1. (35 points) Determine the low frequency response of the EF amplifier shown to the right if \( R_1=20\, \Omega \), \( R_2=2\, \Omega \), \( R_L=100\, \Omega \), \( R_E=50\, \Omega \), \( R_S=1\, \Omega \), \( C_B=100\mu F \), \( C_E=3.3\mu F \), \( V_{cc}=10V \), \( \beta=200 \), \( V_{BE}=0.7V \) and \( V_T=26mV \).

2. (30 points) Given a common emitter amplifier with \( R_S=5k\, \Omega \), \( R_E=500\, \Omega \), \( R_1=19.5k\, \Omega \), \( R_2=185k\, \Omega \), \( R_C=R_L=10k\, \Omega \), \( C_B=4\mu F \), \( C_C=0.2\mu F \), \( V_{CC}=12V \), \( V_{BE}=0.7V \), and \( \beta=200 \), find \( C_E \) such that the low frequency cutoff is approximately 40Hz. Use \( V_T=26mV \).

3. (35 points) Design a single 741 op-amp amplifier \((G_o=10^5, R_o=75\, \Omega)\) which will yield an output given by

\[
v_{out} = 5v_1 + 4v_2 - 10v_3 + 2v_4
\]

The equivalent resistance and the negative and positive terminals is 12k\, \Omega. Determine each resistor value, the input resistance at each amplifier input, and the output resistance. Draw the schematic and show the resistor values.

Extra Credit (Maximum 25 points): Two differential voltages, \( v_A \) and \( v_B \), each of which are balanced with respect to ground, are available as inputs. The \( v_A \) source has a Thevenin resistance between 10k\, \Omega and 210k\, \Omega, whereas the \( v_B \) source has a Thevenin resistance between 50k\, \Omega and 150k\, \Omega. Design a multiple 741 circuit to generate the voltage

\[
v_{out} = 10(v_A-v_B),
\]

with respect to ground without coupling between the two input sources. The bias current balance should be as good as is possible.
Given: $R_1 = 20k\Omega$
$R_2 = 2k\Omega$
$R_L = 100\Omega$
$R_E = 50\Omega$
$R_S = 1k\Omega$
$C_E = 100\mu F$
$C_B = 3.3\mu F$
$V_{cc} = 10V$
$V_{be} = 0.7V$

\[ I_{ce} = \frac{V_{cc}}{R'_e + R_E} \]
\[ R_E = R_1 + R_2 = 20k\Omega + 2k\Omega = 22k\Omega \]
\[ V_{cc} = \frac{R_1}{R'_1 + R_2} \]
\[ I_{ce} = \frac{V_{cc}}{R_E} \]
\[ I_{ce} = \frac{V_{cc}}{R_E} \]
\[ I_{ce} = \frac{V_{cc}}{R_E} \]
\[ I_{ce} = \frac{V_{cc}}{R_E} \]
\[ I_{ce} = \frac{V_{cc}}{R_E} \]

Insert values and solve for respective currents.

\[ R_E = 1k + 1.82k \times 1.82k(100(500 + 100)) = 2.43k\Omega \]
\[ I_{ce} = \frac{V_{cc}}{R_E(100(100))} = 10.3m\Omega \]
\[ I_{ce} = \frac{V_{cc}}{R_E(100(100))} = 10.3m\Omega \]
\[ I_{ce} = \frac{V_{cc}}{R_E(100(100))} = 10.3m\Omega \]

Less than 1 decade, \[ f_L = \sqrt{\frac{I_{ce}}{2\pi}} = 25.1 Hz \]
\[ \text{CE: } R_{CE} = R_C + R_L \\
R_{CE} = R_C \| R_L \]

\[ R_B = R_1 || R_2 = 19.5k \| 18k = 17.4k \Omega \]

\[ V_{BE} = \frac{V_T}{e+1} = 0.7V \]

\[ I_C = V_{BE} - V_{BC} = \frac{V_T}{e+1} - \frac{V_T}{e+2} = 0.7V \]

\[ r_e = \frac{V_T}{I_C} = 3.5k \Omega \]

\[ r_T = \frac{R_C}{V_T} = 10 \Omega \]

\[ R_{CB} = \frac{5k + 17.6k || 7k}{200} = 49 \Omega \]

\[ \omega_{oc} = \frac{1}{\sqrt{C_{oc}R_{oc}}} = \frac{1}{\sqrt{C_{oc}}10k} = 250kHz \]

\[ \omega_{cc} = \frac{1}{\sqrt{C_{cc}R_{cc}}} = \frac{1}{\sqrt{C_{cc}}}20k = 250kHz \]

\[ C_E = \frac{1}{2\pi(60Hz)} = 812\mu F \]

\[ \text{or } 0.812\text{mF} \]
\[ V_o = 5V_1 + 4V_2 - 10V_3 + 2V_4 \]

\[ R_{eq} = 12k\Omega \]

\[ x_1 = 5, x_2 = 4, x_4 = 2 \quad ; \quad X = 11 \]

\[ Y_A = 10 = Y \quad ; \quad Y_1 = 11 \]

\[ Z = X - (Y + 1) = 11 - 11 = 0 \]

\[ R_L = \frac{R_{eq}}{X_1} = \frac{12k\Omega}{5} \]

\[ R_1 = \frac{R_F}{X_1} = \frac{132k\Omega}{5} = 26.4k\Omega \]

\[ R_2 = \frac{R_F}{X_2} = \frac{132k\Omega}{4} = 33k\Omega \]

\[ R_4 = \frac{R_F}{X_3} = \frac{132k\Omega}{2} = 66k\Omega \]

\[ R_A = \frac{R_F}{Y_A} = \frac{132k\Omega}{10} \]

\[ R_{in1} = R_1 + R_2 + R_3 + R_4 = 26.4k\Omega + (33k\Omega + 66k\Omega) = 98.4k\Omega \]

\[ R_{in2} = R_2 + R_1 + R_3 + R_4 = 33k\Omega + (26.4k\Omega + 66k\Omega) = 51.9k\Omega \]

\[ R_{in3} = R_3 + R_1 + R_2 + R_4 = 66k\Omega + (26.4k\Omega + 132k\Omega) = 86.7k\Omega \]

\[ R_{in4} = R_4 = 132k\Omega \quad (= R_{in3}) \]

\[ R_{in5} = \frac{132k\Omega}{10} = 13.2k\Omega \]

\[ g_{m} = \frac{152k\Omega}{10} \approx 8.3m\Omega \]

\[ \text{Diagram:} \]
$R_m(V_o) = 10k \alpha to 20k \alpha - average 110k \alpha or 55k \alpha logged.$

$R_m(V_o) = 50k \alpha in 180k \alpha - average 100k \alpha or 50k \alpha logged.$

Need to decouple inputs.
Use Fig. 9.14(i) for each input and then sum the inputs in another op-amp.

Input - Gain 645; Middle Amp - 1; Output Amp - 2.
Input Amp (Vp);
$R_1 = R_p || R_a = 55k \alpha$
Then $R_a = 68.8k \alpha$
and $R_p = 27.5k \alpha$

Input Amp (Vb);
$R_1 = R_p || R_a = 50k \alpha$
Then $R_a = 62.5k \alpha$
and $R_p = 250k \alpha$. 

---

EC
(P9.54)