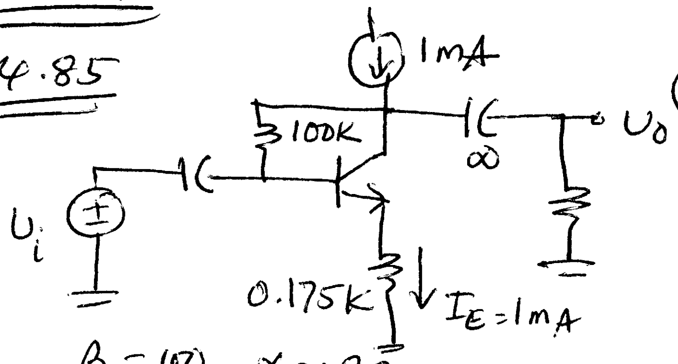
EE341 Solution to Take Home Exam

P 4.85



$\beta = 100 \quad \alpha = .99$

$r_e = \frac{V_T}{I_E} = 0.025K$

(a) $I_E = 1mA \quad I_B =$

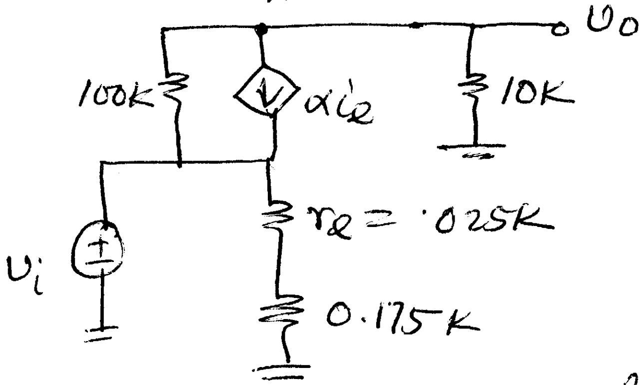
$\therefore I_C = \alpha I_E = 0.99mA$

$V_C = I_E R_E + 0.7 + I_B R_B$

$= 1 * 0.175 + 0.7 + \frac{1}{101} * 100k$

$= 1.875V$

(b)



$i_e = \frac{v_i}{r_e + R_E} = \frac{v_i}{(.025 + .175)K}$

$= \frac{v_i}{0.2K}$

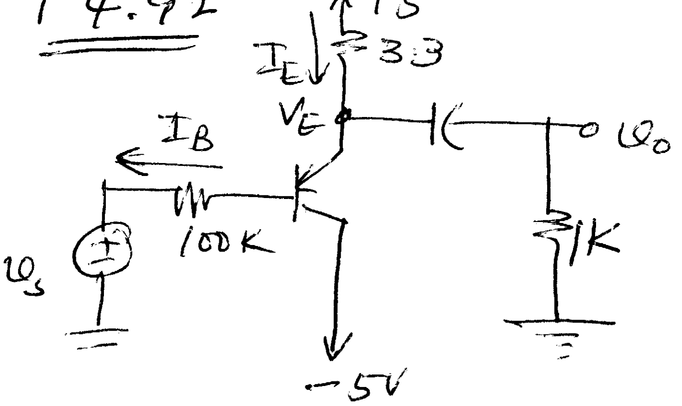
Let us write a node equation at x

$$\frac{v_o - v_i}{100K} + \alpha i_e + \frac{v_o}{10K} = 0$$

$$0.01 v_o - 0.01 v_i + \frac{0.99 v_i}{0.2} + 0.1 v_o = 0$$

$$0.11 v_o = -4.94 v_i \Rightarrow \frac{v_o}{v_i} = A_v = -44.9 V/V$$

P 4.92



$\beta = 120$

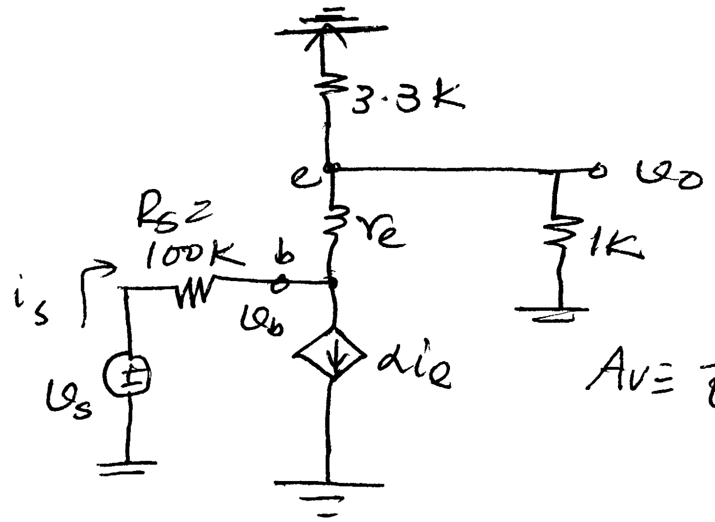
$5 = I_E R_E + 0.7 + I_B R_B$

$\Rightarrow I_E = \frac{5 - 0.7}{3.3 + \frac{100}{121}} = 1.042mA$

$r_e = \frac{V_T}{1.042mA} = 24\Omega$

$V_E = 5 - 3.3 * 1.042 = 1.56V$

Small signal equivalent ckt



$$R_{in} = \frac{v_b}{i_b} = (1+\beta)(r_e + 3.3 \| 1k) = 95.8\ k\Omega$$

$$A_v = \frac{v_o}{v_s} = \frac{v_o}{v_b} \cdot \frac{v_b}{v_s} = \frac{(3.3\|1)}{r_e + (3.3\|1k)} \cdot \frac{R_{in}}{R_{in} + 100k} = 0.474\ V/V$$

$$\frac{i_o}{i_s} = \frac{v_o/R_L}{v_s/(R_S + R_{in})} = \frac{v_o}{v_s} \cdot \left(\frac{R_S + R_{in}}{R_L}\right) = 0.474 \left(\frac{195.8}{1K}\right) = 92.9\ A/A$$

$$R_o = 3.3 \,\|\, \left(r_e + \frac{100}{1+\beta}\right) = 0.676\ k\Omega$$

Max input amplitude:
If we want to limit $\hat{V}_{be} = 5\,mV$ then

$$\hat{V}_{be} = \frac{(1+\beta) r_e \hat{V}_s}{R_s + R_{in}} = \frac{2.9}{195.8} \hat{V}_s$$

$$\therefore \hat{V}_s = \frac{195.8}{2.9} * 5\,mV = 0.338\,V$$

However if we allow $\hat{V}_o$ to be such that the transistor turns off: $(i_E = 0)$:

$v_E = V_E + \hat{V}_o$ when $v_o = +\hat{V}_o$

$$\therefore \frac{5 - (V_E + \hat{V}_o)}{3.3K} = \frac{+\hat{V}_o}{1K} \Rightarrow \hat{V}_o = \frac{5 - 1.56}{4.3} = 0.8\,V$$

$$\therefore \hat{V}_s = \hat{V}_o / A_v = 1.68\,V$$

So the max allowable input voltage is $\hat{V}_s = 0.338\ V$

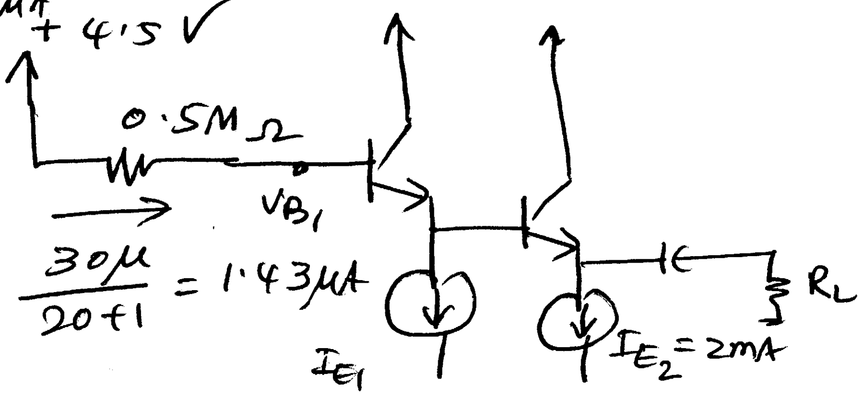
4.96 $I_{E_2} = 2mA$ $I_{E_1} = 20\mu A + I_{B2}$

(a) $= 20 + \frac{2000\mu A}{201} \simeq 30\mu A$

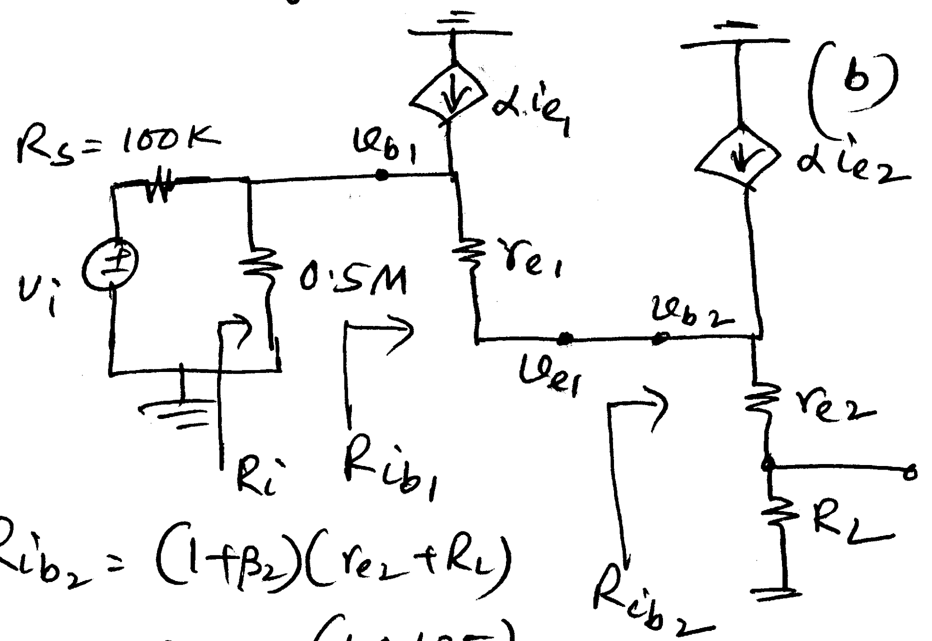
$V_{B_1} = 4.5 - 0.5M * 1.43\mu A$
$= 3.79\ V$

$V_{B2} = 3.79 - 0.7$
$= 3.09\ V$

$\frac{30\mu}{20+1} = 1.43\mu A$



Small signal equivalent ckt



(b) $\frac{v_o}{v_{b_2}} = \frac{R_L}{r_{e_2} + R_L}$

$r_{e_2} = \frac{25}{2} = 12.5\Omega$

$R_L = 1K$

$\frac{v_o}{v_{b_2}} = 0.988\ V/V$

$R_{ib_2} = (1+\beta_2)(r_{e_2} + R_L)$
$= 201 * (1.0125)$
$= 203.5\ k\Omega$

$r_{e_1} = \frac{25mV}{30\mu A} = 0.83k\Omega$

(c) $\frac{v_{e1}}{v_{b_1}} = \frac{v_{b2}}{v_{b1}} = \frac{R_{ib_2}}{r_{e_1} + R_{ib_2}} = \frac{203.5}{203.5 + 0.83} = 0.996\frac{V}{V}$

$$R_i = 0.5M \parallel (1+\beta_1)(r_{e1} + R_{ib2})$$
$$= 0.5M \parallel (21)(0.83 + 203.5)$$
$$= (0.5 \parallel 4.29)M = 0.448\ M\Omega$$
$$= 448\ k\Omega$$

(d) $\dfrac{v_{b1}}{v_s} = \dfrac{R_i}{R_i + R_s} = \dfrac{448}{448 + 100} = 0.818\ V/V$

(e) $\dfrac{v_o}{v_s} = \dfrac{v_{b1}}{v_s} \cdot \dfrac{v_{e1}}{v_{b1}} \cdot \dfrac{v_o}{v_{e1}} = 0.818 * 0.996 * 0.988$
$= 0.805\ V/V$

Max input amplitude

Note $v_{be1} = \dfrac{(1+\beta_1) r_{e1}\, v_{b1}}{R_{ib1}} = \dfrac{(1+\beta_1) r_{e1}\, v_{b1}}{(1+\beta_1) r_{e1} + \underbrace{(1+\beta_1)(1+\beta_2) * (r_{e2} + R_L)}_{(1+\beta_1) R_{ib2}}}$

$$= \frac{21\,(0.81)\, v_{b1}}{21\,(0.81 + 203.5)}$$

& $v_{be2} = \dfrac{(1+\beta_1)(1+\beta_2)\, r_{e2}\, v_{b1}}{21\,(0.81 + 203.5)} = \dfrac{21 * 2.51 * v_{b1}}{21\,(0.81 + 203.5)}$

$\therefore v_{be2} > v_{be1}$

$\therefore \dfrac{v_{be2}}{v_s} = \dfrac{v_{be2}}{v_{b1}} \cdot \dfrac{v_{b1}}{v_s} = \dfrac{21 * 2.51}{21\,(0.81 + 203.5)} * 0.818$

$$= 10^{-2}\ V/V$$

if $\hat{V}_{be} = 5\,mV \Rightarrow \hat{V}_s = \dfrac{5\,mV}{10^{-2}} = 0.5\,V$

when $i_{E_2} = 0$ $\quad I_{R_L} = -2mA$

$\therefore |\hat{V}_o| = (2 * 1) = 2V$

$\therefore \hat{V}_S = \frac{2V}{0.805} = 2.48V$

$\therefore$ the max input amplitude is $0.5V$.