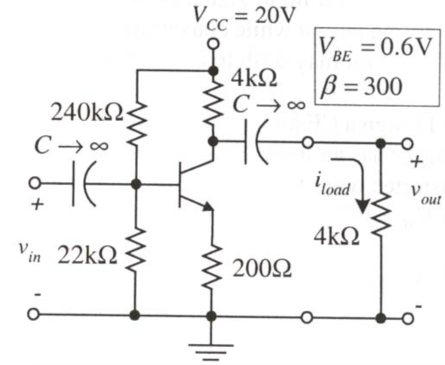
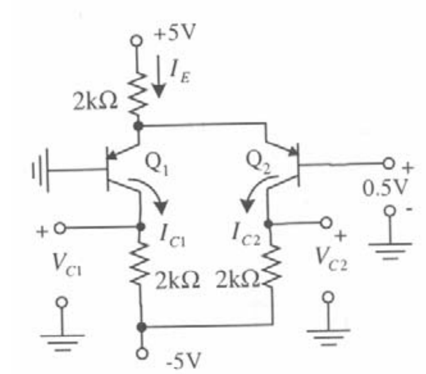
ETEE3211 **Fall 2003** **Test #3** **Name:__________________**

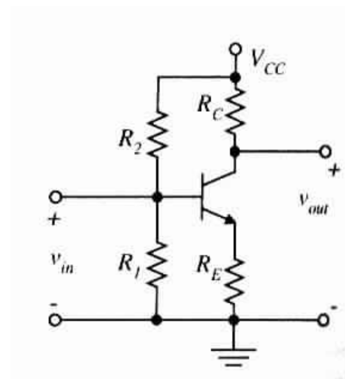
Show all work. Clearly indicate final answer(s).



1. (40 points) Analyze the circuit shown to the right and determine the following:
   a. I_{CQ} and V_{CEQ}
   b. Maximum undistorted output voltage swing
   c. Power supplied from power supply
   d. Voltage gain
   e. Load lines (sketch)



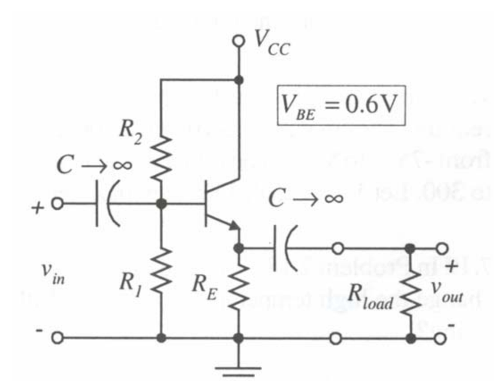
2. (30 points) Using simple analytical techniques for the circuit shown to the right, determine the values of I_E, V_E, I_{C1}, I_{C2}, V_{C1} and V_{C2}. Use V_{BE}= -0.7V as the condition for the transistor(s) to be on.



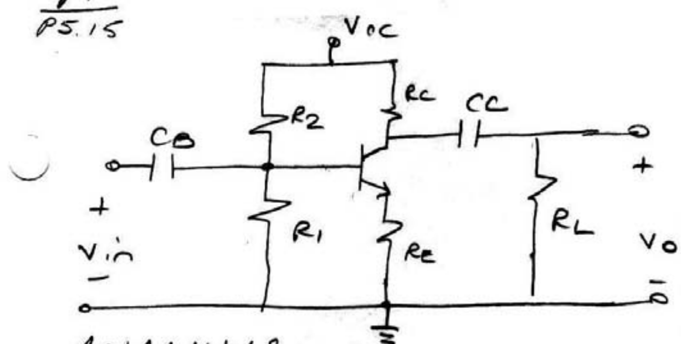
3. (30 points) For the amplifier shown to the right, V_{BE}=0.6V, V_{CC}=12V, β=300, P_{load}(max average)=100mW, and A_V = -10V/V. Design for maximum swing and determine R_1 and R_2. How much power is dissipated in the transistor?

Extra Credit (30 points maximum)

Design an EF (CC) amplifier to drive an 8Ω load. Set the current gain, A_i=10 A/A. Determine the peak-to-peak output voltage swing if the temperature rises to 75^{o}C. Assume I_{CBO}(25^{o}C)=0.008μA, V_{BE}=0.6V, V_{CC}=24V and β varies over the range from 60 to 100. Hint: design for maximum swing at 25^{o}C.



$\frac{P1}{P5.15}$



Given: $C_B = C_C \Rightarrow \infty$
$R_1 = 22k\Omega$
$R_2 = 240k\Omega$
$R_C = 4k\Omega$
$R_E = 200\Omega$
$R_L = 4k\Omega$
$V_{BE} = 0.6V$
$V_{CC} = 20V$
$\beta = 300$

ANALYSIS

assume $i_C \simeq i_E$

a) $I_{CQ} + V_{CEQ}$

$R_B = R_1 \| R_2 = (22k) \| (240k) \simeq 20.2k\Omega$

$V_{BB} = \frac{R_1 V_{CC}}{R_1 + R_2} = \frac{(22k)(20)}{22k + 240k} \simeq 1.68V$

$I_{CQ} = \frac{V_{BB} - V_{BE}}{R_B/\beta + R_E} = \frac{1.68 - 0.6}{20.2k/300 + 0.2k} \simeq \underline{4.04mA}$

$V_{CEQ} = V_{CC} - I_{CQ} \underset{R_C + R_E}{R_{dc}} = 20 - (4.04m)(4.2k) = \underline{3.03V}$

b) max V_{opp} (undistorted)

$V_{CC}' = V_{CEQ} + I_{CQ} \underset{R_C \| R_L + R_E}{R_{ac}} = 3.03 + (4.04m)(2.2k) = 11.92V$

$I_{CC}' = \frac{V_{CC}'}{R_{ac}} = \frac{11.92}{2.2k} = 5.42mA$

$\therefore I_{CQ}$ in upper half of ac ll

$V_{opp} = 2[0.95 I_{CC}' - I_{CQ}] \underset{R_C \| R_L}{R_{Leff}}$

$= 2[(0.95)(5.42m) - (4.04m)](2k)$

$\underline{V_{opp} = 4.44V}$

2/2

P1 (cont)

c) 2 $P_{dc} = \frac{V_{CC}^2}{R_1+R_2} + V_{CEQ} I_{CQ} + I_{CQ}^2 (R_C + R_E)$

$= \frac{20^2}{262K} + (3.03)(4.04m) + (4.04m)^2(4.2K)$

$\cong (1.53 + 12.24 + 68.55) m$

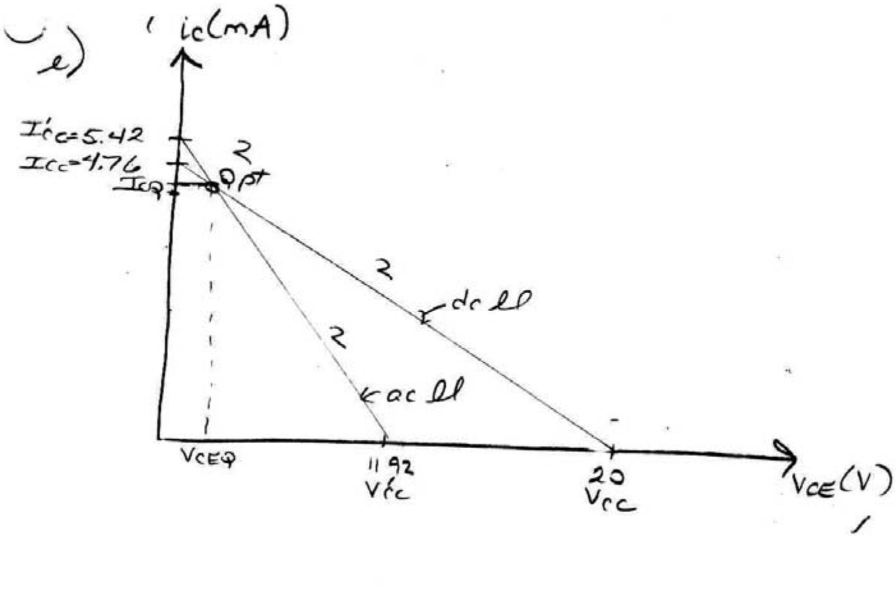
3

$\underline{P_{dc} \simeq 82.32 mW}$

d) $A_v = -\frac{R_C \| R_L}{r_e + R_E}$; 2 $r_e = \frac{V_T}{I_{CQ}} = \frac{26m}{4.04m} = 6.44\,\Omega$

3 $A_v = -\frac{4K \| 4K}{6.44 + 200} = \underline{-9.69 V/V}$

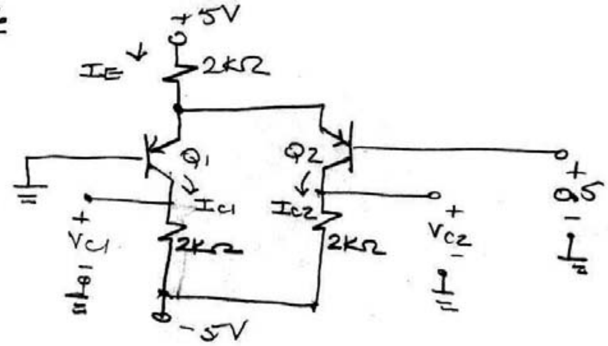
e)



$I_{CC} = \frac{V_{CC}}{R_{dc}} = \frac{20}{4.2K} = 4.76 mA$

P2

P5.56



$V_{BE} = -0.7V$

$V_{B1} = 0 + V_{BE} = -0.7V \therefore \underline{V_{E1} = 0.7V = V_{E2}}$

$I_E = \dfrac{5-0.7}{2K} = \underline{2.15mA}$

Q_1 on, $I_{C1} > 0$

$V_{B2} = 0.5V + V_{E1} = V_{E2} = 0.7V$

$V_{BE2} = 0.5 - 0.7 = -0.2V$, $< -0.7V$ so Q_2 off

Q_2 off, $I_{C2} = 0$

$I_{C1} = I_E = 2.15mA$

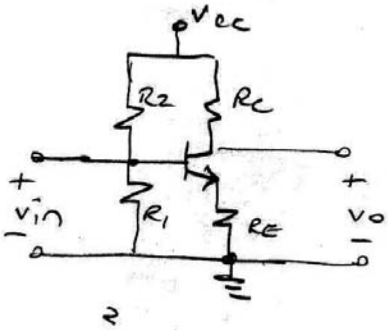
$I_{C2} = 0$

$V_{C1} = -5 + I_{C1}(2K) = -5 + (2.15m)(2K) = \underline{-0.7V}$

$V_{C2} = \underline{-5\ V}$

P3

P5.5



Given: $V_{BE} = 0.6V$

$V_{CC} = 12V$

$\beta = 300$

$P_{load}(\text{max avg}) = 100mW$

$A_v = -10 V/V$

Find: $R_1, R_2, R_{in}, A_i, P_{tran}$

ER Amp: $A_v = -\dfrac{R_C \| R_L}{r_e + R_E}$ ①

Note: no R_L given ($R_L = \infty$) so R_C acts as load

$P_{load} = \frac{1}{2} I_{CQ}^2 R_C$ ②

$I_{CQ} = \dfrac{V_{CC}}{R_{ac} + R_{dc}} = \dfrac{V_{CC}}{(R_E + R_C) + (R_E + R_C)} = \dfrac{V_{CC}}{2(R_E + R_C)}$ ③

from 1 (assume $r_e << R_E$) $-10 = -\dfrac{R_C}{R_E}$; $R_C = 10 R_E$

$\rightarrow 3$: $I_{CQ} = \dfrac{12}{2(11 R_E)} = \dfrac{6}{11 R_E}$

$\rightarrow 2$: $100m = \frac{1}{2}\left(\dfrac{6}{11 R_E}\right)^2 (10 R_E) = \dfrac{1.49}{R_E}$

$R_E = \dfrac{1.49}{0.1} = \underline{14.9 \Omega}$, $R_C = \underline{149 \Omega}$, $I_{CQ} = 36.6mA$

$R_B = 0.1 \beta R_E = (0.1)(300)(14.9) = 447\Omega$

$V_{BB} = V_{BE} + I_{CQ}\left(\dfrac{R_B}{\beta} + R_E\right) = 0.6 + (36.6m)\left(\dfrac{447}{300} + 14.9\right) = 1.2V$

$R_1 = \dfrac{R_B}{1 - V_{BB}/V_{CC}} = \dfrac{447}{1 - 1.2/12} = \underline{497\Omega}$

$R_2 = \dfrac{R_B V_{CC}}{V_{BB}} = \dfrac{(447)(12)}{1.2} = \underline{4.47k\Omega}$

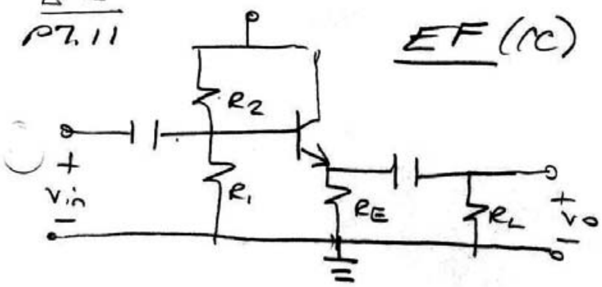
$V_{CEQ} = V_{CC} - I_{CQ} R_{dc} = 12 - (36.6m)(149 + 14.9) = 6V$

$P_{tran} = I_{CQ} V_{CEQ} = (36.6m)(6) \cong 220mW$

pto

EC
P7.11

EF (CC)



Given: $R_L = 8\,\Omega$
$A_i = 10\,A/A$
$I_{CBO}(25°C) = 0.008\,\mu A$
$V_{BE} = 0.6\,V$
$V_{CC} = 24\,V$
$60 \le \beta \le 100$

Want:
a) Design amp for max swing
b) V_{opp} @ 75 °C

* assume β large enough so that $i_C \simeq i_E$

a)

$$A_i = \frac{R_B}{R_B/\beta + r_e + (R_E \| R_L)} \frac{R_E}{R_E + R_L}$$

Let $R_E = R_L = 8\,\Omega$; $R_E \| R_L = 4\,\Omega$
assume r_e negligible
use $\beta = \beta_{avg} = \frac{60+100}{2} = 80$

$$A_i = 10 = \frac{R_B}{R_B/80 + 4} \frac{8}{16} \Rightarrow 20\left(\frac{R_B}{80} + 4\right) = R_B \Rightarrow$$

$$80 = R_B\left(1 - \frac{1}{4}\right) \Rightarrow R_B = \frac{80}{0.75} \cong 107\,\Omega$$

Design for max swing: $I_{CQ} = \frac{V_{CC}}{R_{ac} + R_{dc}} = \frac{V_{CC}}{(R_E \| R_L) + R_E}$

$$I_{CQ} = \frac{24}{4+8} = 2A \; ; \; r_e = \frac{V_T}{I_{CQ}} = \frac{26m}{2} = 13\,m\Omega$$

assumption ok

$$V_{BB} = V_{BE} + I_{CQ}\left(\frac{R_B}{\beta} + R_E\right) = 0.6 + (2)\left(\frac{107}{80} + 8\right) = 19.3\,V$$

$$R_1 = \frac{R_B}{1 - V_{BB}/V_{CC}} = \frac{(107)}{1 - 19.3/24} = \underline{\underline{546\,\Omega}}$$

$$R_2 = \frac{R_B V_{CC}}{V_{BB}} = \frac{(107)(24)}{19.3} = \underline{\underline{133\,\Omega}}$$

b) $\Delta T = T_2 - T_1 = 75 - 25 = 50°C$

$\Delta\beta = 100 - 60 = 40$

$\Delta V_{CC} = 0$ (given as constant)

$\Delta V_{BE} = k_T\,(T_2 - T_1) = (-2mV/°C)(50°C) = -100mV$

$\Delta I_{CBO} = I_{CBO}(T_1)\left[e^{k_i(T_2-T_1)} - 1\right] = (0.0084A)\left[e^{(0.15)(50)} - 1\right] \simeq 14.5\mu A$

1 $\delta_V = -\dfrac{1}{R_E + R_B/\beta} = -\dfrac{1}{8 + 107/80} = -0.107$

1 $\delta_I = \dfrac{\beta}{1 + \beta R_E/R_B} = \dfrac{80}{1 + \frac{(80)(8)}{107}} = 11.46$

1 $\delta_\beta = \dfrac{R_B(V_{BB} - V_{BE})}{(\beta R_E)^2} = \dfrac{(107)(19.3 - 0.6)}{((80)(8))^2} = 4.89\times10^{-3}$

$\Delta I_C = \delta_V \Delta V_{BE} + \delta_I \Delta I_{CBO} + \delta_\beta \Delta\beta$ $\quad(\delta_{V_{CC}}\Delta V_{CC} = 0)$

$= (-0.107)(-100m) + (11.46)(14.5\mu) + (4.89\times10^{-3})(40)$

positive since net of 1st 2 terms is positive

1 $\Delta I_C = 10.7m + 0.17m + 195.6m \cong 206.5mA$

1 $I_{CQ}(75°C) = I_{CQ}(25°C) + \Delta I_C = 2 + 206.5m \cong 2.21A$

1 $V_{CEQ}(75°C) = V_{CC} - I_{CQ}R_{dc} = 24 - (2.21)(8) = 6.32V$

1 $V'_{CC}(75°C) = V_{CEQ} + I_{CQ}R_{ac} = 6.32 + (2.21)(4) \cong 15.16V$

$I'_{CC}(75°C) = \dfrac{V'_{CC}}{R_{ac}} = \dfrac{15.16}{4} = 3.79A$ $\therefore$ I_{CQ} in upper half

2 $V_{opp} = 2\left[0.95 I'_{CC} - I_{CQ}\right]R_{Leff} = 2\left[(0.95)(3.79) - 2.21\right](4) \cong \underline{\underline{11.1V_{pp}}}$
@75°C