1)

$\beta = 180, V_A = 150V.$

(i)

$I_{CQ} = 0.5mA$

$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{0.5}{180} mA$

$= \cancel{0.027}$

$= 0.00277 mA.$

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

At T = 300K, $V_T \cong 0.0259 V.$

$r_\pi = \frac{0.0259}{0.0027} k\Omega$

$= 9.35 k\Omega$

$r_\pi g_m = \beta$

$g_m = \frac{\beta}{r_\pi} = \frac{180}{9.35}$ milli-mho

$= 19.25$ millimho.

$r_o \cong \frac{V_A}{I_{CQ}} = \frac{150V}{.5mA} = 300k\Omega$

(ii) $V_T = 26mV, I_{CQ} = 2mA, I_{BQ} = \frac{I_{CQ}}{\beta} = 0.0111mA$

$r_\pi = \frac{V_T}{I_{BQ}} = \cancel{26} \frac{0.026V}{0.0111} = 2.34k\Omega.$

$g_m r_\pi = \beta$

$\Rightarrow g_m = \frac{\beta}{r_\pi} = \frac{180}{2.34}$ millimho

$= 76.92$ milli-mho.

$r_o = \frac{V_A}{I_{CQ}} = \frac{150V}{2mA} = 75k\Omega$

2. $\beta = 125, V_A = 200V, g_m = 95 mA/V$

$= 95$ millimho.

$g_m = \frac{\beta}{r_\pi}$

$\Rightarrow r_\pi = \frac{\beta}{g_m} = \frac{125}{95 \text{ milli-mho}}$

$= 1.3157 k\Omega$

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

$\Rightarrow I_{BQ} = \frac{V_T}{r_\pi} = \frac{0.026V}{1.3157k\Omega} = 0.019mA$

$I_{CQ} = \beta I_{BQ} = 125 \times 0.019 mA$

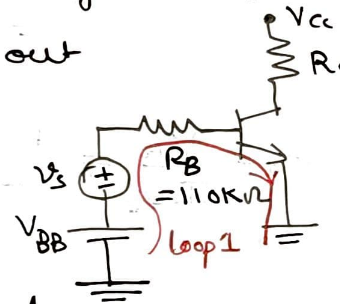
$= 2.47 mA.$

$r_o = \frac{V_A}{I_{CQ}} = \frac{200V}{2.47mA} = 80.97 K\Omega$

3.

$\beta = 120,\ V_{BE(ON)} = 0.7V,\ V_A = 80V.$

We apply KVL in the loop containing the Base to emitter junction, that is, loop 1, to find out the DC value of the base current.



As we discussed in class, when we do DC analysis, we would assume the AC component to be zero, because an ~~So~~ AC voltage source doesnot create a DC current.

$V_{BB} = I_{BQ}R_B + V_{BE(ON)}$

$\Rightarrow 1.10V = I_{BQ} \times 110 + 0.7$

$\Rightarrow I_{BQ} = \frac{.4}{110} mA = 0.0036mA$

$I_{CQ} = \beta I_{BQ} = 0.432mA.$

We will now calculate the hybrid-π parameters or the small signal parameters. Note that we did a DC analysis first because the hybrid π or small signal parameters depend on the DC values ~~of the~~ or Q-point values of the currents.

$r_\pi = \frac{V_T}{I_{BQ}} = \frac{0.026 K\Omega}{0.0036}$ (At T=300K)

$= 7.222 K\Omega$

$g_m = \frac{\beta}{r_\pi} = \frac{120}{7.22}$ millimho

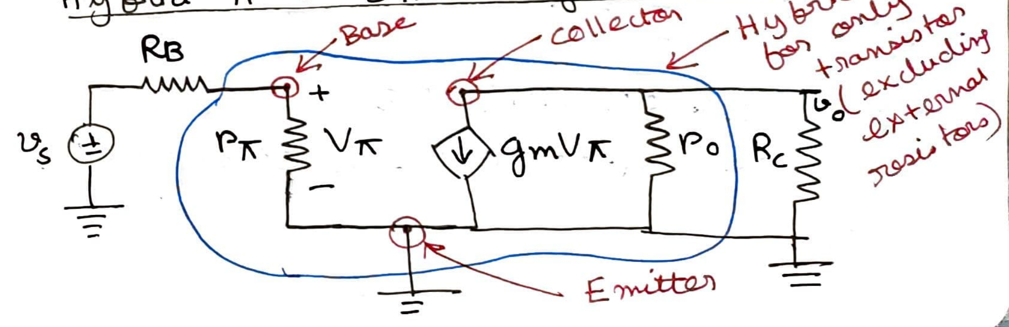
$= 16.62$ millimho.

$r_o = \frac{V_A}{I_{CQ}} = \frac{80}{.432} K\Omega$

$= 185.18 K\Omega$

(b)

Hybrid π or small signal model:



As stated in class, for AC analysis, we ground the DC voltage.
Now, let us find out the expression for gain,

$$V_\pi = v_s \frac{r_\pi}{R_B + r_\pi}$$

$$\cancel{i_B = \frac{V_\pi}{r_\pi} = \frac{v_s}{R_B + r_\pi}}$$

$$i_c = g_m V_\pi = v_s \frac{g_m r_\pi}{R_B + r_\pi}$$

$$= \frac{v_s \beta}{R_B + r_\pi}.$$

i_c flows through the parallel combination of r_o and R_c.

So, $v_o = -(R_c \| r_o)\, i_c$

$\cancel{= (18 \| 1}$

$$= -(4 \| 185) \frac{v_s \times 120}{110 + 7.222}$$

$$= 4.008\, v_s.$$

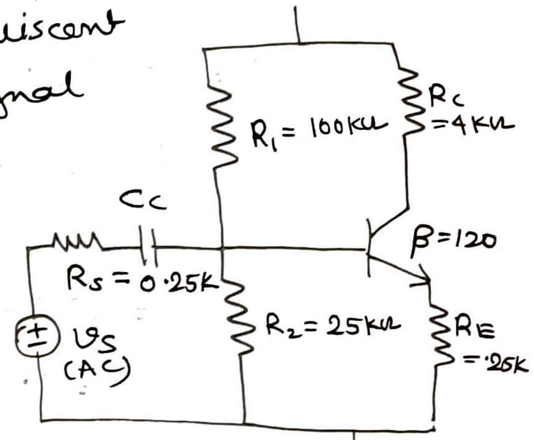
$$\Rightarrow \frac{v_o}{v_s} = 4.008.$$

(c) $v_s = 0.5 \sin(100t)$

$v_o = 4.008\, v_s = 2.004 \sin(100t)$

4)

(b) To find out the quiscent values and small signal parameters, we need to do DC analysis (assuming the AC source to be zero)

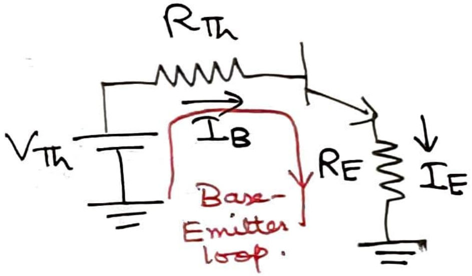


~~We use~~ As discussed earlier in class, we can use Thevenin's theorem to simplify the circuit.

$$V_{Th} = \frac{R_2}{R_1 + R_2} \times V_{cc}$$

$$= \frac{25}{100 + 25} \times 5V$$

$$= 1V.$$



$$R_{Th} = R_1 \| R_2 = (100k\Omega \| 25k\Omega)$$
$$= 20k\Omega$$

Applying KVL to the Base-emitter loop, we get:

$$V_{Th} = I_{BQ} \times R_{Th} + V_{BE(ON)} + I_{EQ} R_E$$

$$\Rightarrow 1V = 20k\Omega \times I_B + 0.7V + 120 I_{BQ} \times .25$$

$$\Rightarrow I_{BQ} = \frac{0.3}{50} mA = 0.006 mA$$

$I_{CQ} = \beta I_{BQ} = 0.72\,mA$

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

$\cong V_{CC} - I_C (R_C + R_E)$

Assuming $I_C \cong I_E$

$= 5V - 4.25 \times .72$

$= 1.94V.$

• $r_\pi = \dfrac{V_T}{I_{BQ}}$

$= \dfrac{0.026}{0.006}\,k\Omega$ (At T=300K)

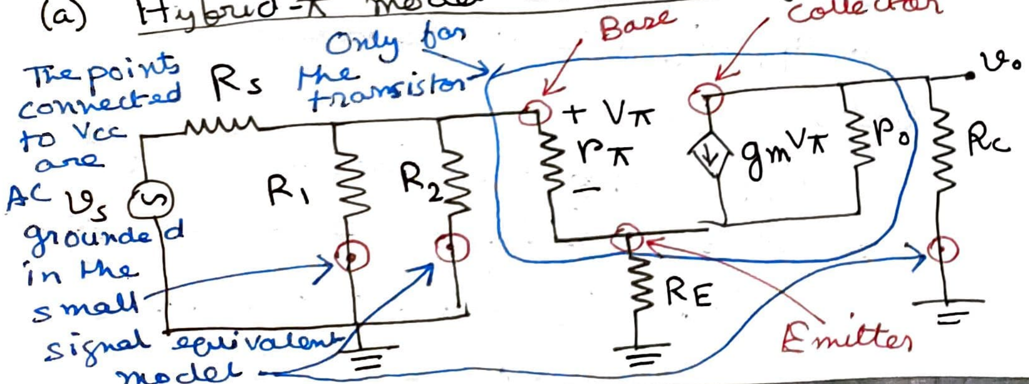
$= 4.333\,k\Omega$

$g_m = \dfrac{\beta}{r_\pi} = \dfrac{120}{4.33}$ millimho

$= 27.692$ millimho.

$r_o = \dfrac{V_A}{I_{CQ}} = \infty \quad (\because V_A = \infty)$

(a) Hybrid-π model or Small signal model:



(c) We have done the exact same problem earlier, ~~both~~ albeit with different sets of parameters.

So, without going into too much detail, the input resistance to the base

Resistance magnified by $(\beta+1)$ due to resistance reflection rule

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

$= 4.33\,k\Omega + 121 \times .25\,k\Omega$

$= 34.58\,k\Omega$

The input resistance to the amplifier

$R_i = \cancel{R_S} + (R_1 \| R_2 \| R_{ib})$

~~0.25kΩ~~ $= 12.67\,k\Omega$

~~= 12.92 kΩ~~

Output resistance :-

$R_o = r_o \| R_C$

$= R_C \quad (\because r_o = \infty)$

$= 4\,k\Omega$

• **Loading effect**: The effect of connecting a load resistor R_L at the output is called loading effect.

Voltage drop across the parallel combination of R_1, R_2 and R_{ib}

Voltage gain:-

$$V_\pi = \frac{v_s}{R_s + (R_1 \| R_2 \| R_{ib})} \times (R_1 \| R_2 \| R_{ib}) \times \frac{r_\pi}{R_{ib}}$$

Fraction of voltage drop across r_π

$$= \frac{v_s}{12.92} \times 12.67 \times \frac{4.33}{34.58}$$

$$= 0.1227\, v_s$$

$$i_c = g_m V_\pi$$

$$= 27.692 \times .1227 v_s \text{ (mA)}$$

$$v_o = -(R_c \| r_o)\, i_c$$

negative sign because current is flowing from the AC ground into the collector.

$$= -R_c i_c \quad (\because r_o = \infty)$$

$$= -4\text{k}\Omega \times .1227\, v_s \text{ (mA)}$$

$$= -0.49\, v_s$$

$$\Rightarrow \frac{v_o}{v_s} = -0.49.$$

Note: Normal ground as well as DC voltage sources might be considered as AC grounds.

~~(d) Do it yourself.~~

~~Source~~ loading effect:

As already derived, the loading effect due to source is given by.

$$\frac{A_v^{R_L \to \infty}}{A_v^{no\text{-}load}} = \frac{R_i}{R_i + R_s}$$

Gain when the source resistance is finite but load is open circuited

Specified by the amplifier manufacturer when $R_s = 0$ and $R_L \to \infty$.

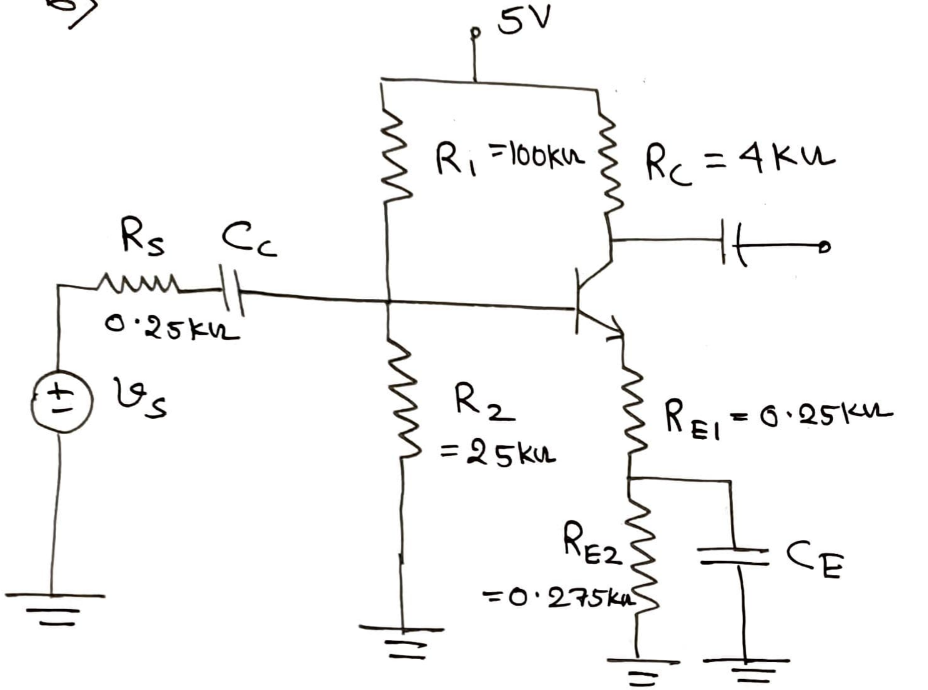
$$= \frac{12.67}{12.67 + .25}$$

$$= 0.9806.$$

Here, there is no load resistor. So, there is no loading effect due to load resistor R_L.

(d) Do it yourself.

6>



$\beta = 75$

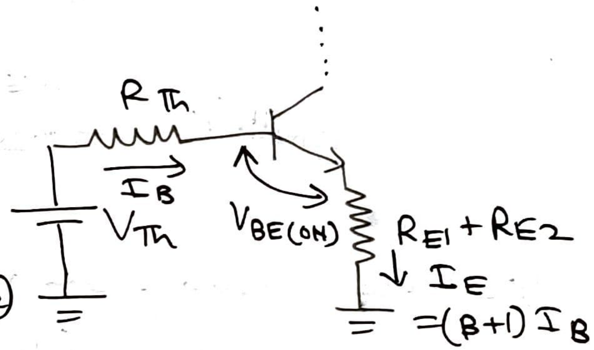
$R_{E2} = 1.1 R_{E1}$
$= 1.1 \times 0.25\,k\Omega$
$= 0.275\,k\Omega$

To get to the hybrid-π equivalent circuit, we need to find the small signal parameters first. The small signal parameters depend on the DC quiescent point first. So we need to do a DC analysis of the problem first.

~~V_{Th}~~ $R_{Th} = R_1 \| R_2 = (25 \| 100)\,k\Omega$
$= 20\,k\Omega.$

$$V_{Th} = \frac{R_2}{R_1 + R_2} \times V_{cc} = \frac{25}{100+25} \times 5\,V$$
$= 1V.$

We now use KVL in the base emitter loop.



$V_{Th} = I_B R_{Th}$
$+ V_{BE(ON)}$
$+ I_E (R_{E1} + R_{E2})$

$\Rightarrow 1V = 20 I_B + 0.7V + 76 I_B (0.525)$

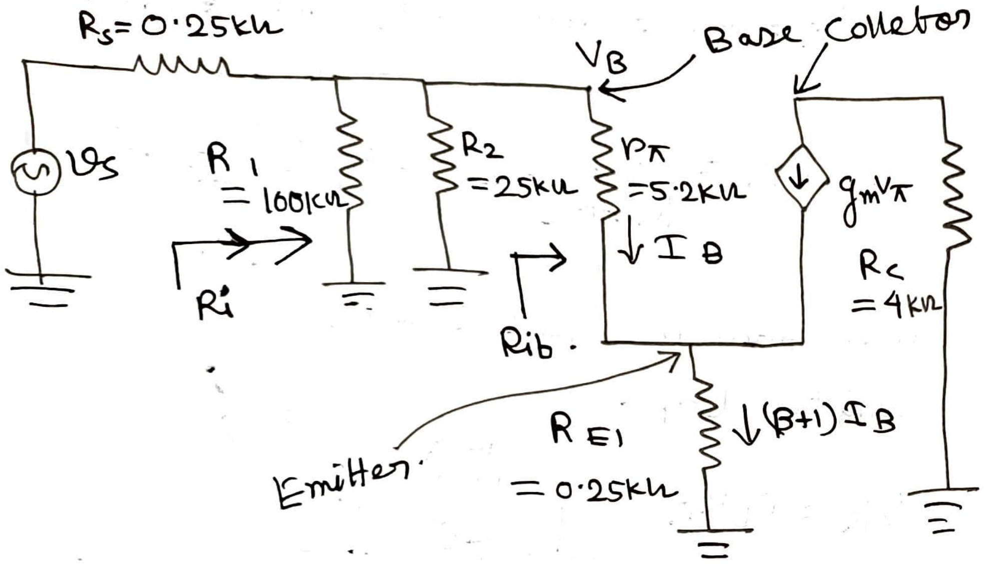
$\Rightarrow 0.3\,V = 59.9 I_B$

$\Rightarrow I_B = \frac{0.3}{59.9}\,mA. = 0.005\,mA.$

$I_C = 75 \times 0.005\,mA$
$= 0.375\,mA.$

$r_\pi = \frac{V_T}{I_B} = \frac{0.026\,V}{0.005\,mA} = 5.2\,k\Omega$

$g_m = \frac{\beta}{r_\pi} = \frac{75}{5.2\,k\Omega} = 14.4$ millimho



We have already seen earlier that ~~Rib~~ the input resistance seen at the base is given by

$$R_{ib} = r_\pi + (\beta+1) R_{E1}$$
$$= 5.2k\Omega + 76 \times .25k\Omega$$
$$= 24.2k\Omega.$$

The input resistance R_i seen by the voltage source v_s is given by :-

$$R_i = R_1 \| R_2 \| R_{ib}$$
$$= (100k\Omega) \| (25k\Omega) \| (24.2k\Omega)$$
$$= 10.95k\Omega$$

The a.c component of the base voltage is given by :-

$$V_\pi = \frac{v_s}{R_s + R_i} \times R_i$$

$$V_\pi = v_s \left(\frac{R_i}{R_s + R_i} \right) \times \frac{r_\pi}{r_\pi + R_{ib}}.$$

$$= v_s \times \frac{10.95}{10.95 + .25} \times \frac{5.2}{5.2 + 24.2}$$

$$= 0.1729\, v_s.$$

$$i_c = g_m V_\pi$$
$$= 14.4 \times 0.1729\, v_s \text{ (mA)}$$
$$= 2.489\, v_s \text{ (mA)}$$

$$v_o = v_c = -i_c R_c$$
$$= -2.489\, v_s \times 4$$
$$= -9.95\, v_s$$

$$\therefore \frac{v_o}{v_s} = -9.95$$

$$A_v = -9.95.$$

Do the other two parts yourself.