EECS105 Midterm 1
2/22/11

Name_____

SID_____

1	/24
2	/16
3	/15
4	/25
5	/20
Total	

1. Give a short answer to each question. No explanation or justification is required.

3 a. If we could operate circuits at 300 Centigrade (not Kelvin), what's a rough estimate of the thermal voltage at that temperature?

26mV * 2 = 52mV

b. How would n_i for silicon change at that temperature: about the same, a little more/less, a lot more/less?

2

a lot more

c. If you measure the reverse leakage current of a diode ($-I_S$) at room temperature to be 1nA, and then increase the temperature to 85C, will the leakage current **increase or decrease**, and by roughly what factor chosen from this list: {a lot less than 2, roughly 2, roughly 10, a lot more than 10}

2

increase, a lot more than 10

d. At a particular temperature, you calculate the intrinsic carrier concentration for silicon to be 10^9/cc. At that temperature, in a sample doped with 10^{14} boron atoms/cc, what are the **majority and minority** carrier concentrations?

4

majority: $10^{14} = p$

minority: $n_i^2/p = \frac{10^{18}}{10^{14}} = 10^4/cc$

e. At room temperature, you apply 0.7V to a diode and measure a current of 1mA. What voltage is necessary to get a current of **2.7mA? 10mA**?

4

0.726 V

0.760 V

f. You have a reverse bias of 5V across a diode, and measure a capacitance of 10fF. What reverse bias should you apply to get 5fF? (accurate to 10%)

3

$\frac{1}{\sqrt{1+\frac{V_R}{V_0}}} \approx \sqrt{\frac{V_0}{V_R}}$ for $V_R >> V_0$ $\quad V_R = 4 * 5V = 20V$

g. You have a reverse bias across a diode of V_0, the built-in potential of that particular diode, and measure a capacitance of 2pF. What reverse bias should you apply to get a capacitance of 1pF? (accurate to 10%)

3

$\frac{1}{\sqrt{1+V_R/V_0}} = \frac{1}{\sqrt{2}}$ $\quad V_R = 7V_0$

h. The current in the channel of an NMOS transistor is due to (pick one) {drift, diffusion} of (pick one) {valence band holes, conduction band electrons}

3

drift of conduction band electrons

16 pts

2. You have invented a new type of transistor with terminals A, B, and C. In the "active" region, defined by $V_{AC}>0$, $V_{BC}>1$, you have determined the formulas for the currents into nodes A and B are:

$I_A = I_0 \alpha V_{AC}$

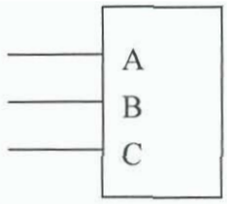
$I_B = I_0 (\beta V_{AC})^3 (\delta V_{BC})^{1/2}$

Where I_0, α, β, and δ are process-related parameters.

Draw the DC small-signal model of your transistor. Clearly label the node voltages and currents!

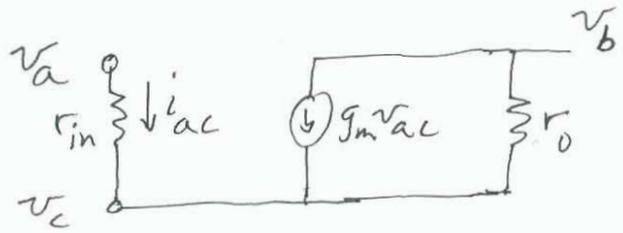
Write down algebraic expressions for the values of the circuit elements of your small signal model.

If you want to make a voltage amplifier, which terminal would you make the input, and which would you make the output? Why?



one pt for each element
one pt for node labels
one pt for current labels

Draw small signal model



5

Expressions for the values of the circuit elements of your model

1 pt for each definition (derivative)
1 pt for each answer
.5 pt each for $g_{in}, g_o \to r_{in}, r_o$

$g_{in} = \alpha I_0 \qquad r_{in} = \frac{1}{g_{in}} = \frac{1}{\alpha I_0}$

$g_m = \beta 3 I_0 (\beta V_{AC})^2 (\delta V_{BC})^{1/2} = \frac{3 I_B}{V_{AC}}$

$g_o = \frac{1}{2} \delta I_0 (\beta V_{AC})^3 (\delta V_{BC})^{-1/2} = \frac{\frac{1}{2} I_B}{V_{BC}} \qquad r_o = \frac{1}{g_o} = \frac{2 V_{BC}}{I_B}$

$r_o = \frac{2(\delta V_{BC})^{1/2}}{\delta I_0 (\beta V_{AC})^3} = \frac{2\delta^{1/2} V_{BC}^{1/2}}{\delta I_0 (\beta V_{AC})^3} = \frac{2\delta^{1/2} V_{BC}^{1/2}}{I_0 (\beta V_{AC})^3}$

7

Input and output node, and why:

1 pt for each I/O
1 pt for each explanation

input is A, because it has a big impact on I_B

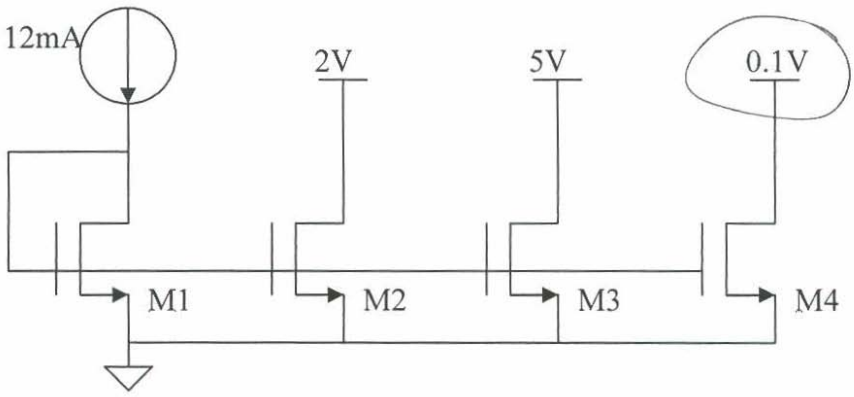
output is B because it has a weak impact on I_B

4

15 pts

226

3. In the current mirror below, assume that $\mu_n C_{ox} = 200uA/V^2$, $\lambda=0.1/V$, and $V_{TN}=1V$. All transistors have W/L = 100u/1u. Calculate the gate bias voltage V_{GS1} resulting from the input current. Calculate the currents flowing in the drains of the other transistors. All calculations should be accurate to a few percent.



5 | V_{GS1}= 2V | I_{D2} = 12mA | 3

3 | I_{D3} = 15mA | I_{D4} = 0.95mA | 4

give partial credit for wrong V_{GS}

$$\frac{\mu_n C_{ox}}{2}\frac{W}{L} = \frac{100\mu A}{V^2}\cdot 100 = 10\frac{mA}{V^2}$$

$$12mA = I_D = 10\frac{mA}{V^2}(V_{GS}-V_t)^2(1+\lambda V_{DS})$$

1V

$V_{GS} = 2$ 1.2

$$I_{D4} = \mu_n C_{ox}\frac{W}{L}\left(2-1-\frac{1}{2}0.1\right)0.1$$

$$= 20\,mA\,(0.95)(0.1)$$

$$= 0.90\,mA$$

2:29

4. For the circuit below, find the input V^*_B necessary to make V^*_C=1V and find the operating point currents I^*_B, and I^*_C. Draw the small signal model for the circuit, and calculate the DC gain. Assume $I_S=10^{-15}$ A, β=100, and V_A=100V. Answers should be accurate to 10%.

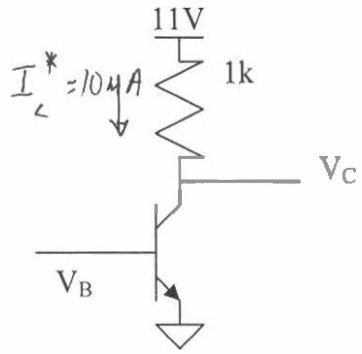
V^*_B = 780mV (4)	V^*_C = 1V	I^*_C = 10mA (3)	I^*_B = 0.1mA (2)
g_m = 0.4S (3) (0.4)	r_o = 10KΩ (3)	r_π = 260Ω (3)	-360 (3)

$\frac{10^{-2}\,A}{10^{-15}\,A} = 10^{13}$

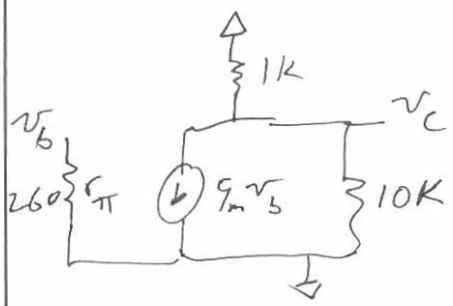
$g_m = \frac{I_C}{V_T} = \frac{10mA}{26mV}$

$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{26mV}{0.1mA}$

$\frac{V_A}{I_D} = \frac{100V}{10mA} = 10^4$



Small signal model for the whole circuit. Label voltages and components. (4)



$A_v = -g_m R_{out} = (0.4)(.9K) = 360$