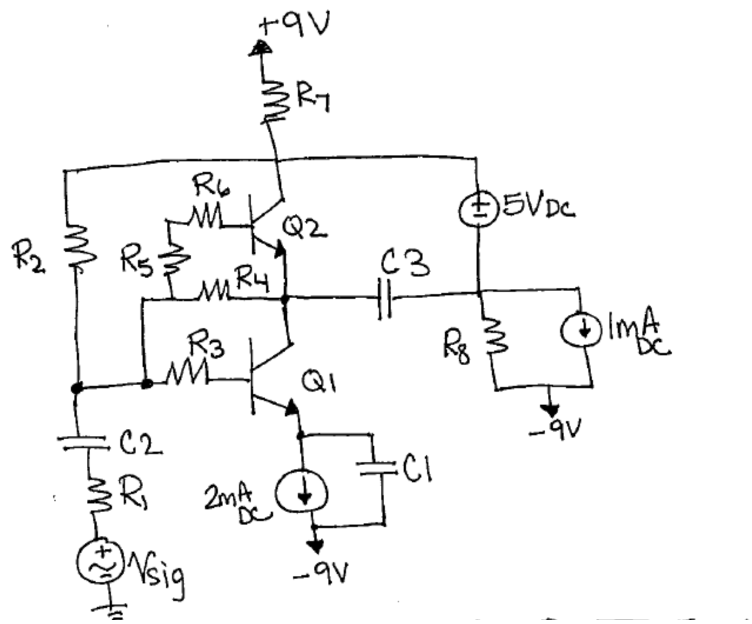
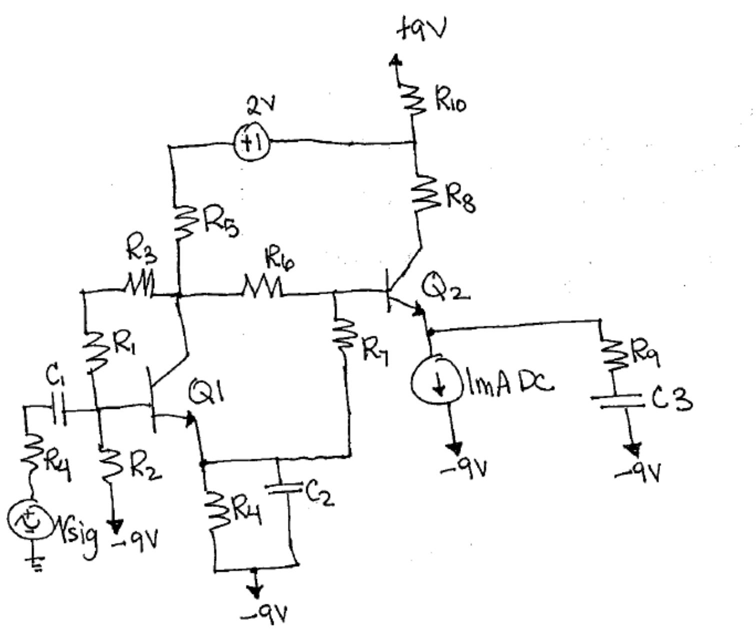
ECE2280 **Homework #5**

1. For the circuit shown below, **draw** the AC small-signal equivalent circuit(use hybrid-π). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, $v_{\pi 2}$, etc.). **Include r_o** for all transistors. v_{sig}=0.001sin(10t) AC. Assume that the capacitors act as a short.



2. For the circuit shown below, **draw** the AC small-signal equivalent circuit(use hybrid-π or model T). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, $v_{\pi 2}$, etc.). **Include r_o** for all transistors. v_{sig}=0.001sin(10t) AC. Assume that the capacitors act as a short.

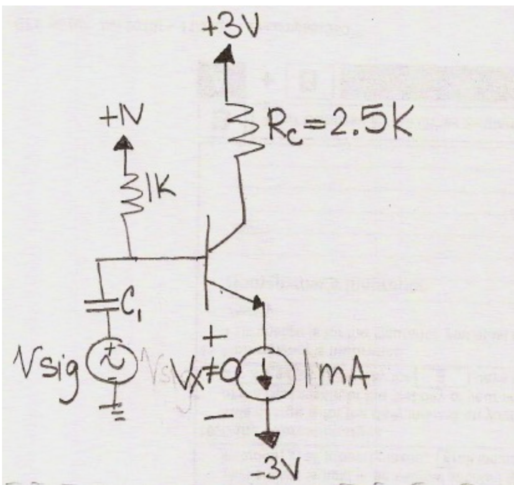


3. $|V_{BE}|$=0.7, β=100, V_T=25mV, $|V_{CE_{SAT}}|$ =0.2V, ignore r_o, v_{sig} ={2+0.1sin(ωt)}Volts. Assume that the capacitor acts as an open for DC operation and short for AC operation. There is an unknown voltage drop across the 1mA current source.

(a) Assume transistor is acting in saturation, write **three independent equations** that would be used to solve for I_B and I_C. (You do not need to solve these equations.)

(b) Assume that your solution from (a) yields $I_B = 900\mu$ and $I_C = 9m$ (not actual values). Determine β_{forced}.

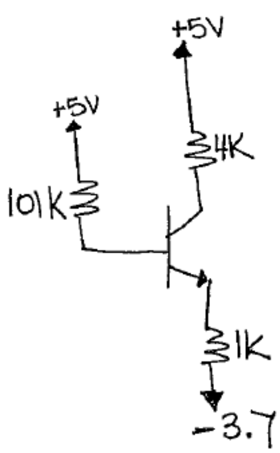
(c) Express the condition for R_C in order to keep the transistor in the **active region.**



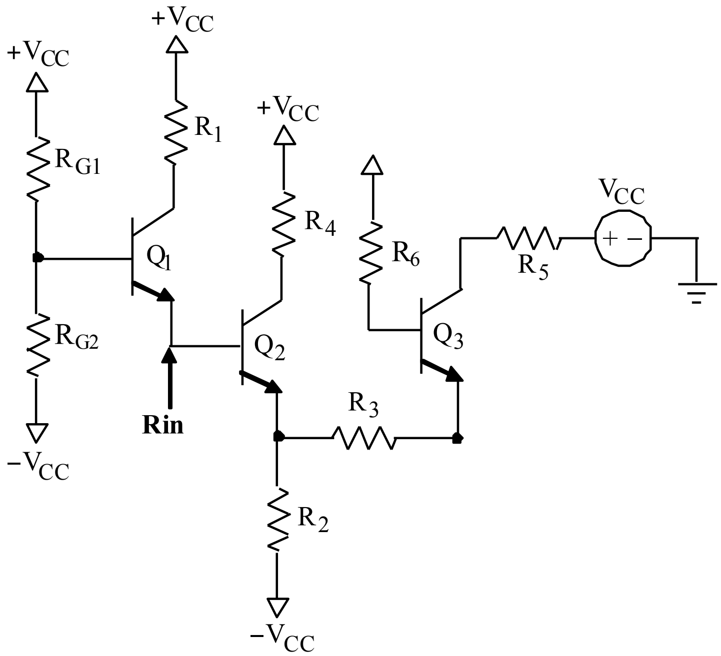
4. Use $|V_{BE}|$=0.7, β=100, V_T=25mV, $|V_{CE_{SAT}}|$ =0.2V.

(a) Assume transistor is acting in saturation, write **three independent equations** that would be used to solve for I_B, I_E, and I_C.

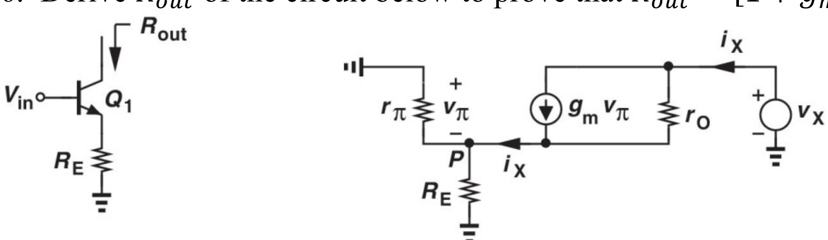
(b) Solve the equations from (a) for the actual values of I_B, I_E, and I_C. What is β_{forced}?



5. (a) Assume the transistors below have a finite β and an infinite Early voltage. Draw the small signal equivalent circuit (hybrid-π or model T)
(b) Write an expression for the input resistance R_{in} in the circuit shown. Your expression should include *only* real resistances (R_1, R_2, R_3, R_4, R_5, R_6, R_{G1}, R_{G2} or a subset of these) and possibly β and r_π. (Assume all transistors have the same β.)

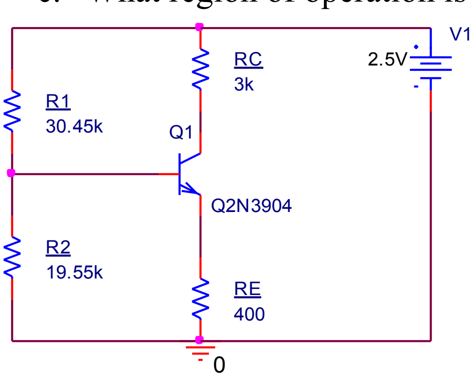


6. Derive R_{out} of the circuit below to prove that $R_{out} = [1 + g_m(R_E||r_\pi)]r_o + (R_E||r_\pi)$.



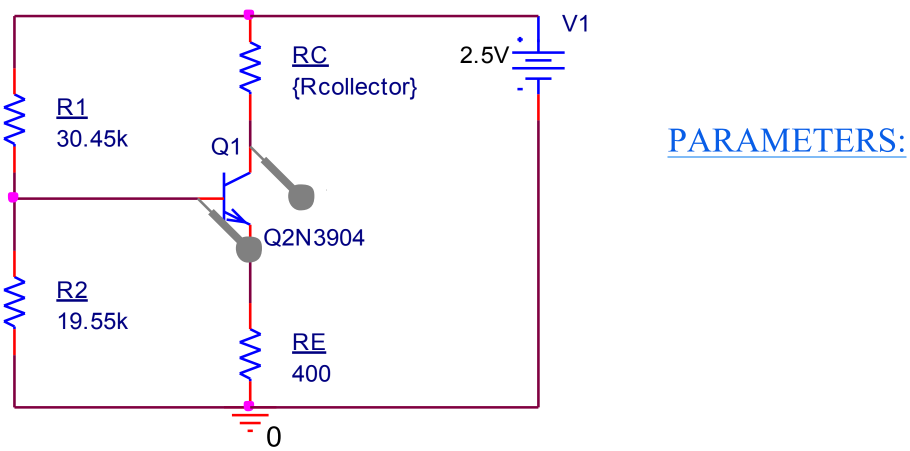
(a) (b)

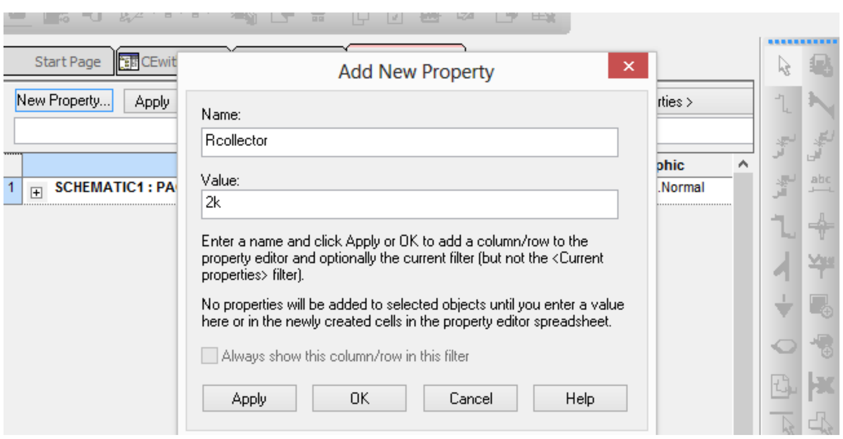
7. Draw the following circuit in PSpice.
   a. Run a transient simulation and find the following values: $I_E, I_B, I_C, V_C, V_B, V_E$.
   b. Compare these to the designed values for $I_C = 0.5mA$, $I_1 = 10I_B$, and $V_{BE} = 778m$ derived in class. What causes the differences in values from the designed values.
   c. What region of operation is this circuit operating in?

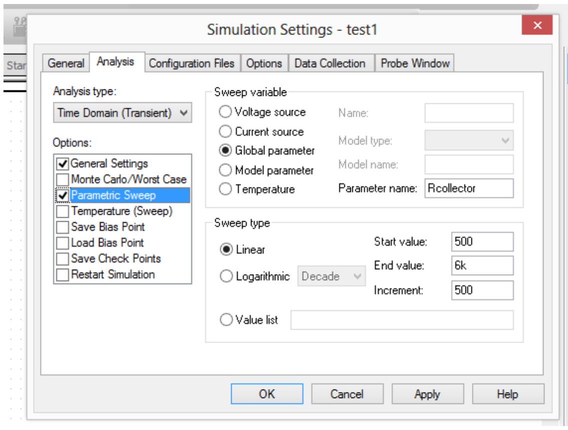


Problems 8-10:

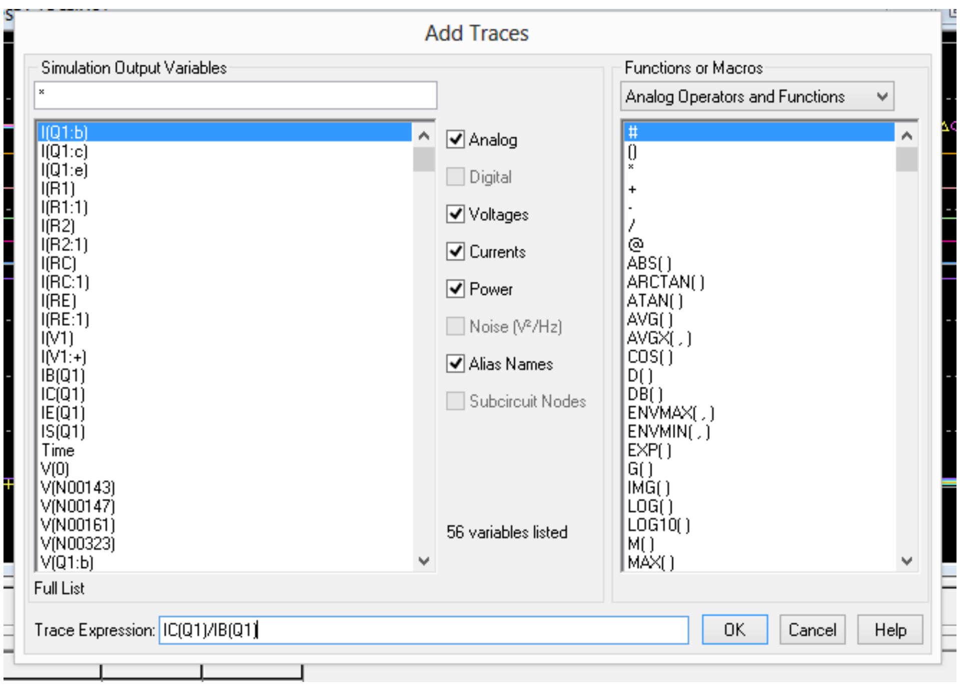
Using the drawn circuit of problem 7, this problem will walk you through "Parameterizing" a resistor. This technique can be used for any component. Double click on the 3k value and change the value to a word surrounded by the squiggly brackets that look like {}. In this case, I used {Rcollector}. Place a part called PARAM(located in the special library) anywhere on the schematic. Double click on the word "PARAMETERS" and a spreadsheet pops up in a new window. Select the box that says "New Property". A window may pop up that says UNDO Warning. Click Yes. Put the name you placed inside the {} without the squiggly brackets. In this examples the name is Rcollector. Put a value in the value box. This value will only be used for simulations that are not parametric analysis. Click Apply and then YES if the warning box comes up again. Close this window and in the schematic page create a new simulation profile. Go to edit simulation profile and choose the type of simulation you want. In this case, select transient analysis. Click on the Parametric Analysis box. Change the sweep variable to Global Parameter and type in the word you typed between the squiggly brackets (without the actual squiggly brackets) in the Parameter name box. Put the sweep type as LINEAR, start value -> 500 to end value -> 6k and increment ->500. Screen shots of these steps are below:



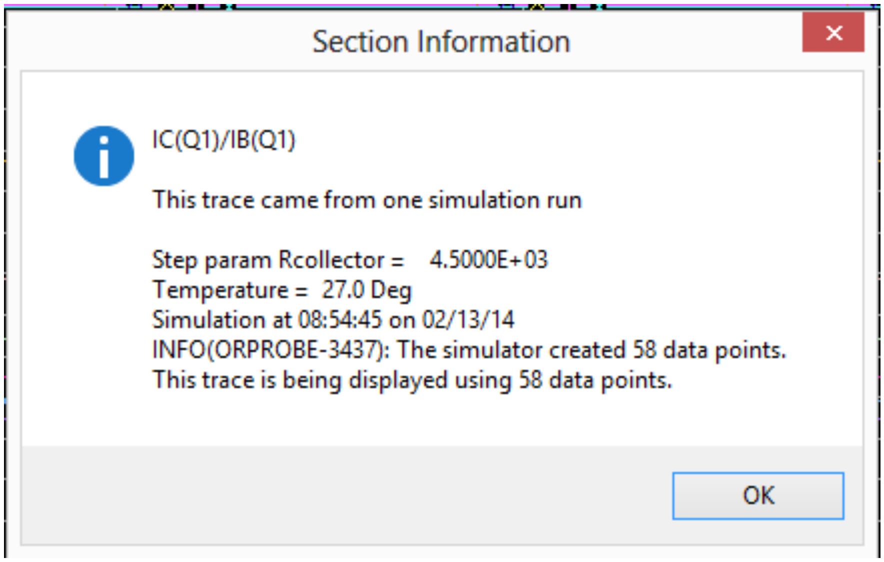




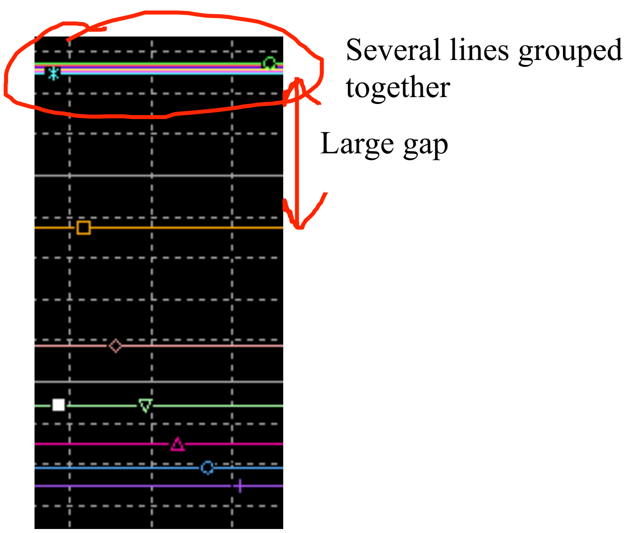
- This problem investigates when Rc is too large and moves the transistor into saturation by changing its value from 500 to 6k and then measuring $\beta = I\_C/I\_B$. Place a current probe at the collector of Q1 and the base of Q1. Run the transient simulation once it is setup as described above. Once the plot comes up, click on the Trace menu and -> Add trace. In the add traces window, type in IC(Q1)/IB(Q1) in the trace expression box at the bottom and click ok. Delete the other traces from the plot by selecting them and hitting the delete button. This is now a plot of β for various values of Rc.



You can select a line, right click on it, select TRACE INFORMATION and a window such as the following pops up:



From this, you can see the value for Rcollector that resulted in the line you selected.
The groupings of the graphs should look like the following:



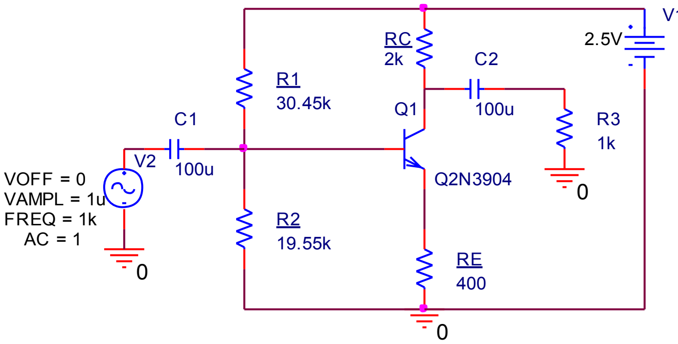
8. (a) What value of β is the nominal value? (this is the value for those lines grouped together keeping β approximately constant)

   (b) What value of Rcollector results in the transistor moving out of the active region. (This is the first line separated by the large gap.)

   (c) Explain in your own words what is happening as Rc is increased.

   (d) Pick a value for Rc that keeps the circuit in the active region. Replace {Rcollector} with this value and rerun the simulation without a parametric analysis. What is the DC bias (IC value) for this Rc?

Modify the circuit to contain the AC source and load resistor. Use this circuit for problems 9-10.



9. (a) Redraw the above circuit using the hybrid pi model. Assume that $\beta = 125$. Assume all capacitors act as a short for the analysis. Find the following:

(i) Overall gain, Vout/Vin where Vout is located above R3 and Vin is to the left of C1.

(ii) Rin

(iii) Rout (ignore the early voltage)

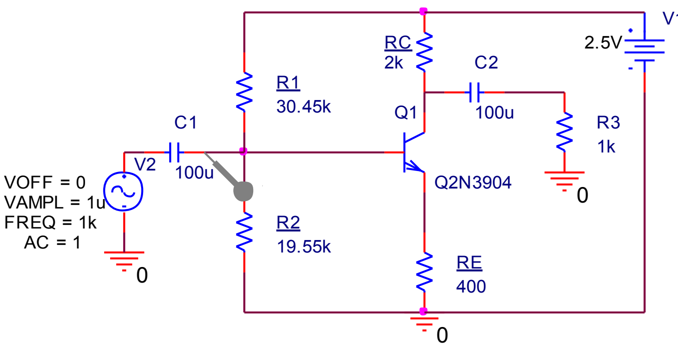
(b) Simulate the above circuit in Pspice. Print out the following:

(i) Circuit schematic

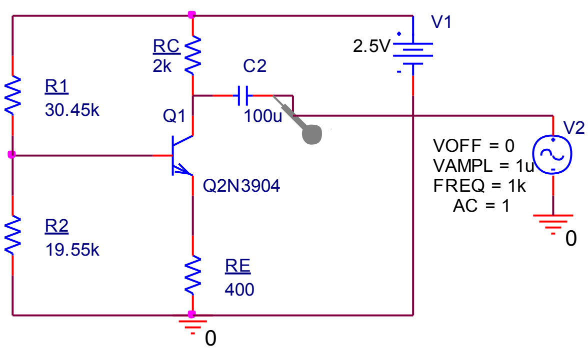
(ii) AC sweep that shows the results for Vout/Vin. Run the simulation from 0.1 to 1Meg (log scale).

(iii) Compare the value to problem 3a.

(iv) Place a current probe as seen in the below circuit. Run an AC sweep and measure the voltage(V2)/current probe to find Rin. The flat region is during the bandwidth. Print this graph. Compare the flat region value(Rin) to the value of 9(i).



(c) Remove the input. Remove R3(the load) and replace it with a voltage source. Run an AC sweep again and measure the voltage(V2)/current probe to find Rout. Print this graph. Compare the flat region value(Rout) to the value of 9(iii).



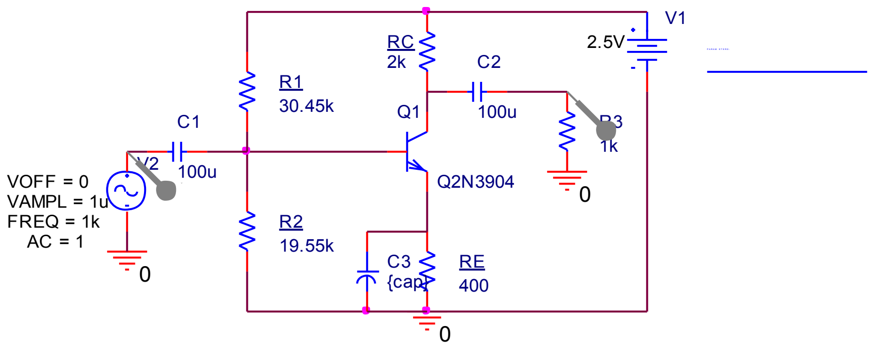
(d) Make C1 from part (b) into a parameter and perform a parametric AC sweep over C1. Vary C1 using the value list option from: 1n, 10n, 100n, 500n, 1u, 10u, 100u, 1000u.

(i) Print the results of Vout/Vin.

(ii) What effect does C1 have on the circuit?
(iii) If this circuit was used to amplify voice, what value would be acceptable for C1 (20Hz-40kHz is audio range)?

10. Add a new capacitor as shown below. Change its value into a parameter and perform a parametric AC sweep over C3. Perform the AC sweep from 0.1 to 100G(log scale). Vary C2 using the value list options of: 1n, 100n, 500n, 1u, 10u, 100u, 1m.

(a) Print the results of Vout/Vin.
(b) What effect does C3 have on the circuit? Comment on the 1pF value and what is observed.
(c) If this circuit was used to amplify voice, what value would be acceptable.



(d) Set the value of C3 to 1mF.
(e) Run a transient analysis and print out the circuit showing voltages and currents. Verify that these DC values are the same as from problem 8.
(f) Run an AC sweep and plot the graph of Vout/Vin. Print this plot.
(g) State the gain value observed.
(h) Using the method described in problem 4d and 4e, print the graphs that show Rin and Rout.
(i) Draw the hybrid pi model of the circuit above. Assume that $\beta = 125$. Assume all capacitors act as a short for the analysis. Find the following:

- Overall gain, Vout/Vin where Vout is located above R3 and Vin is to the left of C1.
- Rin
- Rout (ignore the early voltage)
- Compare all these values with those found (f)-(h).