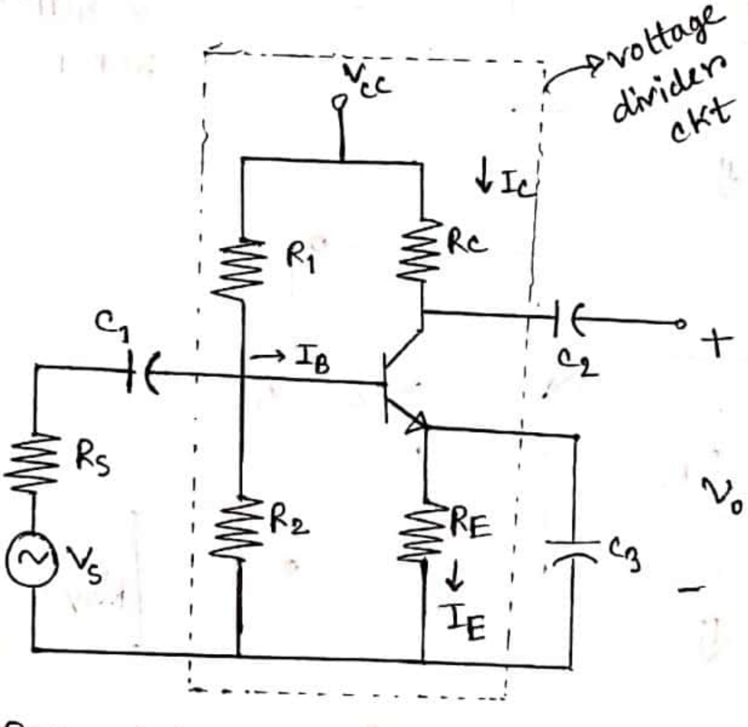
- AC response of BJT → Transistor model
- Small and large signals
- Operating point in small signal. • Q point will not move.
- Total response :- DC response + AC response

$$X_c = \frac{1}{2\pi f c}$$

gain ↓ → if R_E exist

gain ↑ → if R_E eliminated

* একটা ckt কে amplify করার জন্য biasing করা হয়।



* C_1 and C_2 → coupling capacitors

* C_1 and C_2
↳ AC তে short
↳ DC তে open

* R_E ckt এর Q point কে stable করে।

* R_E ckt এ না থাকলে Q-point β এর উপর depend করে।

- AC Response:
  1. AC equivalent ckt
  2. Replace transistor with its equivalent model/ckt.

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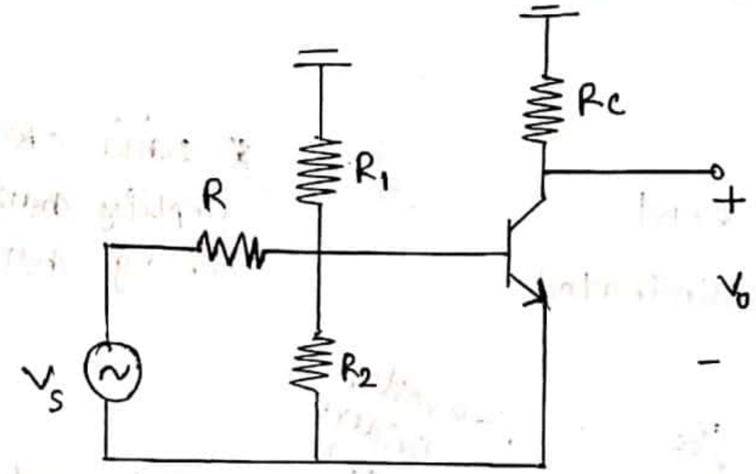
• AC equivalent ckt of BJT transistor:-

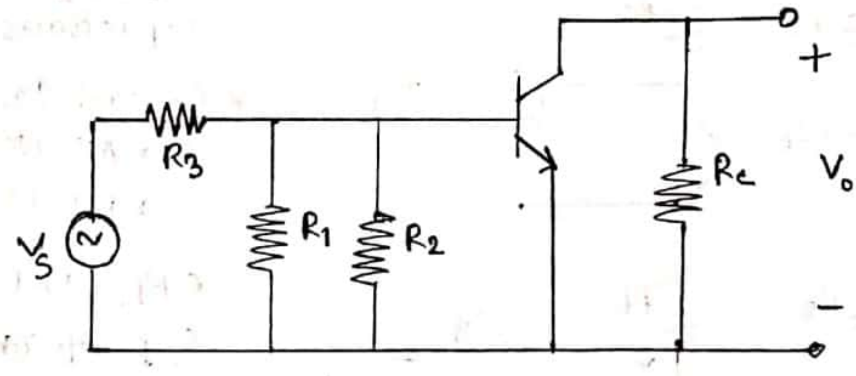
step-1:- short ckt all the DC sources

step-2:- Short ckt all the capacitors

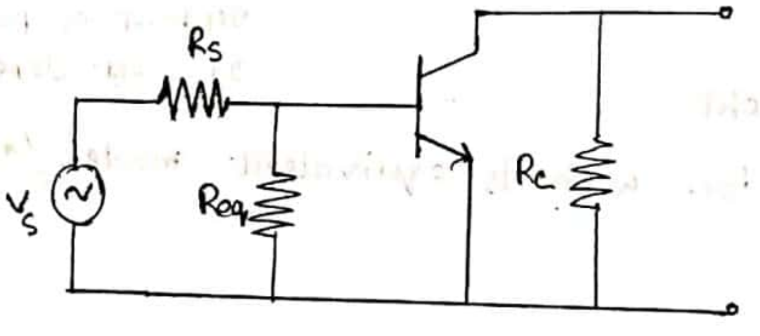
step-3:- Redraw the overall ckt removing items shorted in step 1 and 2.



* Thevenin eq. ckt দ্বারা ckt কে একটা R ও V দ্বারা simplify করে।



$$\boxed{R_{eq} = \frac{R_1 R_2}{R_1 + R_2}}$$



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What is equivalent model?

• An equivalent model is a combination of circuit elements properly chosen to best represent the actual behaviour of device under specific operating points.

• We can't apply network theorems on practical ckts.

As example —

Diode eq. model

- Ideal diode model
- Constant voltage drop model.
  - generally this model is used.
- Piecewise Linear model

BJT equivalent model (small signals)

- Hybrid model (h-parameter)
- $\boxed{r_e}$ model / Dynamic emitter resistance model
- Hybrid π model

In case of transistor we use $\boxed{r_e}$ model. → common emitter ckt এর জন্য বেশি use করা হয়।

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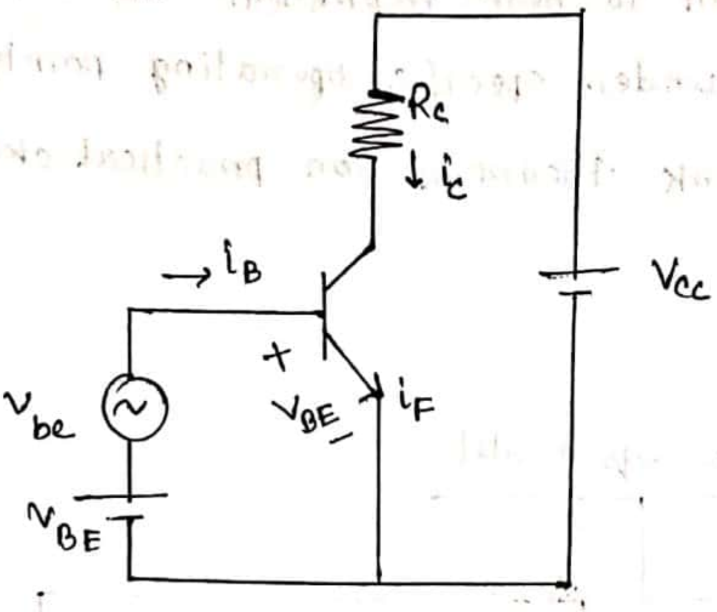
Small signal Analysis:-



$$I_C = I_S e^{V_{BE}/V_T}$$

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

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

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

$$i_C = I_S e^{V_{BE}/V_T}$$

$$= I_S e^{V_{BE} + v_{be}/V_T}$$

$$= I_S e^{V_{BE}/V_T} \cdot e^{v_{be}/V_T}$$

$$= I_C e^{v_{be}/V_T}$$

$$= I_C \left(1 + \frac{v_{be}}{V_T}\right)$$

$$= \underbrace{I_C}_{DC} + \underbrace{I_C \frac{v_{be}}{V_T}}_{AC}$$

$$i_c = I_C \frac{v_{be}}{V_T}$$

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$$\boxed{i_c = g_m v_{be}}$$

where g_m is called trans conductance, $g_m = \frac{I_c}{V_T}$

$$i_B = \frac{i_c}{\beta}$$

$$i_B = I_B + \frac{1}{\beta} I_c \frac{v_{be}}{V_T}$$

$$\therefore i_b = \frac{1}{\beta} I_c \cdot \frac{v_{be}}{V_T}$$

$$= \frac{g_m}{\beta} v_{be} .$$

$$r_\pi = \frac{v_{be}}{i_b} = \frac{\beta}{g_m}$$

$$i_E = \frac{i_c}{\alpha}$$

$$= I_E + i_e$$

$$i_e = \frac{I_c}{\alpha} \cdot \frac{v_{be}}{V_T}$$

$$= \frac{I_E}{V_T} \cdot v_{be}$$

$$r_e = \frac{v_{be}}{i_c} = \frac{V_T}{i_e} = \frac{V_T/I_c}{I_E/I_c}$$

$$= \alpha/g_m \propto \frac{1}{g_m}$$

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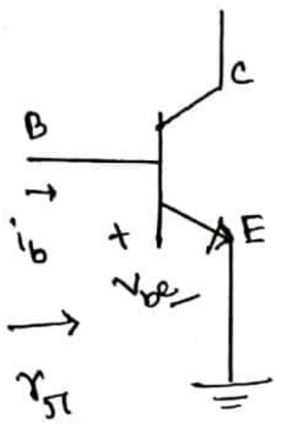
extra class

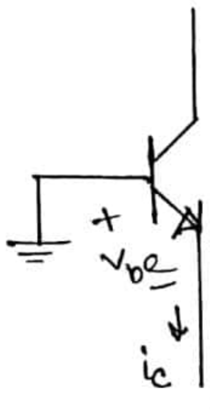
Small signal analysis:-

$$r_\pi = \frac{\beta}{g_m} = \frac{v_{be}}{i_b}$$

$$r_e = \frac{\alpha}{g_m} = \frac{v_{be}}{i_e} = \frac{V_T}{I_E}$$

$$\boxed{r_\pi = (\beta+1)\, r_e}$$





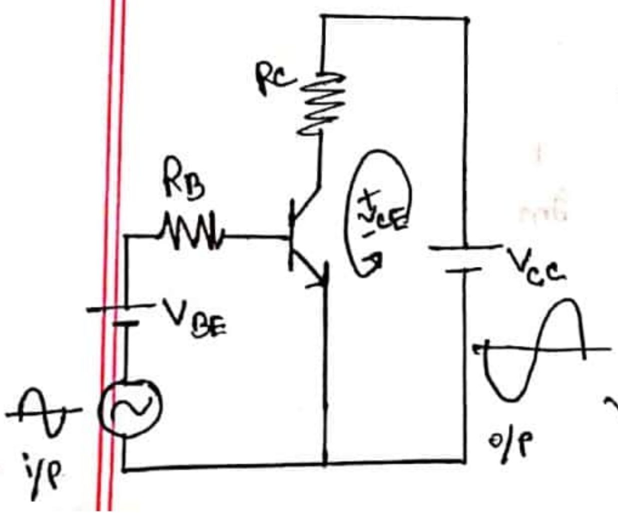
for common base

$$I_C = I_S e^{V_{BE}/V_T}$$

$$V_C = V_{CE}$$

$$i_C = I_S e^{v_{BE}/V_T}$$

$$v_{BE} = V_{BE} + v_{be}$$



$$v_{CE} = V_{CC} - i_C R_C$$

$\therefore\ i_C = I_S e^{v_{BE}/V_T} \cdot e^{v_{be}/V_T}$

$= I_C \left(1 + \dfrac{v_{be}}{V_T}\right)$

$= \underbrace{I_C}_{DC} + \underbrace{I_C \dfrac{v_{be}}{V_T}}_{ac}$

$i_C = I_C + i_c$

$i_c = I_C \dfrac{v_{be}}{V_T}$

$; g_m = \dfrac{I_C}{V_T}$

$i_b = \dfrac{g_m}{\beta} \cdot v_{be}$

$v_{be}/i_b = \beta/g_m$

$r_\pi = \beta/g_m$

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

$= I_B/\beta + i_b/\beta$

$i_B = I_B + i_b$

$* \ i_e = i_b + i_c$

$= v_{be}/r_\pi + g_m v_{be}$

$= v_{be}/r_e$

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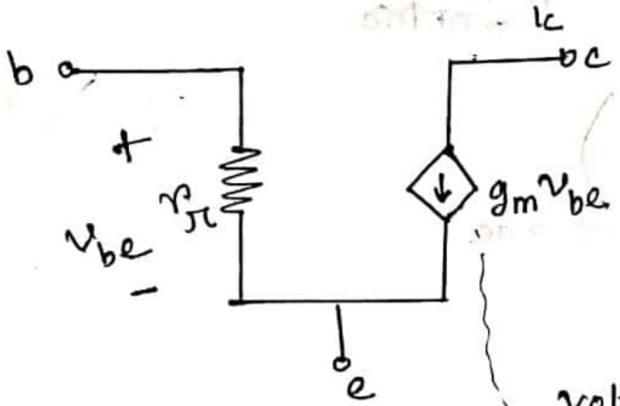
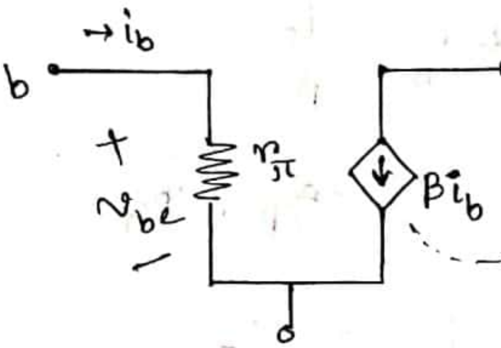
Hybrid π-model:— → emitter grounded



→ i/p voltage এর উপর dependent

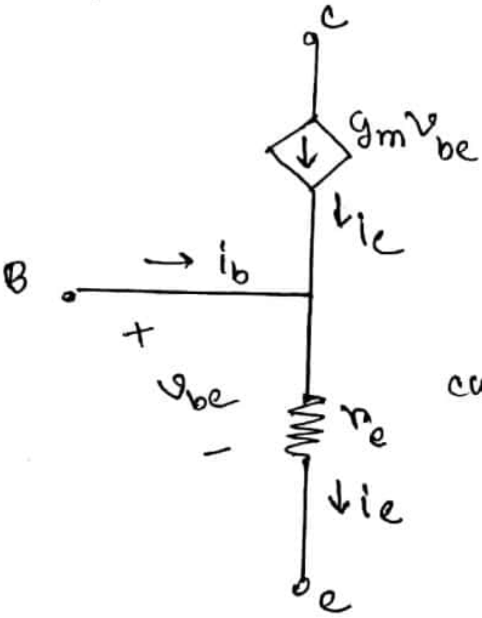
→ voltage control current source

⇓



→ current control current source.

T model:—



voltage control ~~voltage~~ current source.

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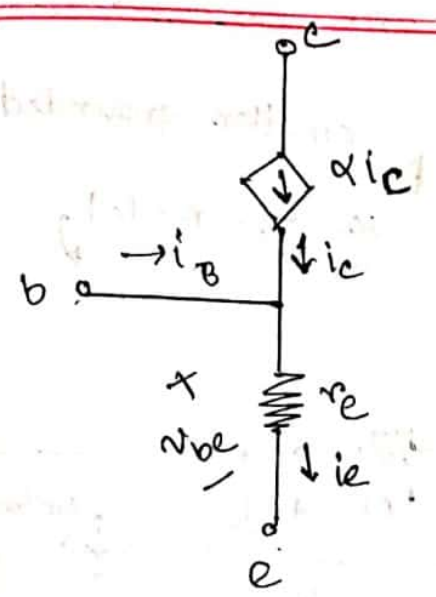
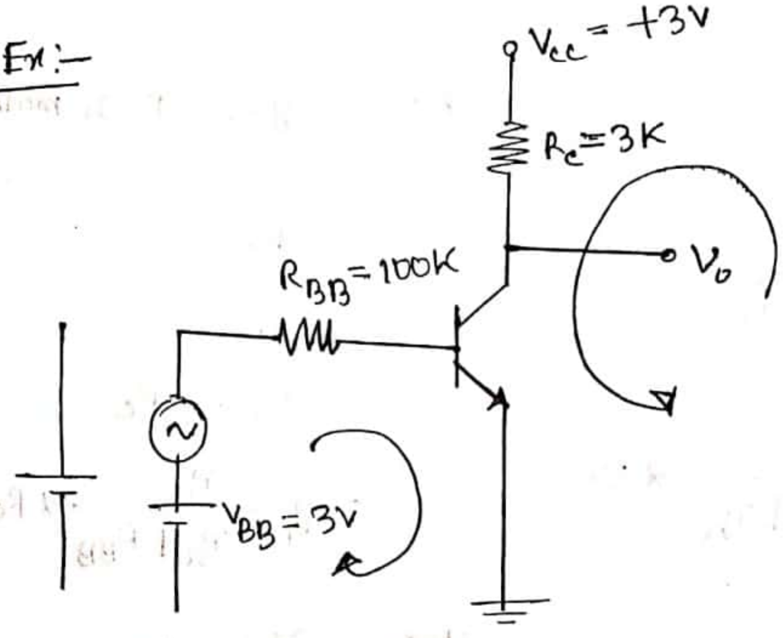
quiz #3 → 29.09.2019
DC biasing math,
Sedra smith's 10 ↑ math



Sedra Smith :-

Ex :-



Determine,
Av (gain) = ?
assume $\beta = 100$

DC analysis, (AC source short করে দিব)

$$-V_{BB} + I_B R_{BB} + V_{BE} = 0$$

$$\Rightarrow I_B = \frac{V_{BB} - V_{BE}}{R_{BB}} = \frac{3 - 0.7}{100k} = 0.023\,mA.$$

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$I_c = \beta I_B$

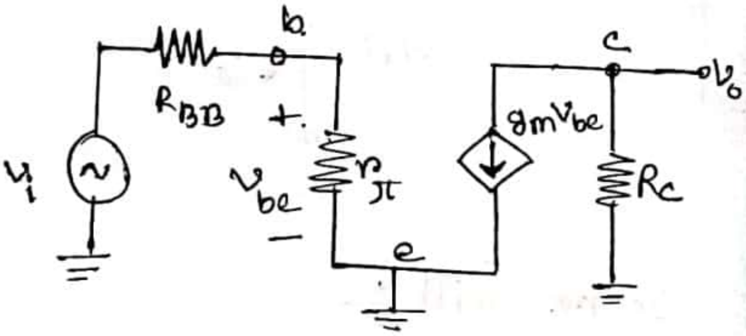
$I_E = I_c + I_B$

$V_{CE} = V_{cc} - I_c R_c$

$V_c = V_{CE} = V_{cc} - I_c R_c$

$\Rightarrow$ emitter grounded

so, π – model,



$$g_m = \frac{I_c}{V_T}$$

$$r_\pi = \beta / g_m$$

$$r_e = V_T / I_E = \alpha / g_m$$

again, $v_{be} = \dfrac{r_\pi}{R_{BB} + r_\pi} * v_i$

AC analysis এর π-model

$\therefore V_o = I_o R_c$

$= -i_c R_c$

$= -g_m v_{be} R_c$

$= -g_m \dfrac{r_\pi}{r_\pi + R_{BB}} * R_c * v_i$

$\Rightarrow A_v = V_o / V_i = -$

180° outer face

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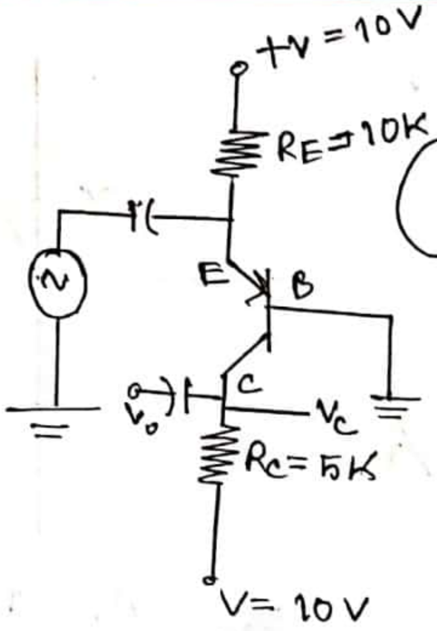
example:—



Determine,

$A_v = ?$

assume $\beta = 100$

$\alpha = 0.99$.

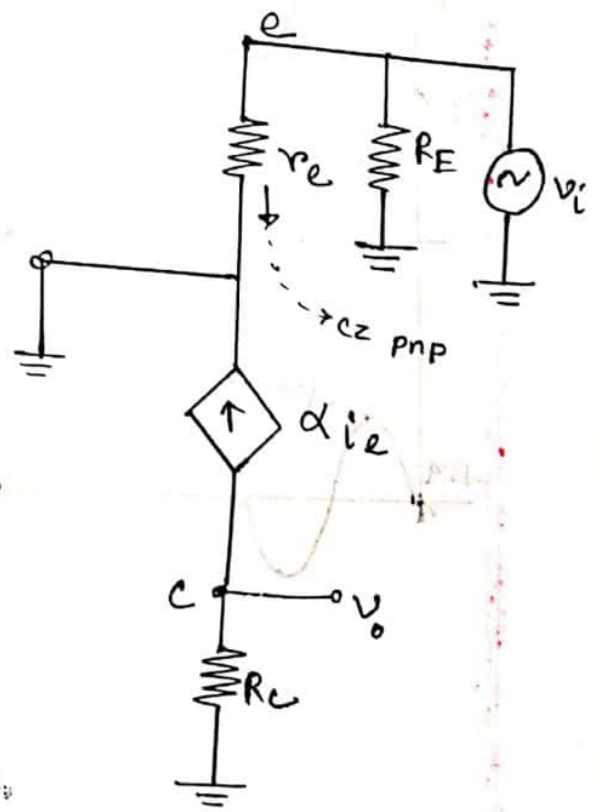
$V_{EB} = V_E = 0.7V$

KVL, $-10 + I_E R_E + V_{EB} = 0$

$$I_E = \frac{10 - 0.7}{R_E}$$

$I_C = \alpha I_E$

$I_B = I_C/\beta$



$r_e = V_T / I_E$

$$i_e = (-)\frac{v_i}{r_e}$$

$$= -\frac{v_i}{r_e}$$

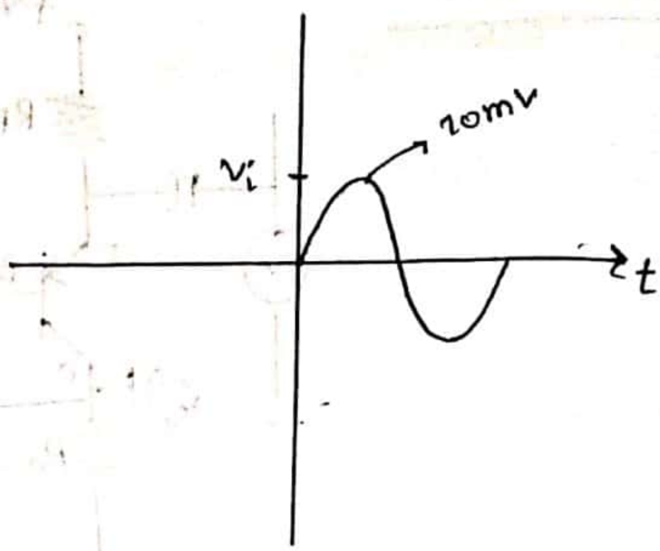
; (−)ve দ্বারা i_e ও output এর current এর direction উল্টো।

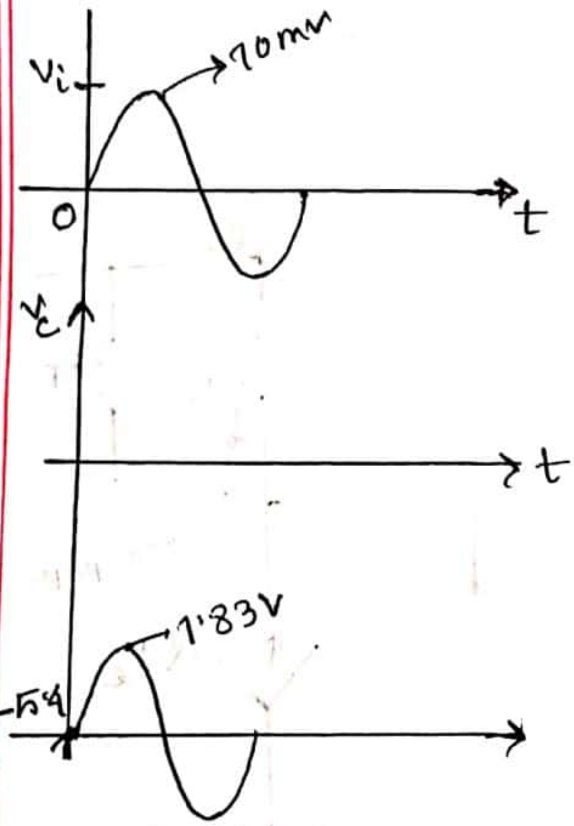
$v_o = -i_c R_c$

$= -\alpha i_e R_c$

$= \alpha \frac{v_i}{r_e} * R$

$\therefore A_v = v_o / v_i = \alpha R_c / r_e$





$v_o / v_i = A_v = 183.3$

$\Rightarrow v_o = 183.3 * v_i$

$= 183.3 * 10mV$

$= 1.83V$

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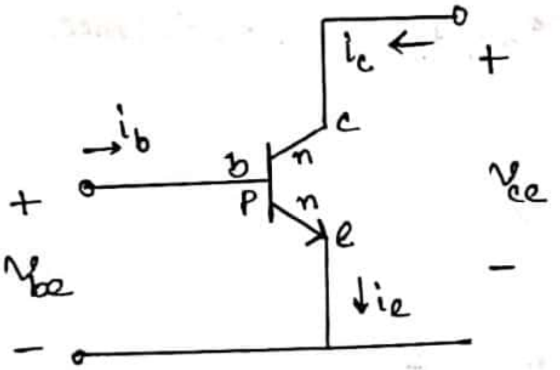
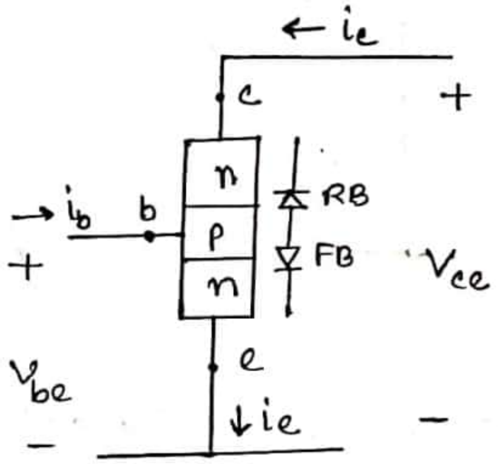
29/09/2019
Sunday

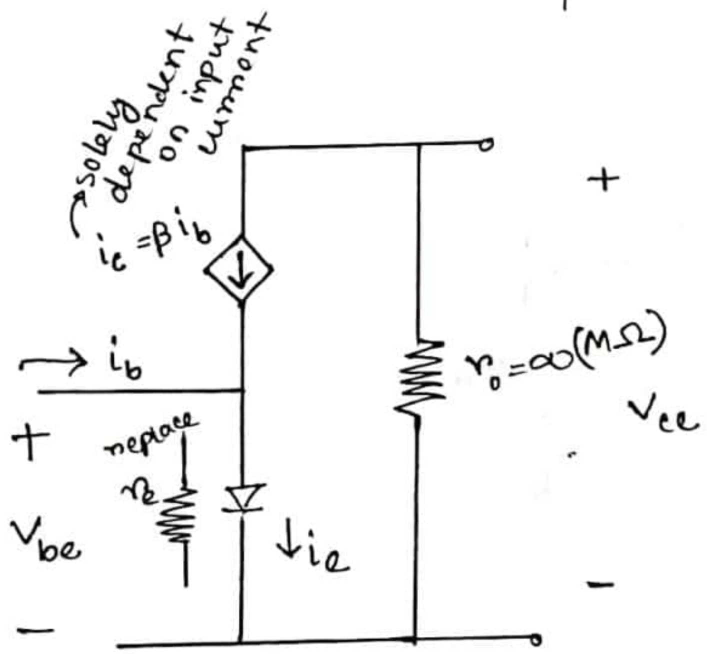
Re transistor Model

- Low frequency
  - h-parameter
  - r_e model
- High frequency
  - Hybrid π
  - Y-parameter

- CE transistor r_e model:







* diode কে dc resistance দিয়ে replace করব।

- dc resistance
  ↳ dynamic "
- AC resistance
  ↳ static "

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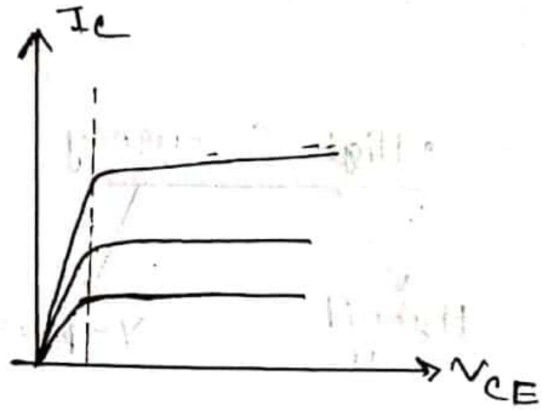
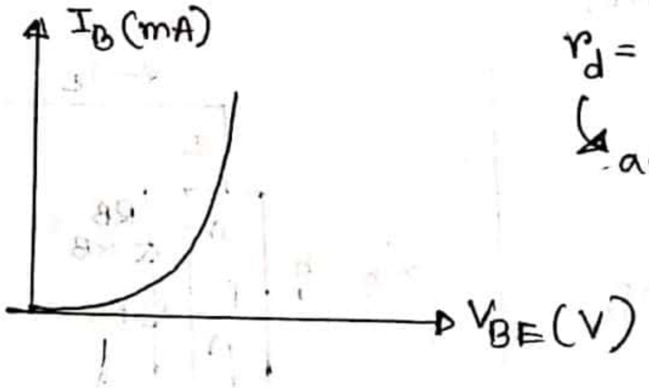


$$r_0 = \frac{1}{slope} = \frac{1}{0} = \infty$$

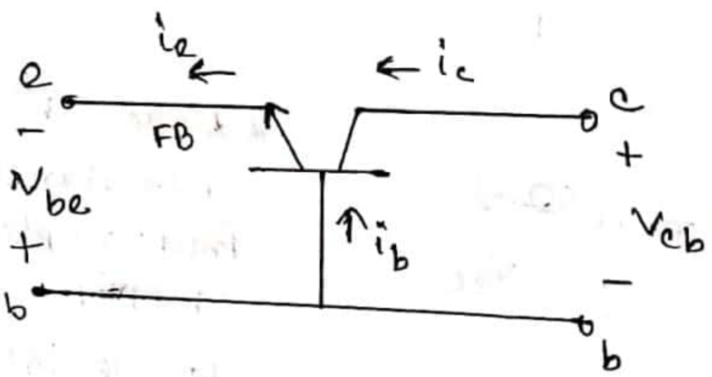


$$r_d = \frac{\Delta v_{be}}{\Delta i_b}$$

ac/dynamic resistance

r_e model is also called T model:-

- common base



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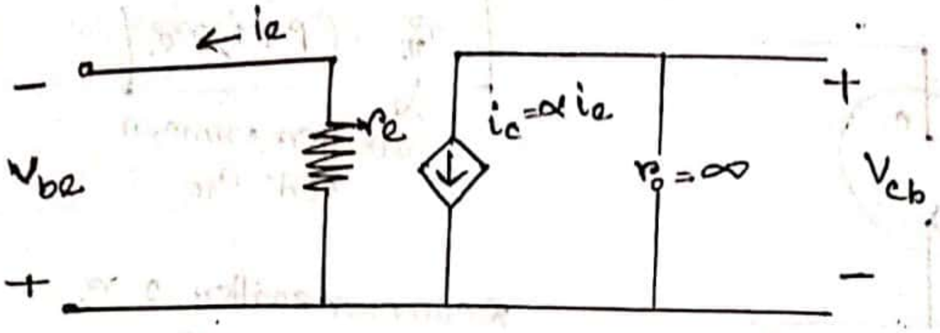
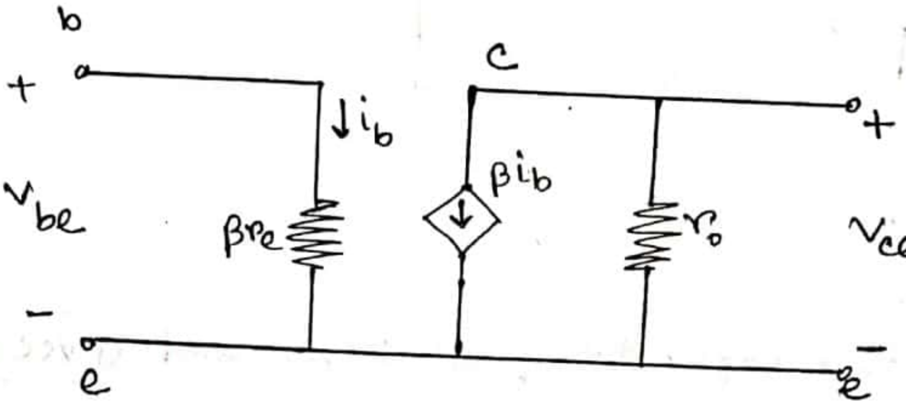


common base configuration r_e model

slope = 0 $\therefore r_o = \infty$

• CE :-



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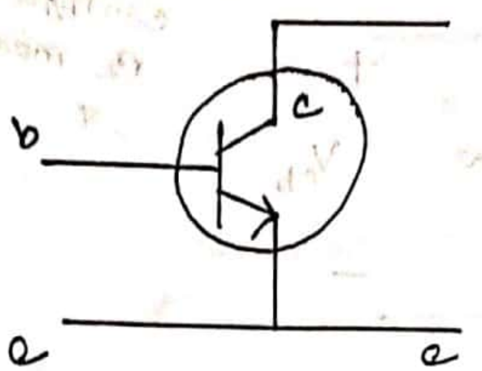
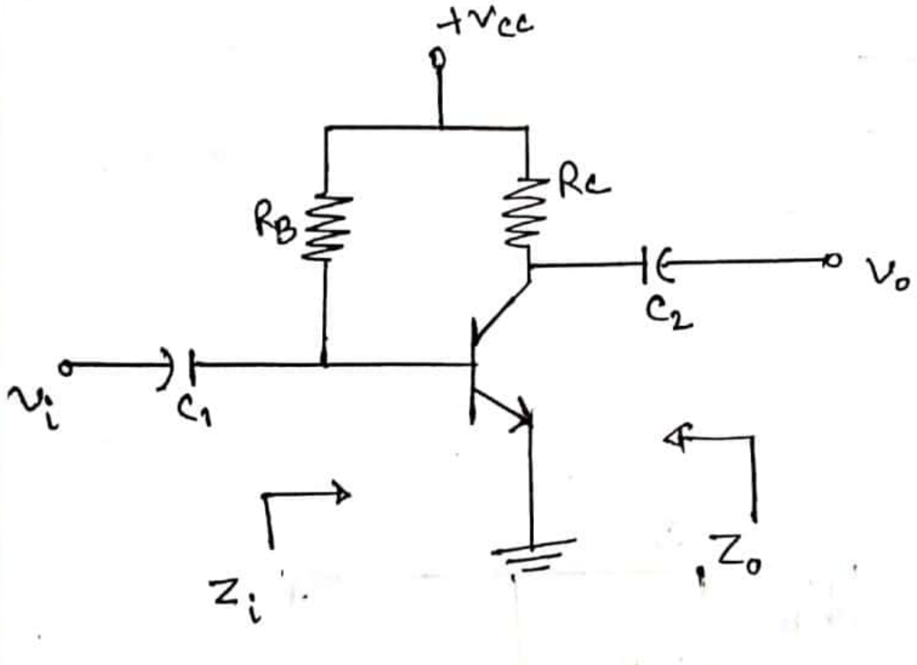


$$\boxed{r_\pi = (\beta+1) r_e}$$

emitter common হলে r_π

*common emitter এ r_o count করতে হবে।

Fixed bias configuration



A_v, A_i

* AC দিলে → capacitor গুলো short and +Vcc short করে দিব।

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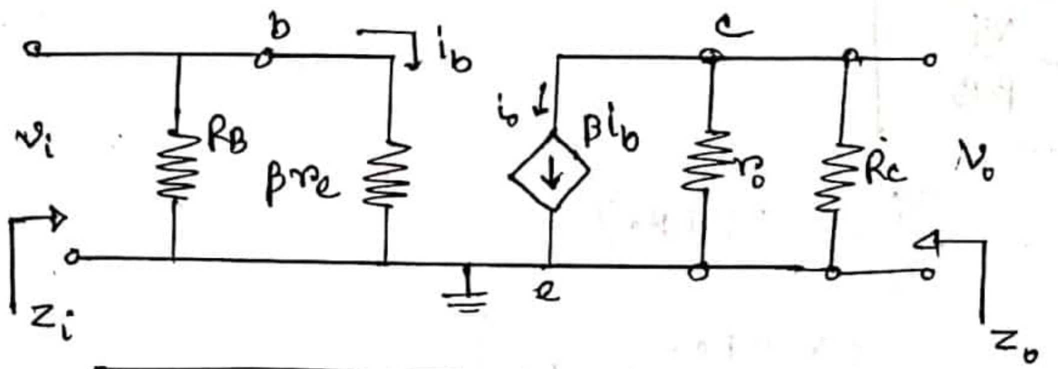
r_e model

- AC equivalent ckt



$$\boxed{Z_i = R_B \parallel \beta r_e}$$

$$\boxed{R_B \geq 10\beta r_e}$$

$$\boxed{\therefore Z_i \approx \beta r_e}$$

→ βre এর value এর সমান হবে। যে $R_B \parallel \beta r_e$ করলে resultant value আসবে βre এর কাছাকাছি।

$$\boxed{Z_o = r_o \parallel R_c}$$

$$\boxed{r_o \geq 10 R_c}$$

$$\boxed{Z_o \approx R_c}$$

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A_v :-

$$v_0 = -I_0 (r_0 \parallel R_C)$$

$$= -\beta I_b (r_0 \parallel R_C) \quad \text{--- (1)}$$

$$\boxed{i_b = \frac{v_i}{\beta r_e}}$$

$$\therefore v_0 = -\frac{v_i}{r_e} (r_0 \parallel R_C)$$

$$\Rightarrow \boxed{\frac{v_0}{v_i} = -\frac{(r_0 \parallel R_C)}{r_e} = A_v} \rightsquigarrow \text{voltage gain}$$

* common emitter ↄ voltage gain always (−)ve.

A_i :-

$$I_0 = \frac{r_0}{r_0 + R_C} * \beta i_b \quad ; \quad [\text{CDR apply}]$$

$$\Rightarrow \boxed{\frac{I_0}{I_b} = \frac{r_0 \beta}{r_0 + R_C}}$$

$$I_b = \frac{R_B}{R_B + \beta r_e} * I_i$$

$$\Rightarrow \frac{I_b}{I_i} = \frac{R_B}{R_B + \beta r_e}$$

$$I_0/I_b * I_b/I_i = A_i = \frac{r_0 \beta}{r_0 + R_C} * \frac{R_B}{R_B + \beta r_e}$$

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if $r_o \geq 10 R_C$

$R_B \geq 10 \beta r_e$

$$A_i = \frac{r_o \beta}{r_o} * \frac{R_B}{R_B}$$

$$= \beta$$

$$\boxed{\begin{aligned} A_i &= -A_v \frac{Z_i}{R_C} \\ &= \frac{R_C}{r_e} * \frac{\beta r_e}{R_C} \\ &= \beta \end{aligned}}$$

Math — Boylested

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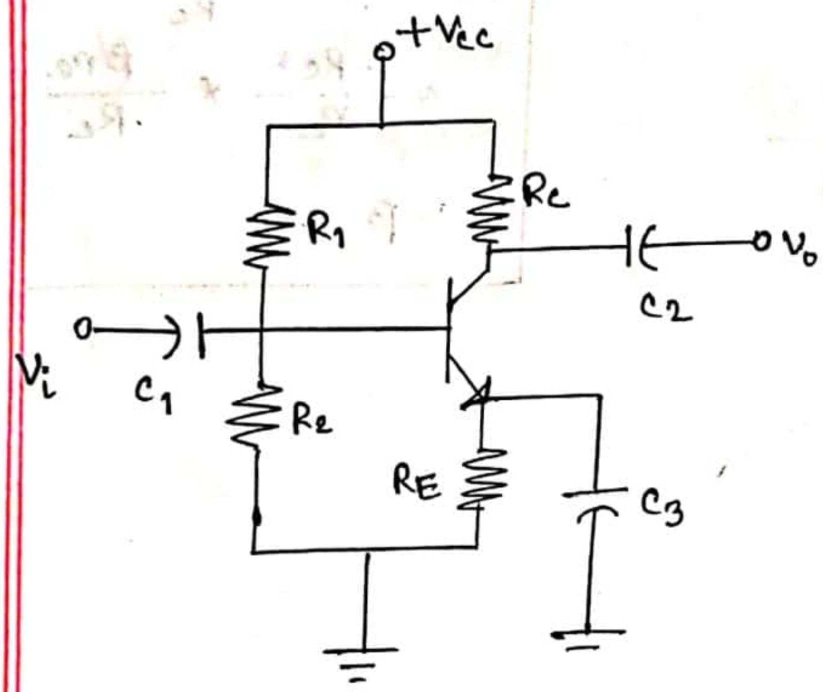
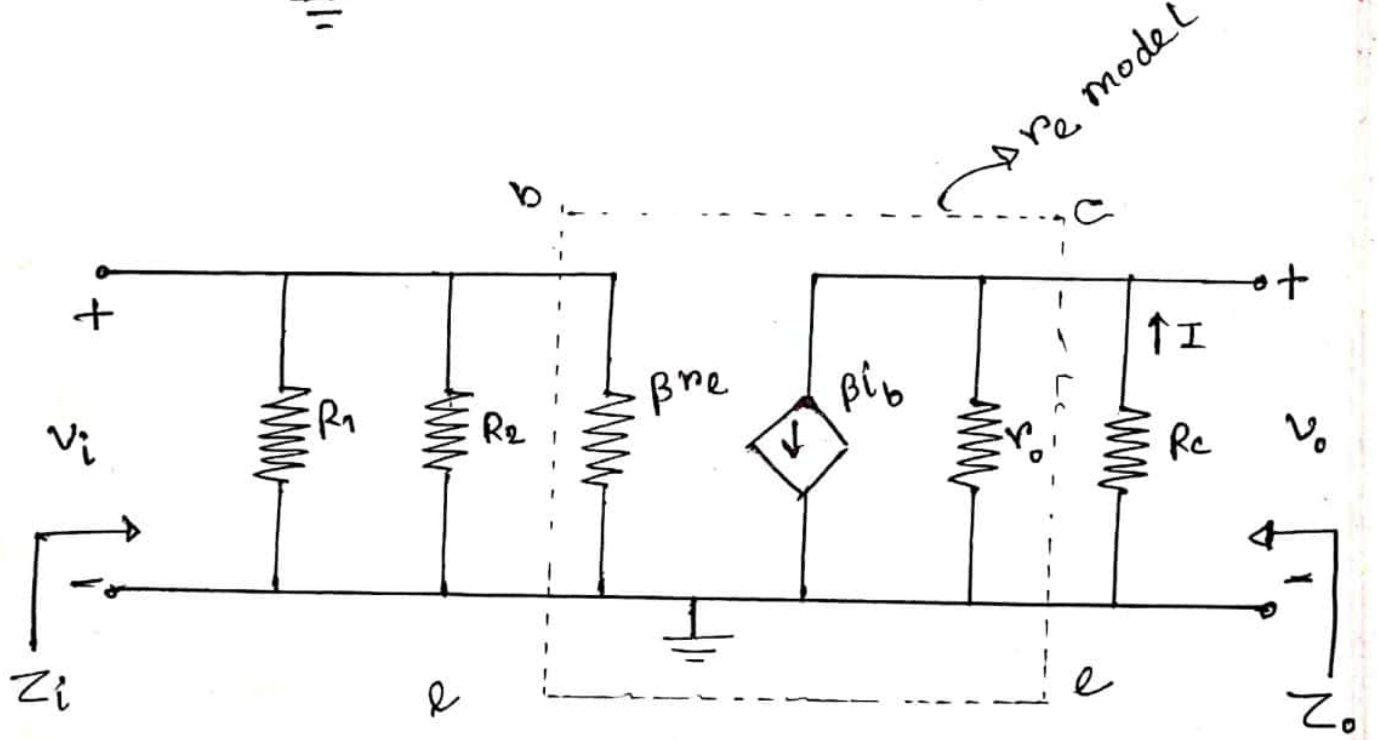
30/09/2019
Monday

VDB:—



emitter এর resistance gain এর value কমিয়ে দেয়।



$Z_i \Rightarrow$

$R' = R_1 \parallel R_2$

$$\boxed{Z_i = R' \parallel \beta r_e}$$

$$\boxed{R' \geqslant 10\beta r_e}$$

$$\boxed{Z_i \approx \beta r_e}$$

$Z_o \Rightarrow$

$$\boxed{Z_o = r_o \parallel R_c}$$

$$\boxed{r_o \geqslant 10 R_c}$$

$$\boxed{Z_o \approx R_c}$$

A_v:— (voltage gain) → current এর direction আলাদা

$$v_o = -\, i_o \,(R_c \parallel r_o)$$

$$= -\beta i_b \,(R_c \parallel r_o)$$

$$\boxed{i_b = \frac{v_i}{\beta r_e}}$$

$$v_o = -\beta \frac{v_i}{\beta r_e} (R_c \parallel r_o)$$

$$\Rightarrow v_o / v_i = -\frac{R_c \parallel r_o}{r_e}$$

$$\therefore A_v = -\frac{R_c \parallel r_o}{r_e}$$

if $\boxed{r_o \geqslant 10 R_c}$

$$\therefore \boxed{A_v = -\frac{R_c}{r_e}}$$

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A_i :— (current gain)

$$i_o = \frac{r_o}{R_c + r_o} * \beta i_b$$

$$\therefore \boxed{\frac{i_o}{i_b} = \frac{\beta r_o}{R_c + r_o}}$$

$$\boxed{i_b = \frac{R'}{R' + \beta r_e} * i_i}$$

; $R' = R_1 \parallel R_2$

$$\therefore \frac{i_b}{i_i} = \frac{R'}{R' + \beta r_e}$$

$$\therefore i_o/i_b * \frac{i_b}{i_i} = \frac{\beta r_o}{R_c + r_o} * \frac{R'}{R' + \beta r_e}$$

; $r_o = \infty$ হলে বাদ and ckt open ; so no ~~of~~ current flow

$$\therefore A_i = \frac{i_o}{i_i} = \frac{\beta r_o R'}{(R_c + r_o)(R' + \beta r_e)}$$

if $\boxed{r_o \geq 10 R_c}$; $\boxed{R' \geq 10 \beta r_e}$

$$A_i = \frac{\beta r_o R'}{r_o \cdot R'}$$

$$= \beta$$

$$\therefore \boxed{A_i = -A_v \frac{Z_i}{R_c}} = + \frac{R_c}{r_e} * \frac{\beta r_e}{R_c} = \beta$$

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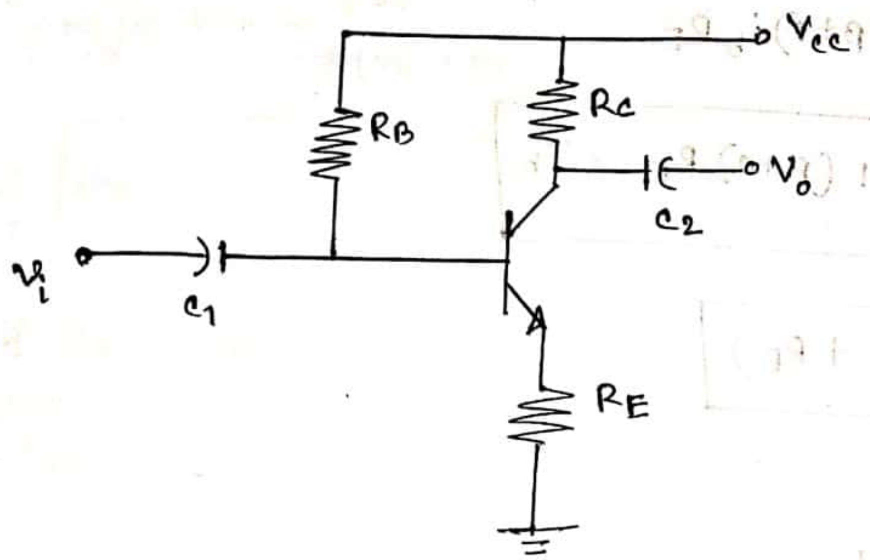
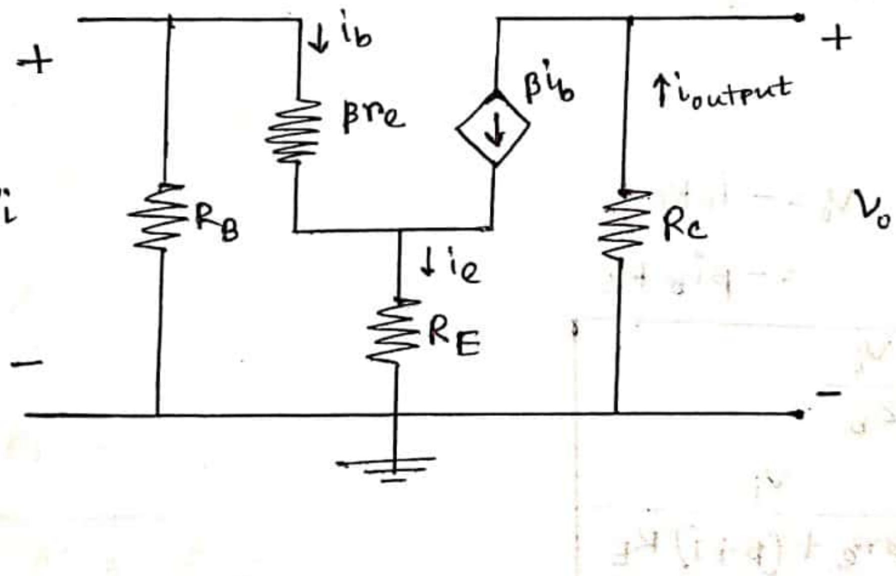
Emitter Bias (unbypassed):— emitter এর সাথে resistance থাকলে





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Z_i :-

$v_i = i_b * \beta r_e + i_e R_E$

$= i_b \beta r_e + (\beta+1) i_b R_E$

$\therefore \boxed{\frac{v_i}{i_b} = \beta r_e + (\beta+1) R_E = Z_b}$

$\therefore \boxed{Z_b \approx \beta(r_e + R_E)}$

if $R_E \gg r_e$

$\boxed{Z_b \approx \beta R_E}$

$\therefore \boxed{Z_i = R_B \parallel Z_b}$

$\boxed{Z_o = R_c}$

$A_v \Longrightarrow \quad v_o = - i_o R_c$:

$= - \beta i_b R_c$

$$\boxed{\begin{aligned} i_b &= \frac{v_i}{Z_b} \\ &= \frac{v_i}{\beta r_e + (\beta+1) R_E} \end{aligned}}$$

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$$\therefore v_o = -\beta \frac{v_i}{\beta r_e + (\beta+1)R_E} * R_C$$

$$\therefore \frac{v_o}{v_i} = -\frac{\beta R_C}{\beta(r_e + R_E)}$$

$$\therefore \boxed{A_v = -\frac{R_C}{r_e + R_E}}$$

if $R_E \gg r_e$

$$\boxed{A_v = -\frac{R_C}{R_E}}$$

$A_i \Rightarrow \quad i_o = \beta i_b$

$$\therefore \boxed{i_o / i_b = \beta}$$

wednesday
extra class
1 pm

$$i_b = \frac{R_B}{Z_b + R_B} * i_i \quad ; \text{CDR}$$

$$\therefore i_b / i_i = \frac{R_B}{Z_b + R_B}$$

$$\therefore A_i = i_o / i_i$$

$$\therefore \boxed{A_i = \beta R_B / R_B + Z_b}$$

$$\boxed{A_i = -A_v \frac{Z_i}{R_C}}$$

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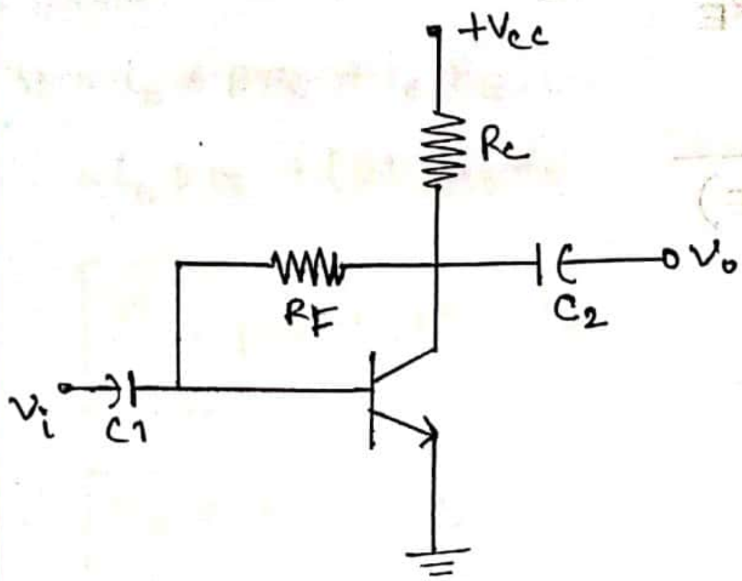
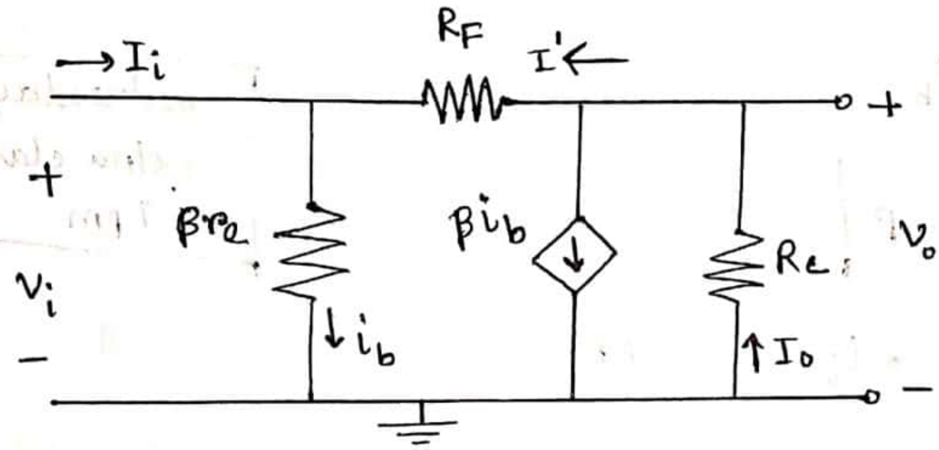
02/10/2019
Wednesday

Collector f/B configuration:-

feedback





$$I' = \frac{V_o - V_i}{R_F}$$

$$V_o = -I_o * R_c$$

$$= -\beta i_b R_c$$

$$\boxed{I_o = I' + \beta i_b}$$

$$\beta i_b \gg I'$$

$$\therefore \boxed{I_o \approx \beta i_b}$$

$$\therefore V_o = -\beta \frac{V_i}{\beta r_e} R_c$$

$$= -\frac{V_i R_c}{r_e}$$

Now, $I' = \frac{v_o}{R_F} - \frac{v_i}{R_F}$

$$= -\frac{v_i R_c}{r_e R_F} - \frac{v_i}{R_F}$$

$$= -\frac{1}{R_F}\left[1 + \frac{R_c}{r_e}\right] v_i$$

$$v_i = i_b \beta r_e$$

$$= (I_i + I') \beta r_e$$

$$= I_i \beta r_e + I' \beta r_e$$

$$= I_i \beta r_e - \frac{v_i}{R_F}\left[1 + \frac{R_c}{r_e}\right] \beta r_e$$

$$\therefore v_i \left(1 + \frac{\beta r_e}{R_F}\left[1 + \frac{R_c}{r_e}\right]\right) = I_i \beta r_e$$

$$\therefore \frac{v_i}{I_i} = \frac{\beta r_e}{1 + \frac{\beta r_e}{R_F}\left(1 + \frac{R_c}{r_e}\right)} = Z_i$$

$\therefore \boxed{R_c >> r_e}$ $\quad \therefore \boxed{1 + \frac{R_c}{r_e} \simeq \frac{R_c}{r_e}}$

$$\simeq \frac{\beta r_e}{1 + \frac{\beta r_e}{R_F} * \frac{R_c}{r_e}}$$

$$\simeq \frac{\beta r_e}{1 + \frac{\beta R_c}{R_F}}$$

$$\therefore \boxed{Z_i = \frac{r_e}{1/\beta + \frac{R_c}{R_F}}}$$

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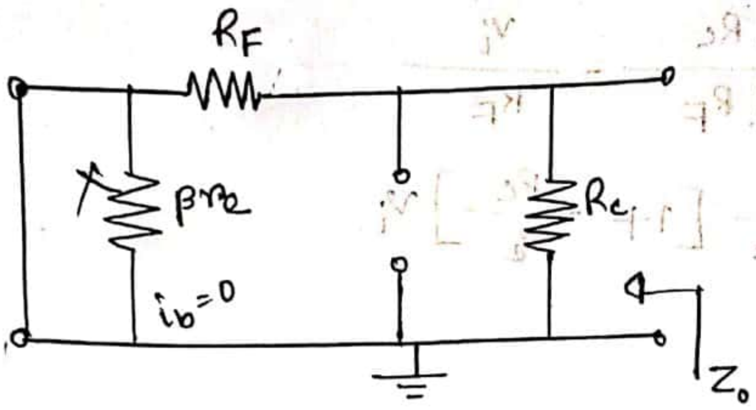
Z_0 :- For Z_0 deactivate all the active sources.



$\therefore$ $Z_0 = R_c \parallel R_F$

A_v :- $v_0 = -I_0 R_c$

$= -\beta i_b R_c$

$= -\beta \frac{v_i}{\beta r_e} R_c$

$$\therefore \boxed{\frac{v_0}{v_i} = A_v = -\frac{R_c}{r_e}}$$

A_i :- Applying KVL at outler loop:-

$v_i + V_{R_F} - v_0 = 0$

$\Rightarrow i_b \beta r_e + (i_b - I_i) R_F + I_0 R_c = 0$; $\boxed{\begin{array}{l} V_{R_F} = I' * R_F \\ i_b = I_i + I' \end{array}}$

$\Rightarrow i_b \beta r_e + i_b R_F - I_i R_F + I_0 R_c = 0$ $\rightarrow$ $\boxed{\begin{array}{l} I_0 = \beta i_b + I' \\ I_0 \approx \beta i_b \end{array}}$

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using, $\boxed{I_o \approx \beta i_b}$

$$\Rightarrow i_b \beta r_e + i_b R_F - I_i R_F + \beta i_b R_c = 0$$

$$\Rightarrow i_b(\beta r_e + R_F + \beta R_c) = I_i R_F$$

Now, $\boxed{i_b = \dfrac{I_o}{\beta}}$

$$\Rightarrow \frac{I_o}{\beta}\left[\beta r_e + R_F + \beta R_c\right] = I_i R_F$$

$$\Rightarrow \frac{I_o}{I_i} = A_i = \frac{\beta R_F}{\beta r_e + R_F + \beta R_c}$$

βr_e too small ; ignored

$$= \frac{\beta R_F}{R_F + \beta R_c}$$

$\beta R_c \gg R_F$

$$\therefore \boxed{A_i \cong \frac{R_F}{R_c}}$$

→ Boylestad

* Lecture - 5.1 : BJT AC Analysis, chapter-5

example

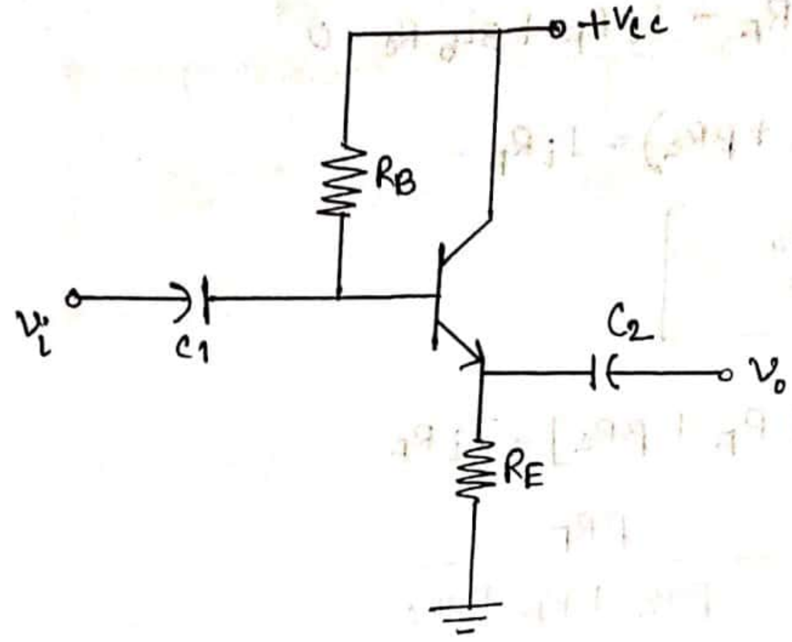
↳ 5.2, 5.3, 5.4, 5.5, 5.7, 5.8, 5.9 (R_o বাদে calculate)

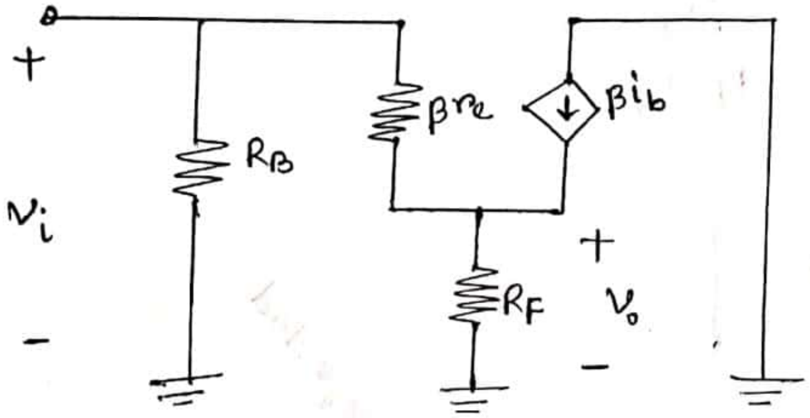
5.10

এই math গুলা sunday তে

যাতে খাতায় থাকে।

Emitter follower configuration:-





$\boxed{Z_i = R_B \parallel Z_b}$

$$i_b = \frac{v_i}{Z_b}$$

$\boxed{Z_b = \beta r_e + (\beta+1)R_E}$

$$= \frac{v_i}{\beta r_e\,(\beta+1)R_E}$$

$\approx \beta(r_e + R_E)$

$\boxed{r_e >> R_E}$ $\boxed{Z_b \approx \beta R_E}$

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$$i_e = (\beta+1)\, i_b$$

$$= (\beta+1)\frac{v_i}{Z_b}$$

$$= \frac{(\beta+1)\, v_i}{\beta r_e + (\beta+1) R_E}$$

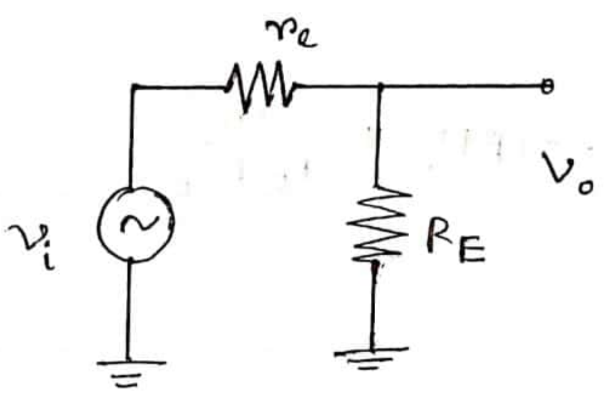
$$= \frac{v_i}{\dfrac{\beta r_e}{\beta+1} + R_E}$$

Again,

$$\frac{\beta r_e}{\beta+1} \approx \frac{\beta r_e}{\beta} \approx r_e$$

$$\therefore\ i_e = \frac{v_i}{r_e + R_E}$$

Now, <u>Redrawing the ckt</u>



$$\boxed{Z_o = r_e \parallel R_E}$$

$$R_E \gg r_e$$

$$\therefore\ \boxed{Z_o \approx R_E}$$

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$$V_o = \frac{R_E}{R_E + r_e} * v_i$$

$$\boxed{\frac{v_o}{v_i} = A_v = \frac{R_E}{R_E + r_e}}$$

$$\boxed{R_E \gg r_e}$$

$$\boxed{A_v \cong 1}$$

$$i_b = \frac{R_B}{R_B + Z_b} * i_i$$

$$\frac{i_b}{i_i} = \frac{R_B}{R_B + Z_b}$$

$$i_o = -i_e$$

$$= -(\beta+1) i_b$$

$$\Rightarrow i_o / i_b = -(\beta + 1)$$

$$\therefore i_b/i_i * i_o/i_b = -(\beta+1) * \frac{R_B}{R_B + Z_b}$$

$$-(\beta+1) \simeq -\beta.$$

$$\therefore \frac{i_o}{i_i} = A_i \cong -\frac{\beta R_B}{R_B + Z_b}$$

$$\boxed{A_i = -A_v \frac{Z_i}{Z_e}}$$

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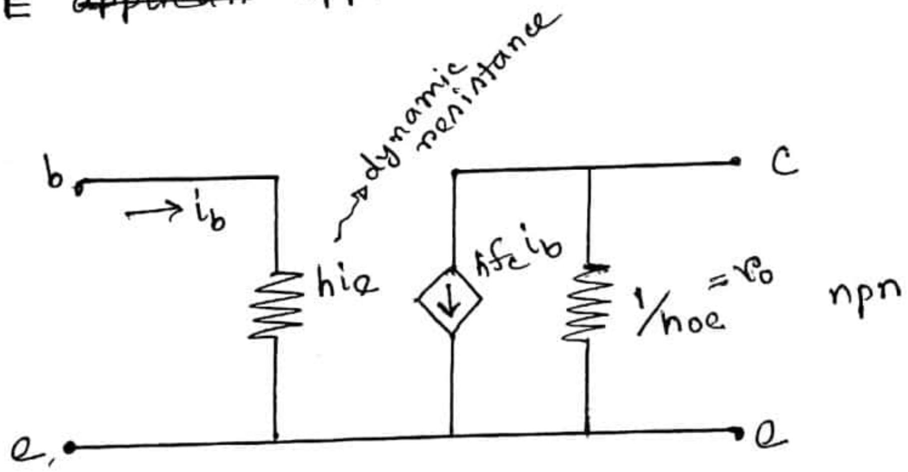
Extra class

Hybrid Model:-

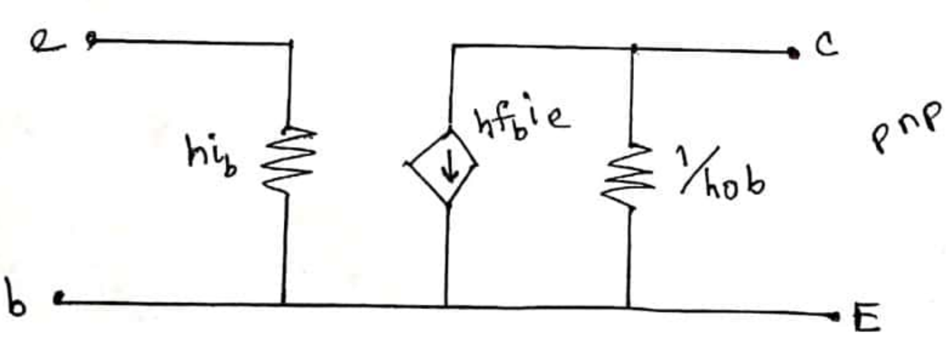
- Equivalent Model of transistor
- Widely used before popularity of r_e model.
- Parameters are defined in general terms for any operating conditions (h-model)
- Parameters are defined by actual operating conditions (r_e model).

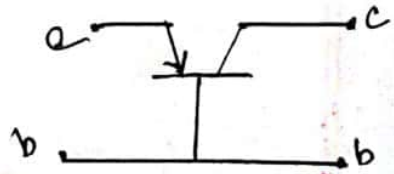
CE ~~applicati~~ approximate hybrid equivalent ckt:-



• $h_{ib} \rightarrow R_E$

Approximate CB hybrid equivalent ckt:-





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$h_f \rightarrow$ forward ~~transis~~ transfer current ratio

$h_i \rightarrow$ i/p resistance

$h_r \rightarrow$ reverse transfer voltage ratio

$h_o \rightarrow$ o/p conductance $= 1/r_o$

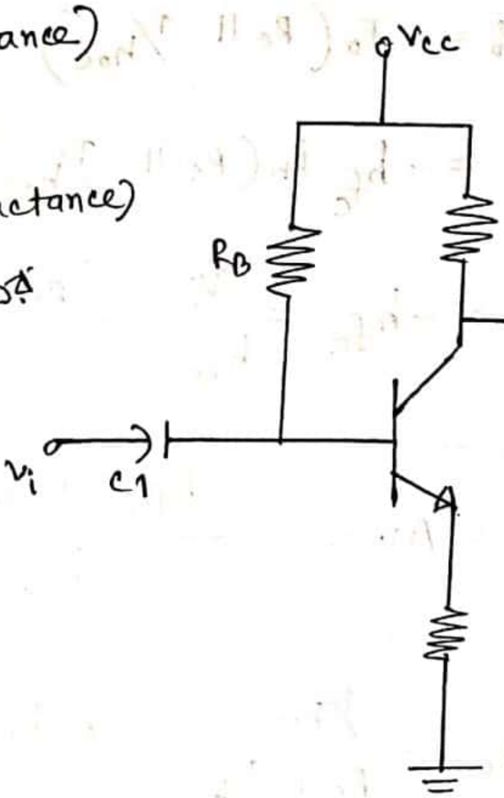
$h_{ie} = \beta r_e \rightarrow$ (i/p resistance)

$h_{fe} = \beta \rightarrow$ (gain)

$h_{oe} = 1/r_o \rightarrow$ (i/p conductance)

$h_{fb} = -\alpha \rightarrow$ (−)ve cz pnp BJT কারণে

$h_{ib} = r_e$

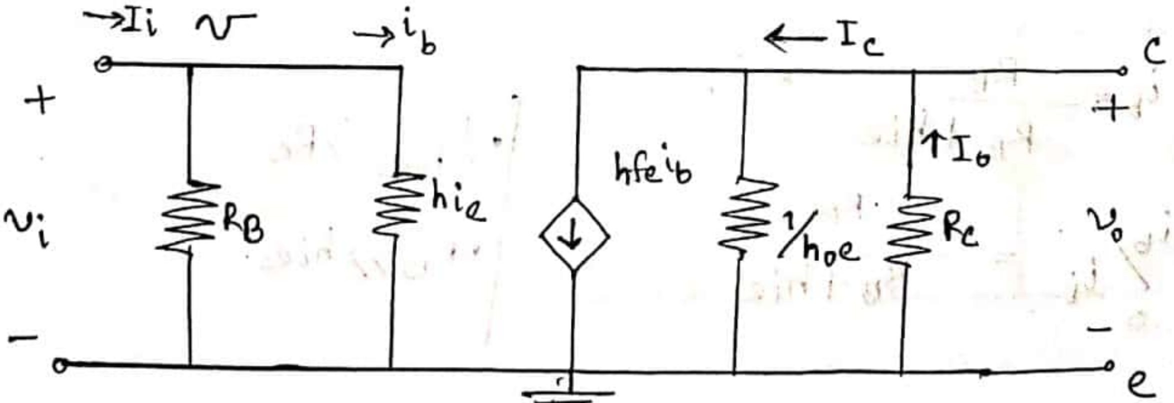


$h_{fe} = 120$

$h_{ie} = 1.175 k\Omega$

$h_{oe} = 20 \mu A/V$

Fixed Bias:-



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$$\boxed{Z_i = R_B \parallel h_{ie}}$$

$$Z_b = \beta r_e + (\beta+1) R_F$$

$$\boxed{Z_o = \frac{1}{h_{oe}} \parallel R_C}$$

<u>Av :-</u> $v_o = -I_o \left(R_C \parallel \frac{1}{h_{oe}} \right)$

$$= -h_{fe}\, i_b \left(R_C \parallel \frac{1}{h_{oe}} \right)$$

$$= -h_{fe} \frac{v_i}{h_{ie}} \left(R_C \parallel \frac{1}{h_{oe}} \right)$$

$$\therefore \boxed{\frac{v_o}{v_i} = A_v = -\frac{h_{fe} \left(R_C \parallel \frac{1}{h_{oe}} \right)}{h_{ie}}}$$

<u>Ai :-</u> $I_o = \frac{\frac{1}{h_{oe}}}{R_C + \frac{1}{h_{oe}}} * h_{fe}\, i_b$

$$\Rightarrow I_o / i_b = \frac{h_{fe} * \frac{1}{h_{oe}}}{R_C + \frac{1}{h_{oe}}}$$

$$i_b = \frac{R_B}{R_B + h_{ie}} * i_i$$

$$i_b / i_i = \frac{R_B}{R_B + h_{ie}}$$

- $\frac{1}{h_{oe}} \gg R_C$
- $R_B \gg h_{ie}$

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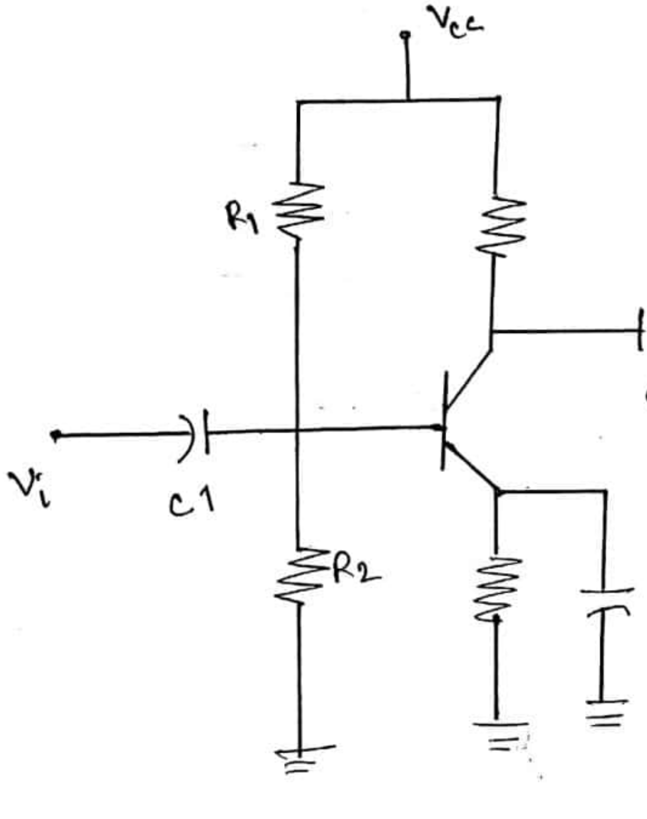
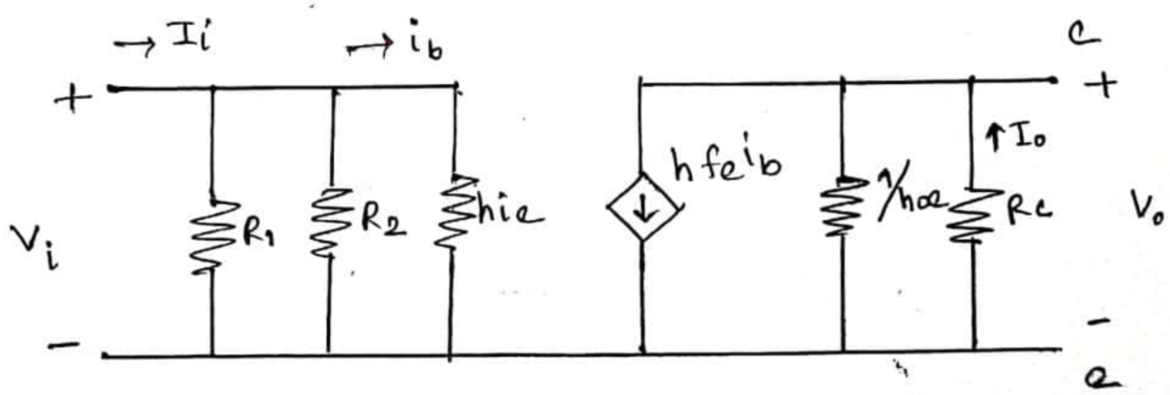
$$\therefore A_i = \frac{i_o}{i_i} = \frac{h_{fe} * 1/h_{oe}}{R_c + 1/h_{oe}} * \frac{R_B}{R_B + h_{ie}}$$

$$\therefore A_i = h_{fe}$$

voltage divider Bias:—





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06.10.2019

Sunday

FET (Field effect transistor) :-

BJT → current controlled device (Bipolar) → npn, pnp

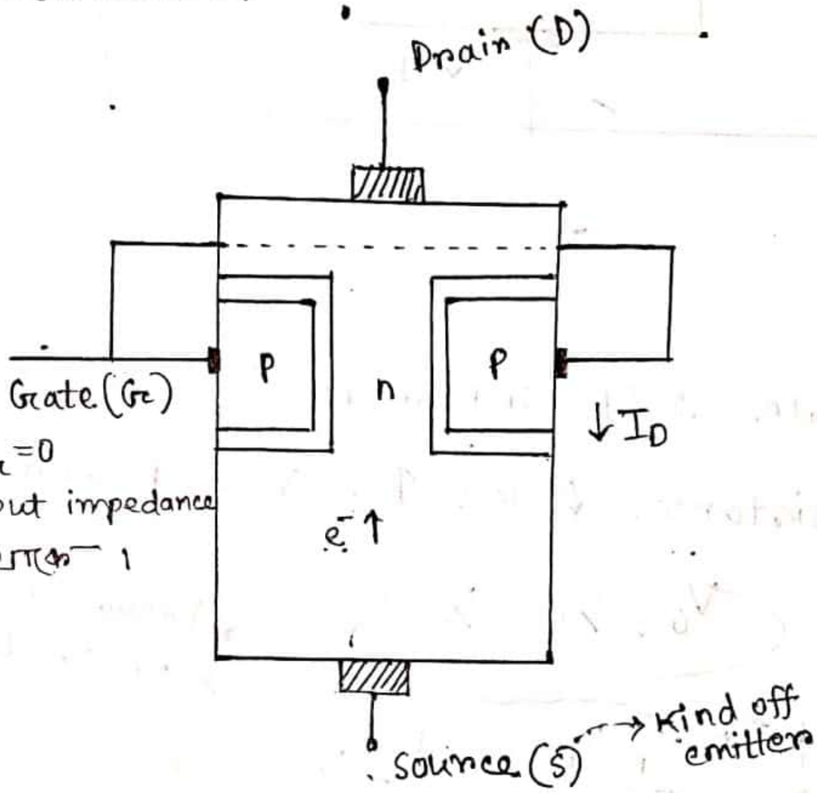
JFET → voltage controlled device (unipolar) → n-ch, p-ch

FET :- 2 types :- 1. JFET

2. MOSFET → D. MOS (amplification), E. MOS (fast switching)

→ Temp stable হলে Q point stable. switching এ বেশি use করা হয়।

JFET construction :-



$I_G = 0$

তাই input impedance বেশি থাকে।

* Gate দিয়ে conduction হবে না। Drain and source দিয়ে হবে।

* D. MOS ⟷ Depletion type MOSFET

* E. MOS ⟶ Enhancement type MOSFET

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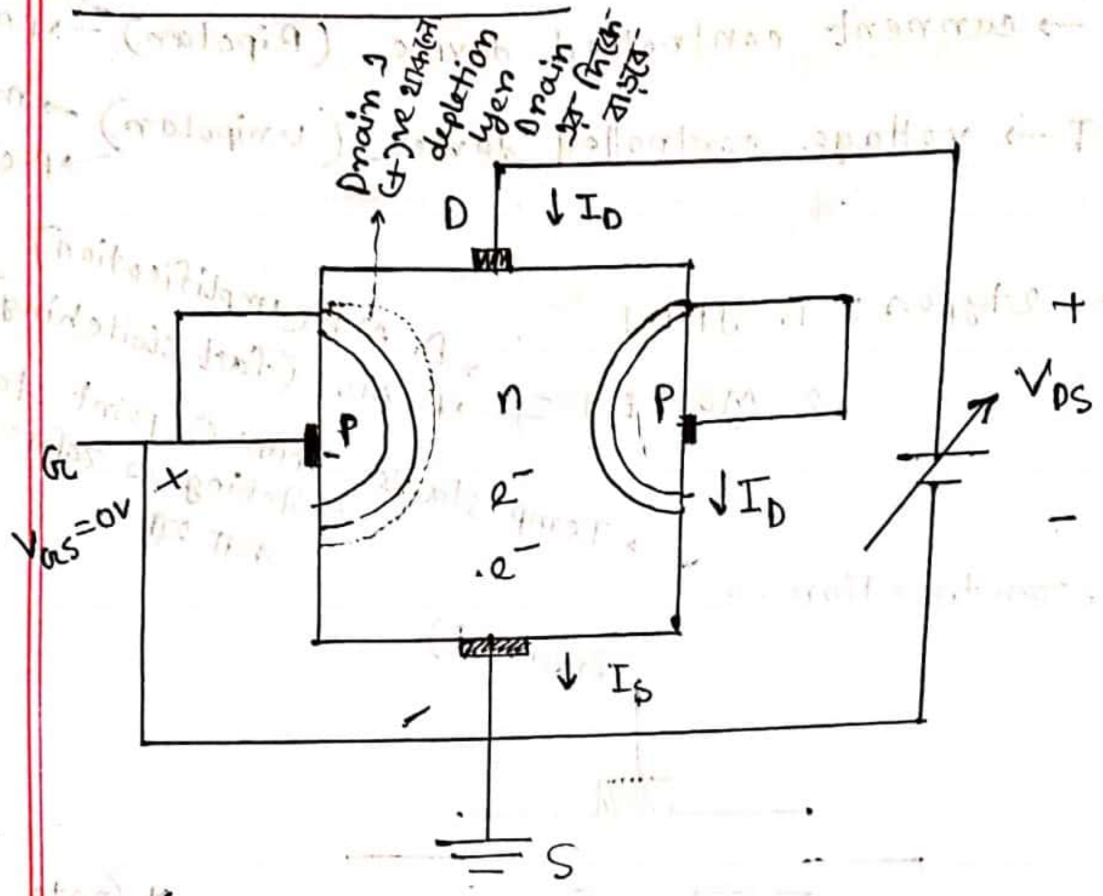
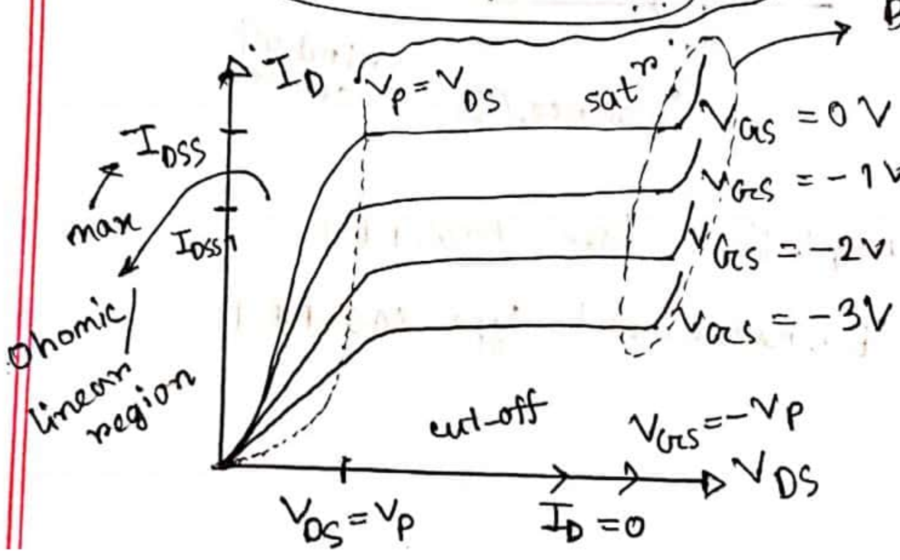
$V_{GS} = 0V$; $V_{DS} > 0$



* Gate এ '+' থাকলে pn junction টা forward bias

* Resistance ↓ loss ↑ ; V_{GS} এর value (+)ve দেওয়া যাবে না।

$V_{GS} > 0$ X



$r_d = \frac{1}{\text{slope}}$

* ohomic region
↳ gain কে control করে।
(automatic gain control)

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voltage controlled resistor

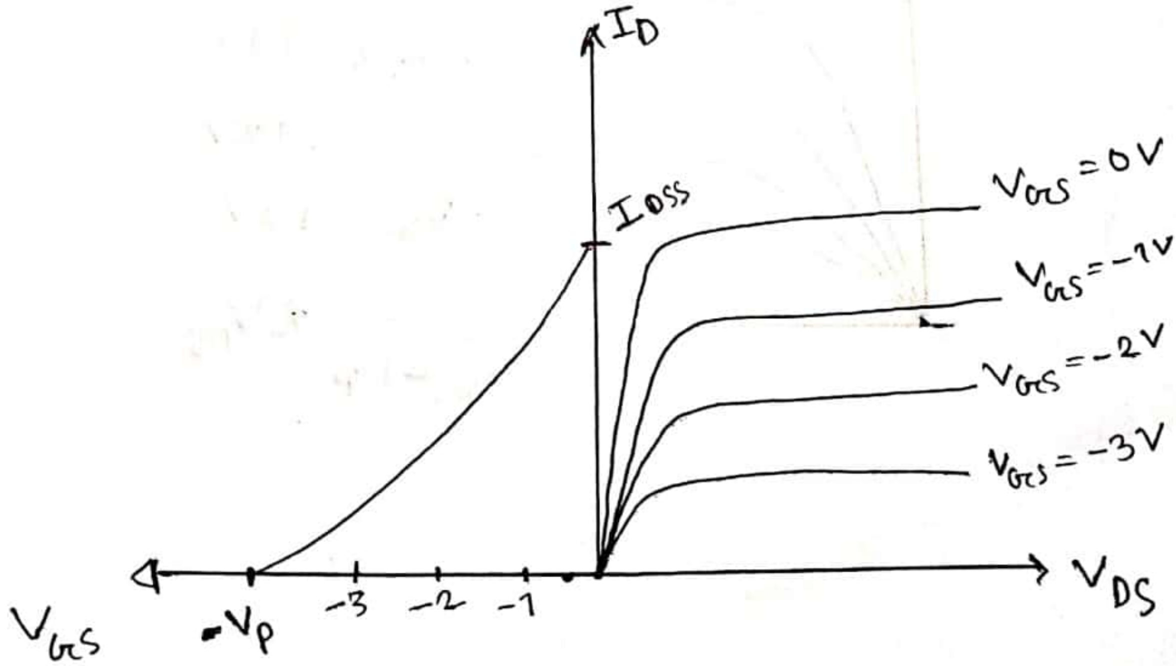
$$\boxed{r_d = \frac{r_o}{\left(1 - \frac{V_{GS}}{V_P}\right)^2}}$$

$r_o \rightarrow$ resistance at $V_{GS} = 0V$

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

$$\boxed{V_{GS} = V_P\left(1 - \sqrt{I_D/I_{DSS}}\right)}$$

* output vs input characteristics curve $\rightarrow$ transfer characteristics curve.



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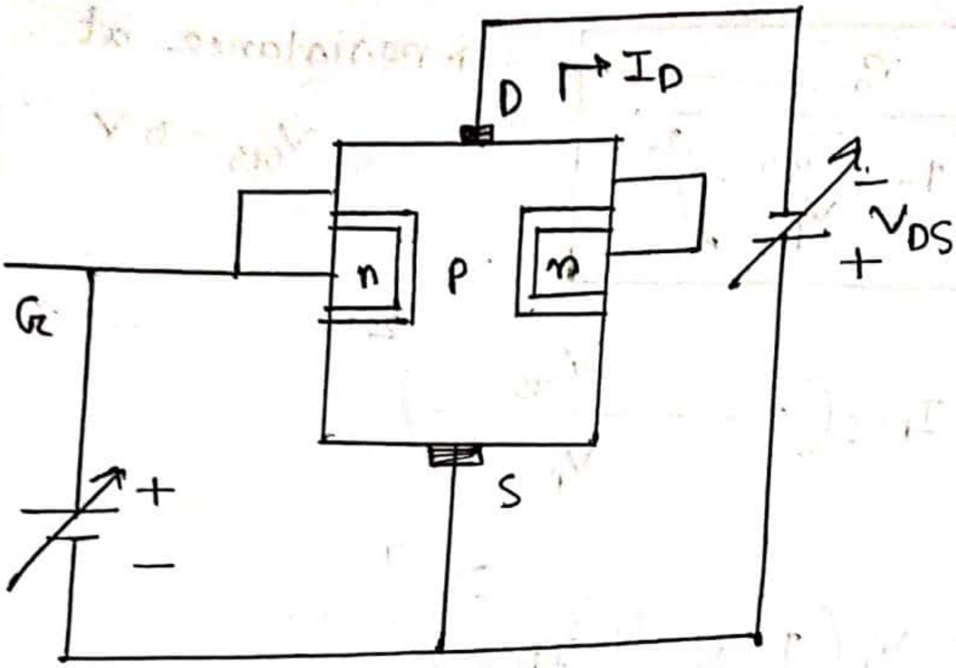

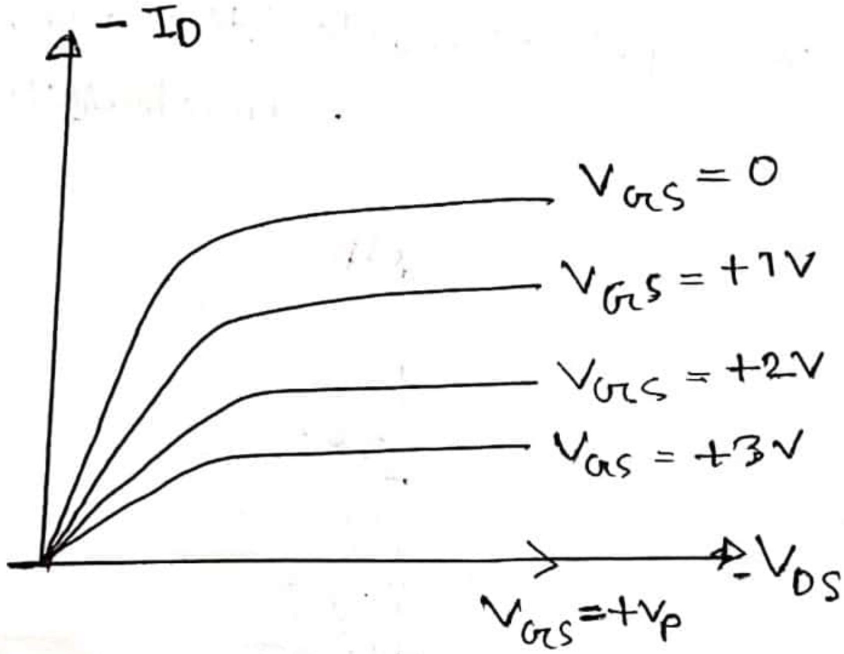

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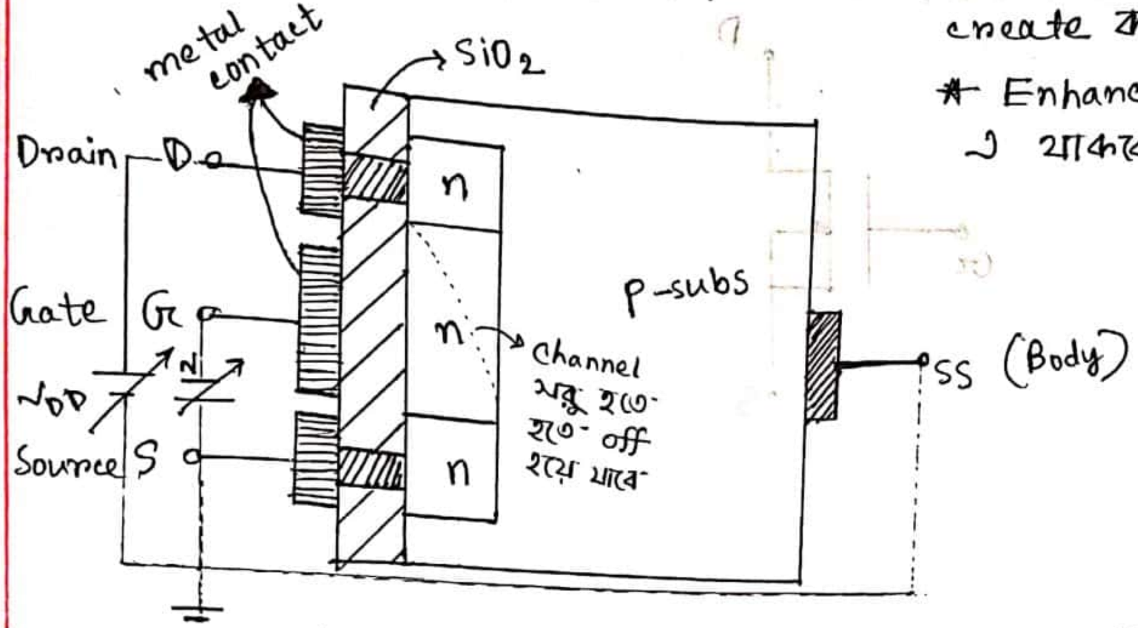
09/10/2019
Wednesday

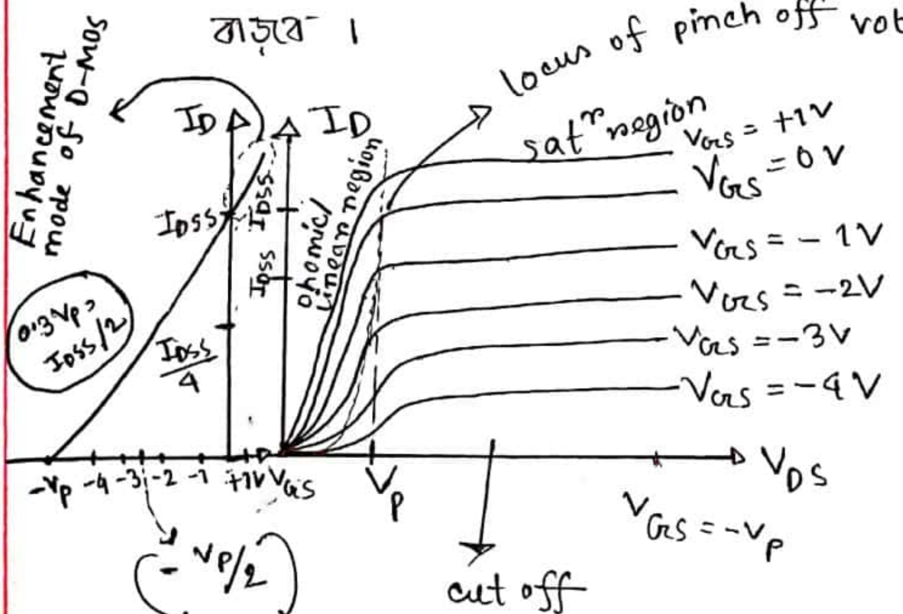
MOSFET:-

Depletion type MOSFET .... channel টি initially create করা থাকবে।

* Enhancement type এ থাকবে না।



* pn junction এ voltage বাড়ার সাথে সাথে depletion layer বাড়বে।



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

$$r_d = \frac{r_o}{\left(1 - \frac{V_{GS}}{V_D}\right)^2}$$

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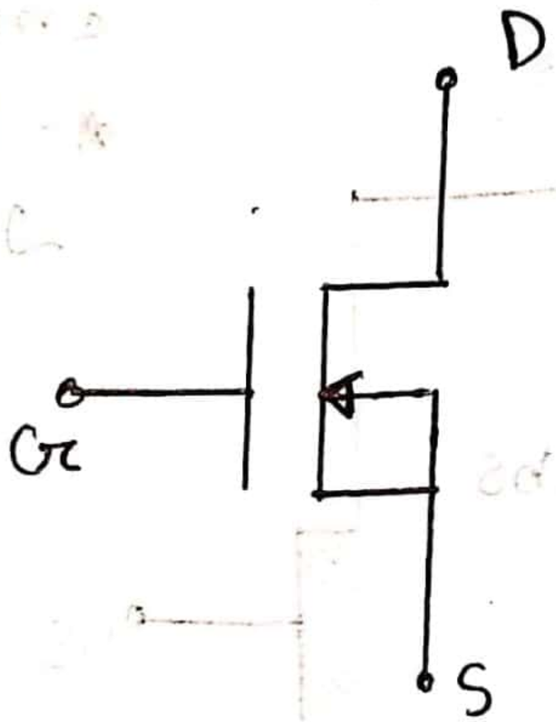
symbol



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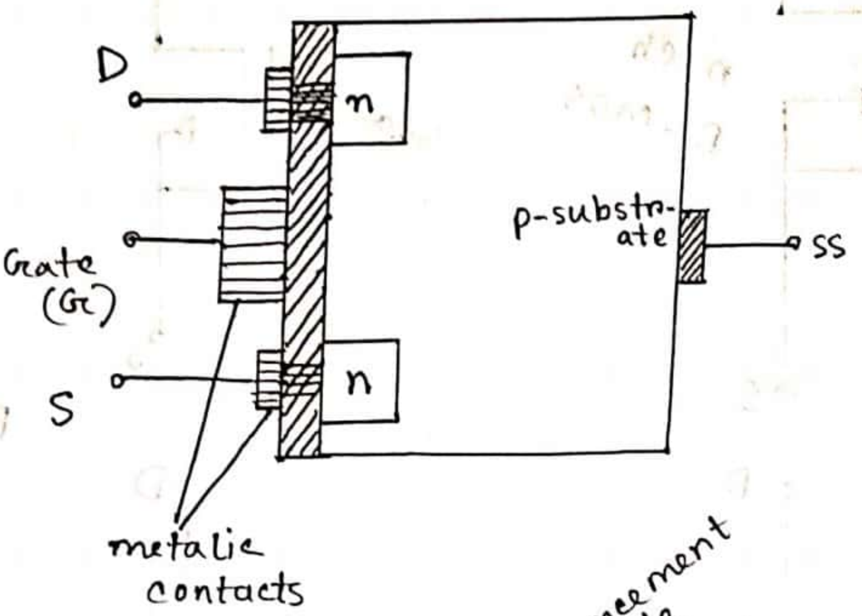
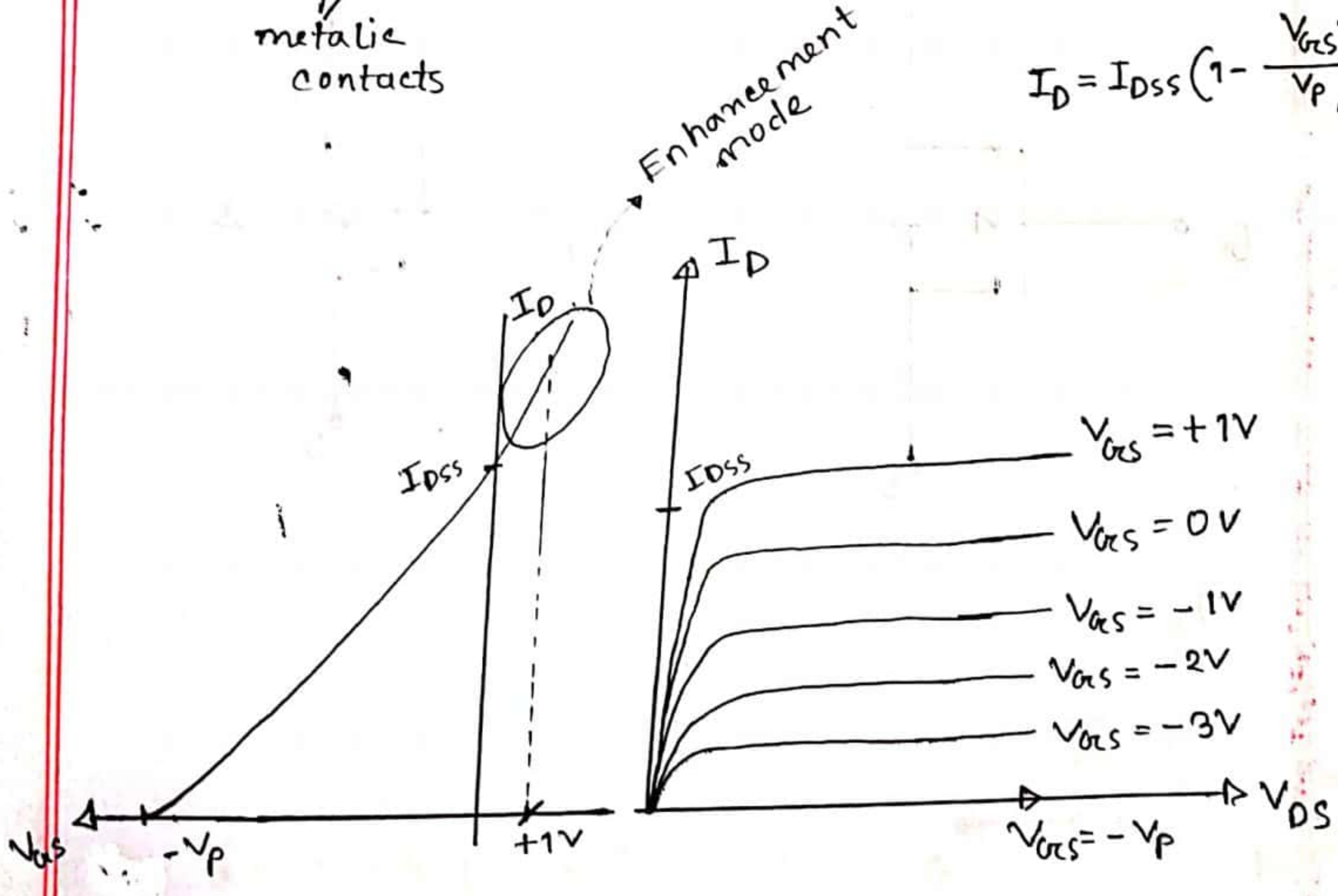
13.10.2019
Sunday

Enhancement type MOSFET :-



* V_{GS} এর যেই voltage এর জন্য channel তৈরি হয়, সেটাই Threshold voltage.

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



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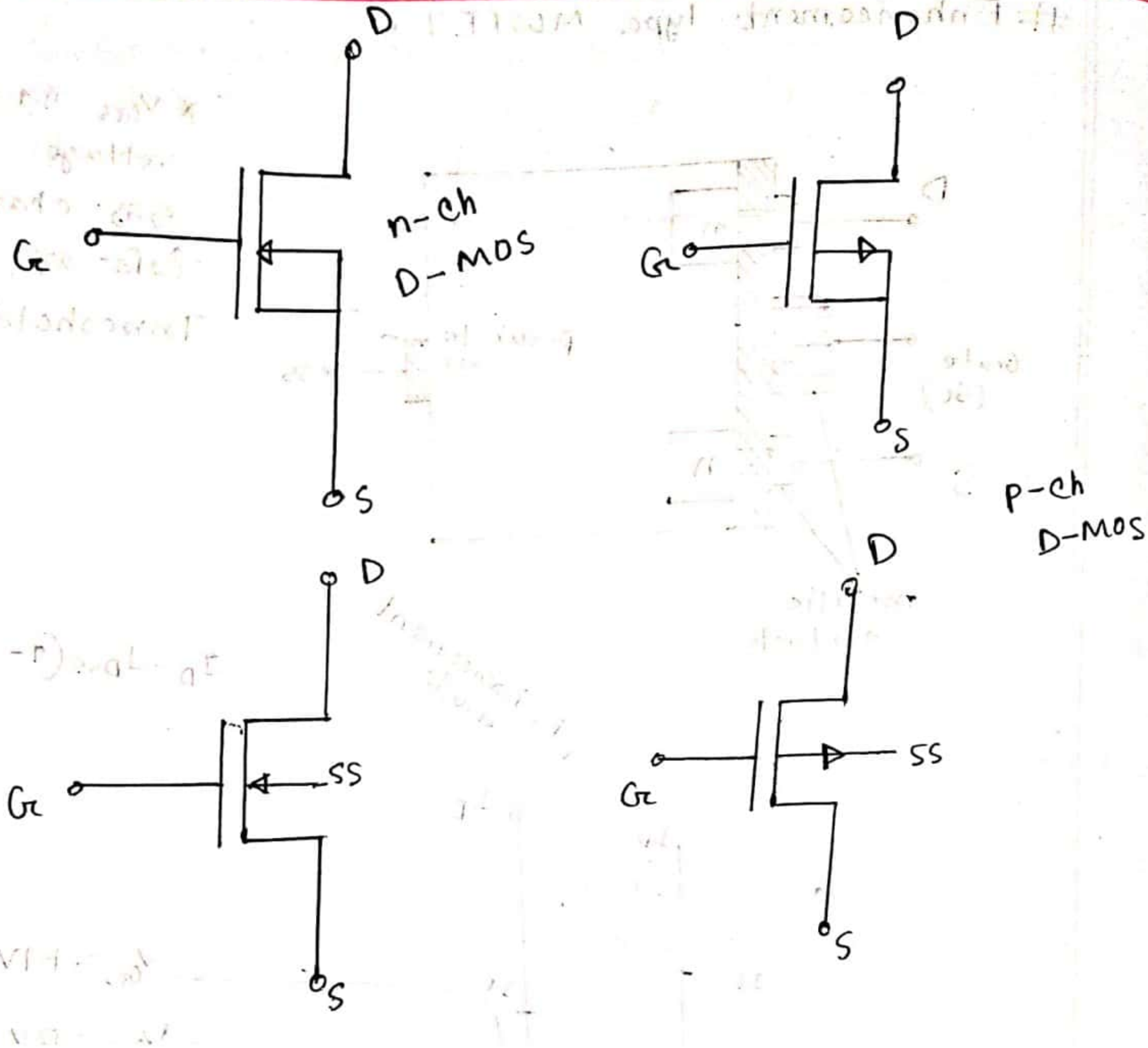

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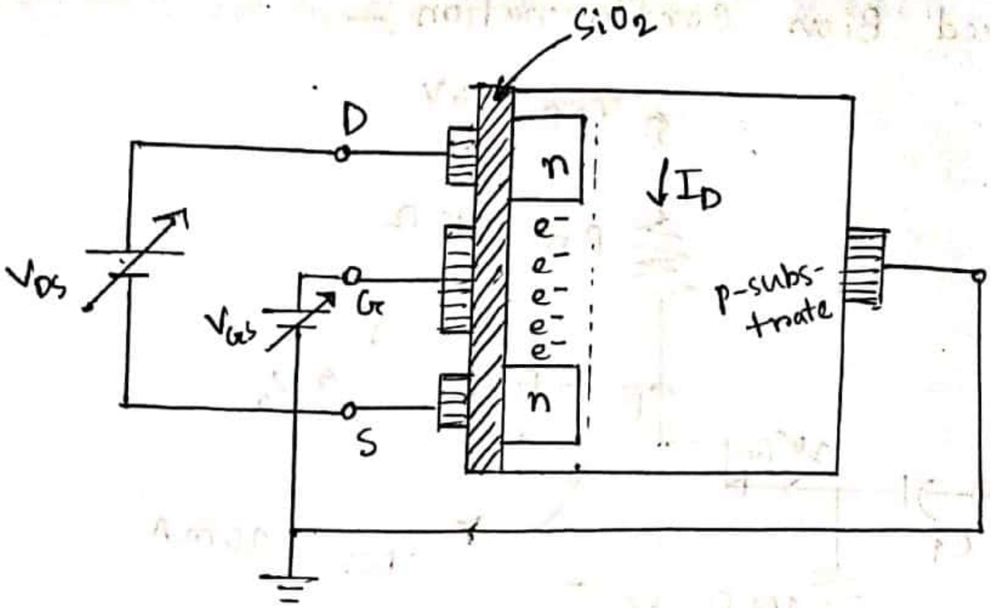
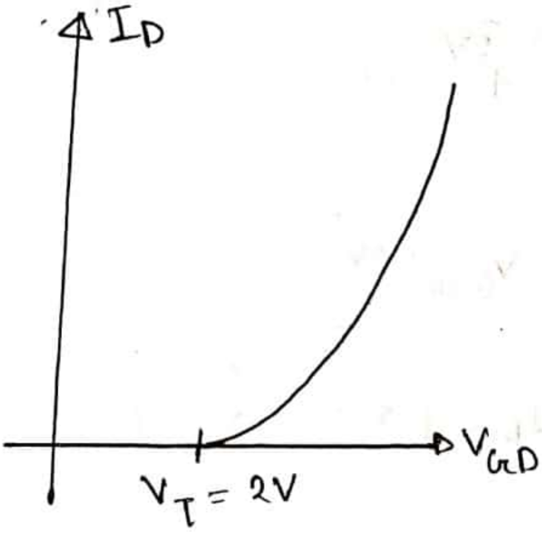
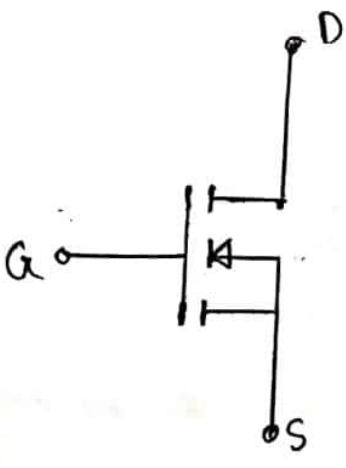




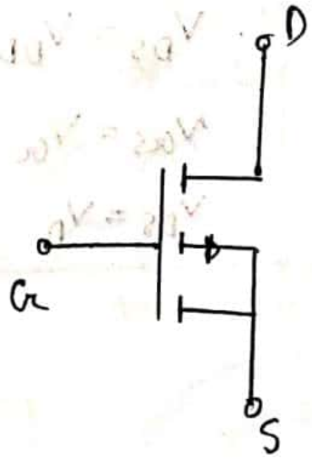
$V_{GS} > V_T$

$$I_D = k(V_{GS} - V_T)^2$$

$$k = \frac{I_D\,(on)}{(V_{GS}\,(on) - V_T)^2}$$



n-ch
E-mos



p-ch
E-mos

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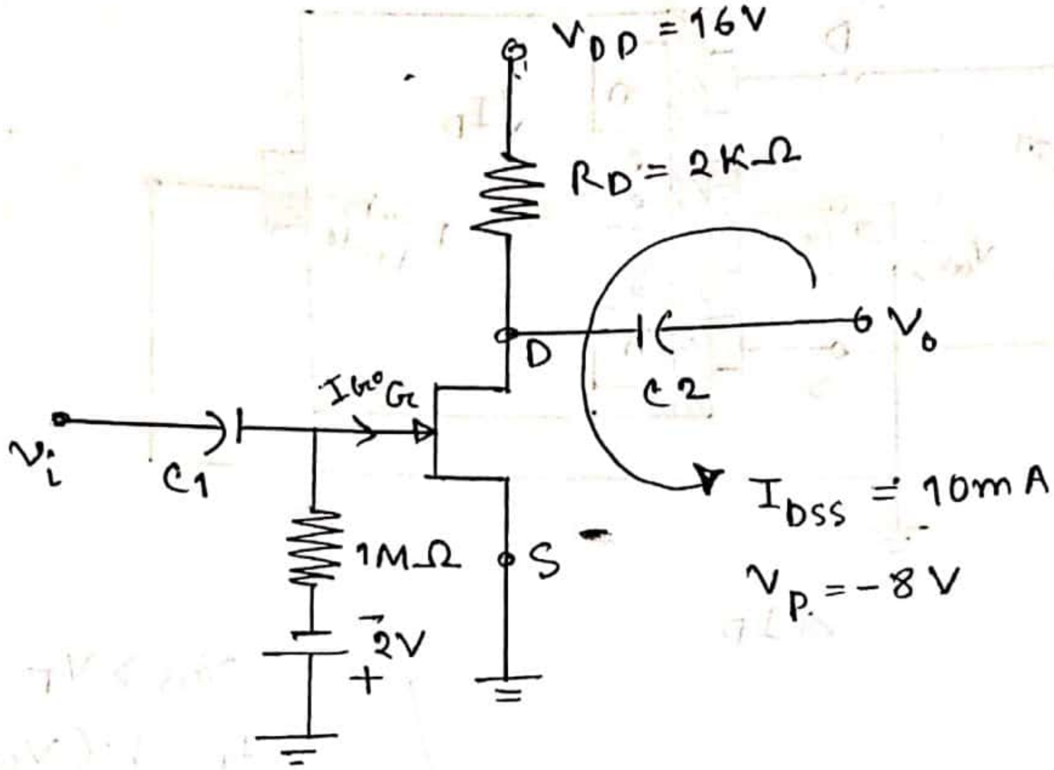
Fixed Bias configuration :-



$$\boxed{V_{GS} = -V_{GG} = -2V}$$

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

$$-V_{DD} + I_D R_D + V_{DS}$$

$$\therefore V_{DS} = V_{DD} - I_D R_D$$

$$V_{GS} = V_G$$

$$V_{DS} = V_D$$

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* Find – (i) V_{GSQ} (ii) I_{DQ} (iii) V_{DS} (iv) V_G (v) V_S

(i) Analytical Method :–

$$V_{GSQ} = -V_{GG} = -2V$$

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

$$= 10\,mA\left(1 - \frac{-2V}{-8V}\right)^2$$

$$= 5.625\,mA.$$

Graphical Method :–

$I_{DSS} = 10\,mA$, $V_{GS} = 0V$

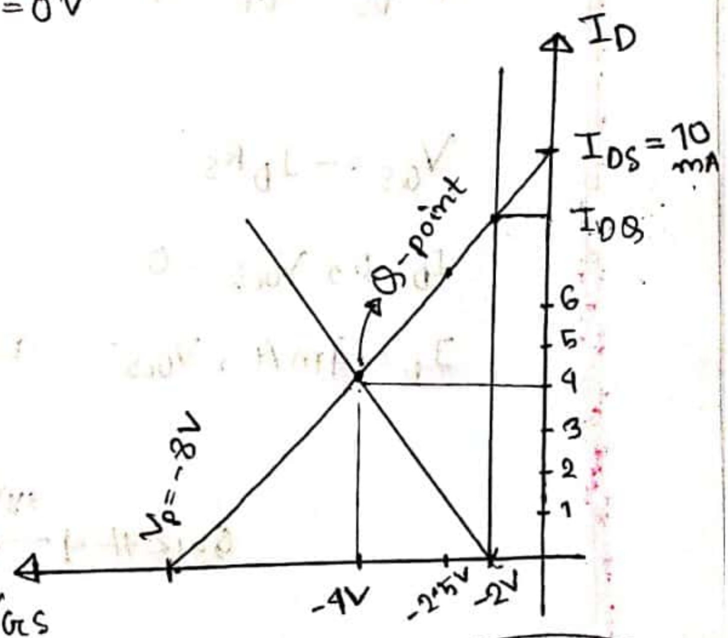
$V_P = -8V$, $I_D = 0$

$-\frac{V_P}{2}$, $\frac{I_{DSS}}{4}$

$\Rightarrow -4$, $2.5\,mA$

$0.3V_P$, $I_{DSS}/2$

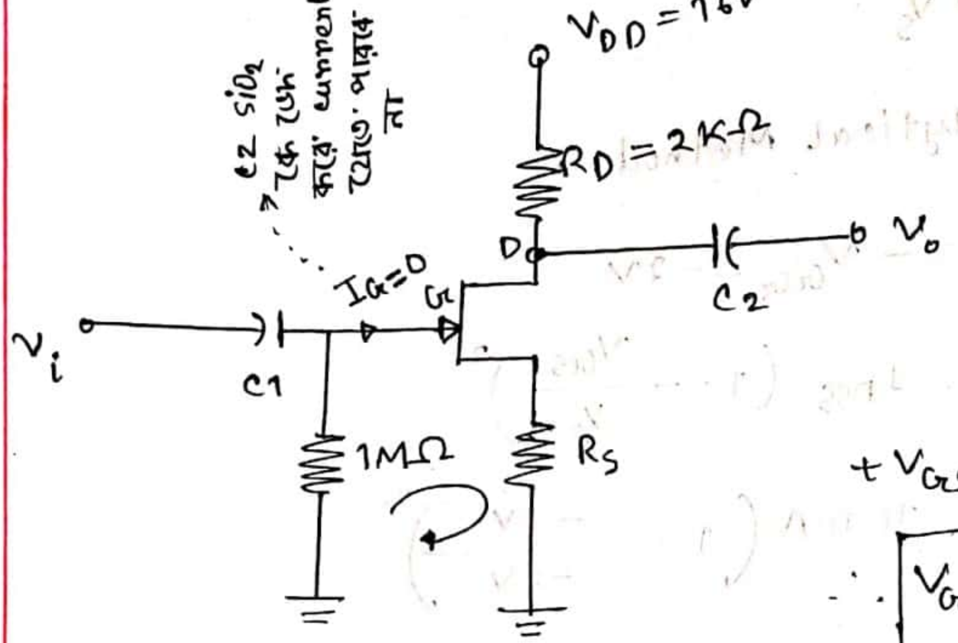
$-2.4V$, $5\,mA$



$$\boxed{V_{DS} = V_{DD} - I_{DQ}R_D}$$

graph আঁকতে হবে

Self Bias configuration:—



$+V_{GS} + I_D R_S = 0$

$\therefore \boxed{V_{GS} = -I_D R_S}$

characteristic equation

$-V_{DD} + I_D R_D + V_{DS} + I_S R_S = 0$

$\Rightarrow V_{DS} = V_{DD} - I_D (R_D + R_S)$

$V_{GS} = -I_D R_S$

$I_D = 0, \; V_{GS} = 0$

$I_D = 4mA, \; V_{GS} = -4V$

Quiz#4 $\xrightarrow{\text{syllabus}}$ শুধু AC analysis
(π, T, re model)

9:40 ↄ exp 17.09.2019

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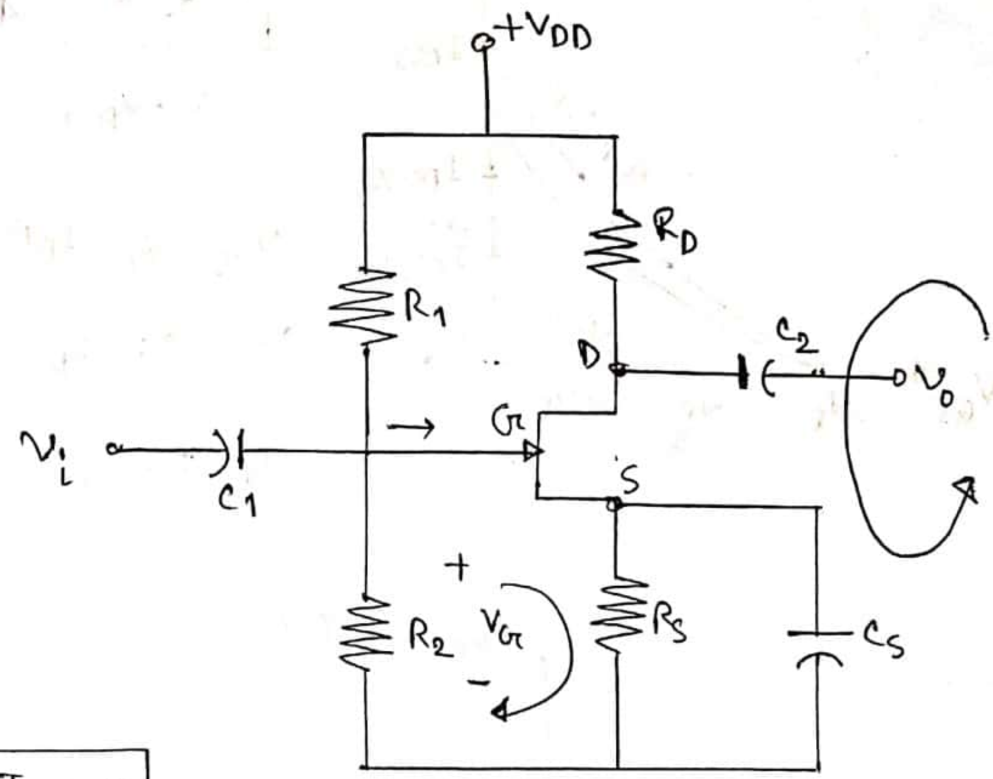
14. 10. 2019

Monday

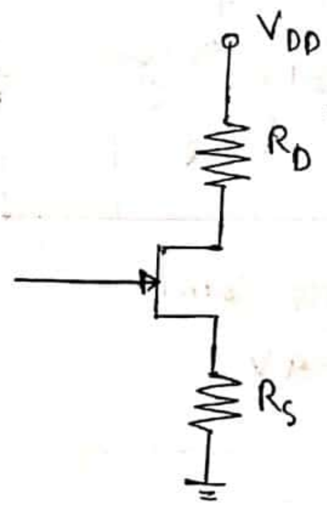
Voltage Divider Biasing:-



$\boxed{I_G = 0}$

$$-V_G + V_{GS} + V_{R_S} = 0$$

$$\Rightarrow \boxed{V_{GS} = V_G - I_D R_S}$$



$$V_{DS} = V_{DD} - I_D (R_D + R_S)$$

$$V_S = I_D R_S$$

$$V_D = V_{DS} - I_D R_D$$

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

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

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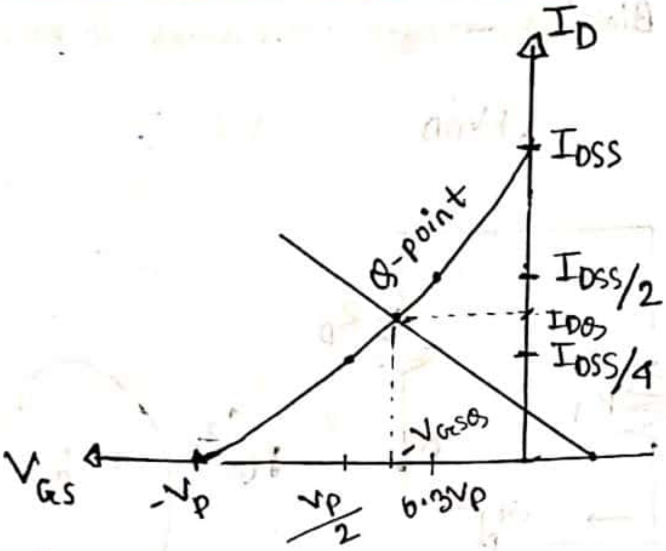


$$\boxed{\frac{V_p}{2}, \frac{I_{DSS}}{4}}$$

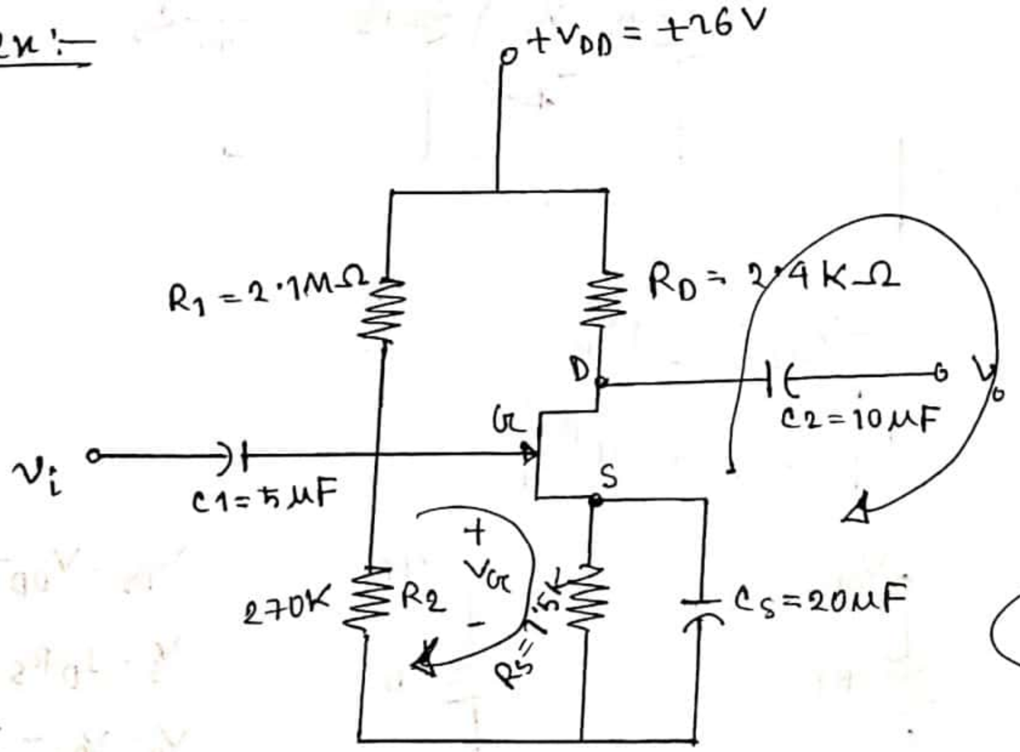
$$0.3V_p, \frac{I_{DSS}}{2}$$

$$V_{GS} = V_G - I_D R_S$$

$$V_{GS} = 0; \quad I_D = \frac{V_G}{R_S}$$

$$I_D = 0, \quad V_{GS} = (+)\text{ve}.$$

ex:-



$I_G = 0$

Given, $I_{DSS} = 8mA$

$V_p = -4V$

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

$$= \frac{270K}{2.1M + 270K} * 16\ V$$

$$= 1.82V$$

$$\therefore V_{GS} = 1.82 - I_D(1.5K)$$

$V_{GS} = 0V$

$$I_D = \frac{1.82V}{1.5K} =$$

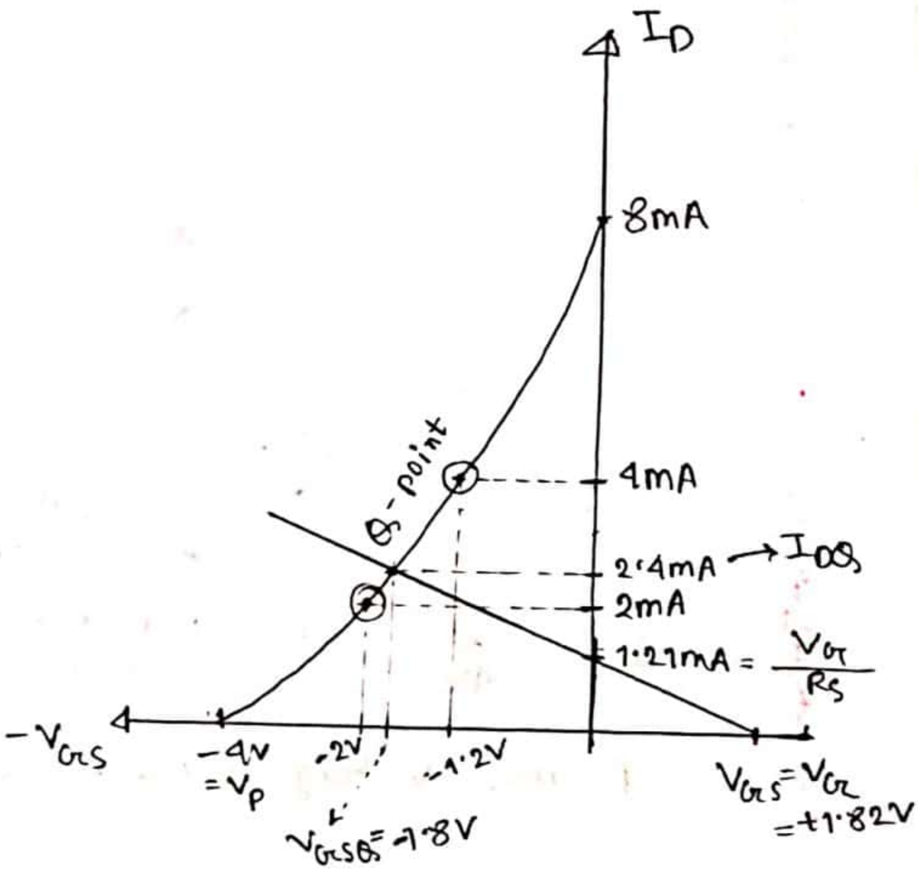
$I_D = 0$

$V_{GS} = 1.82V$

$-2V,\ 2mA$

$\frac{V_P}{2}, \frac{I_{DS}}{4}$

$0.3V_P,\ I_{DSS}/2$



Common gate configuration :- Home

* D-MOS self bias ckt :- Home

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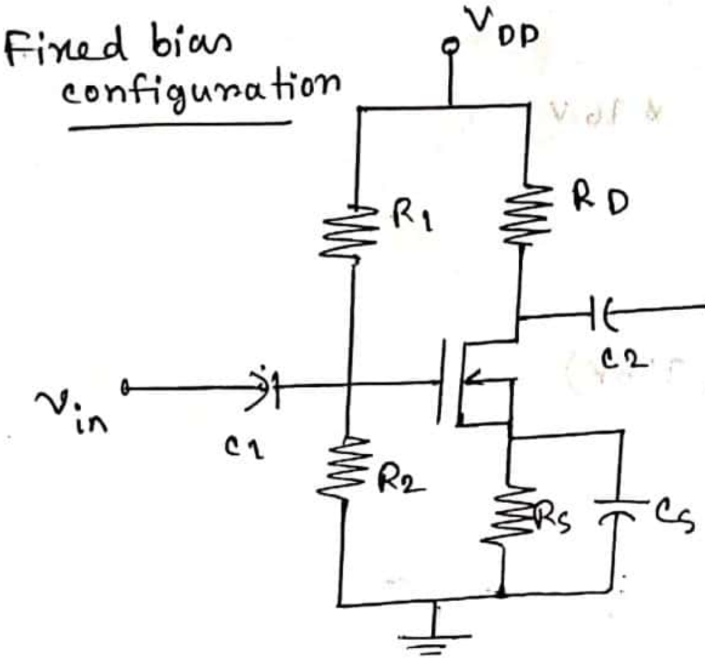
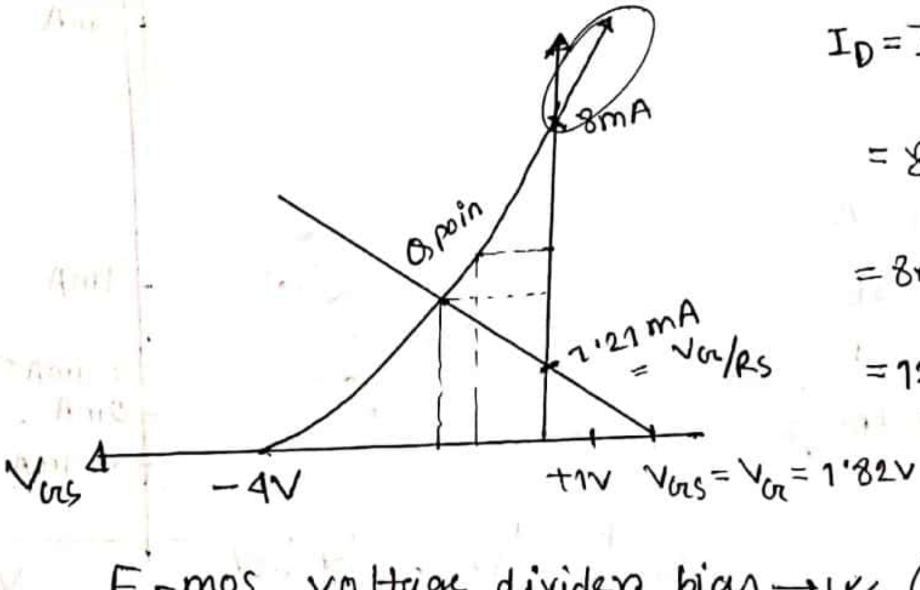
Depletion type MOSFET :-

Fixed bias configuration





$V_{GS} = +1V \sim +3V$

$V_{GS} = +1V$

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

$$= 8mA\left(1 - \frac{+1V}{-4V}\right)^2$$

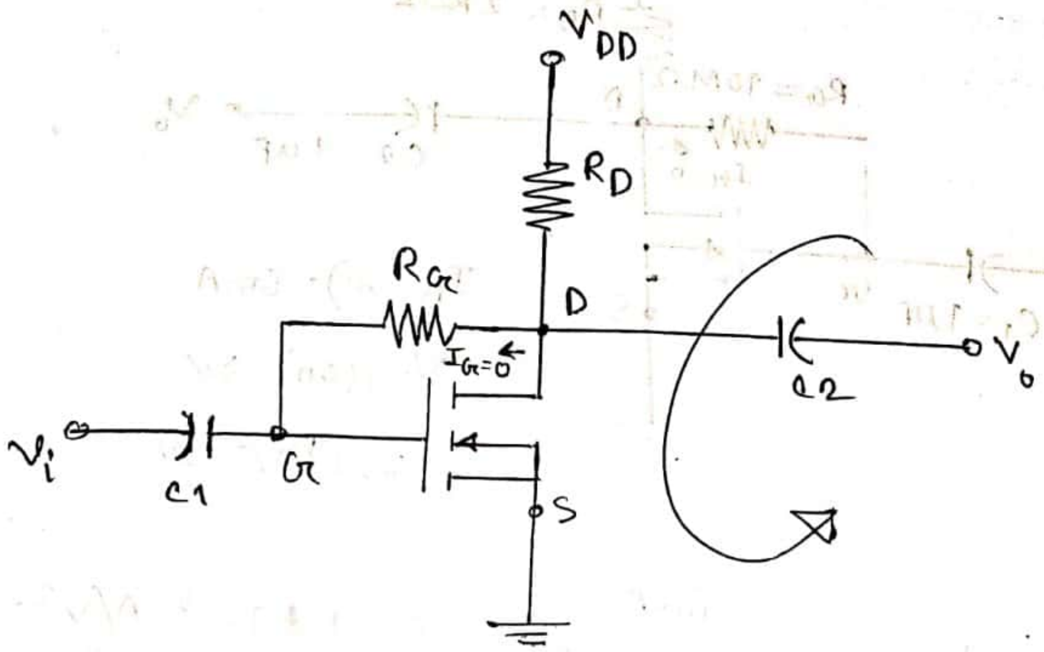
$$= 8mA\left(1 + \frac{1}{4}\right)^2$$

$$= 12.56\ mA$$

E-mos voltage divider bias → w (Home)

E-MOS :-

Feedback Biasing arrangement:-



$I_G = 0$

$$\boxed{I_D = K(V_{GS} - V_T)^2}$$

$$\boxed{K = \frac{I_D\,(on)}{(V_{GS}\,(on) - V_T)^2}}$$

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

$V_{DS} = V_{GS}$

$V_{GS} = V_{DD} - I_D R_D$

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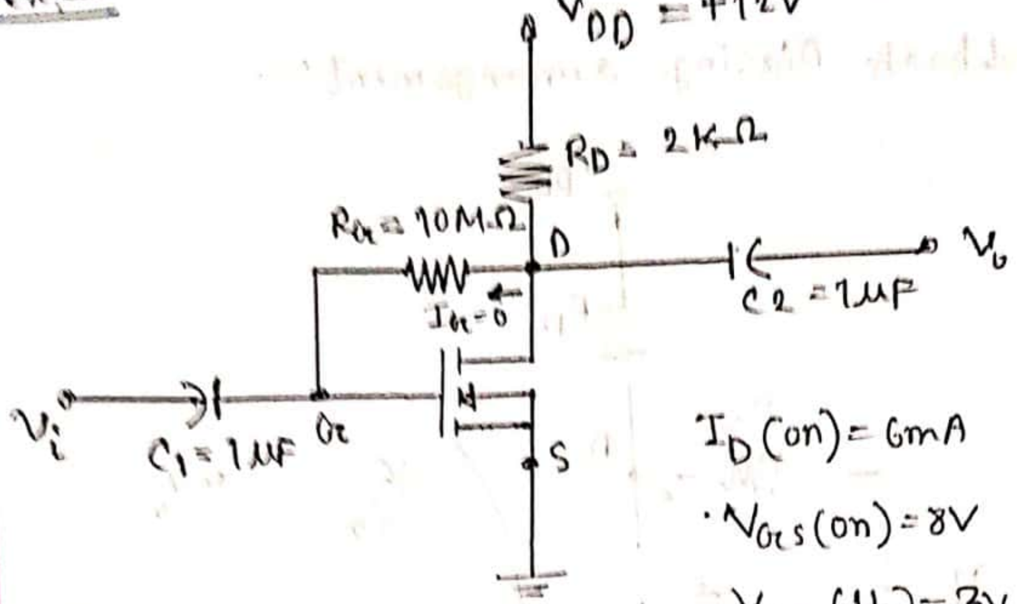
Ex:



$I_D(on) = 6mA$

$V_{GS}(on) = 8V$

$V_{GS}(th) = 3V$

$$\therefore K = \frac{6mA}{(8V - 3V)^2} = 0.24 \times 10^{-3} \ A/V^2$$

assume, $V_{GS} = 6V$

if $V_{GS} = 10V$

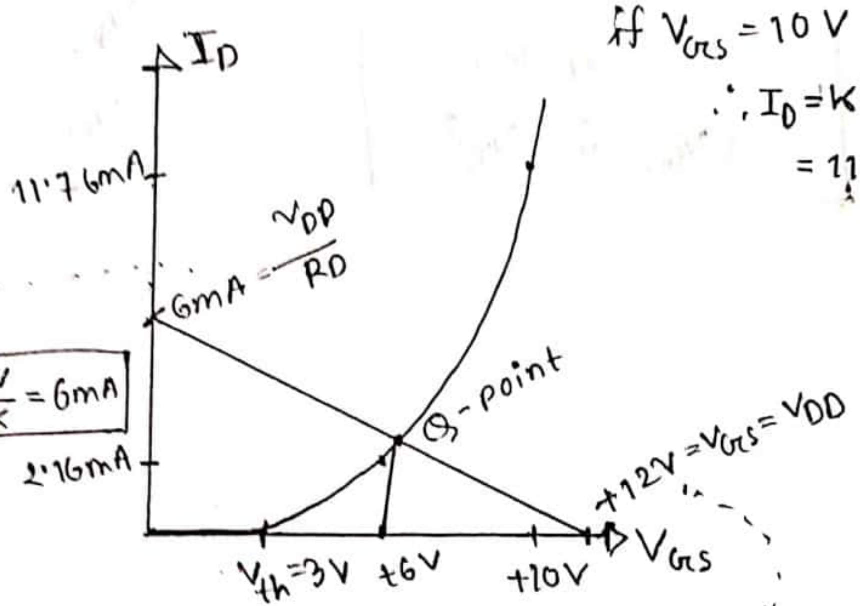
$\therefore I_D = K(10-3)^2$

$= 11.76mA$

$V_{GS} = V_{DD} - I_D R_D$

$V_{GS} = 0$

$I_D = \frac{V_{DD}}{R_D} = \frac{12V}{2K} = 6mA$



$I_D = K(6-3)^2 = 2.16 \ mA$

$I_D = 0$

$V_{GS} = V_{DD} = 12V$

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16/10/2019
Wednesday

JFET small signal Model:- / Depletion type MOS :-

$$\text{trans conductance} \leftarrow g_m = \frac{\Delta I_D \rightarrow \text{output current}}{\Delta V_{GS} \rightarrow \text{control voltage}}$$

$$\therefore g_m = \frac{d I_D}{d V_{GS}} = \frac{d}{dV_{GS}}\left[I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2\right].$$

$$*** \quad \boxed{g_m = \frac{2I_{DSS}}{|V_P|}\left[1-\frac{V_{GS}}{V_P}\right]}$$

for $\boxed{V_{GS} = 0V}$

$$g_m = \frac{2I_{DSS}}{|V_P|}\left[1-\frac{0}{V_P}\right]$$

$$** \quad \therefore \boxed{g_m = \frac{2I_{DSS}}{|V_P|}}$$

$$\therefore \boxed{g_m = g_{m_0}\left[1-\frac{V_{GS}}{V_P}\right]}$$

* ac equivalent formula

$$\boxed{g_m = g_{fs} = y_{fs}}$$

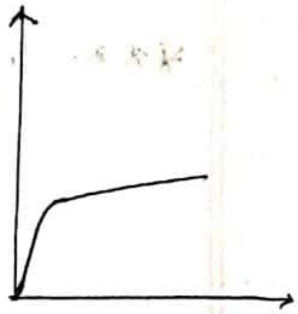
forward transfer conductance.

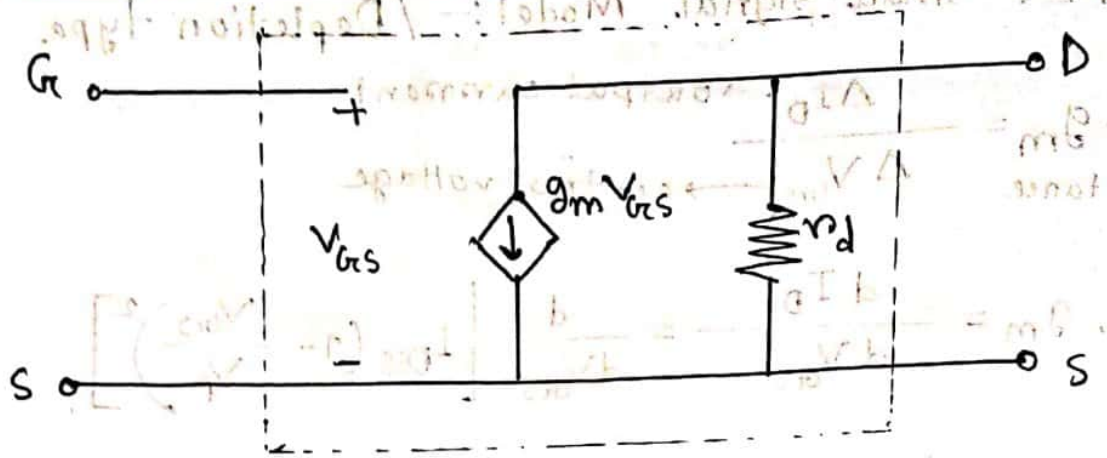
$$\boxed{r_d = \frac{1}{g_{os}}}$$; r_d = resistance for specific V_{GS}

* JFET এ current gain থাকে না ।

$$* \; r_d = \frac{r_o}{\left(1-\frac{V_{GS}}{V_P}\right)^2}$$

* open ckt এ resistance infinity.





JFET ac equivalent model

Enhance type MOSFET:-

$$\boxed{I_D = k\,(V_{GS} - V_{th})^2}$$

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$= \frac{dI_D}{dV_{GS}}$$

$$= \frac{d}{dV_{GS}}\left[k\cdot(V_{GS} - V_T)^2\right]$$

*** $\therefore \boxed{g_m = 2k\,(V_{GSQ} - V_{GS(Th)})}$

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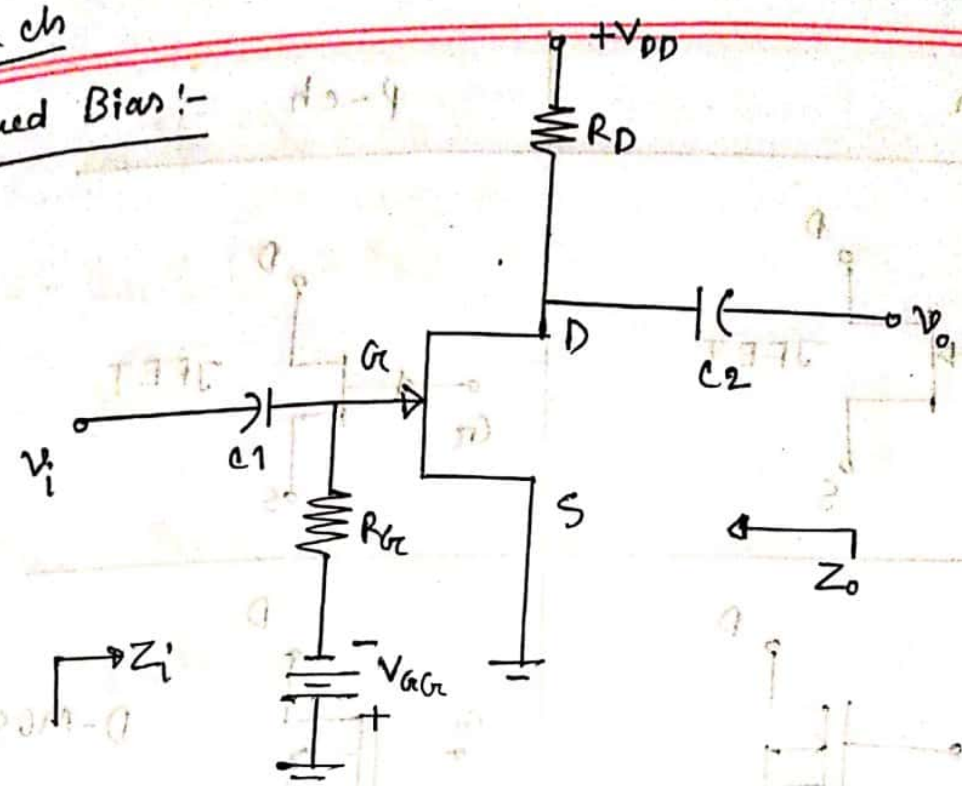
Extra ch

Fixed Bias :-

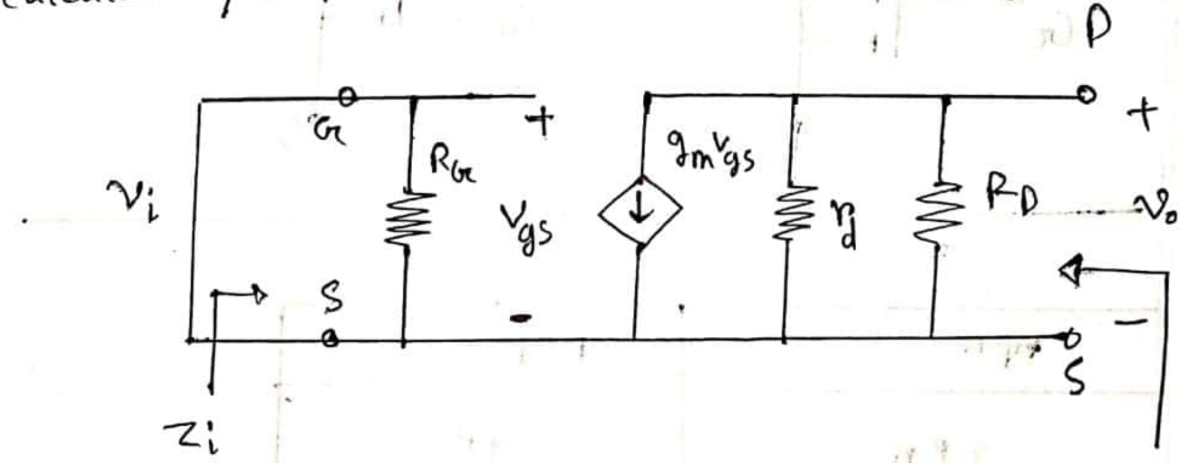
Zi
Zo
AV



(i) DC analysis → I_{DQ}, V_{GSQ}

(ii) Draw AC equivalent ckt of FET

(iii) calculation / simplification



$v_{gs} = v_i$

$\boxed{Z_i = R_G}$

$\boxed{Z_0 = r_d \parallel R_D}$

$r_d \geq 10 R_D$

$Z_0 \approx R_D$

P.T.O

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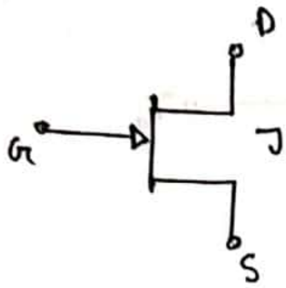
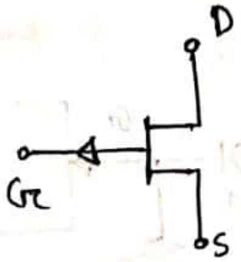
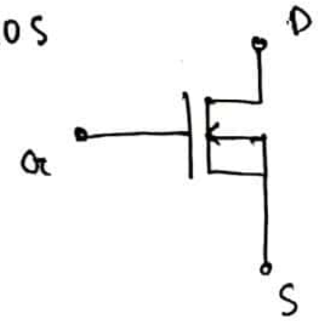
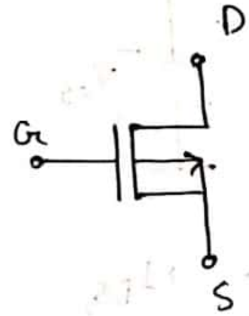
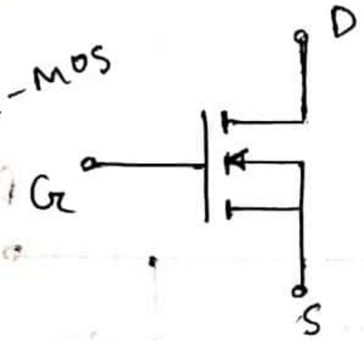
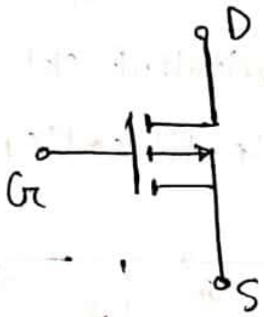
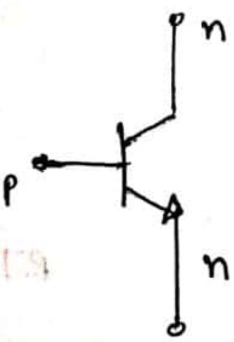
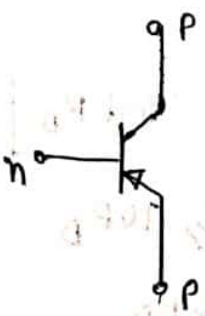
	n-ch	p-ch
JFET	 JFET	 JFET
D-MOS	D-MOS 	 D-MOS
E-MOS	E-MOS 	 E-MOS

npn	pnp
	

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$$v_o = -g_m v_{gs} (r_d \parallel R_D)$$

$$= -g_m v_i (r_d \parallel R_D)$$

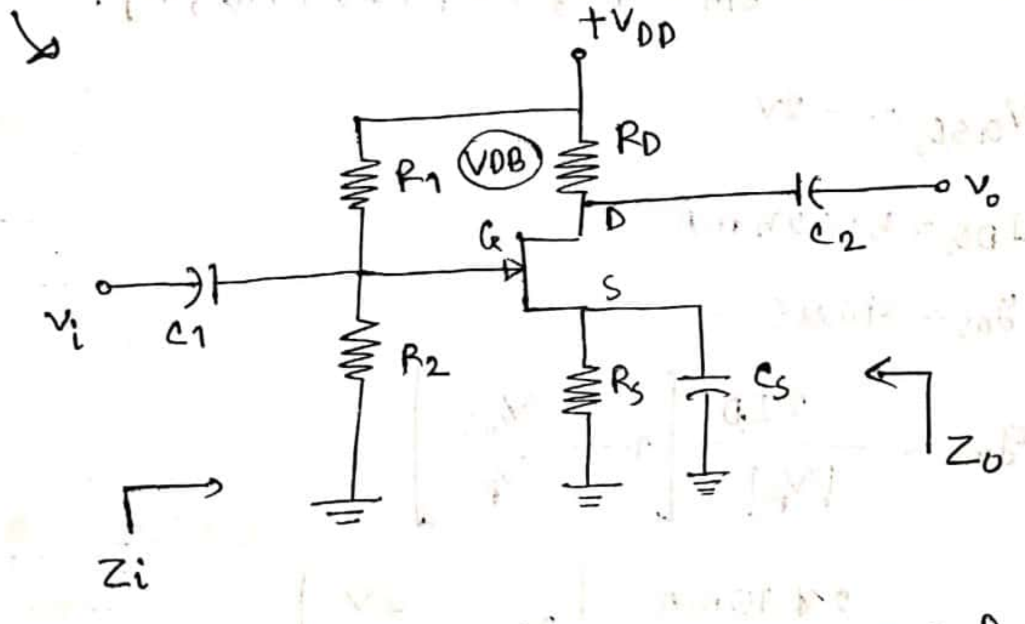
$$\therefore \frac{v_o}{v_i} = -g_m (r_d \parallel R_D)$$

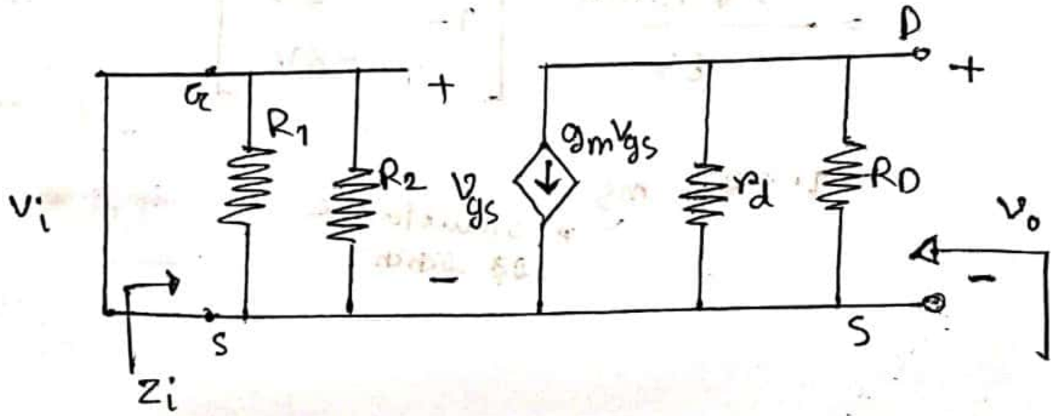
$$\therefore A_v = -g_m (r_d \parallel R_D)$$

$$r_d \geq 10 R_D$$

$$\therefore A_v = -g_m R_D$$

for Voltage Divider Bias





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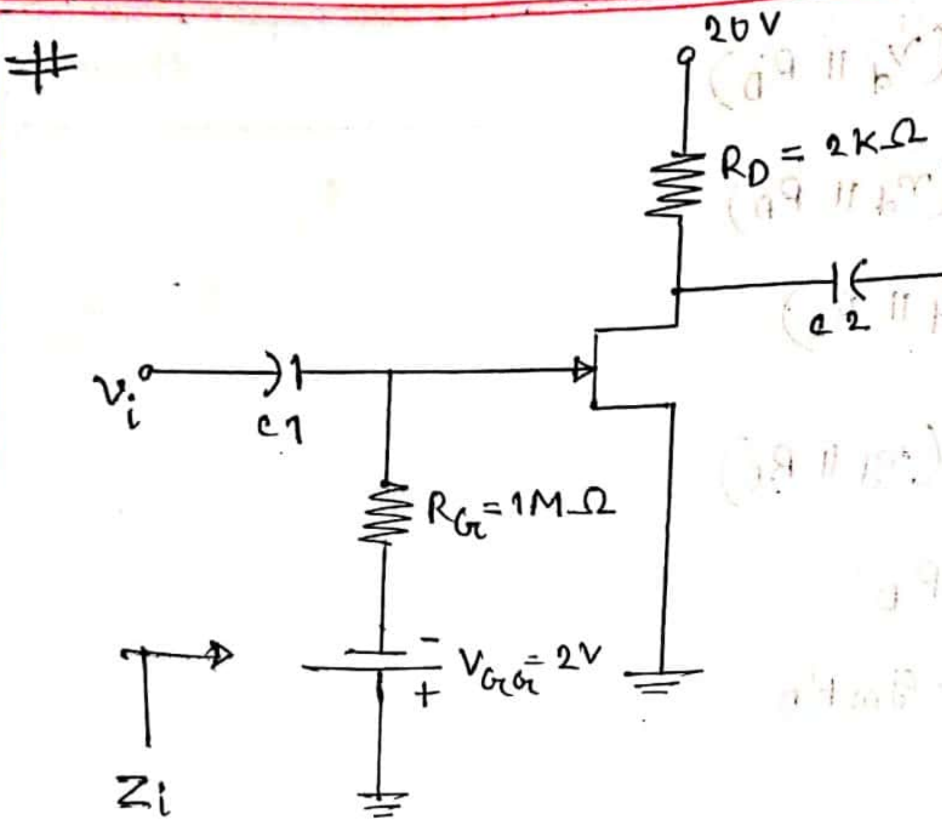

Determine g_m, g_{m_0}, Z_i, Z_o, A_v, r_d.

$V_{GSQ} = -2V$

$I_{DQ} = 5.625mA$

$y_{os} = 40\mu S$.

$$\therefore g_m = \frac{2I_{DSS}}{|V_P|}\left[1 - \frac{V_{GS}}{V_P}\right]$$

$$= \frac{2 * 10mA}{8V}\left[1 - \frac{-2V}{-8V}\right]$$

$$= 1.875 \text{ mS}$$

→ conductance এর একক

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$$g_{m_0} = \frac{2 I_{DSS}}{|V_P|}$$

$$Z_i = R_G = 1M\Omega$$

$$r_d = \frac{1}{y_{os}} = \frac{1}{40\mu S}$$

$$\boxed{Z_o = r_d \parallel R_D}$$

$$A_V = -g_m (r_d \parallel R_D),$$

* self bias (JFET, MOS)

VDB (JFET, D-MOS, E-MOS)

Feeb back Bias
↓
E-MOS

Q. pattern

part-1 :- Diode, MOSFET

part-2 :- BJT, JFET

* π model, T model, r_e model

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