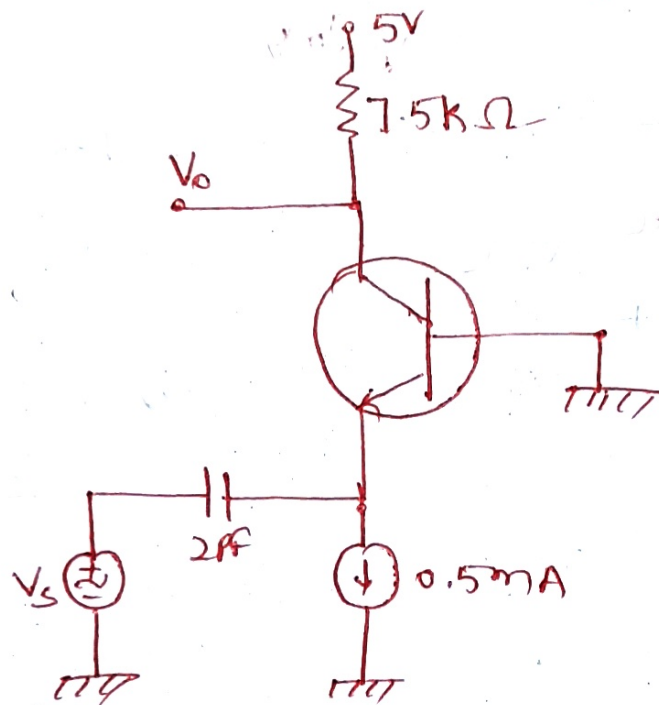


Ex :

Find voltage gain for amplifier design given



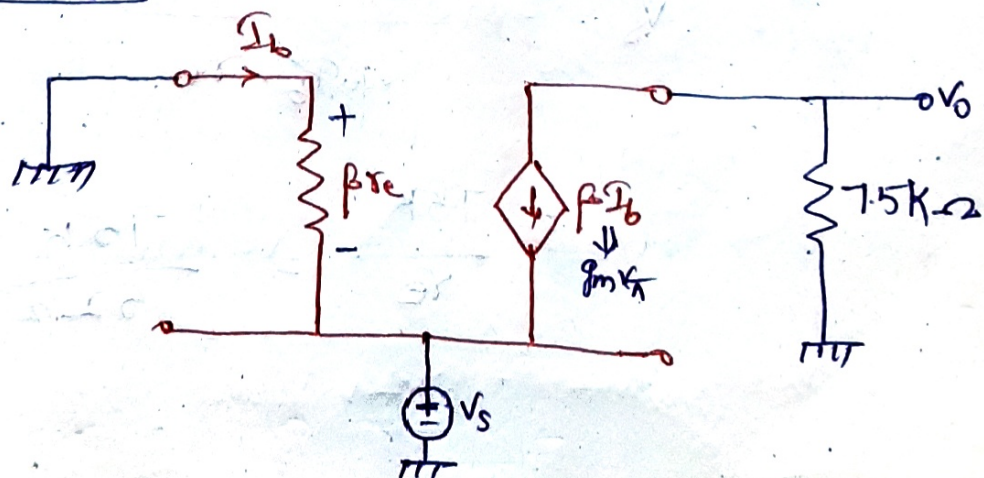
sol. — DC-Analysis

given $(I_e)_{DC} = 0.5mA$

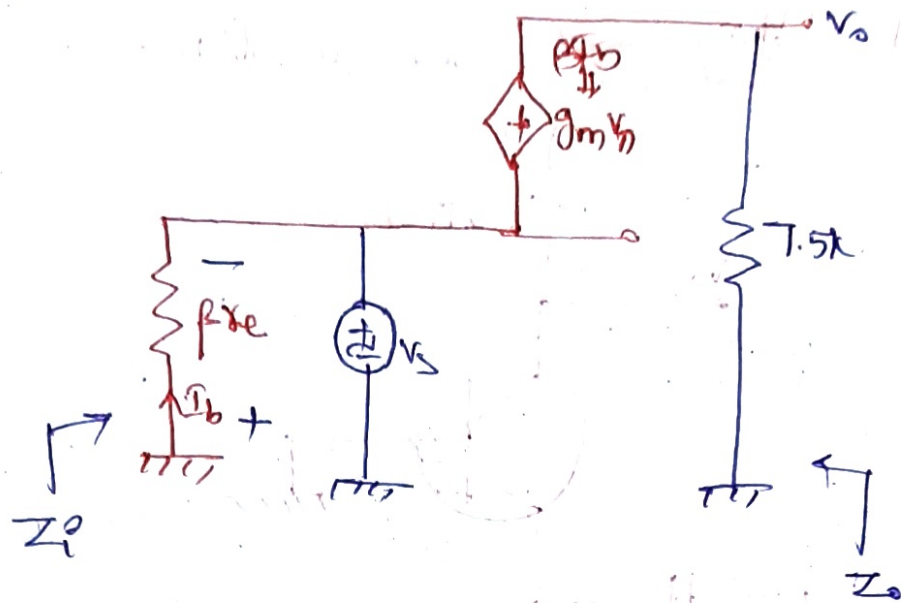
$$\therefore r_e = \frac{26mV}{0.5mA} = 52\Omega$$

$$\left[r_e = \frac{1}{g_m} = \frac{V_T}{(I_e)_{DC}} \approx \frac{V_T}{(I_C)_{DC}} \right]$$

AC-Analysis



(or) Re-draw the circuit:-



* Z_i :-

$$Z_i = \beta r_e$$

$$\begin{aligned} * V_s &= (-I_b) \cdot Z_i \\ &= -I_b \cdot \beta r_e \end{aligned}$$

$$* Z_o = 7.5k\Omega \text{ and.}$$

$$V_o = (-\beta I_b) \cdot 7.5k$$

$$\therefore A_V = \frac{V_o}{V_s} = \frac{(-\cancel{\beta I_b}) \cdot (7.5k)}{-\cancel{\beta I_b} \cdot r_e}$$

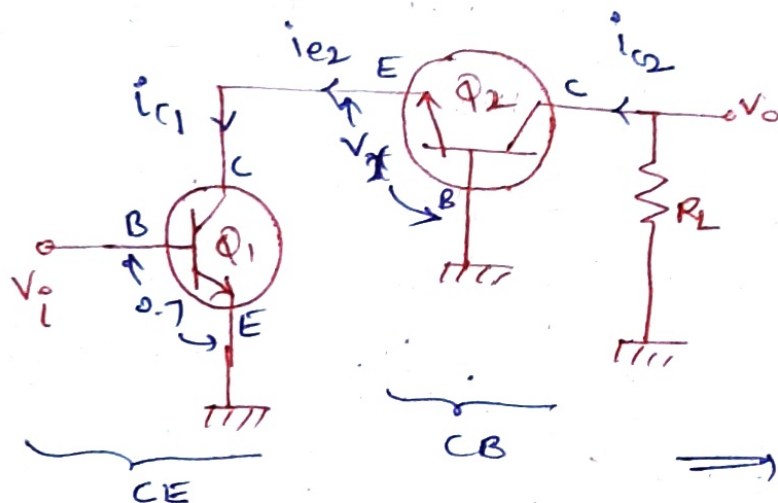
$$= \frac{7.5k}{r_e} = \frac{75k}{52\Omega} = \underline{\underline{144.23}}$$

* Ex :

In Cascaded multistage amplifier given

Calculate overall transconductance?

[Follow blue pen for solution]



eg:-

we have,

$$(g_m)_{Q_1} = \frac{i_{C1}}{V_{o1}}$$

$$(g_m)_{Q_2} = \frac{i_{C2}}{V_{x2}} \text{ and}$$

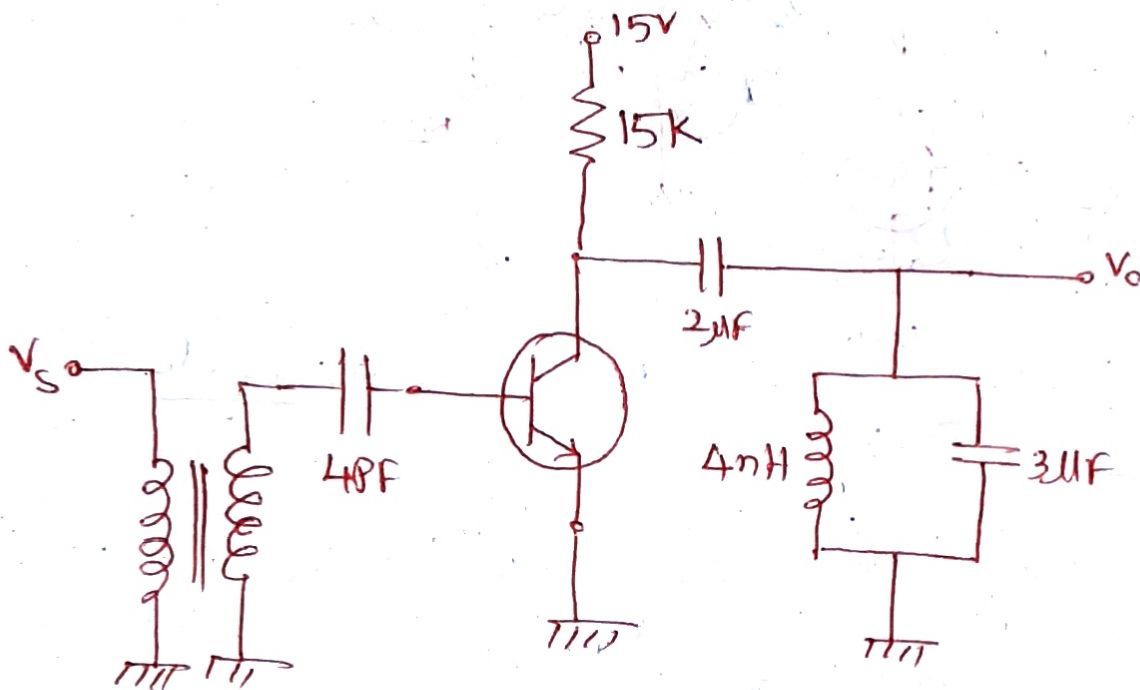
$$(g_m)_{\text{total}} = \frac{i_{C2}}{V_{o1}} \approx \frac{i_{E2}}{V_{o1}} \approx \frac{i_{C1}}{V_{o1}} = g_{m1}$$

$$\therefore (g_m)_{\text{total}} = g_{m1} = \frac{I_C}{V_T} = \frac{1 \text{ mA}}{26 \text{ mV}} = \frac{1}{26} //$$

[' $I_C = 1 \text{ mA}$ ' is taken due to 'amplifier'

word given in question which indicates it is linear for which ' 1 mA ' is assumed)

Ex: in a transformer coupled BJT amplifier design given, if 'lumped' base current is $20\mu A$ with 'DC' current Gain of '99'. Then find ' V_o '



Sol: DC - Analysis

$$\therefore V_o = 15 - (15k) \cdot I_c$$

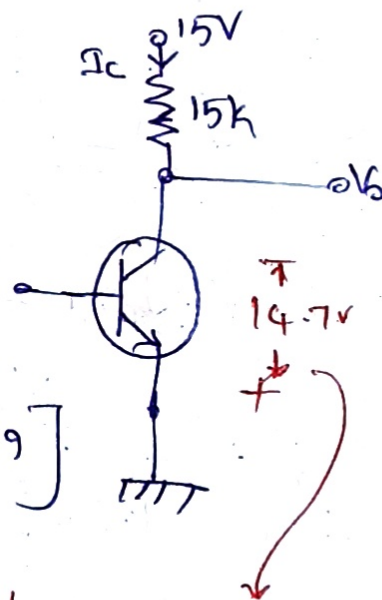
$$= 15 - (15k) \cdot (\beta I_b)$$

$$= 15 - (15 \times 10^3) [20 \times 10^{-6} \times 99]$$

$$V_o = -14.7V \quad \text{X (wrong)}$$

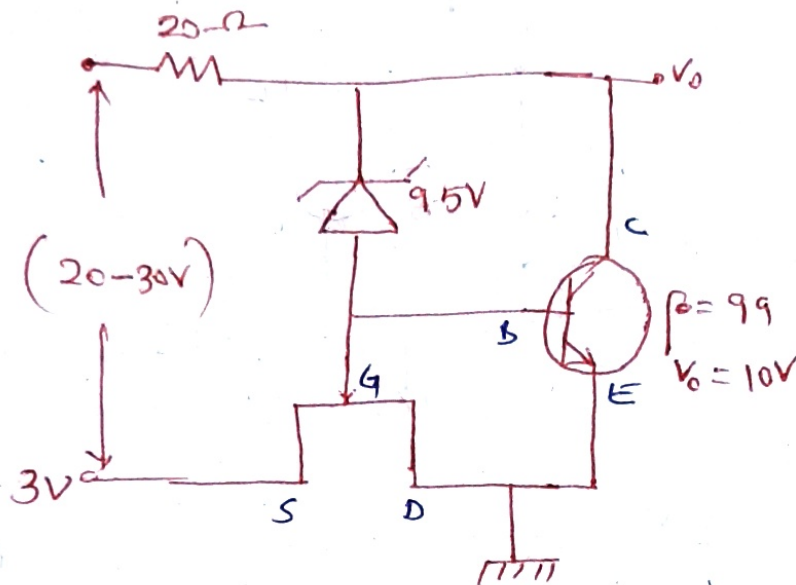
→ Inverting mode / Reverse mode

$$\therefore V_o = V_{sat} = \underline{\underline{0.2V}} \quad (\text{for ngn})$$



* Ex. —

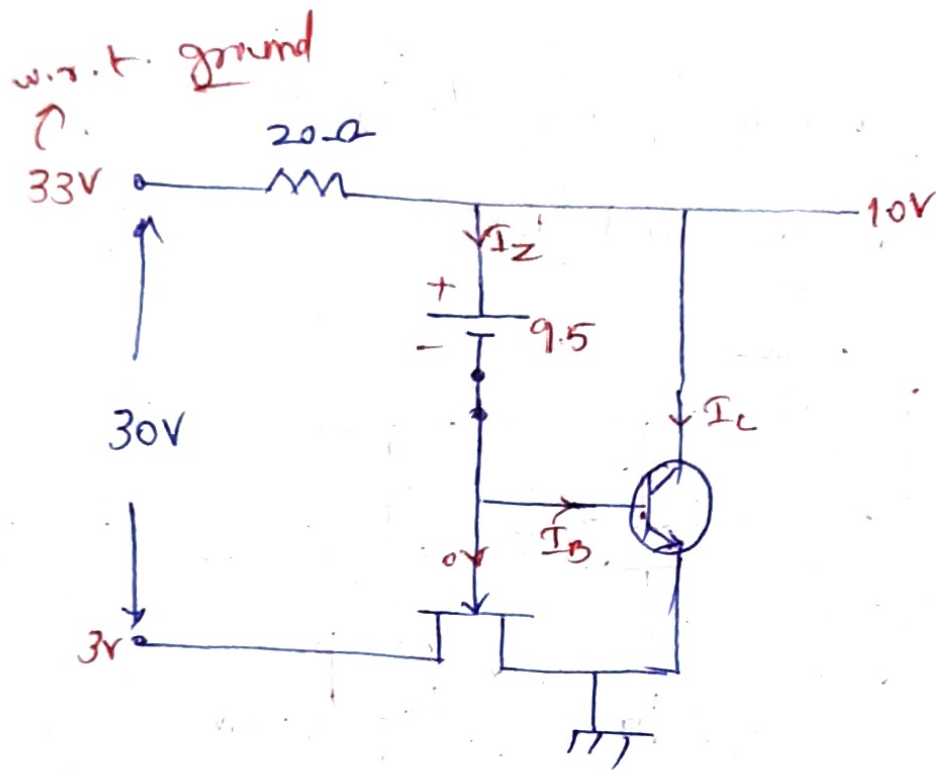
find maximum power dissipated across
zener diode and BJT



∴ the given diode is of avalanche
diode ($\because 9.5V > 6V$) . then
consider " $V_o = 30V$ "

Note : if a range of supply given then
take "Low" value for 'Zener' & "High"
value for avalanche.

Hence the circuit will become
as follows



* from above,

$$I_Z = I_B \quad (\because \text{no current enters into gate of FET})$$

* and,

$$I_Z = \text{maximum},$$

$$I_C = \text{minimum} \quad (\because \text{high collector resistance})$$

$$* P_T = V_o I_C = 10 \cdot I_C$$

$$* P_Z = V_Z I_Z = 9.5 I_Z \quad \text{But}$$

$$I_Z + I_C = \frac{33 - 10}{20} = 1.15$$

$$\therefore I_Z + \beta I_Z = 1.15 \quad (\because I_B = I_Z)$$

$$\therefore I_Z (1 + \beta) = 1.15$$

$$\therefore I_Z = \frac{1.15}{1 + 99} \quad (\because \beta = 99)$$

$$= 11.5 \text{ mA}$$

* Hence,

$$I_Z = 11.5 \text{ mA}$$

$$\therefore I_Z + I_C = 1.15$$

$$\therefore I_C = 1.15 - 11.5 \text{ mA} = \underline{\hspace{2cm}}$$

$$\therefore P_T = |10 \cdot I_C| = \underline{\hspace{2cm}}$$

$$P_Z = (9.5) \times I_Z = (9.5) (11.5 \text{ mA}) = \underline{\hspace{2cm}}$$

*
I

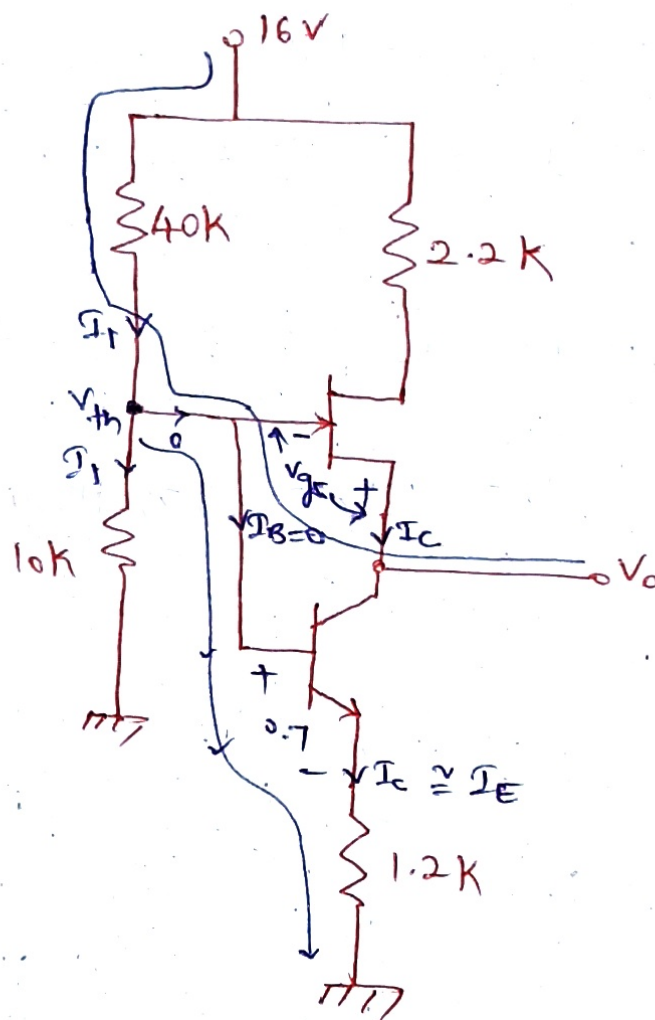
Ex: in the Cascoded design given below

if pinchoff voltage = $-6V$, maximum

drain current of FET = $6mA$ and

β for BJT = 100 , then find V_o if

$V_{BE} = 0.7V$, } follow blue pen for solution



* Since, $Z_o = (Z_o)_{BJT} + (Z_o)_{FET}$
 $= [Z_i]_{BJT} + \infty$

$Z_o \approx \infty$

$\therefore$ Total current flows through $10K$ to ground

apply KVL in the loop shown

$$16 = I_1 (40k) - V_{GS} + V_o \quad \text{--- (1)}$$

But given,

$$V_p = (V_{GS})_{off} = -6V \quad \text{and}$$

$$[I_D]_{max} = I_{DSS} = 6mA$$

$$\therefore \left[V_{GS} = (V_{GS})_{off} \left\{ 1 - \sqrt{\frac{I_D}{I_{DSS}}} \right\} \right] \quad \text{--- (2)}$$

and as it is a self bias circuit

$$V_{th} = V_{10k} = 16 \cdot \left\{ \frac{10k}{10k + 40k} \right\}$$

$$= \underline{3.2}$$

$$\therefore I_1 = \frac{V_{th}}{10k} = \underline{0.32mA} \quad \text{--- (3)}$$

and,

$$V_{th} = I_D R_B + V_{BE} + I_E R_E$$

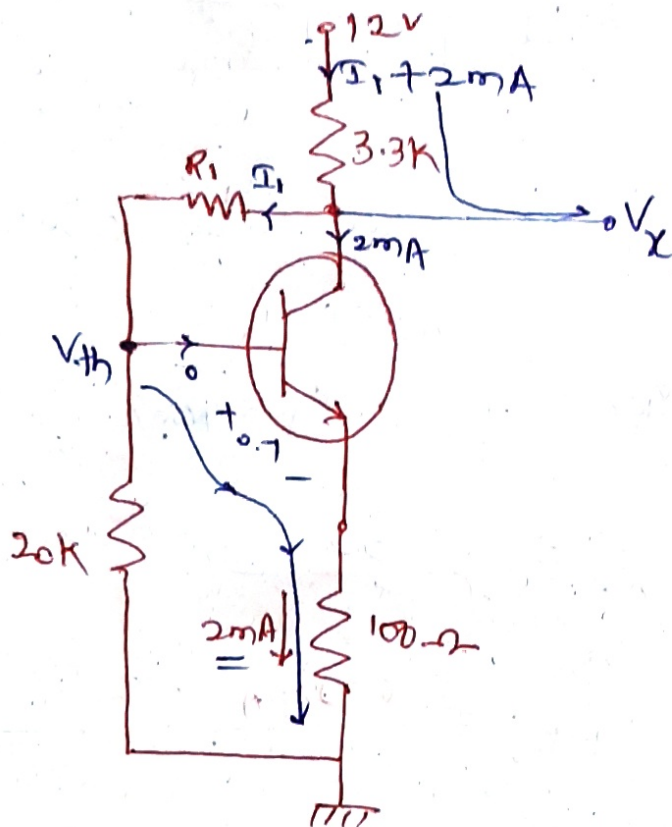
$$\underline{3.2} = 0 + 0.7 + I_D \cdot R_E$$

$$\therefore I_o = I_E = I_D = I_S = \underline{2.08mA} \quad \text{(4)}$$

substitute ②, ③ and ④ in ① to
get V_o .

$$\therefore V_o = \frac{(0.32 \text{ m})(40 \text{ k})}{\dots}$$

Ex: if ' α ' is default parameter, then
find " R_1 "



sol. circuit given is voltage divider/self bias
and $I_E = 2 \text{ mA}$ given ($> 1 \text{ mA}$) $\Rightarrow$ Saturation
Q-point

$$\therefore I_C \approx I_E$$

$$\therefore I_C = 2 \text{ mA}$$

$$\therefore V_{th} = 0.7 + 100(2mA)$$

$$= 0.9$$

$$\therefore I_1 = \frac{V_{th}}{20} = 0.045$$

and,

$$12 = 3.3k \{ I_1 + 2mA \} + V_x$$

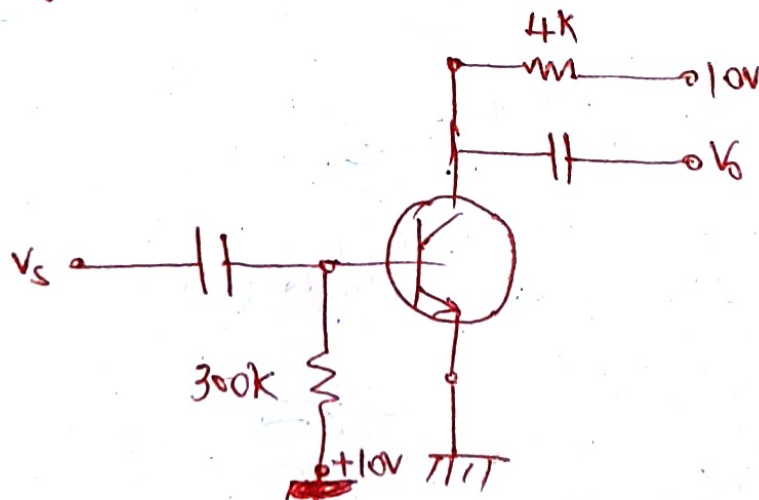
$$\therefore V_x = 12 - 3.3 \times 10^3 (0.045 + 2mA)$$

$$= \underline{\hspace{2cm}}$$

$$\therefore R_1 = \frac{V_x - V_{th}}{I_1}$$

$$= \underline{\hspace{2cm}}$$

Ex: find voltage Gain for amplifier design
given ($\beta = 100$)



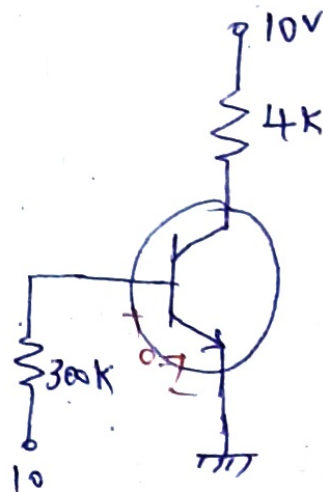
* DC - analysis

$$I_B = \frac{10 - 0.7}{300k}$$

$$= \underline{\hspace{2cm}}$$

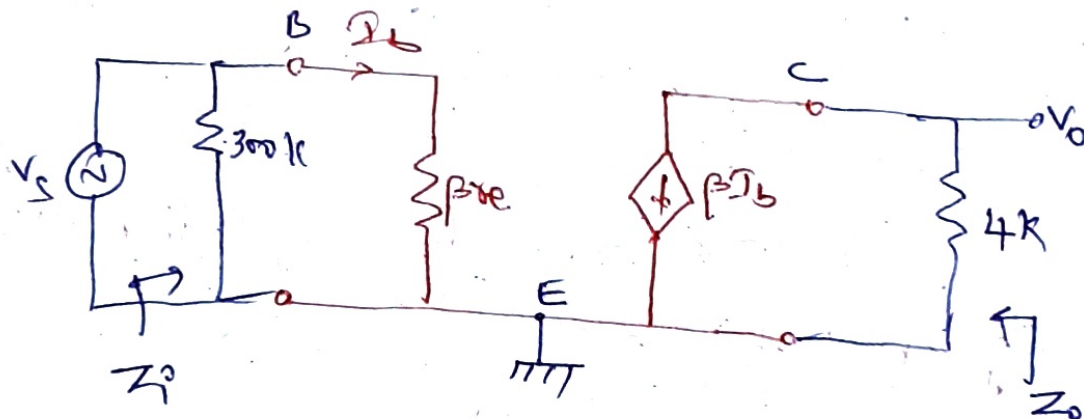
$$\therefore I_C = \beta I_B$$

$$= \underline{\hspace{2cm}}$$



$$\therefore r_e = \frac{V_T}{(I_C)_{DC}} = \frac{26mV}{(I_C)_Q} = \underline{\hspace{2cm}}$$

* AC - analysis :-



$$* Z_i = (300k) \parallel \beta r_e = \underline{\hspace{2cm}}$$

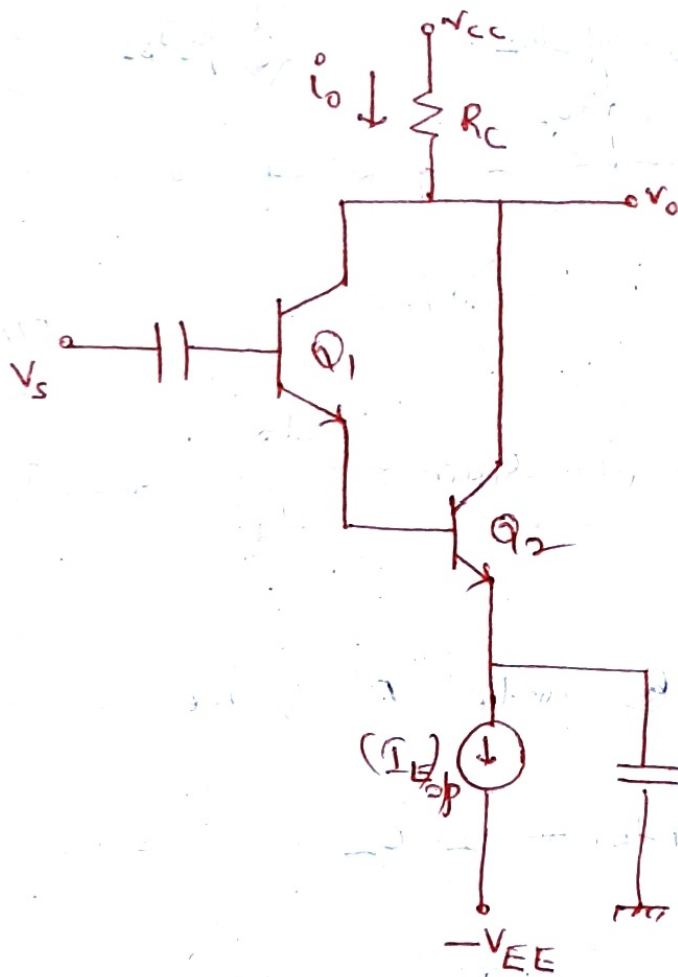
$$* Z_o = 4k \quad (\text{or}) \quad 4k \parallel r_o \approx 4k$$

$$* A_v = \frac{-\beta R_L Z_o}{Z_i} = \frac{-\beta Z_o}{Z_i} = \underline{\hspace{2cm}}$$

ex:

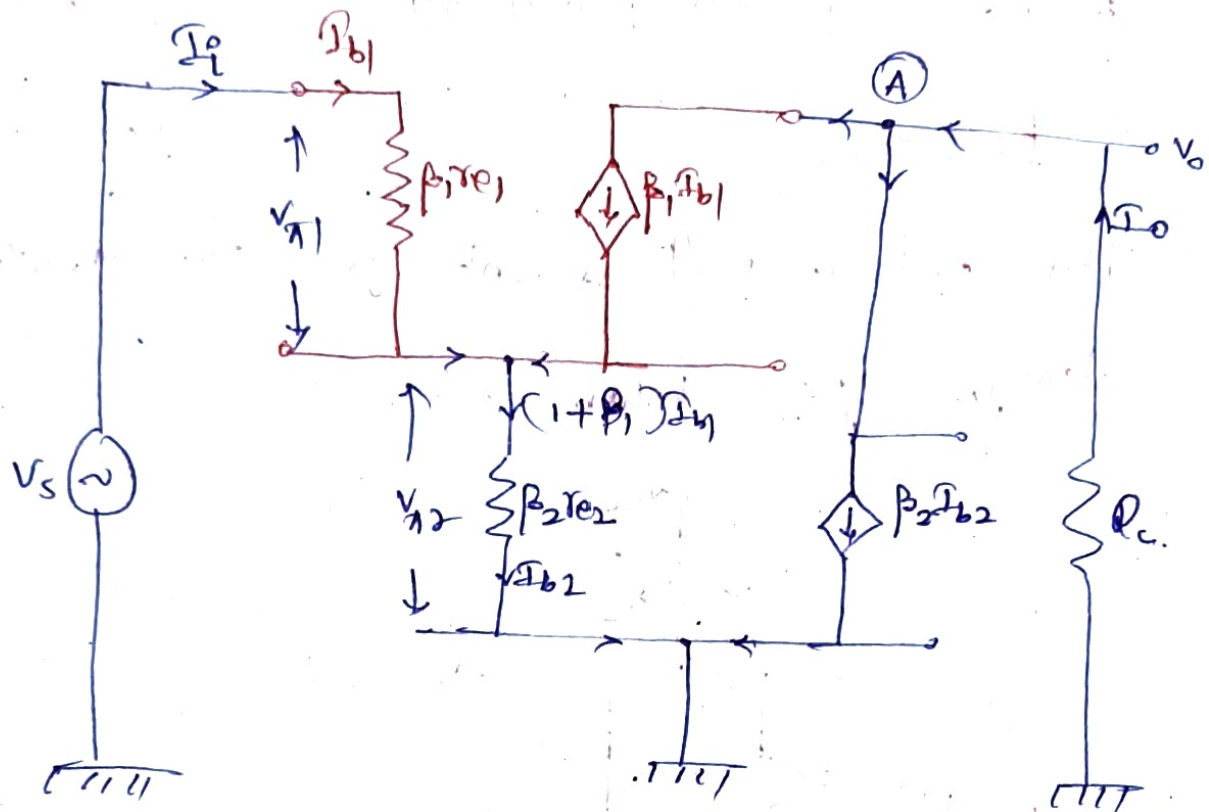
if $\beta_1, r_{\pi 1}$ are parameters of Q_1 and
 $\beta_2, r_{\pi 2}$ " " " " Q_2 .

Then find overall current gain for calculated
design given below



sol:

Use - AC analysis



$$\text{Overall Current Gain} = \frac{I_o}{I_i} \quad \text{--- (1)}$$

Now,

apply KCL @ node 'A', i.e.

$$I_o = \beta_1 I_{b1} + \beta_2 I_{b2} \quad \text{--- (2)}$$

$$\text{but } I_{b2} = (1 + \beta_1) I_{b1} \quad \text{--- (3)}$$

substitute (3) in (2)

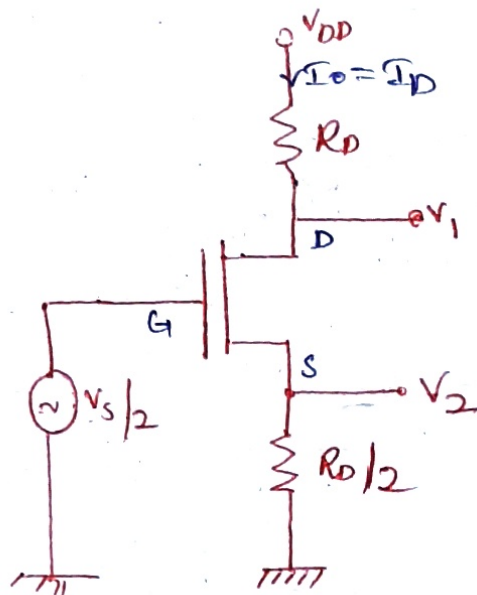
$$\therefore I_o = \beta_1 I_{b1} + \beta_2 (1 + \beta_1) I_{b1}$$

$$= I_{b1} \{ \beta_1 + \beta_2 + \beta_1 \beta_2 \}$$

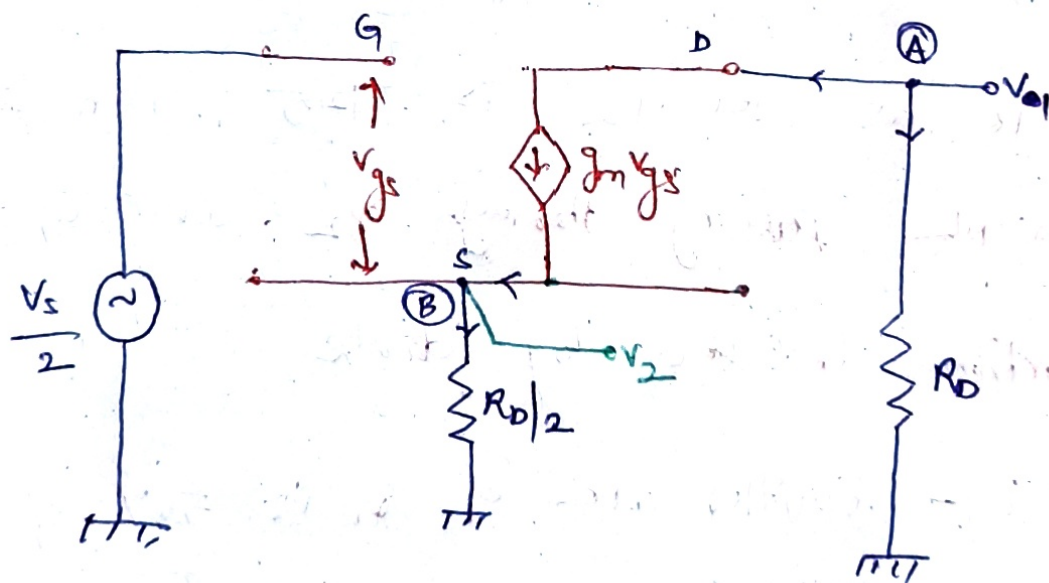
$$\therefore \frac{I_o}{I_{b1}} = \frac{I_o}{I_i} = A_I = \beta_1 + \beta_2 + \beta_1 \beta_2 //$$

$$(\because I_{b1} = I_i)$$

* Find the relation between V_1 and V_2 for following circuit.



Sol:-



@ node (A) ,

$$\frac{V_1}{R_D} = -g_m V_{gs} \quad \text{--- (1)}$$

@ node (B) ,

$$\frac{V_2}{(R_D/2)} = g_m V_{gs} \quad \text{--- (2)}$$

from (1) and (2)

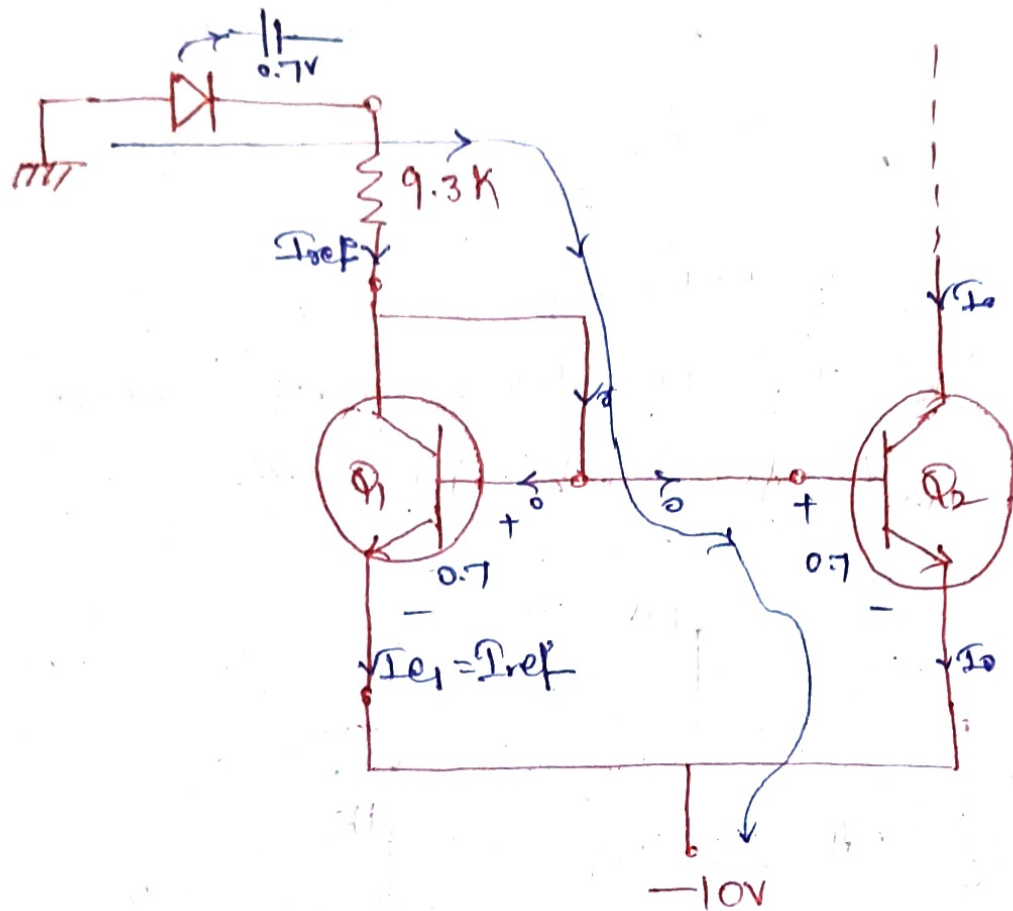
$$\frac{-V_1}{R_D} = \frac{V_2}{(R_D/2)}$$

$$\therefore \boxed{V_1 = -2V_2}$$

Ex:-

if DC current gain for Q_1 is '100'
where as for Q_2 is '125'. Then find
current passing through Q_2 when Q_1 & Q_2
function decided by diode

[let emitter area of Q_1 is 50% of
emitter area of Q_2]



sol: Q_1 and Q_2 will form current mirror but they are not identical as their areas are different

* since β is very large for both Q_1 and Q_2 ,

$$I_{B1} = I_{B2} \approx 0$$

and,

$$I_{e1} = \frac{I_{e2}}{2}$$

$$\therefore I_{ref} = \frac{1}{2}(I_o)$$

KVL

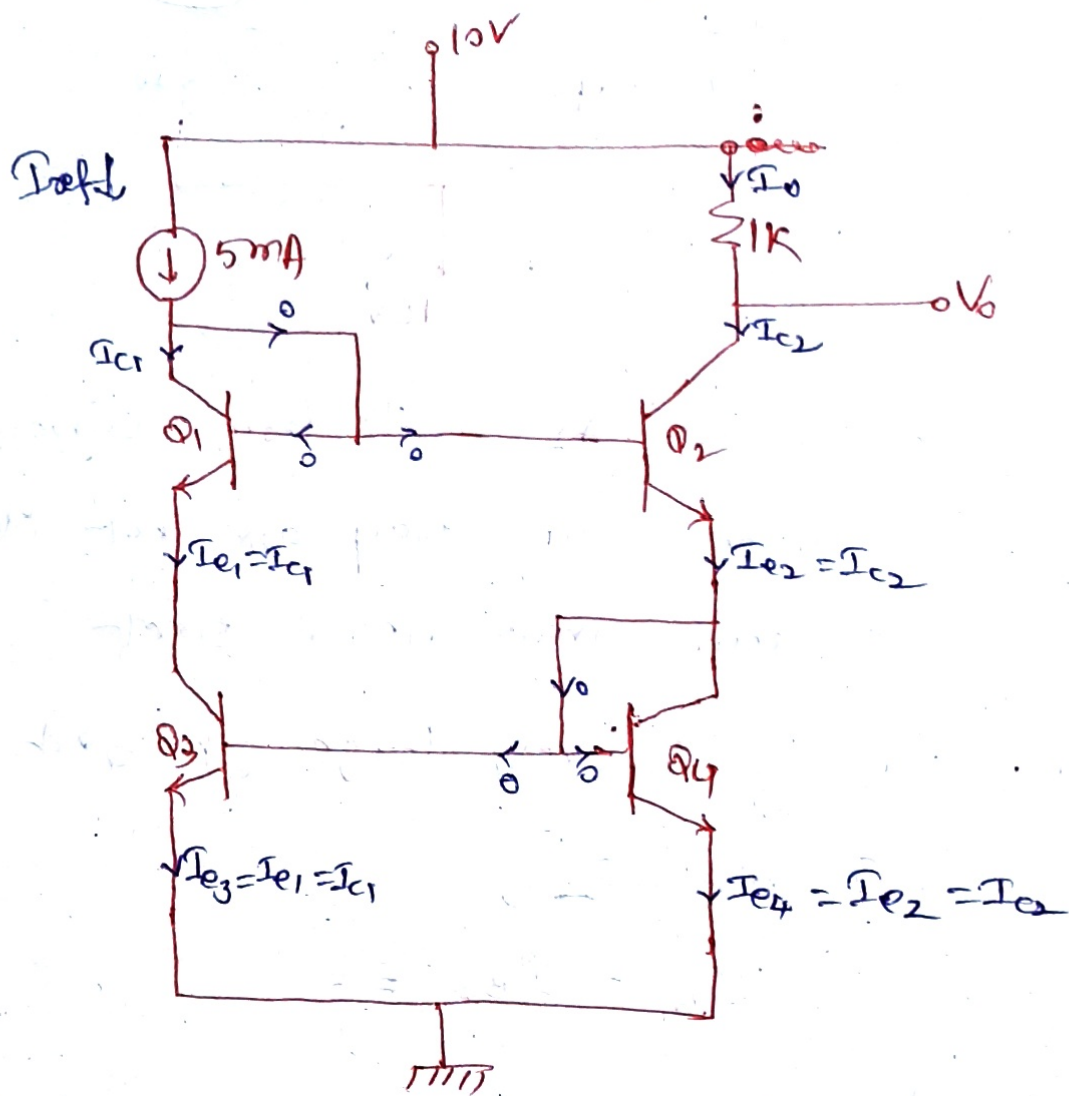
$$-0.7 - (9.3K)I_{ref} - 0.7 + 10 = 0$$

$$\therefore I_{ref} = \underline{0.92mA}$$

$$\therefore I_s = 2 I_{ref}$$

$$= 1.84 \text{ mA}$$

Ex: Find ' V_o ' for IC design given, where $\beta = 100$ for each transistor.



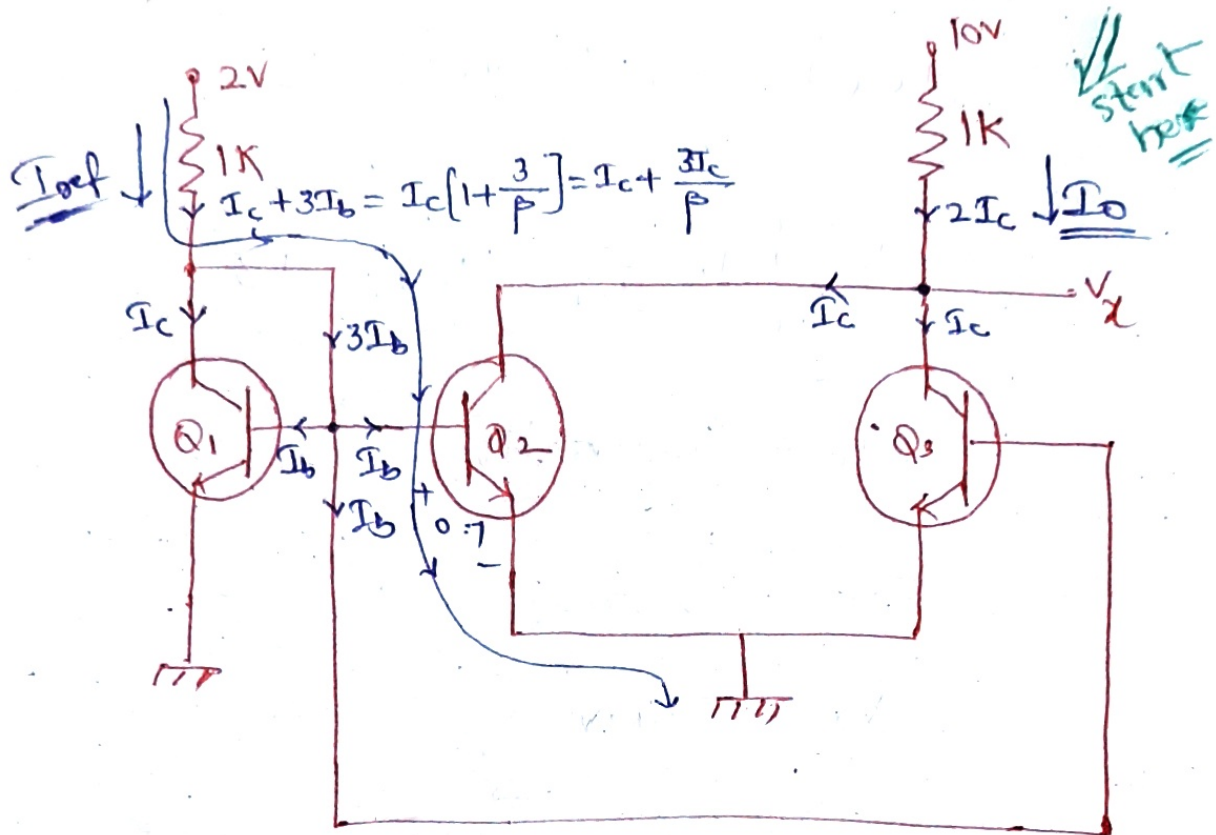
Sol:

$$I_{ref} = I_o \left[1 + \frac{2}{\beta} \right]$$

$$\approx I_o \quad (\because \beta \text{ is large})$$

$$\therefore V_o = 5 \text{ mA} \times 1 \text{ k} \\ = 5 \text{ V}$$

Ex: Find value of ' V_x ' where $\beta = 100$, such that ' Q_3 ' and ' Q_2 ' decides ' Q_1 '



∴ β is same for all transistors $\Rightarrow$ Identical

$Q_1 - Q_2 \Rightarrow$ Current mirror

$Q_1 - Q_3 \Rightarrow$ " "

and $Q_2 - Q_3 \Rightarrow$ differential Amplifier

But $V_x = 10 - (2I_C)(1K) \quad \text{--- (i)}$

$$I_{ref} = I_C + 3I_B$$

$$= I_C + 3\left(\frac{I_C}{\beta}\right)$$

$$I_{ref} = I_C \left(1 + \frac{3}{\beta}\right)$$

apply KVL @ loop shown

$$I_c \left(1 + \frac{3}{\beta} \right) (1k) + 0.7 = 2$$

$$\therefore I_c \left[1 + \frac{3}{100} \right] (1k) = 1.3$$

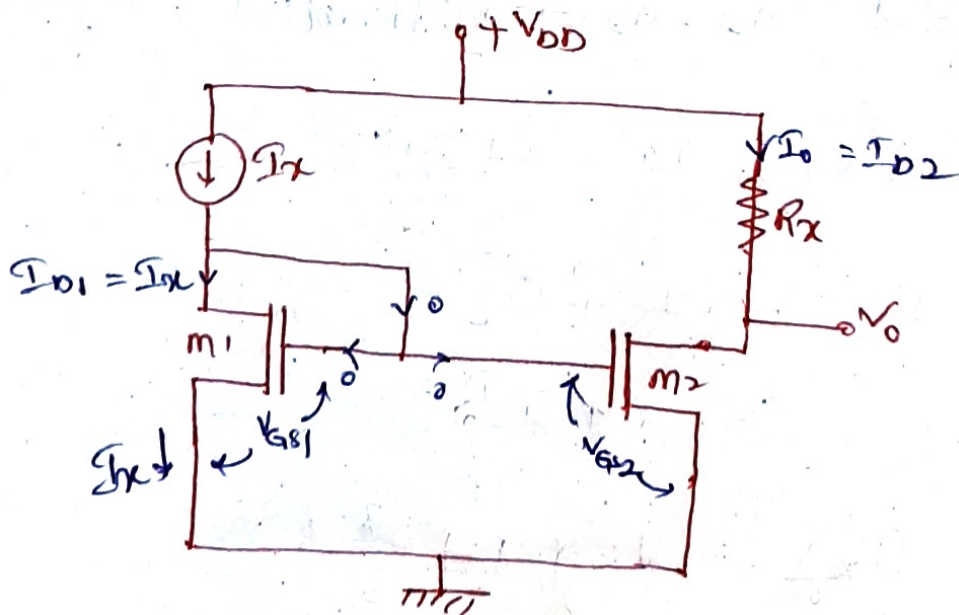
$$\therefore \boxed{I_c = 1.29 \text{ mA}}$$

$\therefore$ from (1),

$$\boxed{V_x = 7.40 \text{ V}}$$

Ex: For circuit - shown if m_2 is in order saturation then find the value of I_0 connected to I_x

[consider m_1 & m_2 are identical]



Sol:

$$V_{GS1} = V_{GS2}$$

$$\therefore I_{D1} = I_{D2} \approx I_{D2} = I_0 \quad (\because \text{Current mirror})$$

$$\therefore I_{D1} = I_0 = \frac{K}{2} (V_{GS} - V_T)^2$$

Ex:-

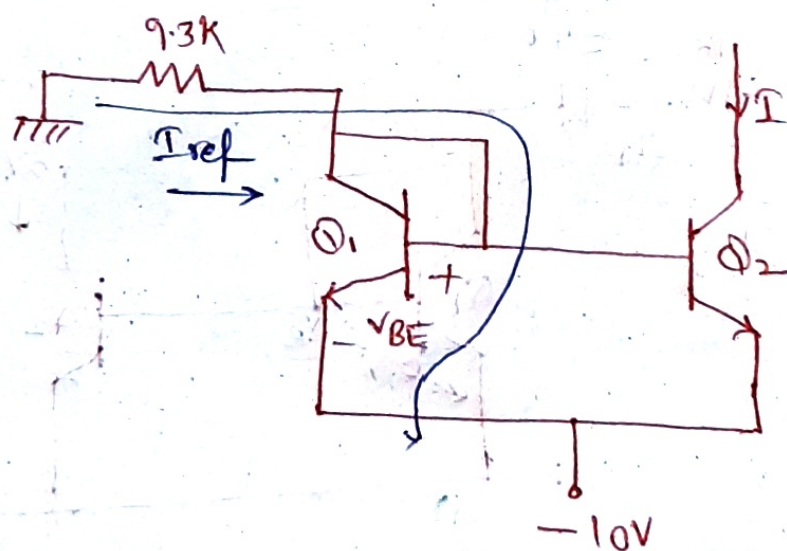
in circuit shown, transistors have large

β and $V_{BE} = 0.7$. Then calculate "I"

if

(a) both transistors are identical

(b) Emitter junction area of Q_1 is half that of Q_2



ref:- apply KVL @ loop shown.

$$(9.3K)I_{ref} + 0.7 - 10 = 0$$

$$\therefore I_{ref} = \frac{10 - 0.7}{9.3} \approx 1 \text{ mA}$$

Now

① if two transistors are identical then it will act as current mirror

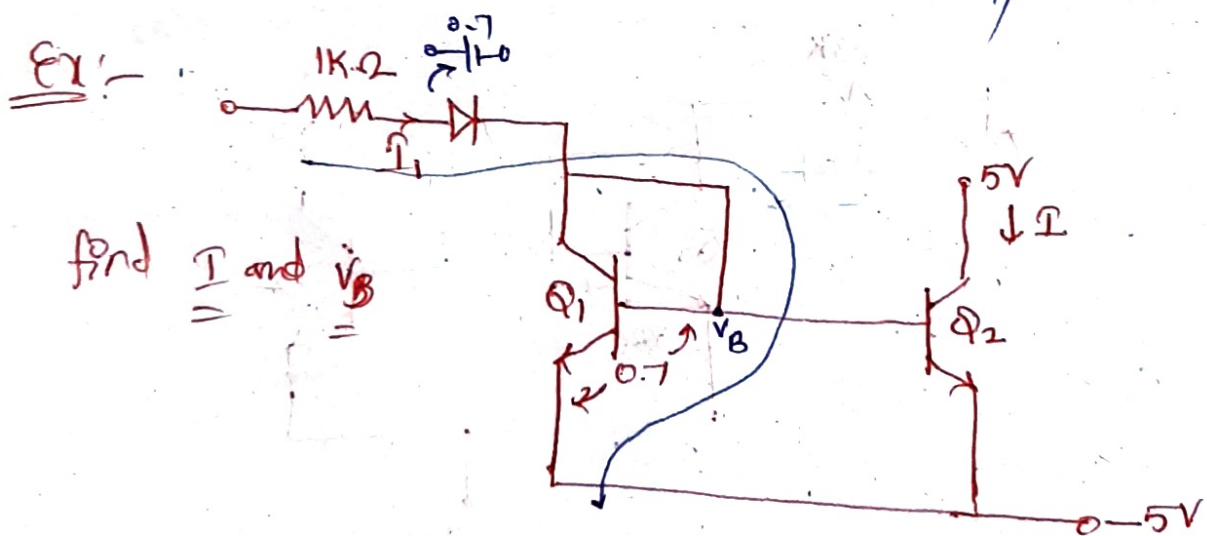
$$\therefore I_0 = I_{ref} = 1 \text{ mA}$$

② Given $(Area)_{Q_1} = \frac{(Area)_{Q_2}}{2}$ i.e.

$$(I_e)_{Q_1} = \frac{(I_e)_{Q_2}}{2}$$

i.e. $I_{ref} = \frac{I_0}{2}$

$$\therefore I_0 = 2 \cdot I_{ref} = 2 \text{ mA}$$



Sol:-

Given $V_{BE} = 0.7$

$$\therefore V_B - V_E = 0.7$$

$$\therefore V_B - (-5) = 0.7$$

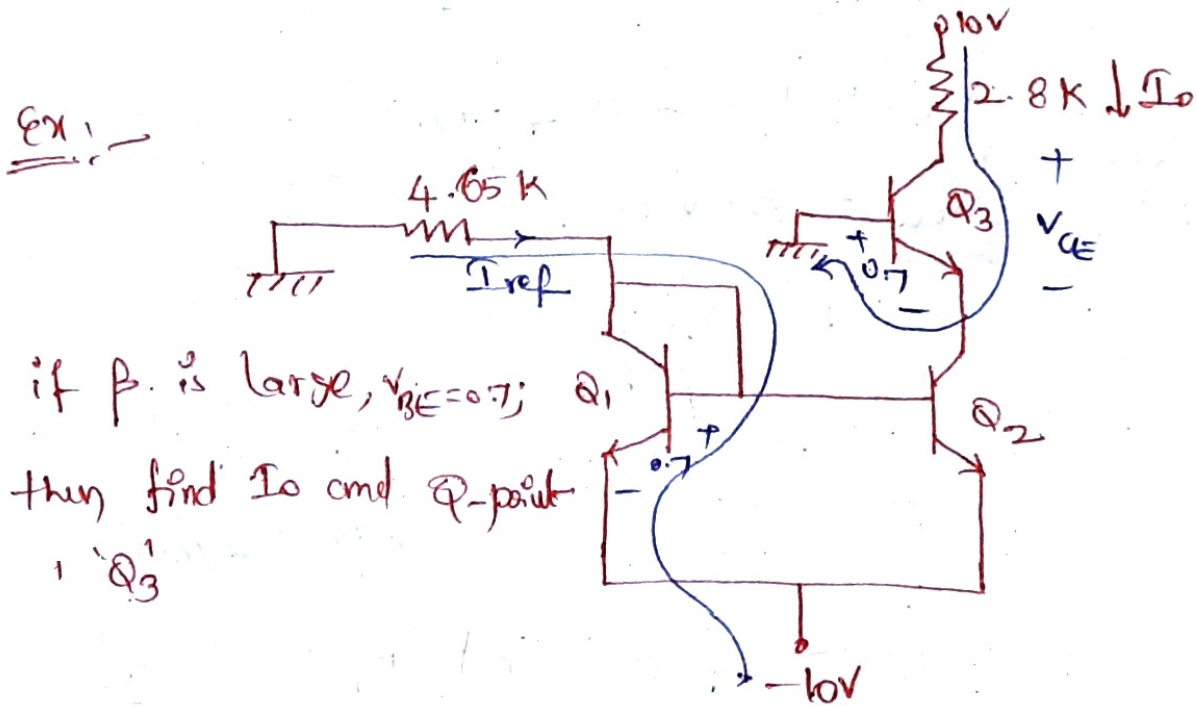
$$\therefore V_B = -4.3V //$$

apply KVL @ loop shown //

$$I_1(1k) + 0.7 + 0.7 - 5 = 0$$

$$\therefore I_1 \approx I_2 = 3.6mA //$$

Ex 1 -



if β is large, $V_{BE} = 0.7$; Q_1
then find I_O and Q-point
of Q_3

Sol. -

KVL @ loop shown

$$(4.65k) I_{ref} + 0.7 - 10 = 0$$

$$\therefore I_{ref} = \frac{10 - 0.7}{4.65} = 2mA //$$

$$\therefore I_O \approx I_{ref} = 2mA$$

($\therefore$ current mirror)

Now for Q_3

$$I_D = I_C = I_E = 2 \text{ mA}$$

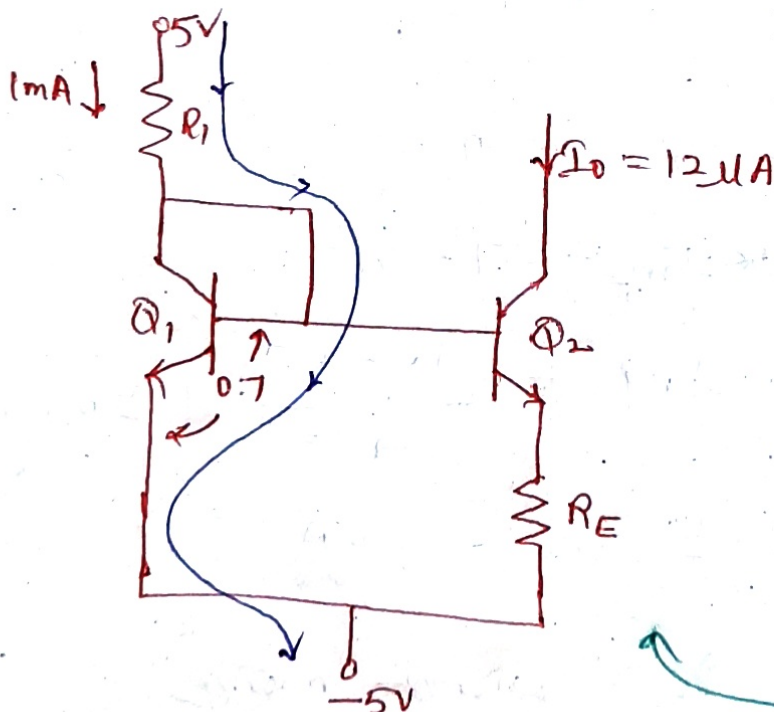
$$\therefore 10 = (2.8k) I_C + V_{CE} - V_{BE}$$

$$\therefore V_{CE} = 10 - (2.8k) 2 + 0.7$$

$$\boxed{V_{CE} = 5.1 \text{ V}}$$

$$\therefore Q_3 \text{ operating point} = (V_{CE}, I_C)$$
$$= (5.1 \text{ V}, 2 \text{ mA})$$

Ex: for circuit shown find ' R_1 ' and ' R_E '



Wilson
Current
mirror

apply KVL @ loop shown, i.e.,

$$5 = (1\text{m})R_1 + 0.7 - 5$$

$$\therefore R_1 = \frac{10 - 0.7}{1\text{mA}} \approx 9.3\text{K}\Omega$$

Now:

$$R_E = \frac{V_T \cdot \ln\left(\frac{I_{\text{ref}}}{I_0}\right)}{I_0}$$

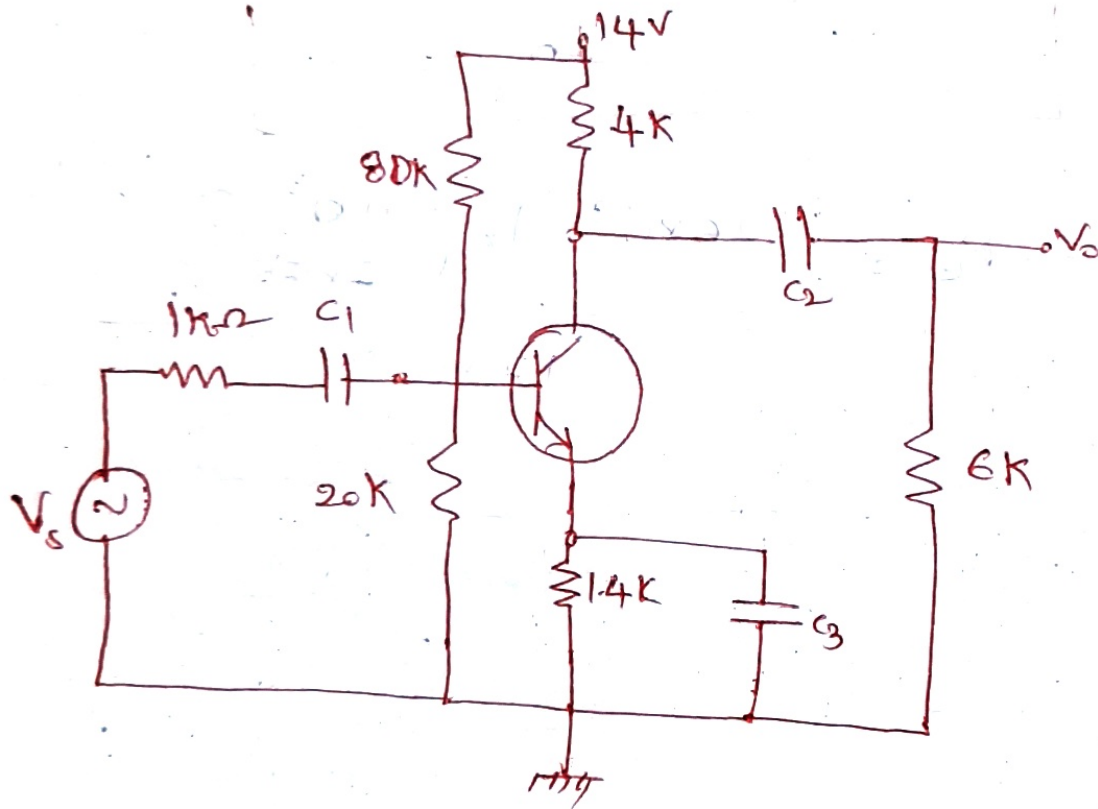
$$\therefore R_E = \frac{26 \times 10^{-3} \cdot \ln\left(\frac{1 \times 10^{-3}}{12 \times 10^{-6}}\right)}{12 \times 10^{-6}}$$

$$= \underline{\hspace{2cm}}$$

Ex:- In an amplifier design shown

$\beta = 100$, $V_{BE} = 0.7$ and $V_A = \infty$, then calculate

- (i) DC-operating point
- (ii) π - parameters
- (iii) voltage Gain $\left(\frac{V_o}{V_s}\right)$
- (iv) a/p & o/p impedances

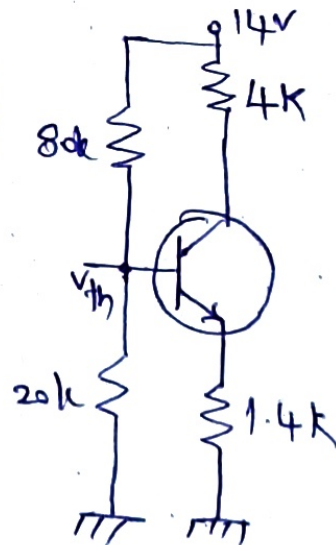


sol) DC-analysis [self-Bias]

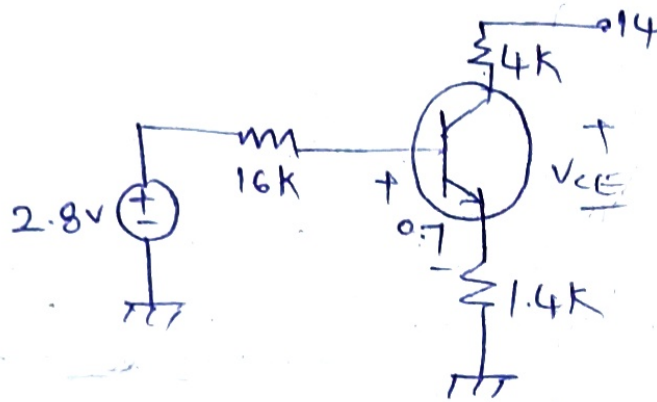
$$V_{th} = 14 \left(\frac{20k}{20k + 80k} \right)$$

$$V_{th} = 2.8V$$

$$R_B = R_{th} = 80k \parallel 20k = 16k,$$



hence circuit will become



Now : apply KVL @ i/p loop

$$2.8 = (16k)I_B + 0.7 + \left[(1+\beta)I_B\right](1.4k)$$

$$\therefore I_B = \frac{2.8 - 0.7}{(16 + 101 \times 1.4)k} = 0.0133mA$$

$$\therefore I_C = \beta I_B = 1.334mA$$

$$\therefore I_E = (1+\beta)I_B = 1.347mA$$

apply KVL @ o/p loop, i.e.

$$V_{CE} = 14 - 4k(1.334mA) - 1.4(1.347mA)$$

$$\therefore V_{CE} = 6.7782V$$

$$\therefore Q \text{ point} = (V_{CE}, I_C)$$

$$= (6.77V, 1.334mA)$$

① π -parameters

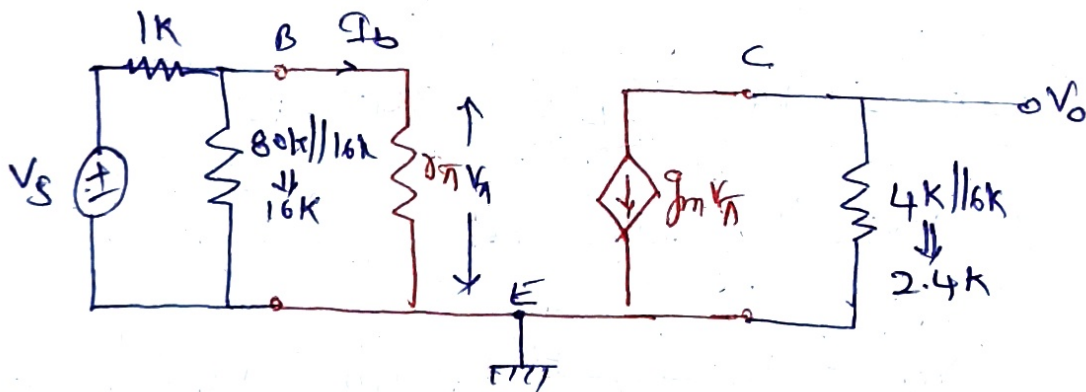
$$* \quad g_m = \frac{I_C}{V_T}$$

$$= \frac{1.334 \text{ m}}{26 \text{ mV}} = 0.0513 \text{ S} = 51.3 \mu\text{S}$$

$$* \quad \beta = g_m \times r_\pi$$

$$\therefore r_\pi = \frac{\beta}{g_m} = 1.949 \text{ k}\Omega$$

② AC - Analysis



$$* \quad V_o = (-g_m V_\pi) \cdot (2.4 \text{ k})$$

$$\therefore \frac{V_o}{V_\pi} = -(51.3 \text{ m}) \cdot (2.4 \text{ k})$$

$$\frac{V_o}{V_\pi} = -123.12 \quad \text{--- (1)}$$

⑫ * i/p impedance (Z_i)

$$\boxed{Z_i = 16k \parallel r_{\pi}} = 1.738k \Omega$$

* o/p impedance (Z_o)

$$\boxed{Z_o = 4k \parallel 6k} = 2.4k \parallel$$

* voltage Gain (A_v)

$$\boxed{A_v = \frac{V_o}{V_i} = \frac{V_o}{V_{\pi}} \cdot \frac{V_{\pi}}{V_i}}$$

$$\text{But } V_{\pi} = V_i \left\{ \frac{Z_i}{Z_i + R_s} \right\}$$

$$\therefore \frac{V_{\pi}}{V_i} = \frac{1.738}{1.738 + 1k} = 0.6398$$

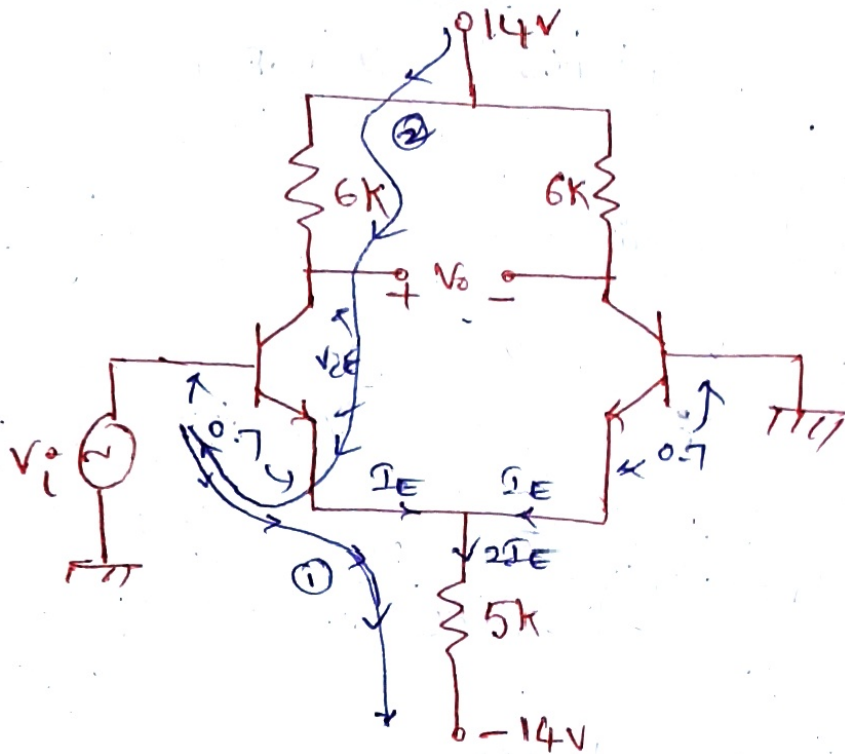
$$\begin{aligned} \therefore A_v &= -123.12 \times 0.6347 \\ &= -78.14 \parallel \end{aligned}$$

Ex: In transistor design shown, $\beta = 100$,

$V_{BE} = 0.7V$ then find

(i) Operating points of Q_1 and Q_2

(ii) voltage gain $\left(\frac{V_o}{V_i}\right)$ if $V_T = 26mV$



sol - (i) DC analysis :- make all AC sources

in-active.

[KVL @ loop ①, remove V_i]

$$\therefore 0.7 + 5(2I_E) - 14 = 0$$

$$\therefore I_E = \frac{14 - 0.7}{10} = 1.33 \text{ mA}$$

$$\therefore I_C = \alpha I_E = \left(\frac{100}{100+1}\right) (1.33)$$

$$I_C = 1.316 \text{ mA}$$

Now

apply KVL

$$14 = 6I_C + V_{CE} - 0.7$$

$$\therefore V_{CE} = 14 + 0.7 - (6) \cdot (1.316)$$

$$V_{CE} = 6.8V$$

$$\therefore Q - \text{point} = (V_{CE}, I_C) \\ = (6.8V, 1.316mA)$$

(2)

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

$$= \frac{1.316m}{26m} = 50.6mV$$

hence, for given circuit—

V_o	$= A_d = -g_m \cdot R_C$
$V_1 - V_2$	

$$= (-50.6m) \times (6k)$$

$$A_d = -303.69$$

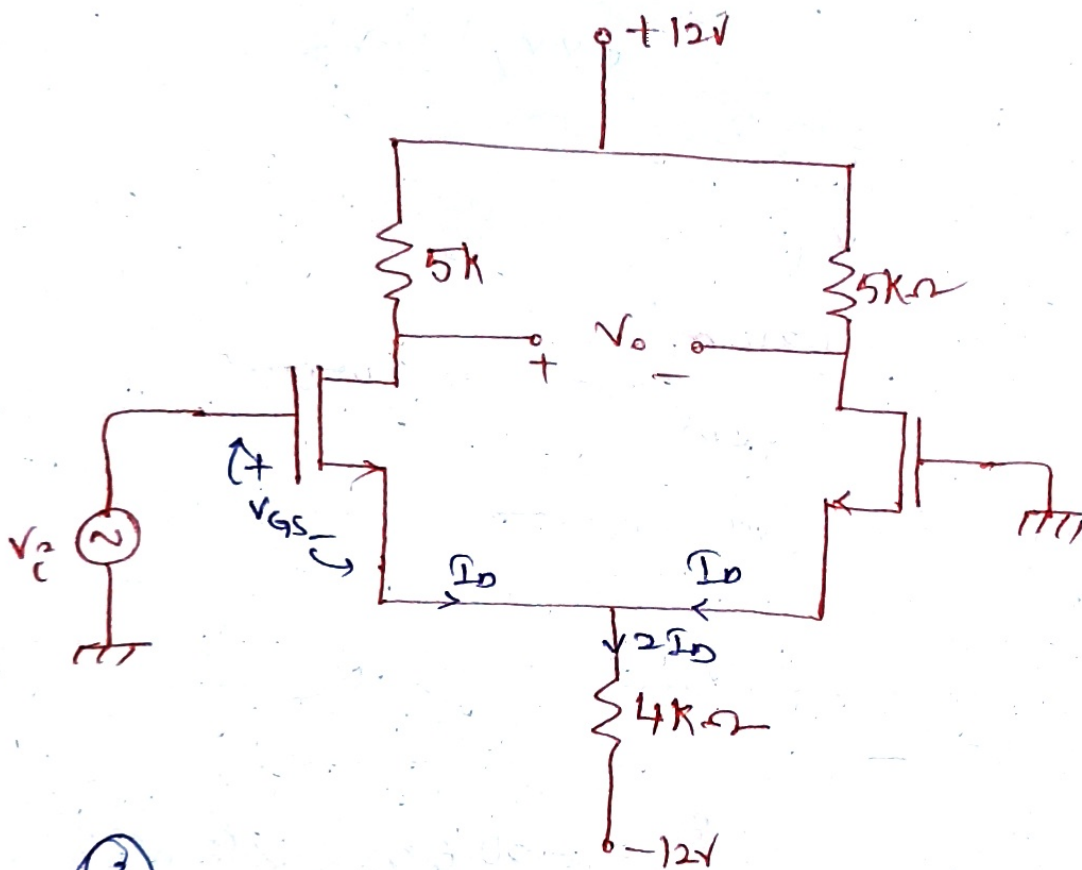
Ex:- in an amplifier design shown,

$$\mu_n C_{ox} \left(\frac{W}{L} \right) = 2 \text{ mA/V}^2, \quad V_T = 1 \text{ V} \quad \text{then}$$

Calculate.

(i) DC - drain current

(ii) voltage gain $\left(\frac{V_o}{V_i} \right)_{||}$



solⁿ (i) DC-analysis

$$V_{GS} + (2I_D)(4k) - 12 = 0$$

$$\therefore V_{GS} = 12 - 8I_{DS} \quad \text{--- (1)}$$

$$\text{But } I_{DS} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L} \right) (V_{GS} - V_T)^2$$

$$\therefore I_{DS} = \frac{2mA}{2} \left\{ 12 - 8I_{DS} - 1 \right\}^2$$

$$\text{But, } I_{DS} = \left(\frac{12 - V_{GS}}{8} \right) \quad (\because \textcircled{1})$$

$$\therefore \left(\frac{12 - V_{GS}}{8} \right) = \frac{2mA}{2} (V_{GS} - 1)^2$$

$$\begin{aligned} \therefore 12 - V_{GS} &= 8(V_{GS}^2 - 2V_{GS} + 1) \\ &= 8V_{GS}^2 - 16V_{GS} + 8 \end{aligned}$$

$$\therefore 8V_{GS}^2 - 15V_{GS} - 4 = 0$$

$$\therefore V_{GS} = \begin{cases} 2.11V \quad \checkmark \text{ valid} \\ -0.236V \quad \times \text{ in-valid} \end{cases}$$

$$\therefore I_{DS} = (1m) \cdot (2.11 - 1)^2$$

$$\boxed{I_{DS} = 1.2321mA}$$

(ii) voltage gain:-

$$\boxed{\frac{V_o}{V_1 - V_2} = \frac{V_{o1}}{-V_{o2}} = \frac{-g_m R_o}{2}}$$

→ Differential half circuit

$$\therefore g_m = \sqrt{2 \mu_n C_{ox} \left(\frac{W}{L} \right) \cdot I_{DQ}}$$

$$= \sqrt{2 \times 2 \times 1.236}$$

$$= 2.223 \text{ mV}$$

$$\therefore \frac{V_o}{V_1 - V_2} = -g_m R_D = (-2.223 \text{ m}) \times (5 \text{ k})$$

$$A_d = -11.1186$$