AMPLIFIERS NOTEBOOK

(ELECTRONICS II)

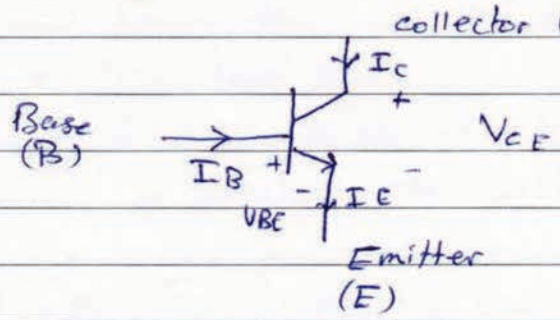
DR . RA'ED AL-ZO'BIE
SPRING - 2014

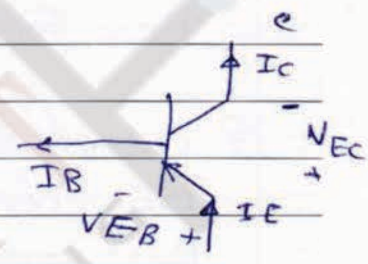
BY . HASAN ABU AL-RUZ

POWER UNIT
ELECTRICAL ENGINEERING

* Transistor:

→ BJT

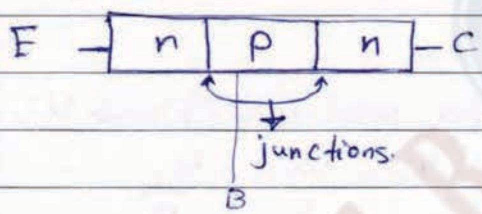




(pnp)

(npn)

$I_E = I_C + I_B$; $I_C = \beta I_B$; $I_E = (1+\beta)\, I_B$; $I_E = \frac{1}{\alpha} I_C$ → $\frac{1+\beta}{\beta}$



* Modes of operations:- for BJT

① forward active mode (or active region) [Default Mode]

BE: Forward _ biased

BC: Reverse _ biased

BJT is used as amplifier

$V_{BE} = V_{BE(on)} = 0.7V$; $V_{CE} > V_{CE(sat.)} = 0.2$ or $0.3V$

② Saturation mode

BE: Forward

Bc: Forward

BJT is used as a switch.

$V_{BE} = 0.7V$

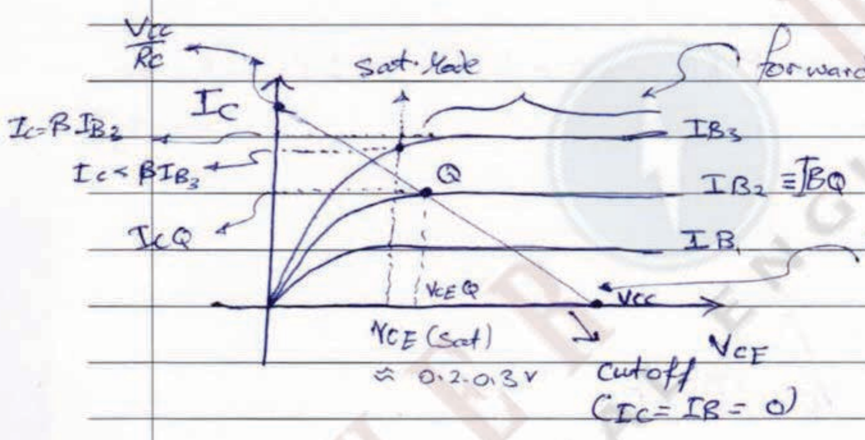
$V_{CE} = V_{CE(sat)}$

$I_C < \beta I_B$

No.

③ inverse - active mode.
BE : reverse - biased.
Bc : Forward - biased.

④ Cut off Mode:
BE : reverse - biased
Bc : reverse - biased.
$I_C = I_B = I_E$ = Zero.



Dc load line ($I_C \propto V_{CE}$)

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

we control Dc load line by changing Rc or RB; raising the RB will move the Q poin into the forward active mode.

* V_T : thermal voltage (V_T = 0.026 v at room temp. 300k)

* $50 < \beta < 300$

* $\alpha \approx 0.999 \approx 1$

* I_S: reverse - bias Saturation Current

$\approx 10^{-15} - 10^{-12}$ A

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

No.

* Dc analysis of BJT: we will study the following:

⇒ Finding the mode of Operation.
⇒ Dc load line.
⇒ Finding the relation between V_o and V_I
⇒ Dc analysis of multi stage circuit.

* steps for finding the mode of operation:-
1) assume forward active mode:-
⇒ $V_{BE} = 0.7\ V$
⇒ $I_C = \beta I_B$

2) check your assumption.
⇒ $I_B > 0$ & $V_{CE} > V_{CE(sat)}$.

if yes: stop, otherwise:-

3) assume saturation:-
⇒ $V_{BE} = 0.7\ V$
⇒ $V_{CE} = V_{CE(sat.)}$
⇒ $I_C \neq \beta I_B$
⇒ check your assumption in 3
⇒ $I_C < \beta I_B$
if yes, stop; otherwise:-

5 cut off Mode.

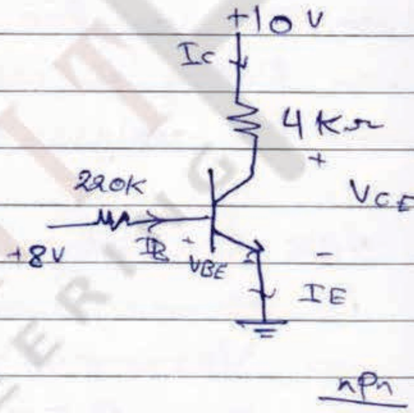
No.

lecture 2:

Ex: consider the following circuit:

Given $\beta = 100$, $V_{BE(on)} = 0.7$ v

$V_{CE(sat)} = 0.2$ V



[1] Find the mode of operation.

[2] Find the Q point values.

[3] Find the Draw the Dc load line.

@ * assume forward active mode.

$V_{BE} = 0.7$

$I_C = \beta I_B$

⇒ Input loop : $-8 + 220\,I_B + 0.7 = \text{Zero}$

$I_B = \frac{8-0.7}{220} = 33.2 * 10^{-3} * 10^{-3} = 33.2\,\mu A \overset{?}{>} 0$ yes

$I_C = \beta I_B = 3.32\,mA$

⇒ output Loop:-

$-10 + 4 \times 3.32 + V_{CE} = 0$

$V_{CE} = 10 - 4 \times 3.22 = 3.28V \overset{?}{>} V_{CE(sat)}$, NO

so it is wrong assumption.

⇒ assume Saturation mode:-

$V_{BE} = 0.7$, $V_{CE} = V_{CE(Sat)} = 0.2$ V

⇒ input loop

$I_B = 33.2\,\mu A$

→ Output loop:

$-10 + 4\,I_C + 0.2 = 0$

$I_C = 2.45\,mA$

No.

⇒ check $I_c \overset{?}{<} \beta I_B$

$2.45 \overset{?}{<} 3.32\,mA$ yes ∴ Saturation mode.

b. Q-point values

$I_{BQ} = 33.2\,\mu A$

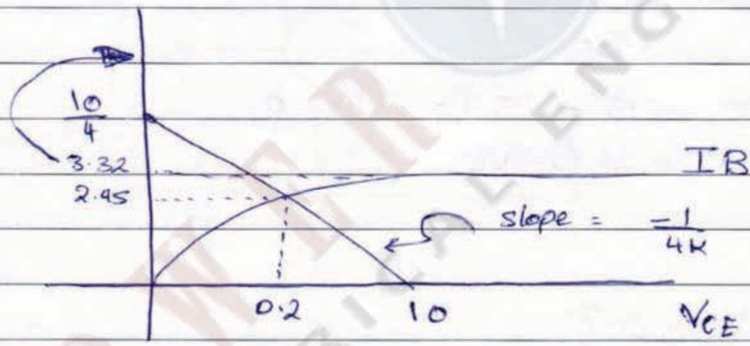
$I_{CQ} = 2.45\,mA$

$V_{CEQ} = 0.2\,V$

c.

$-10 + 4 I_c + V_{CE} = 0$

$I_c = \frac{10}{4} - \frac{V_{CE}}{4}$ Dc load line.

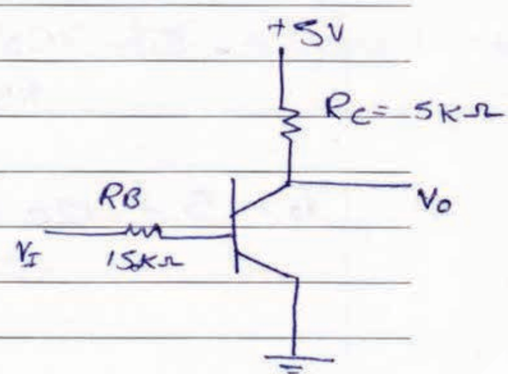


Ex: Draw the voltage transfer curves ($V_o \propto V_I$) for the following circuit

Given $V_{BE(on)} = 0.7\,V$

$V_{CE(sat)} = 0.2\,V$

$\beta = 120$



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* cut off

$I_C = I_B = I_E = 0 \Rightarrow V_o = 5V$

* Saturation

$V_{CE(sat)} = 0.2 \Rightarrow V_o = 0.2V$

* forward active mode:-

$V_{BE} = 0.7$

$I_C = \beta I_B$

$\Rightarrow$ input loop:

$$-V_I + 150 I_B + 0.7 = \text{Zero}$$

$$I_B = \frac{V_I - 0.7}{150}$$

$\Rightarrow$ Output Loop $\Rightarrow -5 + 5 I_C + V_o = 0$

$$I_C = \frac{5 - V_o}{5}$$

$\Rightarrow I_C = \beta I_B$

$$\frac{5 - V_o}{5} = 120 \frac{V_I - 0.7}{150}$$

$$V_o = 5 - \frac{120 (V_I - 0.7) R_C}{R_B}$$

$$= 5 - \frac{120 R_C V_I}{R_B} + \frac{120 R_C + 0.7}{R_B}$$

$$V_o = 5 + \frac{120 R_C * 0.7}{R_B} - \frac{120 R_C}{R_B} V_I$$

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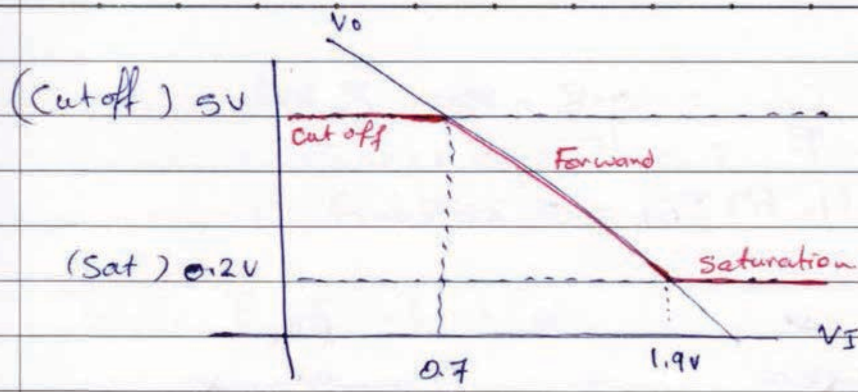
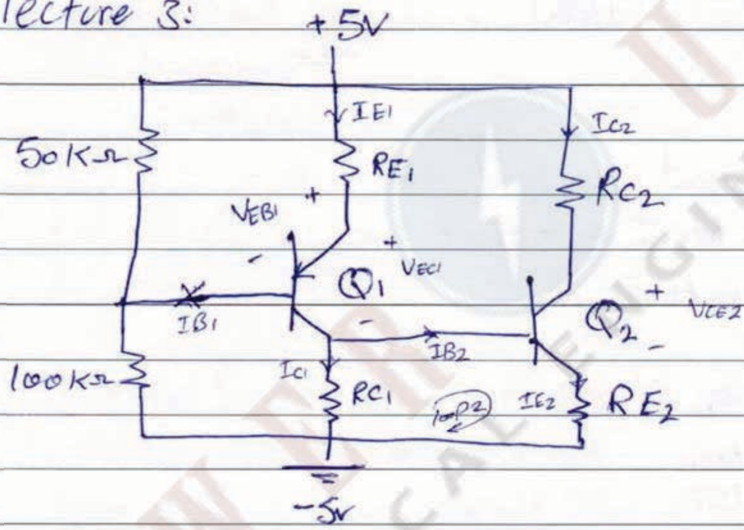


lecture 3:



Given:

$\beta = 100$ for both Q_1 and Q_2

$I_{C1} = I_{C2} = 0.8mA$

$V_{EB1} = V_{BE2} = 0.7v$

$V_{EC1} = 3.5\,v$, $V_{CE2} = 4\,v$ → So Q_1 & Q_2 are forward mode

Find $R_{E1}, R_{C1}, R_{E2}, R_{C2}$

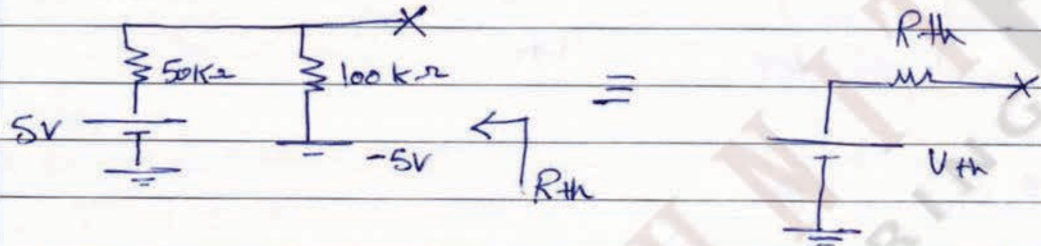
Q_1 : pnp

Q_2 : npn

No.

$I_{B1} = I_{B2} = \frac{I_{C1}}{\beta} = \frac{0.8}{100} = 8\,\mu A$

$I_{E1} = I_{E2} = (1+\beta) I_{B1} = 0.808\, mA$



$R_{th} = 33.3 k\Omega$

Calculate the current

$-5 + 50I + 100I + -5 = 0$

$I = \frac{10}{150}\, mA$

$-V_{th} + I100 - 5 = 0$

$V_{th} = -5 + \frac{1000}{150}$

input loop1

$-5 + I_{E1}R_{E1} + 0.7 + I_{B1}R_{th} + V_{th} = 0$

$R_{E1} = 2.93\, k\Omega$

output loop1: $-5 + I_{E1}R_{E1} + V_{EC1} + R_{C1}(I_{C1} - I_{B2}) - 5 = 0$

$R_{C1} = 5.215\, k\Omega$

input loop2: $-(-5) - R_{C1}(I_{C1} - I_{B2}) + V_{BE2} + I_{E2}R_{E2} - 5 = 0$

$R_{E2} = 4.25\, k\Omega$

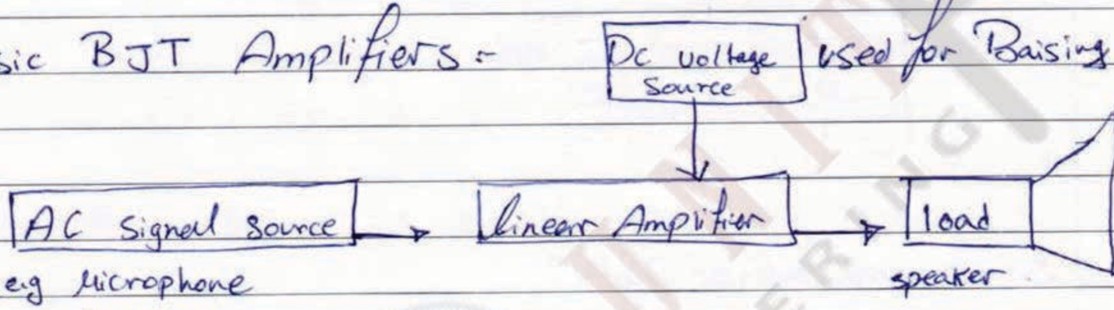
No.

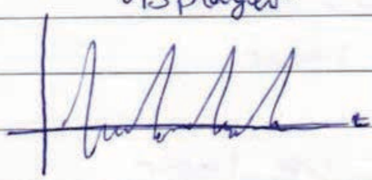
Output loop 2:

$$-5 + I_{C2}R_{C2} + V_{CE2} + R_{E2}I_{E2} - 5 = 0$$

$$R_{C2} = 3.215\ k\Omega$$

Basic BJT Amplifiers :-



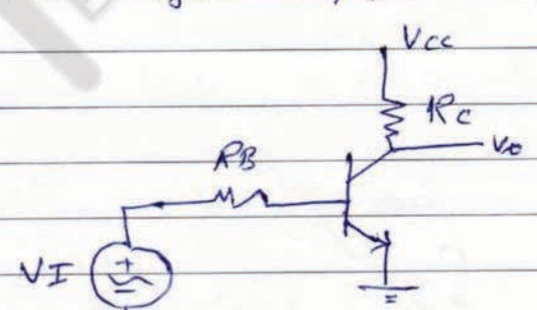


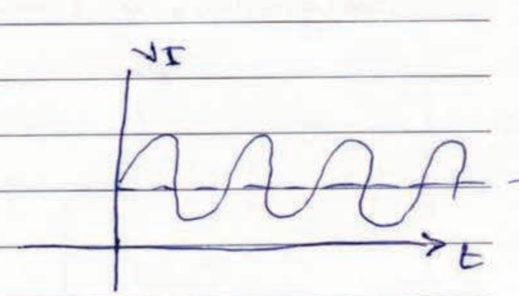
Dc voltage Source: to set the Q-point in the forward active mode.

Ac signal Source: it should Be small Ac signal.

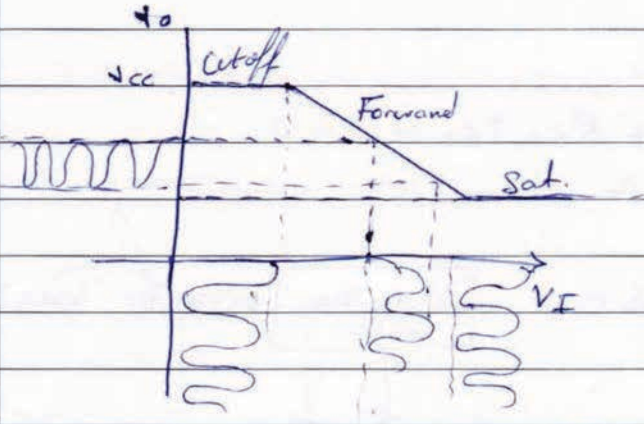
linear Amp. : it must Be linear

* the transistor in amplifier circuit should be in the forward active region. why?





$$V_I = 3 + 2\sin\omega t$$



2. we need alinear, why?

→ linear element —MM— , —||— , —ooo—

$I \propto V$ is linear

⇒ linear circuit : all its component are linear

⇒ Linear amplifier : means that the relationship between V_I & V_o is linear.

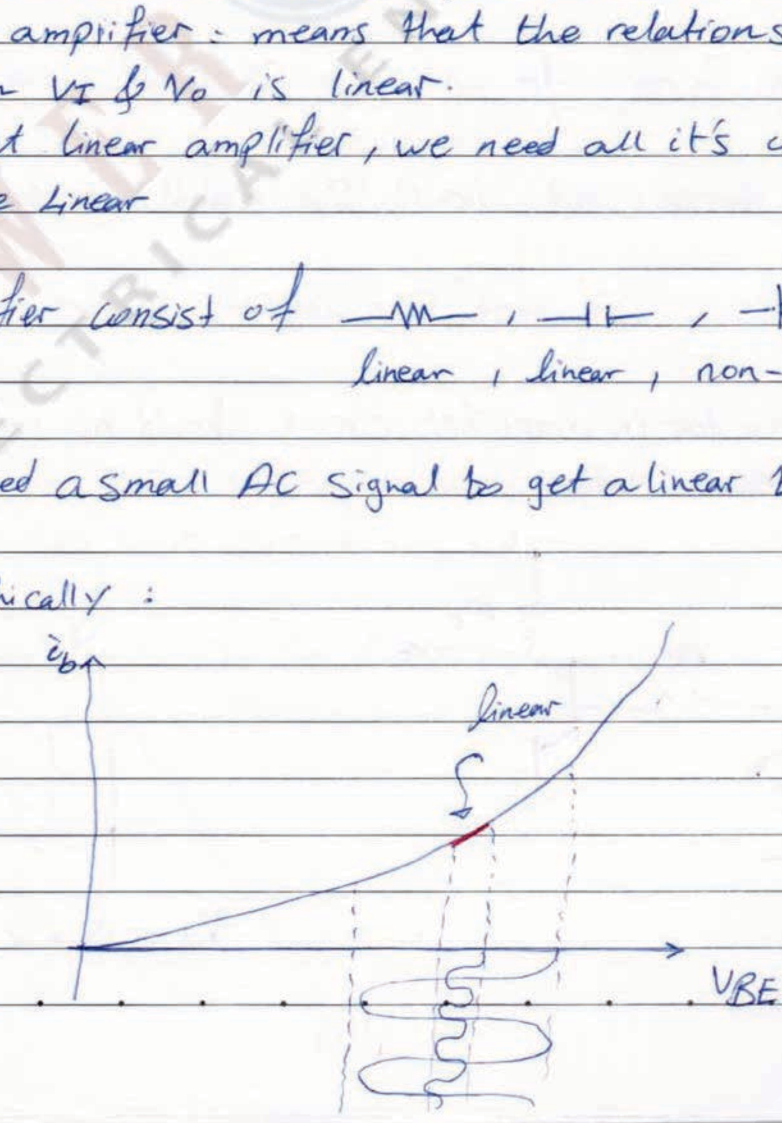
⇒ to get linear amplifier, we need all it's component to be Linear

⇒ Amplifier consist of —MM— , —||— , (transistor)

linear , linear , non-linear !

(3) we need a small AC signal to get a linear transistor How?

→ graphically :



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* Mathmatically :-

Note: I_B : Dc Current ; $I_B = 3A$
i_b : Ac Current ; $i_b = 25 \sin(wt)$
i_B : Ac + Dc current , $i_B = 5 + 3\sin(wt)$.
I_b : phasor form , $I_b = 3 \angle 30°$

we know that : $i_B = \frac{I_s}{1+\beta} \exp\left(\frac{V_{BE}}{V_T}\right)$

$$= \frac{I_s}{1+\beta} \exp\left(\frac{V_{BEQ} + V_{be}}{V_T}\right)$$

(V_{BEQ}: Dc, V_{be}: Ac)

$$i_B = \underbrace{\frac{I_s}{1+\beta} \exp\left(\frac{V_{BEQ}}{V_T}\right)}_{I_{BQ}} \cdot \exp\left(\frac{V_{be}}{V_T}\right)$$

$$i_B = I_{BQ} \exp\left(\frac{V_{be}}{V_T}\right)$$

Note: taylor Series : $e^{\theta} = \frac{\theta^0}{0!} + \frac{\theta^1}{1!} + \frac{\theta^2}{2!} + \cdots$

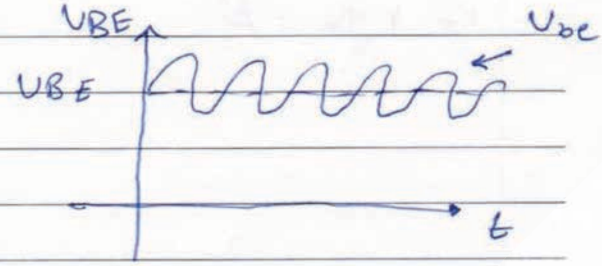
→ if $\theta << 1$

$e^{\theta} \simeq 1 + \theta$ [exponential relationship will be linear]

→ $e^{\frac{V_{be}}{V_T}} \simeq 1 + \frac{V_{be}}{V_T}$

if $\frac{v_{be}}{V_T} << 1$

⇒ $V_{be} << V_T$



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if V_{be} is small value:-

$$i_B \simeq I_{BQ}\left(1+\frac{V_{be}}{V_T}\right)$$

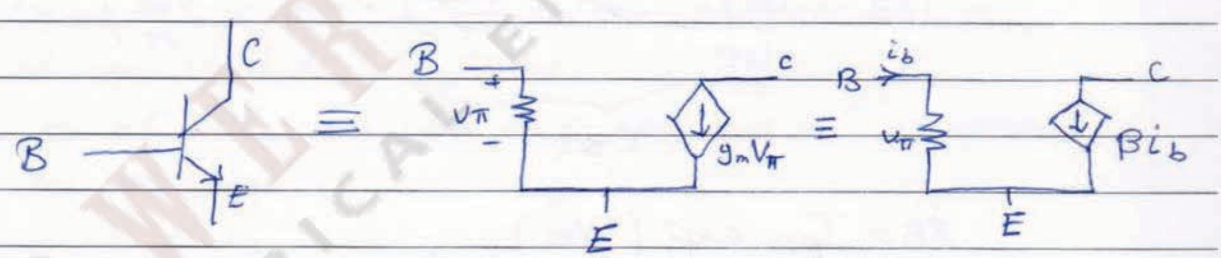
$$I_{BQ}+i_b \simeq I_{BQ}+\frac{I_{BQ}}{V_T}V_{be}$$

$$i_b \simeq \frac{I_{BQ}}{V_T}V_{be}$$

constant

So, Linear relationship between i_b & V_{be}. & can be implemented as (r_π)

Small Signal Hybrid - π equivelent Circuit



$r_\pi = \frac{V_T}{I_{BQ}}$ → diffusion resistance.

$g_m = \frac{I_{CQ}}{V_T}$ A/V (℧) trans conductance.

$r_\pi \times g_m = \beta$

No.

* General steps to solve an amplifier circuit

1] Dc analysis

⇒ Draw Dc equivelant circuit

1. Kill all Ac Sources
2. replace all capacitors by open circuit
3. Keep all Dc Sources.

⇒ Find I_{BQ}, I_{CQ}, I_{CEQ}

2] Ac analysis:

⇒ Draw the Ac equivelent circuit

1. replace the transistor by Hybrid-π equivelent circuit.
2. Kill all Dc sources
3. replace all capacitors by short-circuit

⇒ Find Voltage gain $A_V = \frac{V_o}{V_I}$

i_b, i_c, V_{ce}, R_i, R_o

4] by using super position:-

Find result = Ac + Dc

$i_B = i_b + I_{BQ}$

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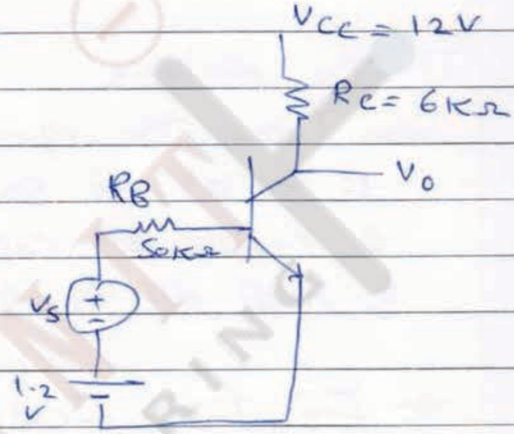
lecture 4:

Ex:

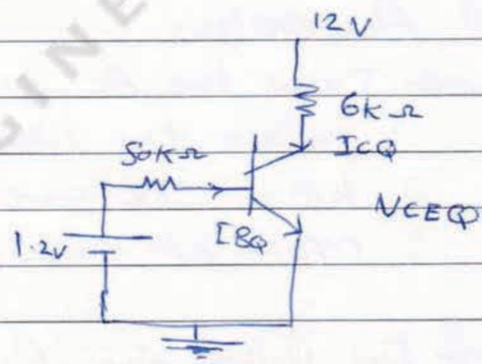
$\beta = 100$, $V_{BE(on)} = 0.7\ V$



find the voltage gain $A_v = \frac{V_o}{V_s}$

Dc analysis

⇒ Dc equivelent circuit



⇒ input loop

$-1.2 + I_{BQ}\,50 + 0.7 = 0$

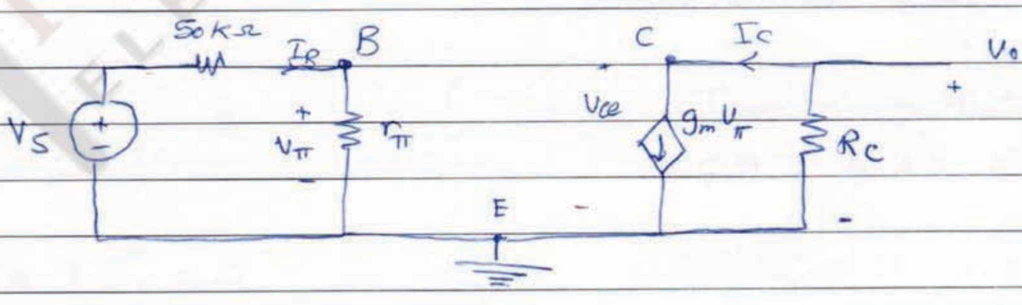
$I_{BQ} = 10\,\mu A$

⇒ $I_{CQ} = \beta I_{BQ}$

$= 1mA$

* Ac analysis

⇒ Ac equivelent circuit:



No.

$A_v = \frac{V_o}{V_s}$

$\Rightarrow V_o = -g_m V_\pi R_C$ ⇝ (1)

$V_\pi = \frac{V_s\, r_\pi}{V_\pi + R_B}$ ⇝ (2)

⇝ Sub (2) in (1)

$V_o = -g_m R_C * \frac{V_s\, V_\pi}{V_\pi + R_B}$

$A_v = \frac{V_o}{V_s} = \frac{-g_m R_C\, V_\pi}{r_\pi + R_B}$

$r_\pi = \frac{V_T}{I_{BQ}} = \frac{0.026}{10 \times 10^{-6}} = 2.6\, K\Omega$

$g_m = \frac{I_{CQ}}{V_T} = 38.5 \times 10^{-5}\, \frac{A}{V}$

$A_v = -11.4$ * the minus sign makes a phase shift 180°

B] find and draw i_B, i_C, v_{CE} if $V_s = 0.25 \sin \omega t$

$i_B = i_b + I_{BQ}$

$= \frac{0.2 \sin \omega t}{50 + 2.6} + 10\ \mu A$

$i_B = 4.75 \sin \omega t + 10\ \mu A$

No.

Sol.

$i_C = i_c + I_{CQ}$

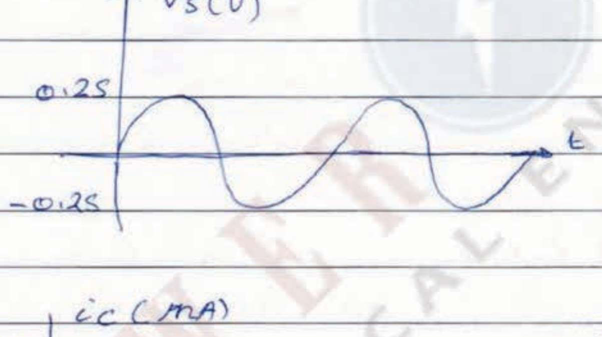
$\beta I_b + 1 \quad mA$

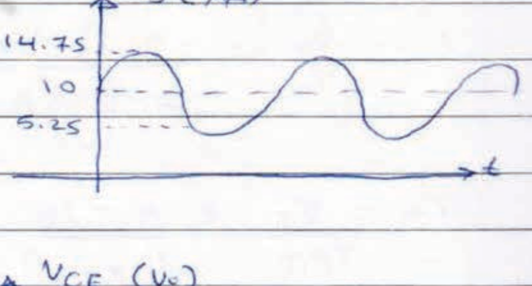
$i_C = 0.475 \sin wt + 1 \quad mA$

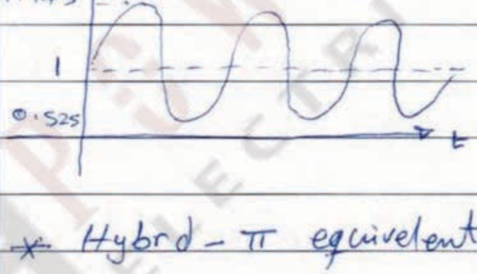
$V_{CE} = V_{ce} + V_{CEQ}$

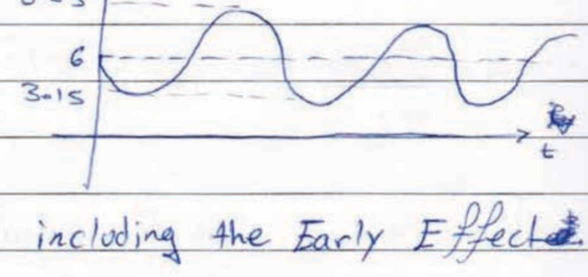
$-i_c R_C + 12 - I_{CQ} * 6$

$V_{CE} = -2.85 \sin wt + 6 \quad V$



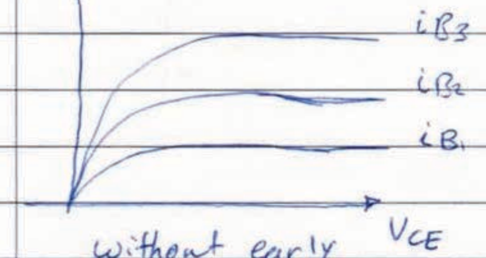


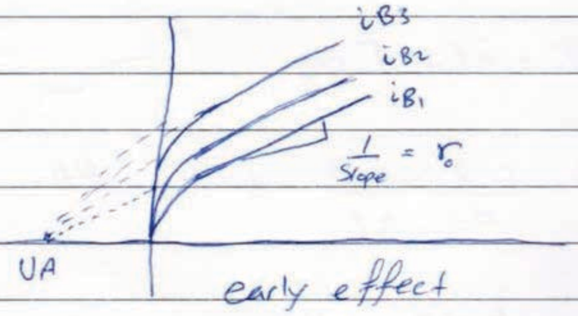




* Hybrd-π equivelent model including the Early Effect.

Early effect





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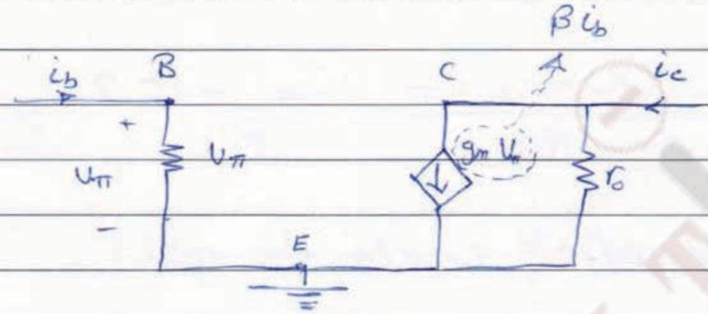


$$r_o = \frac{V_A}{I_{CQ}} \ \Omega$$

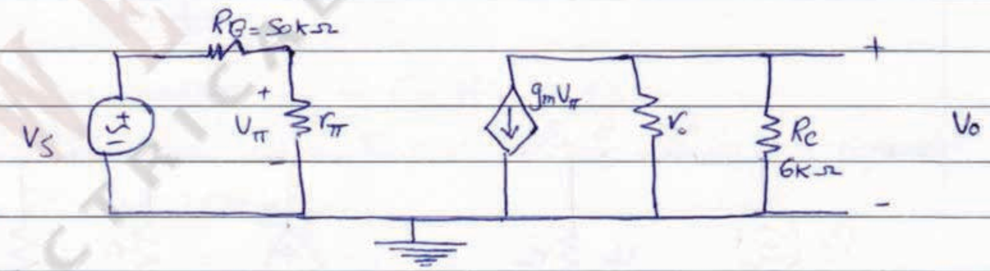
Lecture 5:

Ex: consider the last example:-

find $A_v = \frac{V_o}{V_s}$, if $V_A = 50$ V

$$r_o = \frac{V_A}{I_{CQ}} = \frac{50}{1mA} = 50 k\Omega$$

⇒



$$A_v = \frac{V_o}{V_s}$$

$$V_o = -g_m V_\pi (R_C // r_o) \rightsquigarrow (1)$$

$$V_\pi = V_s \frac{r_\pi}{r_\pi + R_B} \rightsquigarrow (2)$$

Sub 2 in 1

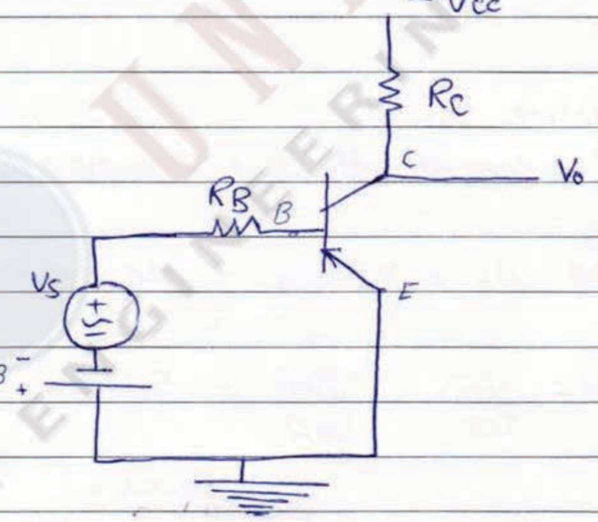
$$V_o = \frac{-g_m (R_C // V_o) V_s r_\pi}{r_\pi + R_B}$$

No.

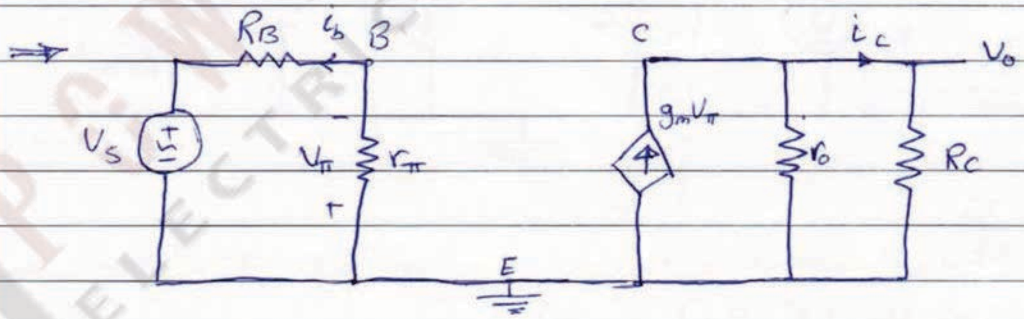
$$A_v = \frac{-g_m (R_C // r_o)\, r_\pi}{r_\pi + R_B} = -10.2$$

⇒ Early effect reduces the gain

* pnp transistor



⇒

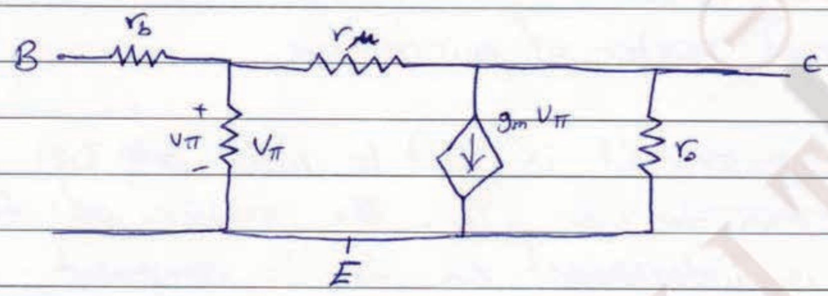


$$v_o = g_m V_\pi (r_o // R_C)$$

$$V_\pi = \frac{-V_s\, r_\pi}{r_\pi + R_B}$$

No.

Note:



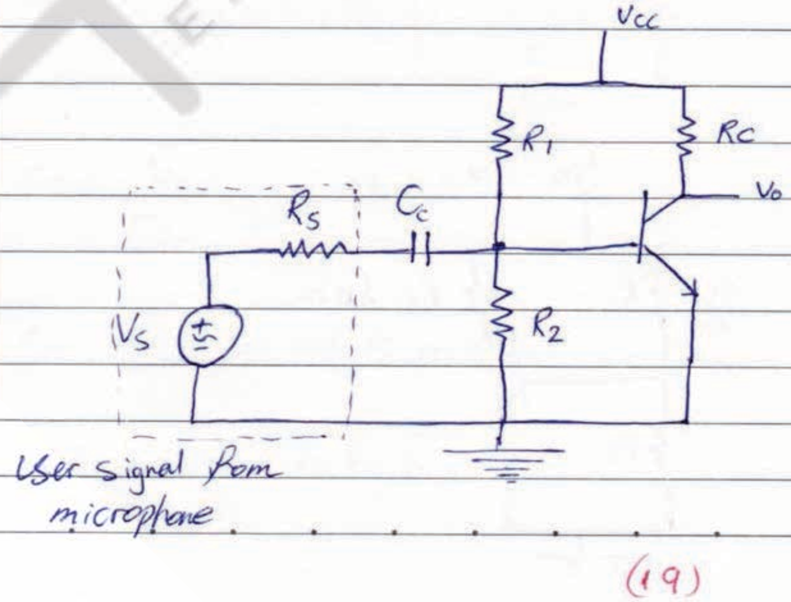
* Basic Transistor Amplifier Confeguration:-

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

* CE amplifier:-

1) Basic CE amplifier
2) Basic CE amplifier with Emitter resistor
3) Basic CE amplifier with Emitter resistor and By pass Capacitor
4) Advanced CE amplifier.

* Basic CE amplifier.



C_c: Coupling capacitor
R_S: internal resistor of microphone.

Coupling capacitor: it is used to block any DC component from the user. So, the position of the Q-point is independant on the dc component from the user

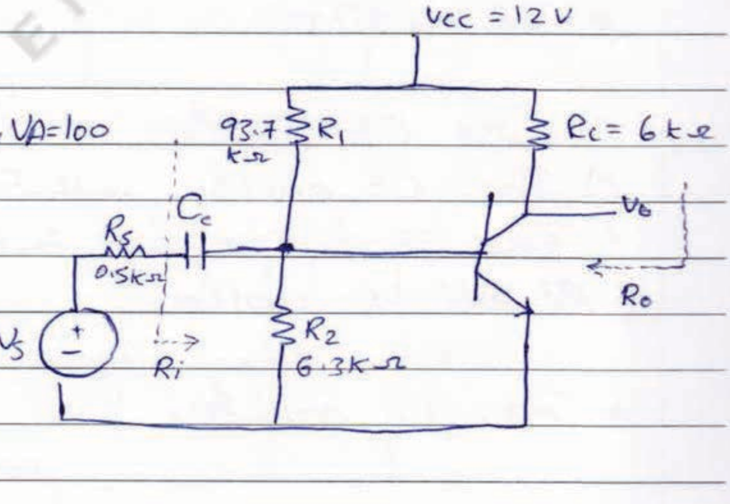
lecture 5: 6/3/2014

1) Basic CE amplifier:-

Ex:

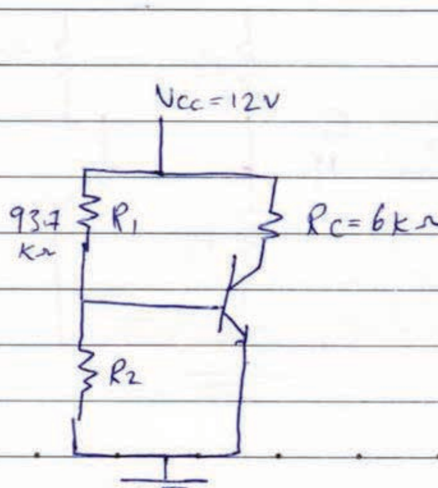
$\beta = 100$, $V_{BE(on)} = 0.7V$, $V_A = 100$

find :-
1) the voltage gain A_V
2) R_i (input impedance)
3) R_o (output impedance)



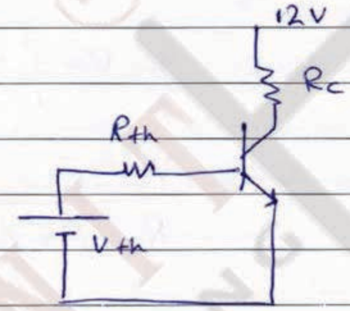
Dc analysis:-

Dc eq. circuit



No.

this Circuit can be represented in thevenen circuit:-



$R_{th} = R_1 // R_2$

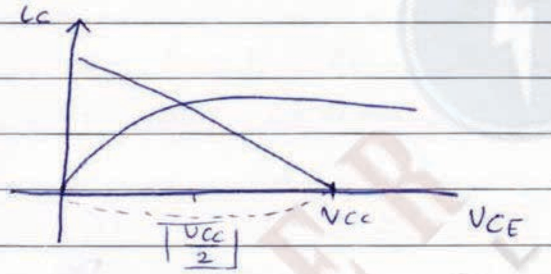
$V_{th} = \frac{12 \; R_2}{R_2 + R_1}$

$\Rightarrow -V_{th} + R_{th} I_{BQ} + 0.7 = 0$

$I_{BQ} = 9.5 \; \mu A$

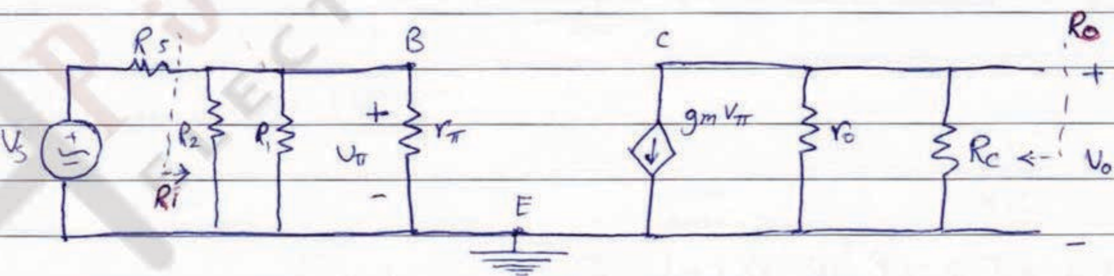
$I_{CQ} = \beta I_{BQ} = 0.95 \; mA$

$V_{CEQ} = 12 - I_{CQ} R_C = 6.31 V$



* Ac analysis

Ac eq. circuit



$r_\pi = \frac{V_T}{I_{BQ}} = 2.74 \; K\Omega$

$g_m = \frac{I_{CQ}}{V_T} = 36.5 \; mA/V$

$r_o = \frac{V_A}{I_{CQ}} = 105 \; K\Omega$

No.

$A_v = \frac{v_o}{v_s}$

$\Rightarrow V_o = -g_m V_\pi (R_C // R_o) \rightsquigarrow (1)$

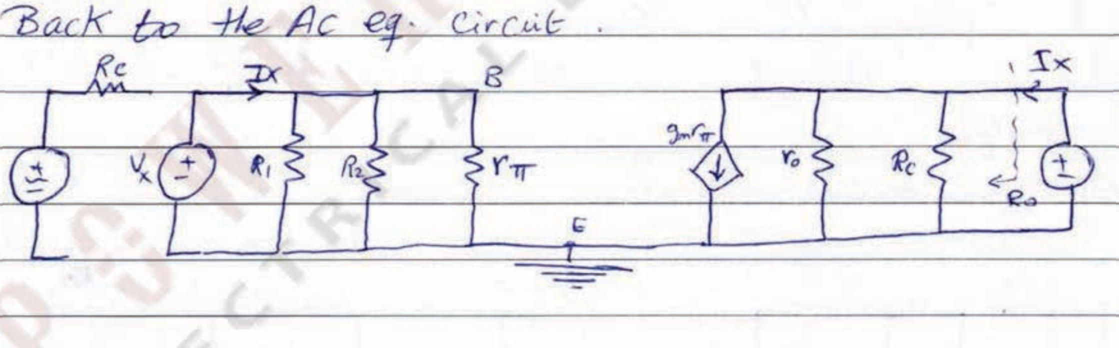
$\Rightarrow V_\pi = \frac{V_S (R_1 // R_2 // r_\pi)}{R_1 // R_2 // r_\pi + R_S} \rightsquigarrow (2)$

Sub 2 in 1 :-

$A_V = \frac{v_o}{V_s} = \frac{-g_m (R_C // r_o)(R_1 // R_2 // r_\pi)}{R_1 // R_C // r_\pi + R_S}$

$= -163$

(2) Back to the AC eq. circuit.



$R_i = \frac{V_x}{I_x}$

$-V_x + I_x (R_1 // R_2 // r_\pi) = 0$

$R_i = \frac{V_x}{I_x} = R_1 // R_2 // r_V$

$= 1.87\ k\Omega$

No.

to find R_o reconnect V_s & R_s & delet V_x

$R_o = \frac{V_x}{I_x}$

$R_o = r_o // R_C$

$= 5.68 K\Omega$.

* Advantage:-

high A_v

* Disadvantages:-

1. very sensitive to $V_{BE(on)}$
2. unstable performance.

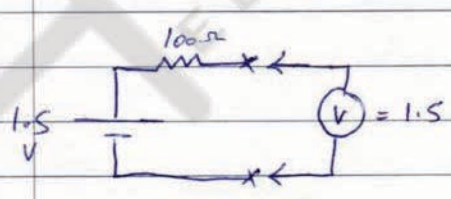
⇒ if $V_{BE(on)} = 0.7 V$

$I_{BQ} \rightarrow I_{CQ} \rightarrow V_{CEQ} = 6.31 V$ (forward.

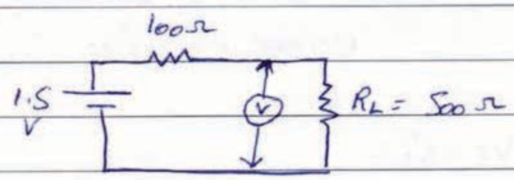
⇒ if $V_{BE(on)} = 0.6 V$

$I_{BQ} \rightarrow I_{CQ} \rightarrow V_{CEQ} = -3.6 V$ (it is not forword.)

[2] high loading effect:-



Source without load.



Source with load.

$V = 1.25 < 1.5$

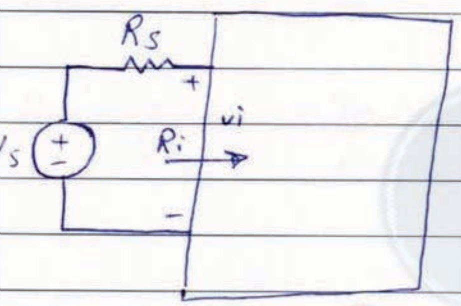
(loading effect)

to reduce the loading effect ($V_o \simeq V_s$)

R_L should be $>> R_s$

$\Rightarrow$ in our example

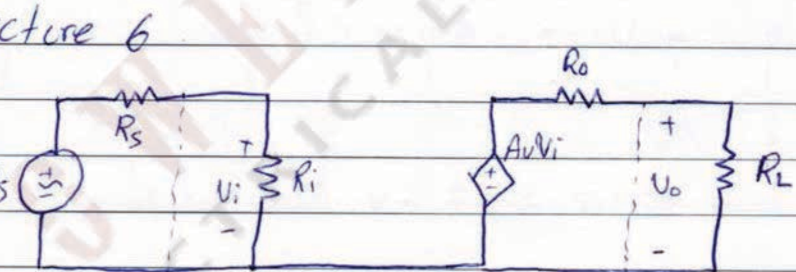
$R_i = 1.87\ k\Omega$
$R_s = 0.5\ k\Omega$
$\Rightarrow R_s \not\ll R_i$



$$v_i = \frac{V_s\ R_i}{R_i + R_s}$$

$$v_i = 0.789\ V_s$$

lecture 6 9/3/2014



two-port eq. circuit for
voltage amplifier.

$$V_i = \frac{V_s\ R_i}{R_i + R_s}$$

$\Rightarrow$ to reduce the loading effect on the input circuit ($v_i \approx V_s$)
we need high R_i

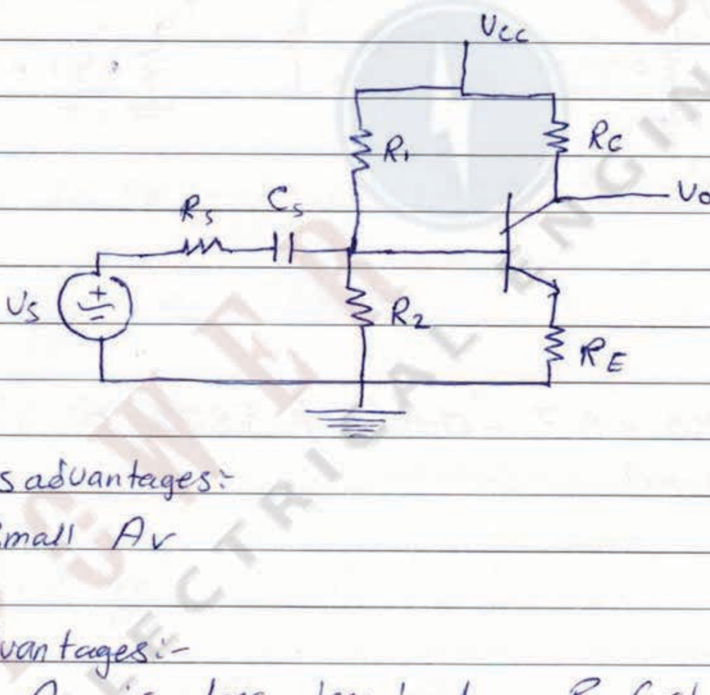
No.

$$V_o = A_v V_i * \frac{R_L}{R_L + R_o}$$

⇒ to reduce the loading effect on the circuit's output ($v_o \approx A_v V_i$) we need low R_o

⇒ for current amplifier we need low R_i and high R_o

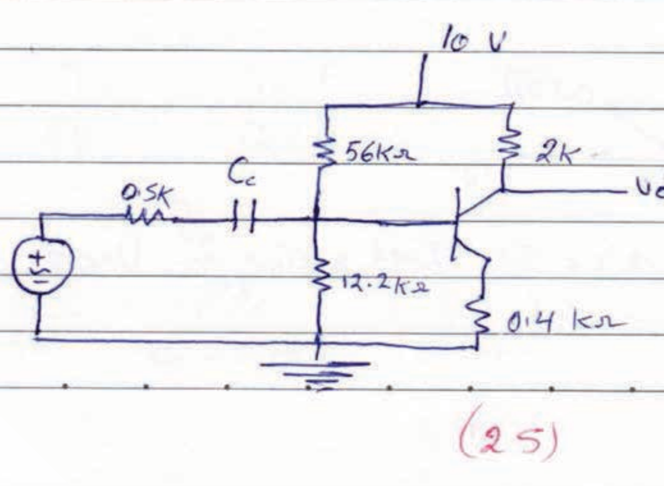
2] CE amplifier with RE



* Disadvantages:-
  Small A_v

* Advantages:-
  1. A_v is less dependant on β (stable gain)
  2. small loading effect.

Ex:-

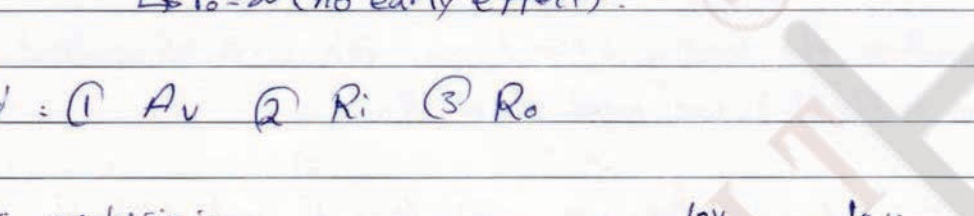


No.

$\beta = 100$, $U_A = \infty$, $U_{BE(on)} = 0.7\ V$
↳ $r_o = \infty$ (no early effect).

find : ① A_v ② R_i ③ R_o

Dc analysis :-

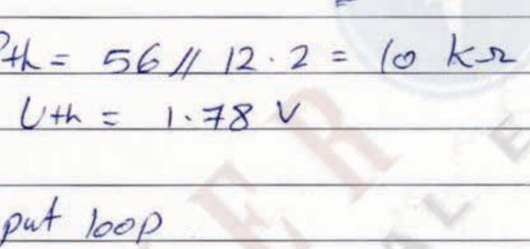


$R_{th} = 56 \parallel 12.2 = 10\ k\Omega$
$U_{th} = 1.78\ V$

→ input loop
$-U_{th} + R_{th} I_{BQ} + 0.7 + 0.4(1+\beta) I_{BQ} = 0$
$I_{BQ} = 0.0216\ mA$

$I_{CQ} = \beta I_{BQ}$
$= 2.16\ mA$

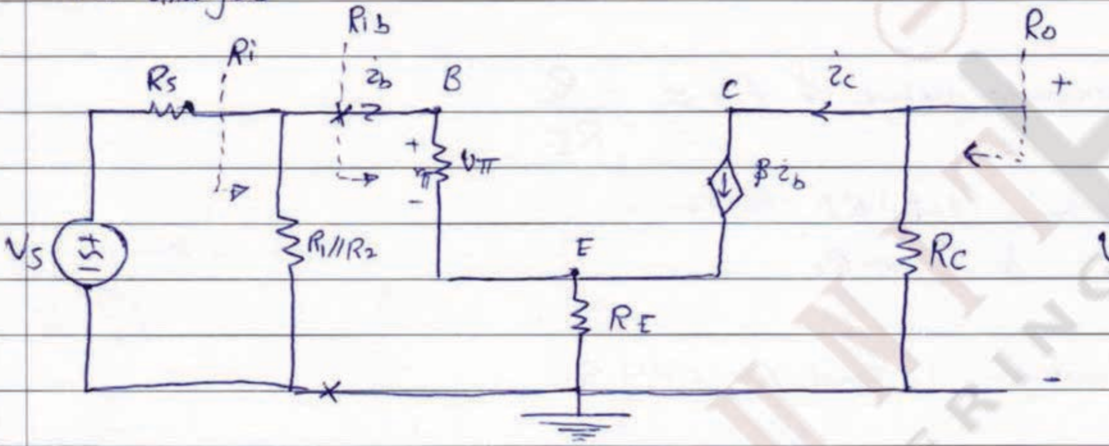
$V_{CEQ} = 4.81\ V$



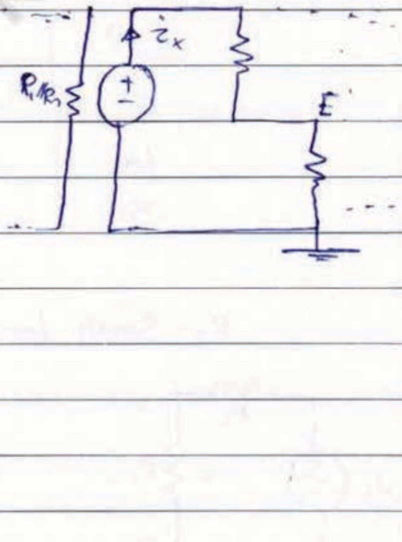
$V_{CEQ} \left(\frac{10 + 0.2}{2} \right) = 5.1$ best value for V_{CEQ}

No.

Ac analysis



$$R_{ib} = \frac{V_x}{I_x}$$



$$-V_x + i_x r_\pi + (1+\beta) i_x R_E = 0$$

$$R_{ib} = \frac{v_x}{i_x} = r_\pi + (1+\beta) R_E$$

$$R_i = R_1 // R_2 // R_{ib} = 8.06k\Omega$$

~~Ro~~

$$A_v = \frac{v_o}{v_s}$$

$$\Rightarrow v_o = -\beta i_b R_C \rightsquigarrow (1)$$

$$\Rightarrow v_i = v_s \frac{R_i}{R_i + R_s}$$

$$\Rightarrow i_b = \frac{v_i}{R_{ib}} = \frac{v_s R_i}{R_{ib}(R_i + R_s)} \rightsquigarrow (2)$$

from 1 & 2

$$A_v = \frac{v_o}{v_s} = \frac{-\beta R_c}{r_\pi + (1+\beta) R_E} \left(\frac{R_i}{R_i + R_s} \right) \rightsquigarrow A_v = -4.53$$

exact value.

No.

lecture 6 :- 11/3/2014

approximate value of $A_v \approx \frac{-R_C}{R_E}$.

because:- $(1+\beta)R_E >> r_\pi$

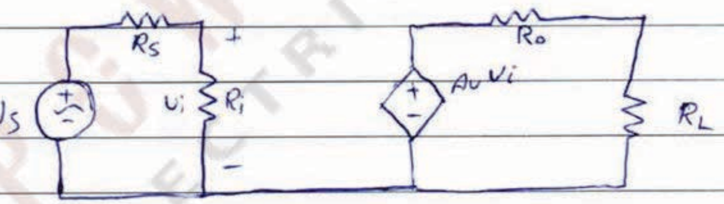
& $R_i >> R_s$

disadvantage:- 1. Small $A_v = -4.53$

advantage: 1. A_v is less dependant on β

β	A_v
50	-4.41
100	-4.53
150	-4.57

2. Small loading effect

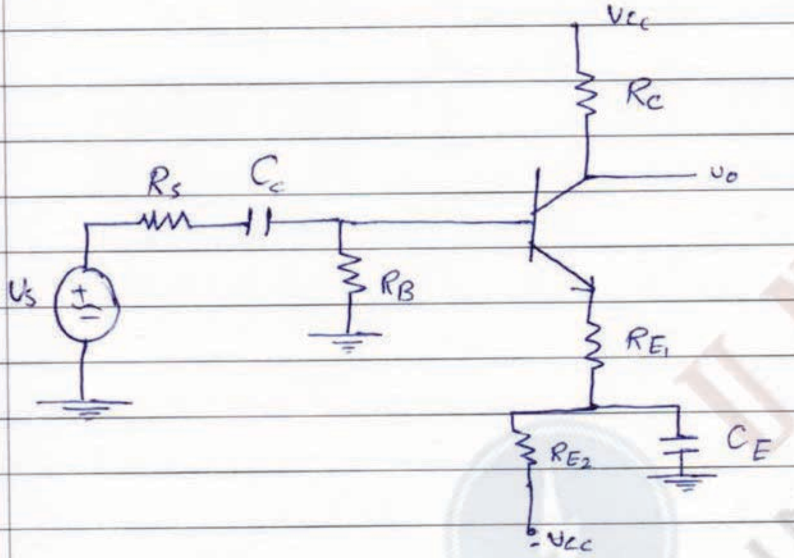


$\Rightarrow v_i = \frac{v_s R_i}{R_i + R_s}$

$v_i = 0.942\ V_s$

No.

3] CE with RE and Bypass Capacitor



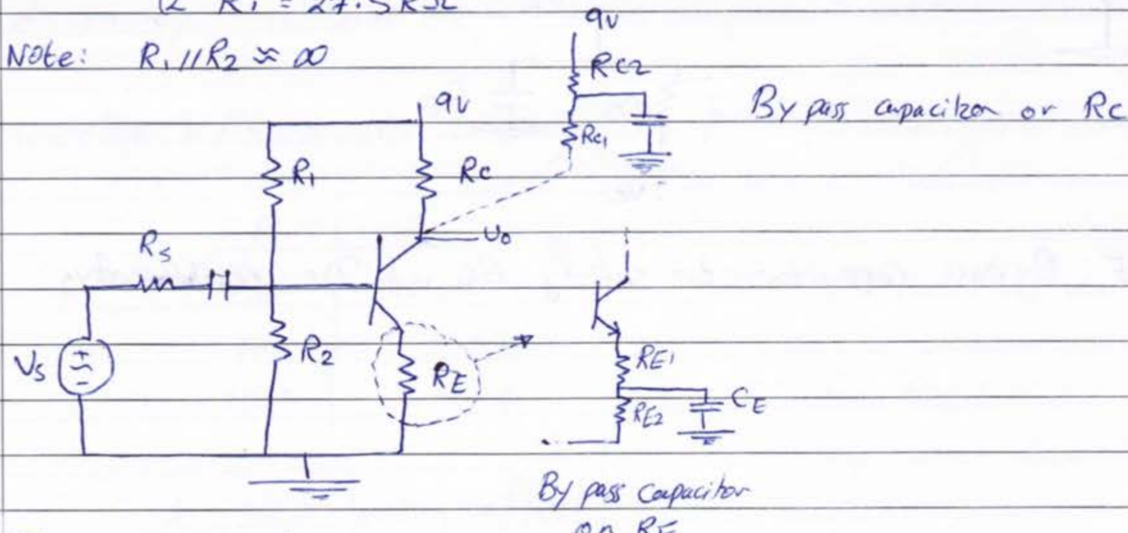
CE: Bypass capacitor to satisfy AC & DC requirement lecture 7: 16/3/2014

Consider a CE amplifier with R_E. use the approximate gain $A_v = \frac{-R_c}{R_E}$. assume that $I_{CQ} = 1mA = I_{EQ}$

$V_{CEQ} = 5V$, $\beta = 99$, $V_{cc} = 9V$, find R_c & R_E such that: ① $A_v = -8$

② $R_i = 27.5 k\Omega$

Note: $R_1 // R_2 \approx \infty$



⇝ Dc requirements:

⊛ $I_{CQ} = 1mA$

⊛ $V_{CEQ} = 5V$

⇝ Ac requirements:-

⊛ $A_v = -8$

⊛ $R_i = 27.5 k\Omega$.

* from Dc requirement take the out put loop:

$$-9 + I_{CQ} R_c + V_{CEQ} + I_{EQ} R_E = 0$$

$$\boxed{R_c + R_E = 4 k\Omega} \rightsquigarrow ①$$

No.

from Ac requirements:-

⇝ $A_V = -8 = \frac{-R_C}{R_E}$ ⇒ $\boxed{R_C = 8R_E}$ ⇝ (2)

⇝ $R_i = R_1 // R_2 // R_{ib}$

$27.5 = r_\pi + (1+\beta) R_E$

$r_\pi = \frac{V_T}{I_{BQ}} = 2.574$

⇝ $R_E = 0.25\ k\Omega$

from 1 ⇒ $R_C = 3.75\ k\Omega$

from 2 ⇒ $R_C = 2\ k\Omega$

conflict !!

⇝ solution : use Bypass Capacitor on R_E or R_C

Bypass capacitor on R_E :-

<u>DC</u>

$-9 + I_{CQ} R_C + V_{CEQ} + I_{EQ} (R_{E1} + R_{E2}) = 0$ ⇝ (1)

$\boxed{R_C + R_{E1} + R_{E2} = 4\ k\Omega}$

<u>AC</u>

$-8 = \frac{-R_C}{R_{E1}}$ ⇒ $R_C = 8 R_{E1}$ ⇝ (2)

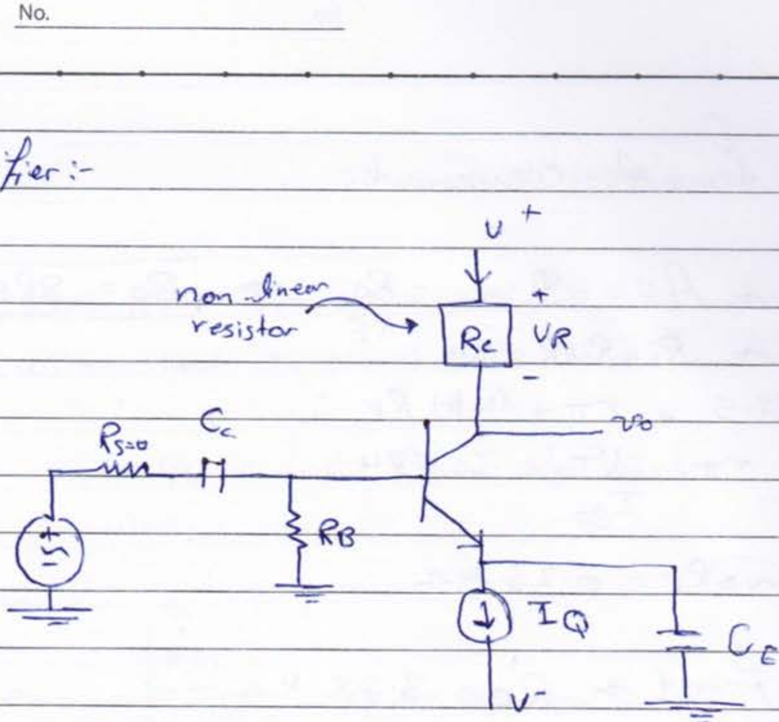
$R_i = r_\pi + (1+\beta) R_{E1}$ ⇒ $R_{E1} = 0.25\ k\Omega$

⇝ from (2) $R_C = 2\ k\Omega$

from (1) $R_{E2} = 1.75\ k\Omega$

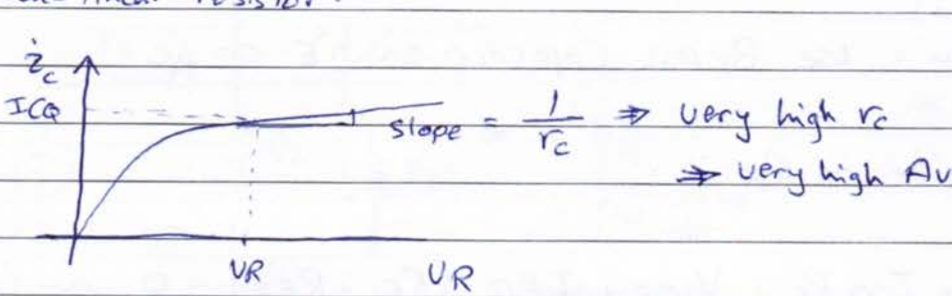
No.

* advanced CE amplifier:-



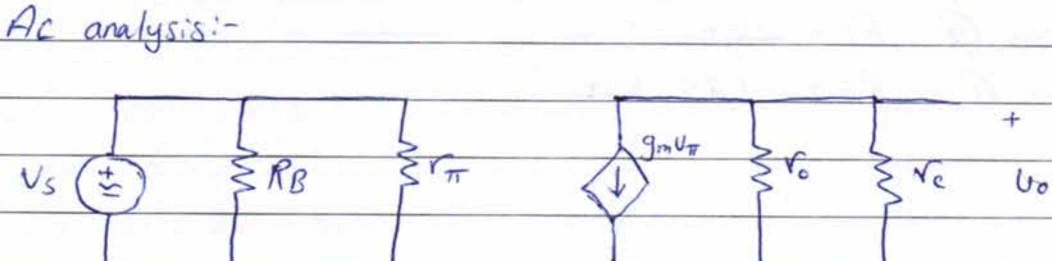
Advantages:
very high A_v

non-linear resistor:-



Ex: if $I_Q = 0.5mA$, $\beta = 120$, $V_A = 80\ V$, $r_c = 120k\Omega$
find A_v?

Ac analysis:-



No.

$I_{EQ} = I_Q = 0.5mA$

$r_o = \frac{V_A}{I_{CQ}} = 160k\Omega$

$g_m = \frac{I_{CQ}}{V_T} = 19.2mA$

$A_v = -g_m (r_o // R_C)$

$= -1317$ ⟶ very high gain

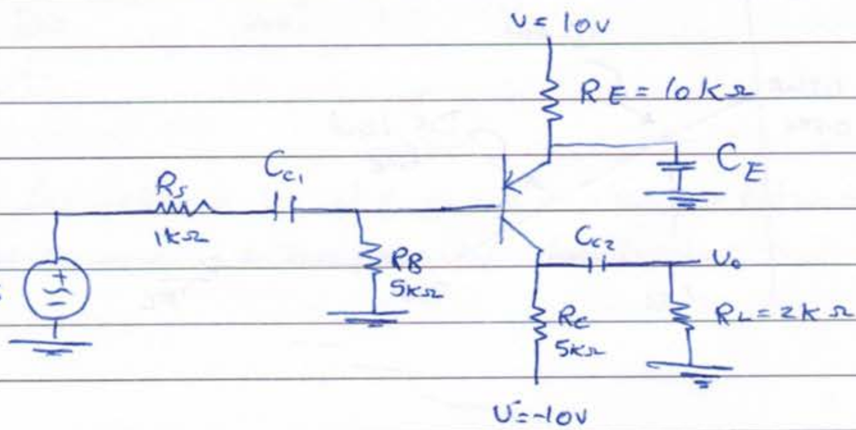
lecture 8: 18/3/2014

* Ac load Line :-

⟶ Dc load Line : $I_C \propto V_{CE}$ (Dc circuit)

⟶ Ac load Line :- $i_c \propto v_{ce}$ (Ac circuit).

Ex:



$\beta = 150$

$V_A = \infty$

$V_{EB(on)} = 0.7V$

[Common Emitter amplifier]

find & draw the Dc and Ac load line :-

No.

Dc analysis:-

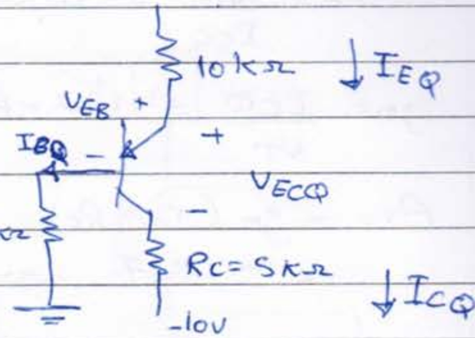
input loop:

$-10 + I_{EQ}\,10 + 0.7 + 5\,I_{BQ} = 0$

$\rightarrow (1+\beta)\,I_{BQ}$

$\Rightarrow I_{BQ} = 5.96\ \mu A$

$\Rightarrow I_{CQ} = \beta I_{BQ} = 0.894\,mA$



$\Rightarrow$ output loop:-

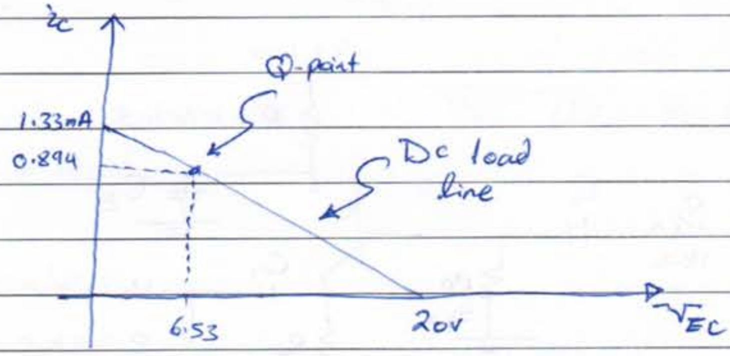
$-10 + I_{EQ}R_E + V_{EQ} + I_{CQ}R_C - 10 = 0$

~~V_{CEQ}~~ $V_{ECQ} = 6.53\ V$

Dc load Line:-

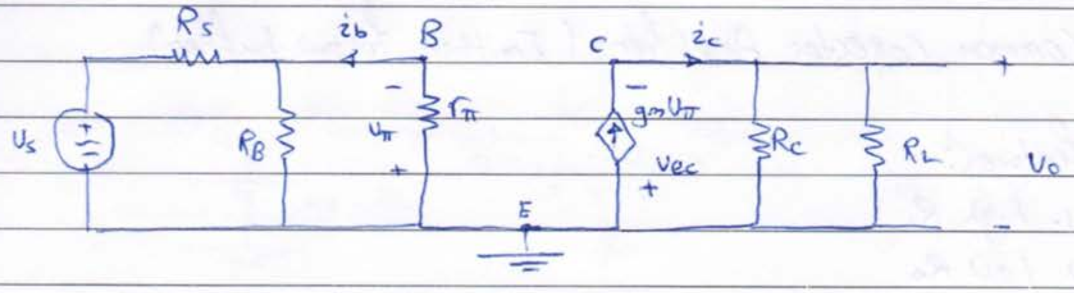
$-V^+ \; (-10) + R_E\,\frac{(1+\beta)}{\beta}\,I_C + V_{EC} + I_C R_C = 0 \;\rightarrow +V^-$

$$I_C = \frac{(V^+ - V^-)}{R_C + \frac{(1+\beta)}{\beta}R_E} - \frac{V_{EC}}{R_C + \frac{(1+\beta)}{\beta}R_E}$$



No.

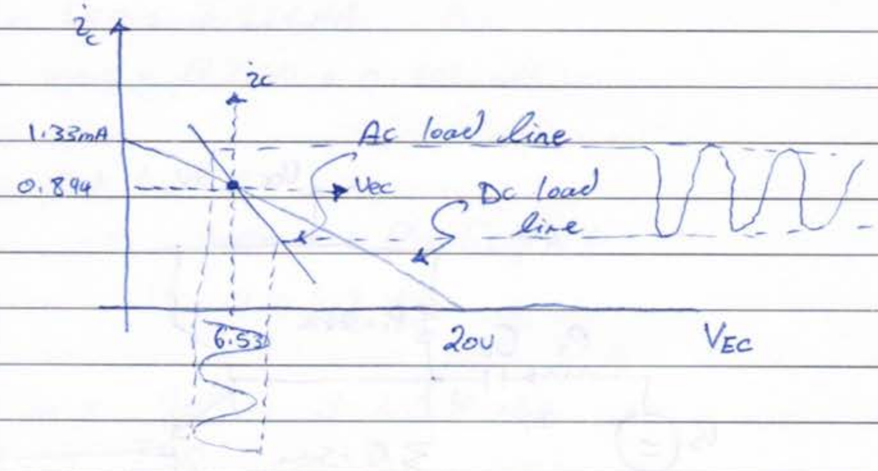
Ac analysis:-



Ac load Line:-

$$V_{ec} = -i_c (R_C // R_L)$$

$$i_c = \frac{-1}{R_C // R_L} V_{ec}$$



→ Ac load line helps in visualizing the relationship between the small signal response and the transistor characteristics.

No.

lecture 9: 20/3/2014

Common Collector Amplifier (Emitter follow buffer)

features:-

1. high R_i
2. low R_o
3. $A_v \approx +1$
4. $A_i = 1+\beta \approx \beta$
5. it is used as a final stage in multi-stage amplifier.
6. R_1 & R_2 should be very large to take the advantage of high R_{ib}

Ex:-

given:-

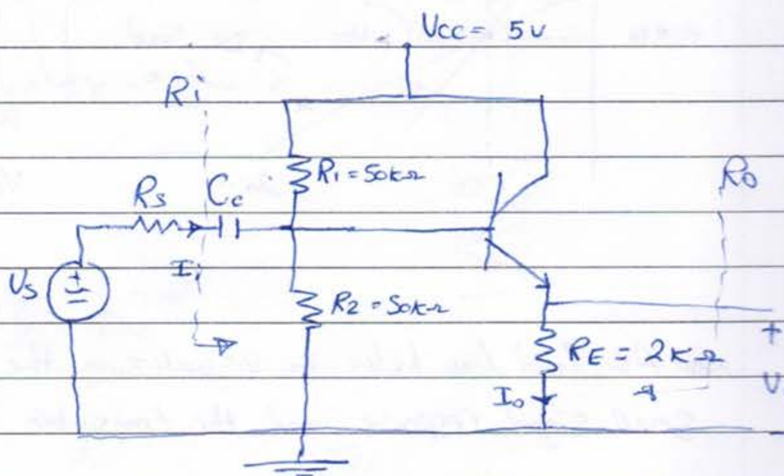
$\beta = 100$

$V_A = 80\ V$

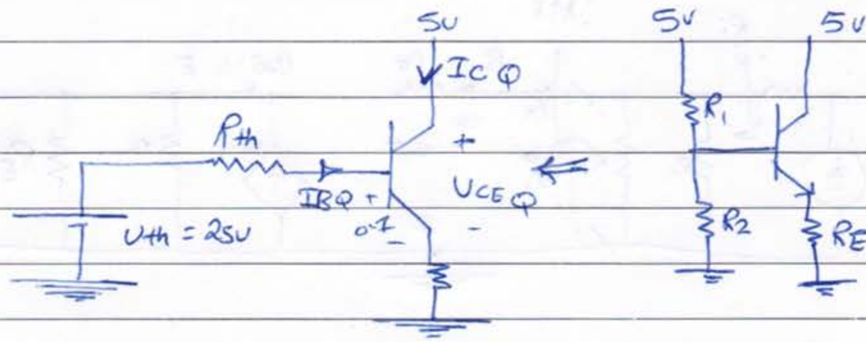
find,

$A_V = \frac{V_o}{V_s}$

$R_i, R_o, A_i = \frac{I_o}{I_i}$



Dc analysis:-



input loop:

$$-2.5 + I_{BQ}25 + 0.7 + R_E(1+\beta)I_{BQ} = 0$$

$I_{BQ} = 7.929\ \mu A$

$I_{CQ} = \beta I_{BQ} = 0.793\ mA$

output loop:

$$-5 + V_{CEQ} + R_E I_{EQ} = 0$$

$$V_{CEQ} = 3.4\ V$$

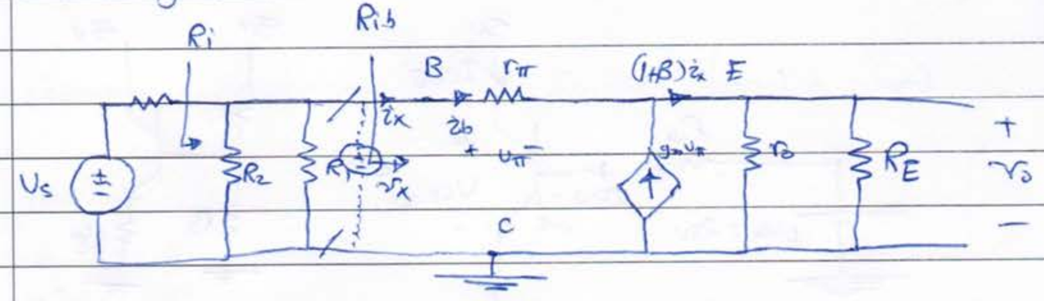
$$r_\pi = \frac{V_T}{I_{BQ}} = 3.28\ k\Omega$$

$$g_m = \frac{I_{CQ}}{V_T} = 30.5\ mA/V$$

$$r_o = \frac{V_A}{I_{CQ}} = 100\ k\Omega$$

No.

Ac analysis :-



$\Rightarrow R_i = R_1 // R_2 // R_{ib}$

$R_{ib} = \frac{v_x}{i_x}$

$-v_x + i_x r_\pi + (1+\beta) i_x \, (r_o // R_E) = 0$

$\Rightarrow R_{ib} = \frac{v_x}{i_x} = r_\pi + (1+\beta)(r_o // R_E)$

$= 201 \ K\Omega$

$R_i = R_1 // R_2 // R_{ib} = 22.2 \ K\Omega$ (high value) ~~this~~ with respect to R_S

$\Rightarrow A_v = \frac{v_o}{v_s}$

remove v_x & reconnect the lines back.

$v_o = (1+\beta) \, i_b \, (r_o // R_E) \Rightarrow (1)$

$v_{in} = v_s \frac{R_i}{R_i + R_s}$

$i_b = \frac{v_{in}}{R_{ib}} \Rightarrow (2)$

No.

$$A_v = \frac{v_o}{v_s} = \left(\frac{r_\pi + R_1 \| R_2 \| R_s}{1+\beta}\right) \| R_E \| r_o$$

$$= 0.962 \approx 1$$