EECS140
Fall 2009
Midterm 1

Name __________________________

SID __________________________

<table>
<thead>
<tr>
<th>Prob.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/15</td>
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<tr>
<td>2</td>
<td>/15</td>
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<tr>
<td>3</td>
<td>/25</td>
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<td>4</td>
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<td>5</td>
<td>/30</td>
</tr>
<tr>
<td>Total</td>
<td></td>
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</table>

1) For the following problems, the drain, gate, and source voltages are given. You may assume that $V_{SB}=0$. Indicate if the devices are off, in the linear or triode region, or in saturation. If the devices are in saturation, calculate $V_{dsat}$.

2) You have an RC lowpass filter with a 1MΩ resistor and a 1pF capacitor.
   a. Sketch a cycle of the input and steady state output when the input is $\sin(4 \times 10^6 t)$.
      
   b. Sketch the transient response from 0 to 6μs to the following input assuming that the output starts at 0 at $t=0$. 

   ![Graph of input and output for part a]

   ![Graph of transient response for part b]
3) For a common emitter amplifier like what some of you used in the audio amplifier lab,
   a) Choose the value of $R_C$ to give a small signal gain of approximately -10

   $R_C = 100k$ or "10x $R_E$"

   5 pts

   b) What is the approximate range of $V_B$ for which this circuit gives a gain of approximately -10? You may assume that the input signals are less than 10mV.

   $V_B = \begin{cases} 
   0.8 \text{ to } 1.6 \\
   \text{ or } 0.9 \text{ to } 1.7
   \end{cases}$

   Start w/ $V_E$: max $V_E$ is < 1V since $V_c$ drops 10x $V_E$
   min $V_E$ set by $G_m = \frac{g_m}{1 + g_m R_E} = \frac{1}{R_E}$

   5 pts

   c) What is the purpose of the capacitor?

   DC blocking - input can be of any DC value so need
   and bias point is unaffected.

   $I_c \cdot R_E \gg 1$

   $\frac{V_E}{V_{TH}} \gg 1$

   $V_E > 200mV$ or so.

   5 pts
3) Fill in the following table where each row is a different single-pole amplifier

<table>
<thead>
<tr>
<th>$G_m$ [S]</th>
<th>$R_o$ [$\Omega$]</th>
<th>$C_L$ [F]</th>
<th>$A_v$</th>
<th>$\omega_p$ [rad/s]</th>
<th>$\omega_u$ [rad/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1u</td>
<td>10M</td>
<td>50f</td>
<td>10</td>
<td>$\frac{1}{500} \cdot 10^9 = \frac{1}{500 K}$</td>
<td>20M</td>
</tr>
<tr>
<td>4mS</td>
<td>100K</td>
<td>1p</td>
<td>400</td>
<td>10M</td>
<td>$\frac{100}{2} = 10^7$</td>
</tr>
<tr>
<td>100m</td>
<td>100</td>
<td>$\frac{10}{10^6} = 10^5$</td>
<td>10</td>
<td>1G</td>
<td>10G</td>
</tr>
<tr>
<td>10n</td>
<td>1M</td>
<td>10f</td>
<td>1000</td>
<td>100M</td>
<td>1G</td>
</tr>
</tbody>
</table>

2 pts each

4) You have a single-pole amplifier with a gain of 10 at 100kHz, and a low frequency gain of 10,000. What is the gain at 10 Hz, 20kHz, and 500 kHz?

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Gain</th>
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<tbody>
<tr>
<td>10 Hz</td>
<td>10,000</td>
</tr>
<tr>
<td>20 kHz</td>
<td>500</td>
</tr>
<tr>
<td>500 kHz</td>
<td>2</td>
</tr>
</tbody>
</table>
5) What is the total low frequency impedance and the low frequency impedance seen "looking up" and "looking down" at the output node indicated in each circuit? Assume that all devices have transconductance $g_m$ and output resistance $r_o$, and that $g_m \times r_o >> 1$. Write the simplified expression for up and down, and then the simplified total impedance. You may ignore all capacitors.

| $R_{o1, up}$ | $\frac{g_m \times r_o}{2} \\ \frac{2}{g_m}$ | $\frac{1}{g_m} \| \frac{2}{g_m} = \frac{2}{3} \frac{1}{g_m}$ |
| $R_{o1, down}$ | $\frac{1}{g_m}$ | $\frac{2}{3} r_o$ |
| $R_{o2, up}$ | $r_o$ | $\frac{2}{3} r_o$ |
| $R_{o2, down}$ | $r_o (1 + g_m \frac{1}{5}) = 2r_o$ | |
| $R_{o3, up}$ | $g_m r_o^2$ | $r_o$ |
| $R_{o3, down}$ | $r_o$ | |

5B) [10pts] What is the low-frequency capacitance seen looking into $V_B$?

$$C_{in} = \left[1 + \frac{g_m r_o}{3}ight] C_{gd} + \left(\frac{2}{3}\right) C_{gs}$$

$A_{V_B12}$: $C_m = \frac{g_m}{r_o} = \frac{-g_m}{c}$  
$A_v = \frac{2m \times C_{gs}}{3} = \frac{1}{3}$

$A_{V_B02}$: $C_m = \frac{g_m}{r_o} = \frac{2m}{2}$  
$A_v = \frac{g_m r_o}{3}$