**1.** Consider the following common-emitter amplifier circuit (Figure 1). Estimate the Q-point, small signal voltage gain, input and output resistances. Given that $\beta = 65$ and $V_A = 50$ V. Assume $V_{BE\_ON} = 0.7$ V.

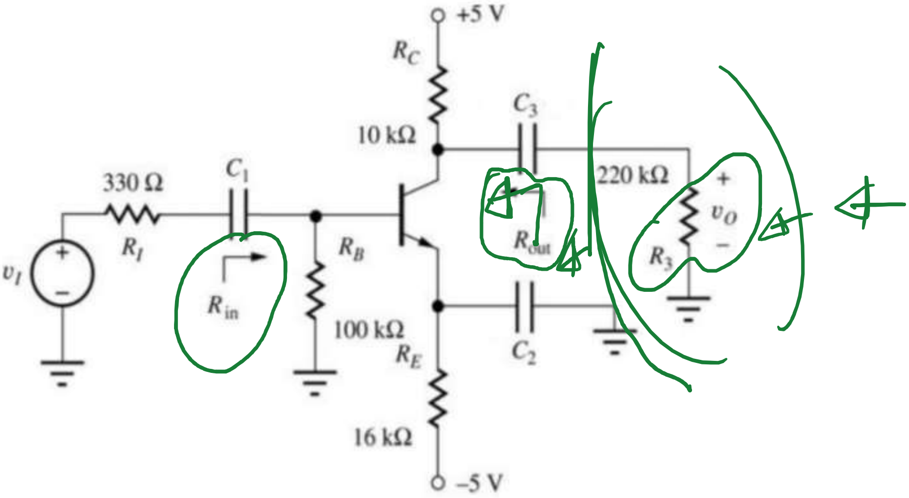
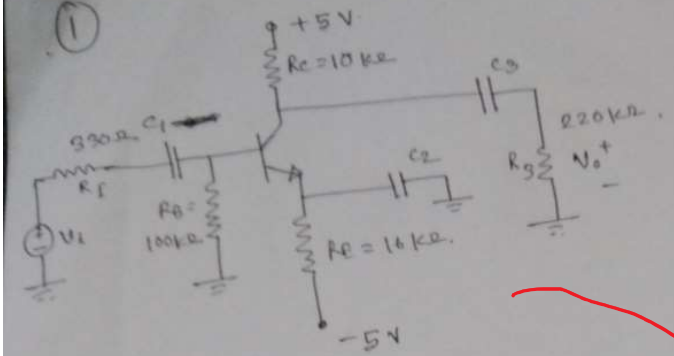



Figure 1

① 

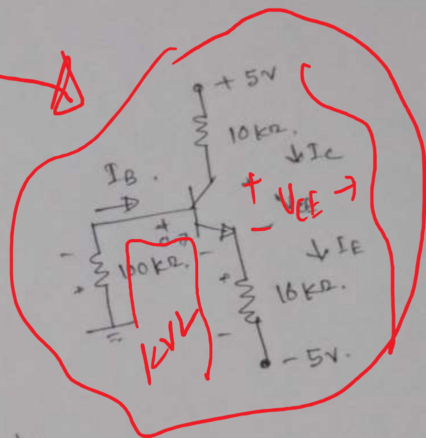



$\beta_F = 65$V.
$V_A = 50$V.
$V_{BE-ON} = 0.7$V.

DC analysis

KVL base loop.

$100 \times 10^3 \times I_B + 0.7 + (1+\beta) \times 16 \times 10^3 I_B = 5$ ; $[I_E = (1+\beta) I_B]$.




$I_B = 3.71\ \mu A$.

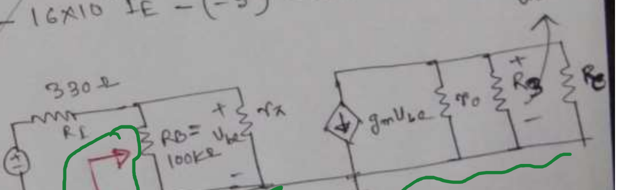
$I_C = 65 \times 3.71\ \mu A = 241\ \mu A$. → Q-point.

$I_E = 244.86\ \mu A$.

KVL in outer loop.

$5 - 10\times10^3 I_C - V_{CE} - 16\times10^3 I_E - (-5) = 0$.

$V_{CE} = 3.67$ V.




AC analysis:

$g_m = \frac{I_C}{V_T} = 9.27 \times 10^{-3}$ S.

$v_o = -g_m v_{be} \cdot (r_o \| R_C \| R_3)$.

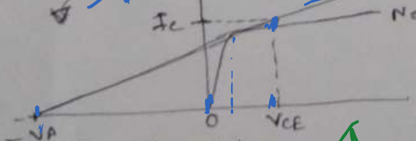
$(r_o \| R_C \| R_3)$

AC analysis:

$g_m = \frac{I_C}{V_T} = 9.27 \times 10^{-3}\, S.$

$r_\pi = \frac{\beta}{g_m} = 7.03 \times 10^{3}\, \Omega.$

$r_o = \frac{V_A + V_{CE}}{I_C} = 222.69\, k\Omega.$




Input resistance

$R_{in} = R_B \parallel r_\pi = 6.54\, k\Omega.$

output resistance

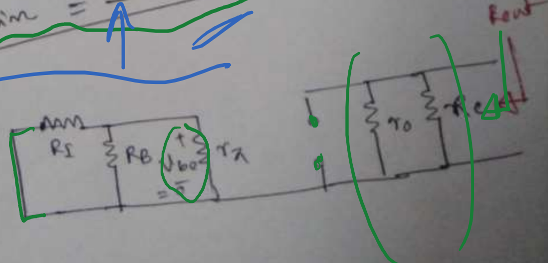
$R_{out} = R_C \parallel r_o = 9.57\, k\Omega.$

$v_o = -g_m v_{be} \cdot (r_o \parallel R_C \parallel R_3).$

$\therefore v_o = -g_m \left(\frac{R_B \parallel r_\pi}{R_B \parallel r_\pi + R_S}\right) \cdot v_i \, (r_o \parallel R_C \parallel R_3)$

$\therefore \frac{v_o}{v_i} = -g_m \left(\frac{R_B \parallel r_\pi}{R_B \parallel r_\pi + R_S}\right)(r_o \parallel R_C \parallel R_3).$

Gain $= -81.26.$




**2.** For the following amplifier circuit (shown in Fig. 2) the Si BJT has $\beta = 200$ and $V_A = 150$ V.

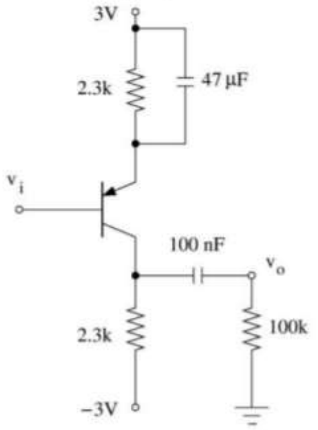
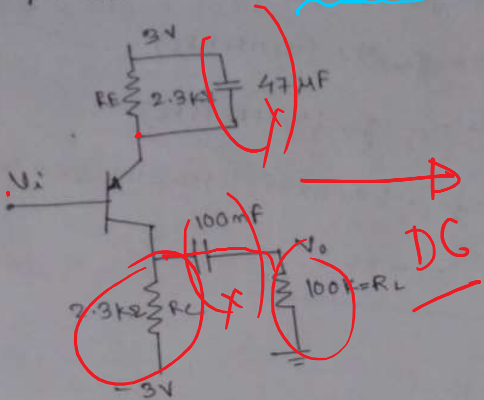


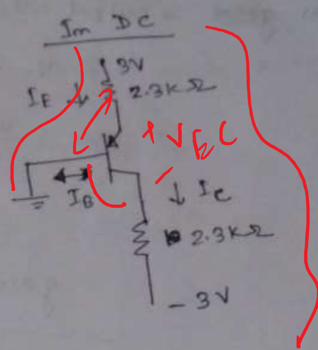

Figure 2

(a) Calculate $I_C$, $I_B$, $I_E$, $V_{EC}$. You can ignore the Early effect in DC bias calculations.
(b) Draw the AC equivalent circuit and determine the AC model parameters.
(c) Calculate the voltage gain.

(2) [redacted]

$\beta = 200$ and $V_A = 150$ V. (Early voltage)




p-n-p Common emitter amplifier

$I_B\ r_o\ g_m$

p-n-p Common emitter amplifier

(a) Assuming the BJT is in active mode:

$V_{EB} = 0.7\ V$, $I_C > 0$ and $V_{EC} > 0.7\ V$.

Apply KVL in B-E loop, $3 = 2.3\times10^{3} \times I_E + V_{EB}$

$\therefore I_E = 1\ mA \approx I_C$

[as $\beta = 200$]

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

Apply KVL in C-E loop, $3 = 2.3\times10^{3} I_E + V_{EC} + 2.3\times10^{3} I_C - 3$

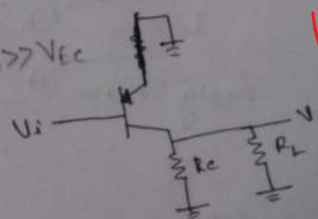
$\therefore V_{EC} = 1.4\ V$ ($> 0.7$)

so, in active region as assumed.

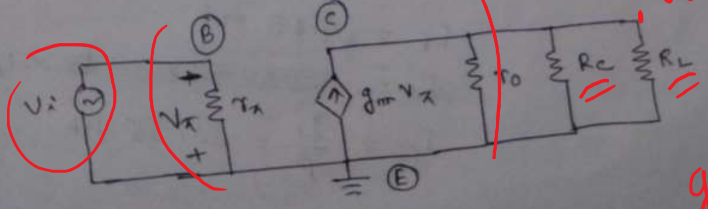
(b) $g_m = \frac{I_C}{V_T} = \frac{10^{-3}}{26\times10^{-3}} = 38.5\ mS$

$r_o = \frac{V_A}{I_C} = \frac{150}{1\ mA} = 150\ k\Omega$ ; $V_A \gg V_{EC}$

$r_\pi = \frac{\beta V_T}{I_C} = 5.2\ k\Omega$




($r_o \| R_C \| R_L$)




$\frac{v_o}{v_i}$

gain =

**5.** The parameters of the transistor in the circuit in Figure 5 are $\beta = 100$ and $V_A = 100$ V.
(a) Find the dc voltages at the base and emitter terminals.
(b) Find $R_C$ such that $V_{CEQ} = 3.5$ V.
(c) Assuming $C_C$ and $C_E$ act as short circuits, determine the small-signal voltage gain $A_v = v_o/v_s$.
(d) Repeat part (c) if the magnitude of source resistance ($R_S$) is changed to 500 Ω.

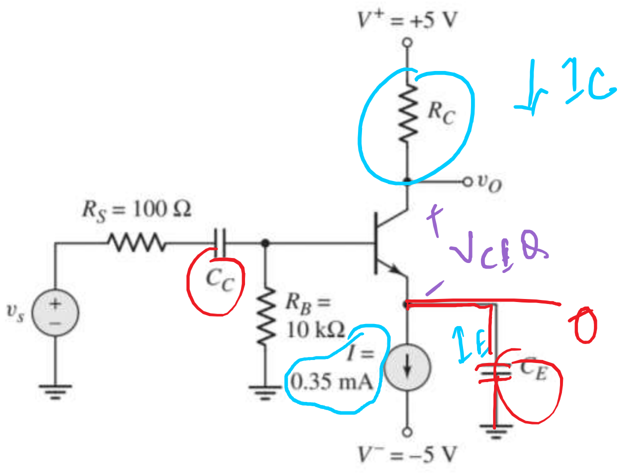
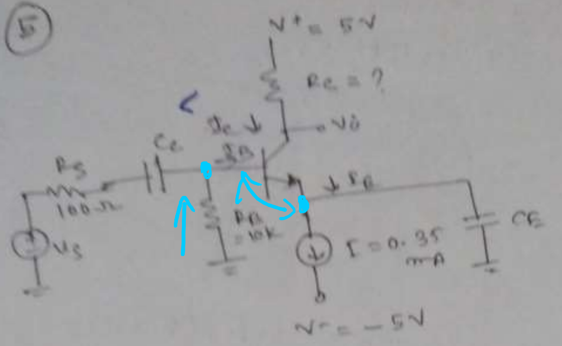



Figure 5

(5)




$\beta = 100$

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

(a)

So, $I_E = 0.35$ mA.

$\therefore I_B = \frac{0.35}{101} = 0.00347$ mA. $= 3.47\,\mu A$

$\therefore V_B = -I_B R_B = -(3.47\,\mu A) \times 10K.$

$V_B = -0.0347$ V.

$V_{BE(ON)} = 0.7.$

$\therefore V_B - V_E = 0.7.$

$\therefore V_E = -0.7 + V_B = -0.7347$ V.

~~(b) KVL ...~~

(b)

$\frac{5 - V_0}{R_C} = I_C = \frac{\beta}{1+\beta} I_E$

$\therefore \frac{5 - 2.77}{R_C} = 0.347.$

$\therefore R_C = 6.43\ k\Omega.$

$V_{CEQ} = 3.5$ V.

$\therefore V_0 = V_{CEQ} + V_E$

$= 3.5 - 0.7347$

$\cong 2.77$ V.

(c) $V_A = 100$ V,

$r_0 = \frac{V_A}{I_C} = 288\ k\Omega.$

$g_m = \frac{I_C}{V_T} = 13.3$ mA/V.

$r_\pi = \frac{100 \times V_T}{I_C} = 7.49\ k\Omega$

$gain(A_v) = \frac{V_0}{V_S} = -g_m \cdot \left(\frac{R_B \| r_\pi}{R_S + R_B \| r_\pi}\right)(R_C \| r_0)$

$= -81.7.$

(d) if, $R_s = 500\,\Omega$

$$A_v = -g_m \times \frac{R_B \,\|\, r_\pi}{R_B \,\|\, r_\pi + R_S} \times (R_C \,\|\, r_o)$$

$$= -74.9$$ (Comment: gain reduces when $R_s$ increases)

**6.** Find the expression of small signal voltage gain for the following circuit (Figure 6)

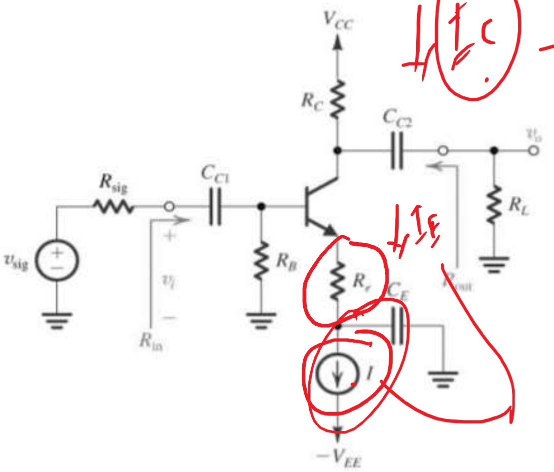
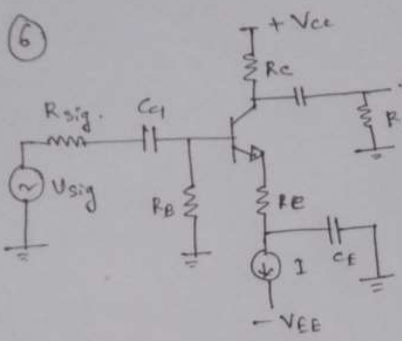
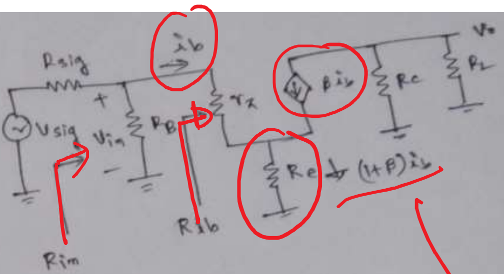



Figure 6

(6)




$v_{in} = i_b r_\pi + (1+\beta) i_b R_e$ ∴ $R_{ib} = \frac{v_{in}}{i_b} = r_\pi + (1+\beta) R_e$

$R_{in} = R_B \,\|\, R_{ib}$

∴ $v_{in} = \frac{R_{in}}{R_{in} + R_{sig}} \, v_{sig}$

$v_o = -\beta i_b (R_C \,\|\, R_L)$

$v_o = -\beta \cdot \frac{v_{in}}{R_{ib}} (R_C \,\|\, R_L)$

$v_o = -\frac{\beta (R_C \,\|\, R_L)}{r_\pi + (1+\beta) R_e} \cdot v_{in}$

∴ $\frac{v_o}{v_{in}} = -\frac{\beta (R_C \,\|\, R_L)}{r_\pi + (1+\beta) R_e}$

∴ $\frac{v_o}{v_{sig}} = -\frac{\beta R_{in} (R_C \,\|\, R_L)}{(R_{in} + R_{sig})[r_\pi + (1+\beta) R_e]} = A_v$ (Small-signal voltage gain).

doubt??

$$\therefore \frac{v_o}{v_{sig}} = -\frac{\beta R_{in} (}{(R_{in} + R_{sig})\left[r_\pi + (1+\beta) R_e\right]}$$

voltage g