HW 8 Sample ECE250 Test 2 (KEH) 10 points,max (Each problem worth 0.1 x marked point value)
Allowed: 2 Pre-Published Formula Sheets & Open Laptop MAPLE (Duration: 160 Minutes)

Name: ___________________________________ CM#___________

<u>Important Notes:</u>

i. *You may use MAPLE on this test and/or a calculator, but to receive full credit, you must* ***<u>show all key steps</u>*** *in your problem solution in the space provided in order to properly document your solution.*

ii. *If you need more space, continue your work on the back of the page.*

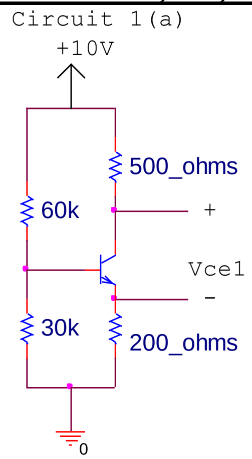
iii. *All currents and voltages referred to in your solution must be clearly marked, along with polarity or reference direction, on the accompanying schematic diagram.*

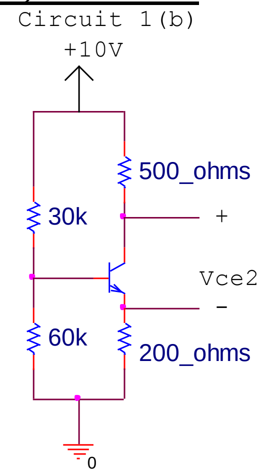
iv. *Unless otherwise indicated in a specific problem, assume that all circuits are at room temperature (V_T = 26 mV), all BJTs (whether NPN or PNP) have* ***n = 1***, ***β_F = 100***, ***β_R = 5***, ***V_A*** *= ∞, and the NPN BJTs have* ***V_{BE}on = 0.7 V***, ***V_{CE}sat = 0.2 V*** *while the PNP BJT's have* ***V_{EB}on = 0.7 V*** *and* ***V_{EC}sat = 0.2 V***.

v. *Remember to append the correct <u>UNITS</u> to your answer, where units are appropriate.*

1. (*16 points---Each of the 4 circuits is worth 4 points*) ***Bipolar Junction Transistor (BJT) DC Analysis***
Find the indicated output voltage for each of the NPN or PNP BJT circuits below. Also indicate the operating mode of the BJT (forward active, reverse active, cutoff, or saturated)

<u>Scrambled Answers: 0.2 V, Sat; 5.40 V, Fwd Active; 6.74 V, Fwd Active; 7.62 V, Fwd Active.</u>



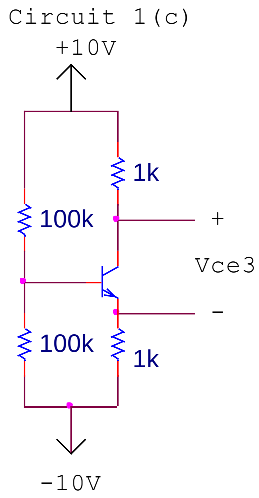


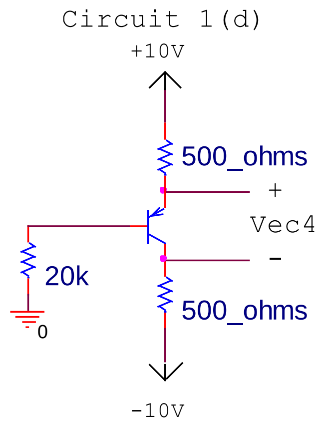
Vce1 = _______________

Mode= _______________

Vce2 = _______________

Mode = _______________





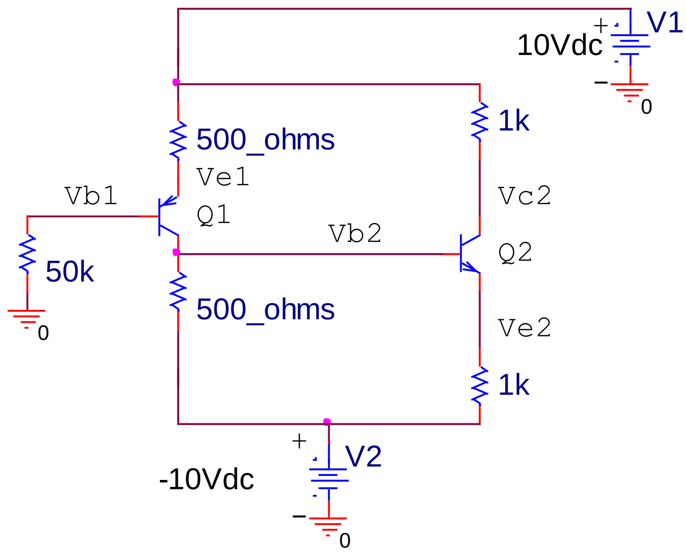
Vce3 = ____________________

Mode = ___________________

Vec4 = ___________________

Mode = __________________

2. (14 points) ***Multiple-Transistor Bipolar Junction Transistor (BJT) DC Analysis***
Find the indicated node voltages in the circuit below that contains both an NPN and a PNP BJT, assuming the transistor parameters that are listed at the beginning of this exam.
Scrambled Answers: -6.093 V, 4.627 V, 6.131 V, 5.327 V, -5.393 V



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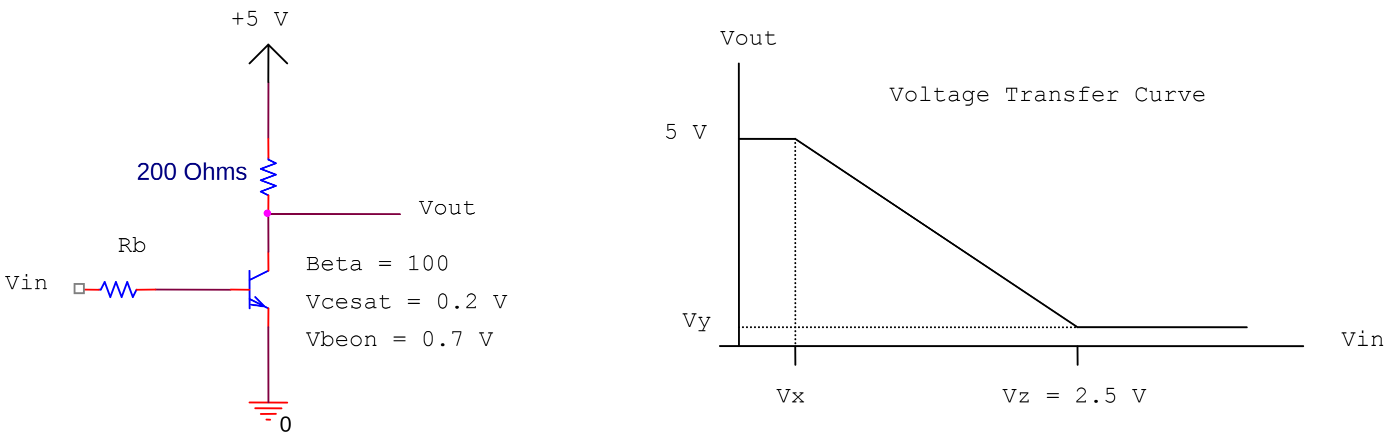
Vb1 = __________ Ve1 = __________ Vb2 = __________ Vc2 = __________ Ve2 = _________

3. (*14 points*) **BJT Inverter Design**. A BJT inverter is shown in Fig. P2, along with its voltage transfer curve. ***Scrambled Answers: 0.2 V, 7.5 kohm, 0.7 V***

Figure P2. BJT Inverter and its associated VTC



(a) (8 pts) Find the value of Vx, Vy, and also find the value of Rb that will make **Vz = 2.5 V**.

Vx = ________________

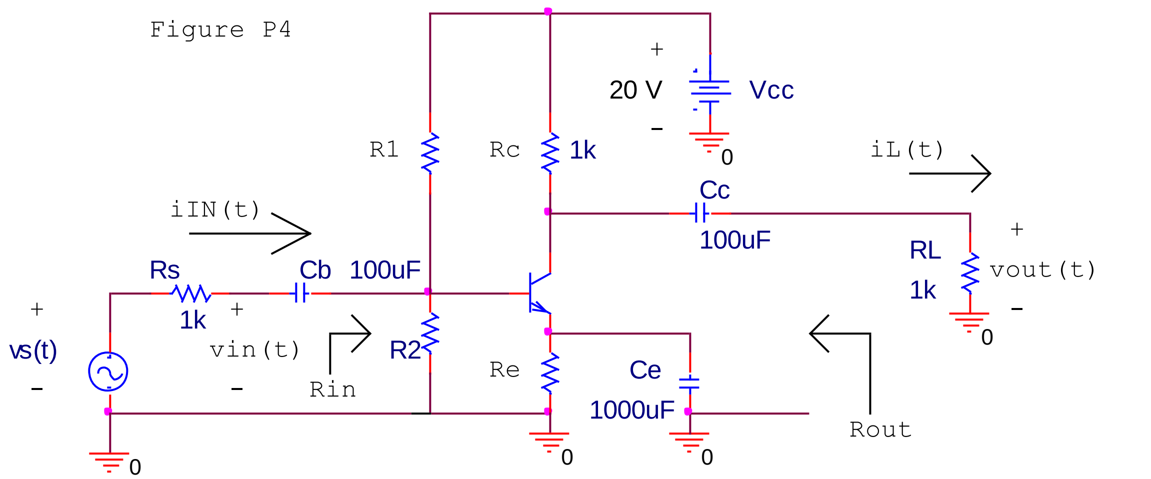
Vy = ________________

Rb = ________________

(b) (6 pts) Draw a circuit diagram in the space below that interconnects ***FOUR NPN BJTs*** that are identical to the BJT in Part (2a), two 200 ohm resistors, and four resistors of the value "Rb" that was calculated above in order to form an ***S-R Latch*** that is the same as the one you built and demonstrated in Lab 5. Be sure to clearly label the **S** and **R** inputs as well as the **Q** output of the SR latch on your diagram.

4. *(24 points)* ***Common-Emitter Amplifier***
See Figure P4 below. Assume the BJT parameters given at the beginning of this test, except (just for this problem) assume that the BJT has an Early Voltage of $\underline{\boldsymbol{V_A = 50\ V}}$.

Scrambled Answers: 1.374 kohm, 123.7 ohms, 13.89 kohm, 862.1 ohm, 258.0 ohms, -265.3, 1073, -36.75, -142.45, -29.21, 10.5 V, 3.47 V, 6.94 Vpp, 325 ohms, 0.308 S, 6.25 kilohm



Assume Cb, Cc, and Ce are all large enough that they may be considered short circuits at the signal frequencies being amplified.

(A) (8 pts) Find the values of Re, R1, and R2 so that the BJT's Q point will be Vceq = 11 V and Icq = 8 mA, and so that the Q-point will be "reasonably stable" by following the "design rule of thumb" that was proposed in the course lecture notes: ***$(\beta+1)Re = 10*(R1 // R2)$.*** (As we have done in class, ignore VA when performing the dc modeling of the BJT.)

Re = ______________

R1 = ______________

R2 = ______________

(B) (3 pts) Recalling that for this problem, $\boldsymbol{V_A = 50\ V}$, calculate the small-signal BJT model parameters rpi, gm, and ro. *Remember to include appropriate units, as with all of the answers on this test!*

rpi = _______________

gm = _______________

ro = ________________

(C) (4 pts) Draw the small-signal (ac) model of this circuit, and calculate the amplifier circuit's input resistance Rin, output resistance Rout, and the unloaded voltage gain Avo = $(vout/vin)_{RL\_removed}$.
Remember to include "ro" in your model!

Rin = _______________

Rout = ______________

Avo = ______________

(D) (4 pts) Draw the *general voltage amplifier model* (consisting of the Rin, Rout, and Avo values obtained above), and then terminate it with the load resistance of R_L = 1 kΩ at the output, and with the generator (consisting of vs(t) in series with Rs) at the input. From this model, determine the overall small-signal "ac" voltage gain Av = vout/vs, the transducer voltage gain Avt = vout/vin, the ac current gain Ai = i_L/i_{IN}, and the ac power gain Ap = Pload/Psource.

Av = _______________

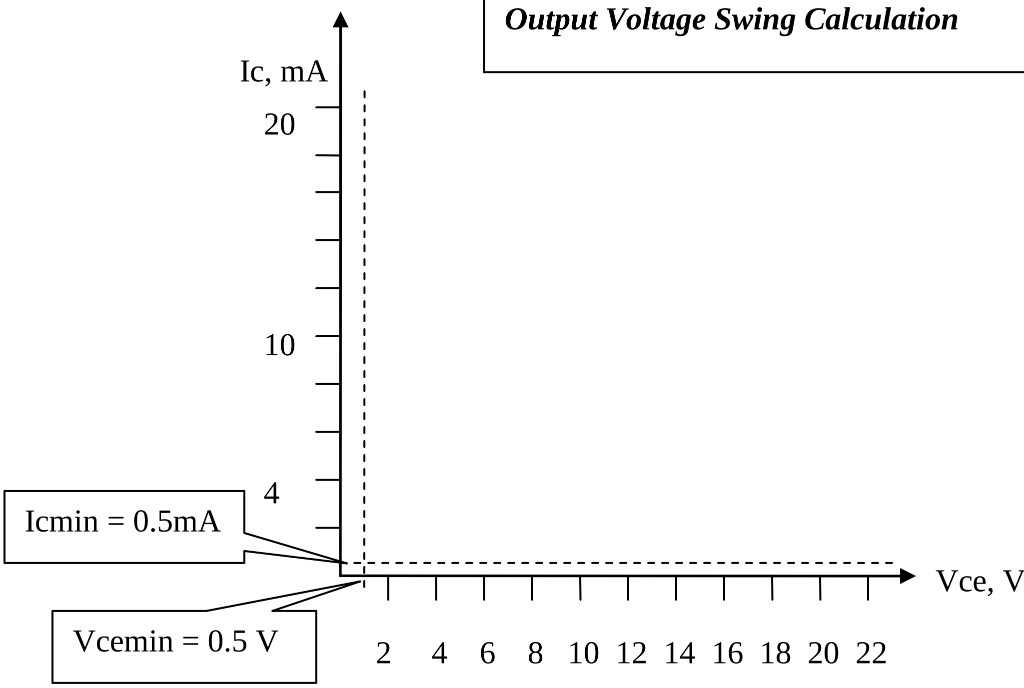
Avt = _______________

Ai = _______________

Ap = _______________

(E) (5 pts) On the Ic(t) vs. Vce(t) axes drawn below, plot the Q-point (Vce_Q and IC_Q). Then plot the dc and ac load lines. In order to promote better amplifier linearity, assume that we desire to restrict the minimum allowable value of Ic to **Ic_{MIN} = 0.5 mA** and the maximum allowable value of Vce to **Vce_{MIN} = 0.5 V**. Calculate how far Vce(t) may swing both ***above*** and ***below*** the Vce_Q value. From these two results, determine the *maximum (peak-to-peak) symmetrical output voltage swing* exhibited by this amplifier.

DC and AC Load Lines and Maximum Symmetrical Output Voltage Swing Calculation

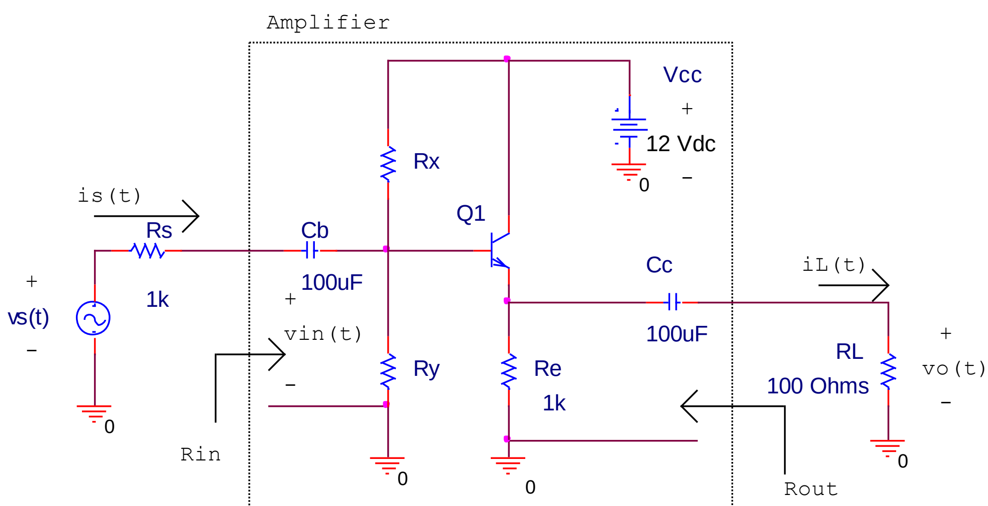


Amount Vce may swing ABOVE Vceq = _______________ V

Amount that Vce may swing BELOW Vceq = ____________ V

Max Symmetrical Output Voltage Swing = ______________ V,pp

Figure P5. Common-Collector (Emitter Follower) Amplifier



Note: Assume Cb and Cc are short circuits at the signal frequencies being amplified.

5. (*20 points*) ***Common-Collector Amplifier***

Scrambled Answers: 7.752 V, 4.206 mA, 618 ohms, infinite ohms, 0.162 S, 0.994, 154 ohms, 20 kilohms, 7 kilohms, 54.1, 65.96, 0.820, 0.861

A. (4 pts) Consider the circuit shown in Fig. P5. If Rx = 50 kΩ and Ry = 50 kΩ and the BJT has the parameters listed at the beginning of the test (note that VA is once again infinity), calculate the Q-point in the space below, showing ***clearly*** that the Q-point is ***Vceq = 7.75 V*** and ***Icq = 4.21 mA***.

B. (1 pt) Recall the design rule for an excellent "β – stable Q-point" was found to be ***(β+1)Re >> Rth*** Based on this conclusion, how would you rate the stability of the Q-point of this circuit with respect to β?

(a) Excellent (b) moderate (c) poor

Defend your choice in the space below (evaluate both sides of the design rule stated above.)

C. (3 pts) Assuming that $V_A = \infty$ in this problem, determine the BJT ac model small-signal ac parameters rpi, gm, and ro. Draw the ac model of the BJT, clearly marking the B, C, and E terminals.

rpi = ___________

gm = ___________

ro = ___________

D. (8 pts) Draw the AC model of the entire circuit, and calculate the input resistance with, and without, the load resistor R_L attached, the output resistance Rout, and the unloaded voltage gain Avo = $(vout/vin)_{RL\_removed}$

Rin_noRL = _________

Rin_withRL = ________

Rout = ______________

Avo. = $(vout/vin)_{RL\_removed}$ = _________

E. (4 pts) Draw the ***general voltage amplifier model*** (in terms of Rin, Rout, and Avo) and determine the overall voltage gain Av = vout/vs (*be careful about which value of Rin that you use*!)and the transducer voltage gain Avt = vout/vin. Also find the current gain Ai = i_L/i_S (*be careful about which value of Rin that you use*!), and finally find the power gain Ap = P_{LOAD}/P_{SOURCE}

Av = ___________

Avt = ___________

Ai = ___________

Ap = ___________

(12 points) ***Concept Questions***. (*2/3 point per blank*) Circle the ONE best answer per blank.

A. As Vce is increased across a forward-active BJT, the width of the depletion region of the reverse-biased base-collector junction _*Blank 0*_so that its effective base width _*Blank 1*_ so that its β _*Blank 2*_. Therefore its Ic vs Vce family of curves (*each curve drawn for a constant base current value*) tend to _*Blank 3*_ as Vce is increased. If the straight part of each of these curves is extended back, they all intersect the Vce axis at _*Blank 4*_, and this so-called "*base width modulation effect*" is accounted for in the ac model of a BJT by adding a relatively large resistor "ro" across _*Blank 5*_.

Blank 0: a. decreases b. increases c. stays the same
Blank 1: a. decreases b. increases c. stays the same
Blank 2: a. decreases b. increases c. stays the same
Blank 3: a. slope slightly downward b. slope slightly upward c. remain horizontal
Blank 4: a. –ro b. –gm c. –rπ d. V_{CE}sat e. $-V_A$
Blank 5: a. rπ b. the C-E terminals c. the C-B terminals d. the B – E terminals.

B. Removing the emitter bypass capacitor that is across the emitter resistor in a ***common-emitter*** BJT amplifier will _*Blank 1*_ and also _*Blank 2*_

Blank 1: a. increase Ic_Q b. decrease Ic_Q c. increase its Avo d. decrease its Avo
Blank 2: a. increase its Rin b. decrease its Rin c. increase its Rout d. decrease its Rout

C. Let us compare the *common-emitter* (CE) and the *common-collector* (emitter-follower) (CC) BJT amplifier configurations.

i. Which amplifier configuration is known for its relatively low output resistance, and would therefore be the best choice for a stage whose output connects to a relatively low-impedance load (such as a loudspeaker in a PA system like the one considered in lab)?

a. CE b. CC

ii. Which amplifier configuration is known for its relatively high voltage gain, and would therefore be the best choice for a microphone voltage preamplifier stage in a PA system such as the one built in lab?

a. CE b. CC

iii. Which amplifier configuration is known for its relatively high input resistance, and would therefore not significantly "load down" the output voltage from a high-impedance signal source or transducer?

a. CE b. CC

D. In a forward-active ***PNP*** BJT, the principle current conduction mechanism is _*Blank 1*_ diffusing from the _*Blank 2*_ region, through the very thin _*Blank 3*_ region, and then being SWEPT across the reverse-biased _*Blank 4*_ junction by the intense electric field that exists in the depletion region of that junction.

Blank 1: a. electrons b. holes c. positrons d. Neutral silicon atoms
Blank 2: a. emitter b. base c. collector
Blank 3: a. emitter b. base c. collector
Blank 4: a. base-emitter b. base-collector c. collector-emitter

E. In order to optimize the operation of a modern BJT, its _*Blank 1*_ region is typically doped much **more** intensely than its _*Blank2*_ region, which in turn is doped much **more** intensely than its _*Blank3*_ region.

Blank 1: a. emitter b. base c. collector
Blank 2: a. emitter b. base c. collector
Blank 3: a. emitter b. base c. collector