University of Michigan
EECS 311: Electronic Circuits
Fall 2008

Quiz 2

11/3/2008

NAME: _____

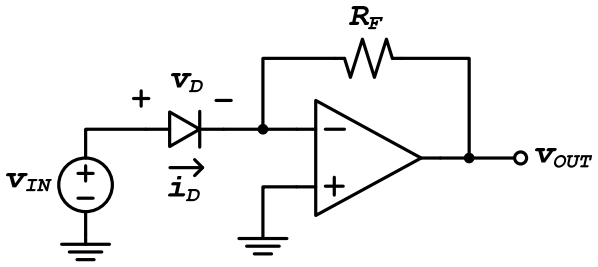
Honor Code:
I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code.

Signature _____

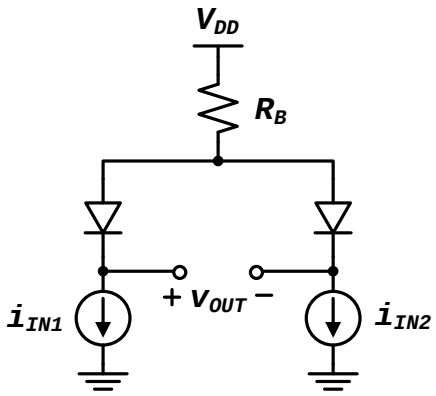
Problem	Points	Score	Initials
1	**26**		
2	**20**		
3	**30**		
4	**24**		
	Total		

Problem 1 (26 Points): Potpourri – this problem has four unrelated parts.

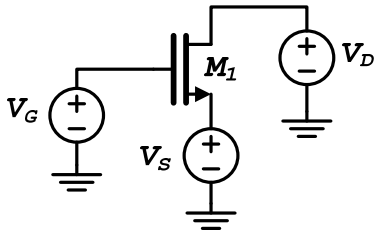
a) Find the expression for gain $A_v = v_{OUT}/v_{IN}$ of the circuit below. Use the exact model for the diode, $i_D = I_S\left(e^{v_D/V_T} - 1\right)$. Assume the opamp is ideal.



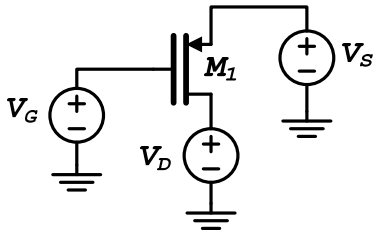
b) Find an expression for the voltage v_{OUT} for the circuit below assuming $i_{IN1} > 0$ and $i_{IN2} > 0$. Use the exact model for the diodes, $i_D = I_S\left(e^{v_D/V_T} - 1\right)$, assuming the two diodes are identical (same values for I_S and same temperature).



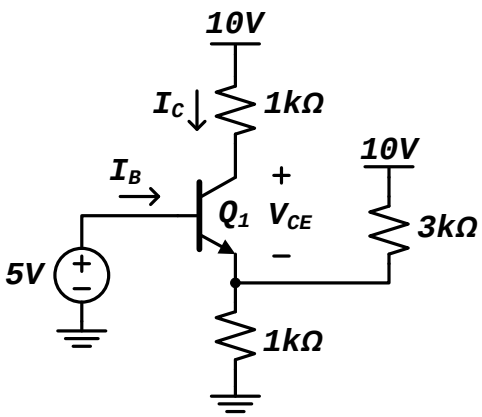
c) Identify the region of operation of M_1 in the circuit below when $V_G = 2\ V, V_D = 3\ V$, and $V_S = -1\ V$. Assume $V_{TN} = 1\ V$ and ignore the body-effect on threshold voltage.



d) Identify the region of operation of M_1 in the circuit below when $V_G = 3\ V, V_D = 5\ V$, and $V_S = 5\ V$. Assume $V_{TP} = -1\ V$ and ignore the body-effect on threshold voltage.



Problem 2 (20 Points): Use the following circuit and ignore base-width modulation for all parts.



$V_{be(on)} = 0.7\ V$

$V_{ce(sat)} = 0.5\ V$

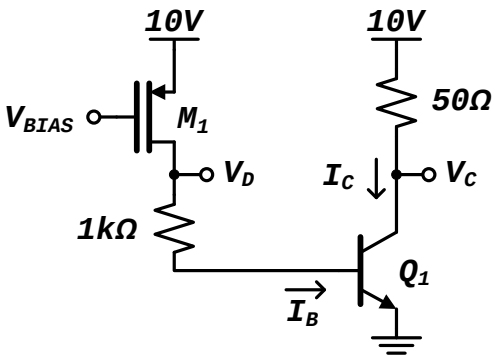
$\beta_F = 100$

a) Substitute the simplified large-signal model for the BJT in the forward-active region using the constant-voltage source model for the base-emitter junction diode. Solve for the values of I_C and V_{CE}.

b) Substitute the simplified large-signal model for the BJT in the saturation region using the constant-voltage source models for the base-emitter and collector-emitter voltages. Solve for the values of I_B and I_C.

c) Given your answers to parts a) and b), is Q_1 in the forward-active or saturation region.

Problem 3 (30 Points): Use the circuit shown below to answer all of the following parts. Use the constant-voltage source model for the base-emitter junction diode of Q_1. Ignore channel-length modulation, body effect, and base-width modulation for all parts.



$\mu_p C_{ox} \frac{W}{L} = 500\ \mu A/V^2$

$V_{tp} = -1.0\ V$

$V_{be(on)} = 0.7\ V$

$V_{ce(sat)} = 0.5\ V$

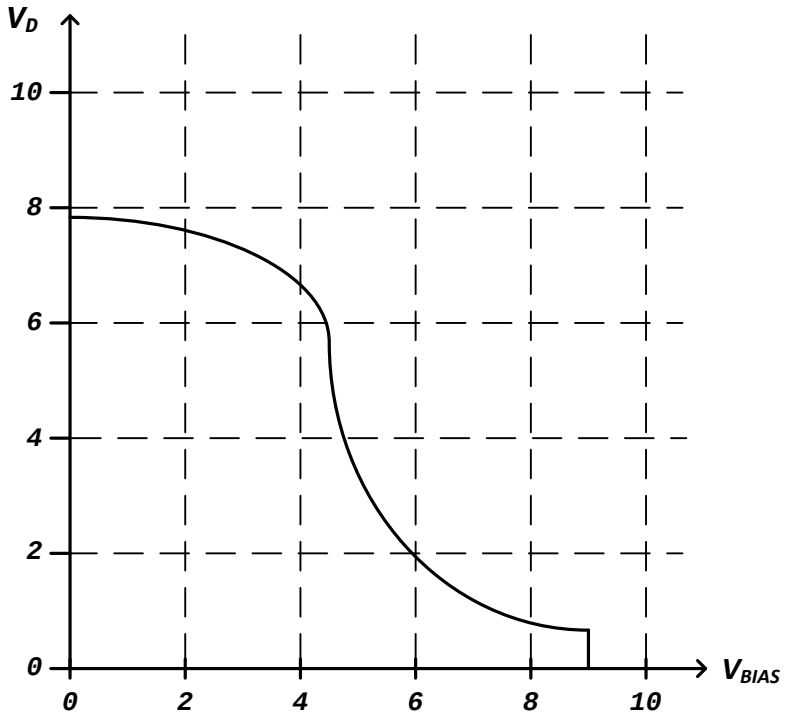
$\beta_F = 100$

a) Assuming Q_1 is kept in the forward-active region, find the numerical value of I_B required to support $I_C = 1\ mA$.

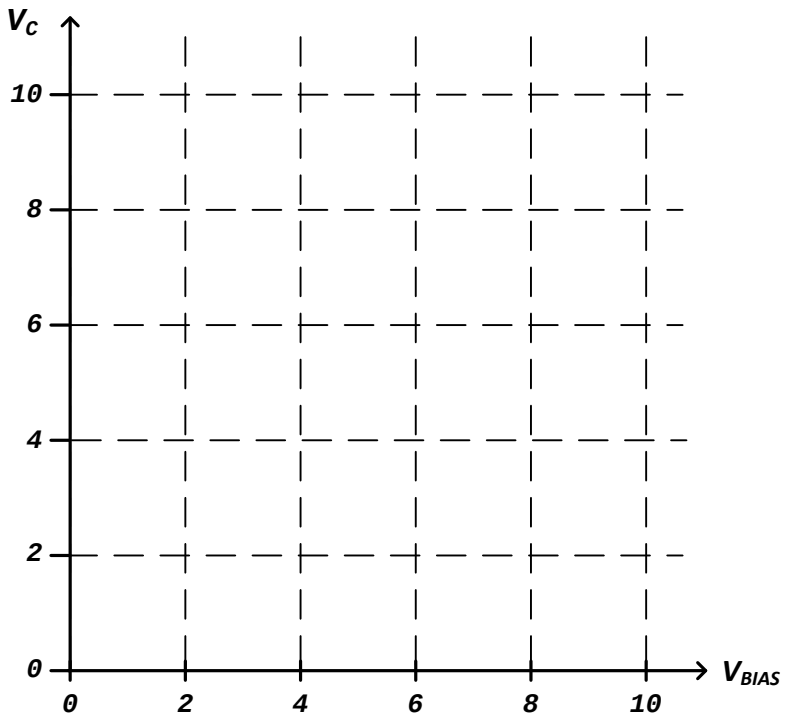
b) Assuming M_1 is kept in saturation, find the numerical value of V_{BIAS} required to support I_B from part a).

c) Find the maximum value of I_C allowed while keeping Q_1 in the forward-active region.

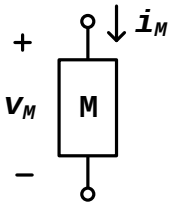
d) As V_{BIAS} is swept from0 to $10\ V$, the drain voltage V_D follows the graph shown below. Label the regions on the graphs where M_1 is in *cutoff*, *linear*, and *saturation*, specifically showing the values of V_{BIAS} at the boundaries between regions.



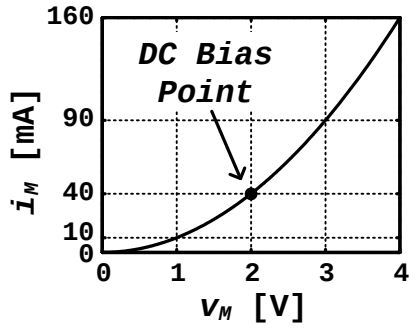
e) Sketch the voltage at node V_C as V_{BIAS} is swept from0 to $10\ V$. Use the graph from part d), giving you V_D as V_{BIAS} is swept over the same range, to generate your sketch. Label the regions on the graph where Q_1 is in *off*, *forward-active*, and *saturation*.



Problem 4 (24 Points): A non-linear two-terminal device *M* has the following I-V relationship, given in an expression and also plotted. Use this device to answer the following questions about small-signal analysis.



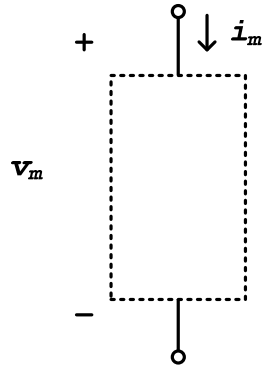
$$i_M = 0.01 \cdot v_M^2 \; A$$



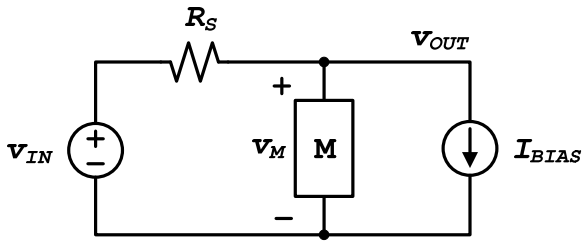
a) Derive an expression for the small-signal conductance i_m/v_m, linearized around a DC operating point defined by variables I_M and V_M.

b) Complete the small-signal model by drawing the circuit element in the box that should be used to model the device in small-signal. Evaluate the value of this element at the bias current of $I_M = 40\ mA$ as shown in the graph above.

Small-Signal Model



c) The device is used in the following circuit. Draw the complete small-signal circuit, substituting the model for the device found in part b). Assume I_{BIAS} is a DC bias current.



(Space for additional work)