Problem #1 – Deriving the $V_m$ calculation
a) Starting with unified model equations (p. 102 in Figure 3-23), derive equation 5.4 on page 185 in the textbook.

Problem #2: Load Curves for an inverter
Examine figures 5-4 and 5.5 in the textbook on page 183. Explain the following:
When $V_{out} = 2.5$, $V_{in} = 0$, why is the NMOS off and PMOS in the linear region?
When $V_{out} = 1.25$, $V_{in} = 1.25$, why is the NMOS & PMOS in saturation?
When $V_{out} = 0$, $V_{in} = 2.5$, why is the PMOS off and NMOS in the linear region?

Problem #3 – Device Parameters

Below is a table showing a set of measurements performed on a newly fabricated MOS transistor.

<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>$V_{GS}$</th>
<th>$V_{DS}$</th>
<th>$V_{SB}$</th>
<th>$I_D$</th>
<th>Operation Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2.5V</td>
<td>-2.5V</td>
<td>0</td>
<td>-84.375uA</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.0V</td>
<td>1V</td>
<td>0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.7V</td>
<td>-0.8V</td>
<td>0</td>
<td>-1.04uA</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-2.0V</td>
<td>-2.5V</td>
<td>0</td>
<td>-56.25uA</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-2.5V</td>
<td>-2.5V</td>
<td>-0.8V</td>
<td>-72.0uA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>-2.5V</td>
<td>-1.5V</td>
<td>0</td>
<td>-80.625uA</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-2.5V</td>
<td>-0.8V</td>
<td>0</td>
<td>-66.56uA</td>
<td></td>
</tr>
</tbody>
</table>
You may assume that $V_{DSAT} = -1.0V$ and $-2\Phi_F = 0.6V$.

3A Is the measured transistor a PMOS or an NMOS device? Explain your answer.

3B From measurements above, determine the following parameters: $V_{TO}$, $\gamma$, $\lambda$.

3C Complete the missing column in the table above using the values you obtained in 3B. Fill in either “LINEAR”, “CUTOFF”, “SATURATION”, or “VEL. SATURATION.” (You don’t have to recopy the whole table, just the last column is sufficient.>

**Problem #4 – Static & Dynamic Analysis:**
Consider the following logic circuit: The voltage source applies a step input waveform $V_{in}$ to the circuit. CONSIDER THE BODY EFFECT IN ALL YOUR CALCULATIONS.

Assume $\gamma = 0.5$ V$^{1/2}$
- $V_{TO} = 0.7$ V
- $-2\Phi_F = 0.6$ V
- $k' = 20$ $\mu$A/V$^2$
- $\lambda = 0$

4A Spend a few minutes to understand how this circuit works. Do no hand in anything for part 4A.

4B Assume that $V_{out}(t=0) = 0V$. Determine $V_{out}(t=\infty)$ when $V_{in}$ is raised from 0V to $V_{DD}$ at $t=0$. Assume $V_{DD}=3V$.

4C Based on your answer in 4B, determine $t_{PH}$, the time between the step input changes from 0 to $V_{DD}$ and $V_{out}$ reaching it's 50% switching point.