Problem #2:

An NMOS amplifier is shown with the input bias voltage $V_i$. Both the input and output small signals are marked as the low-case $v_i$ and $v_o$, respectively. Use the followings: $\mu_{C_{ox}} = 200\mu A/V^2$, $V_{th} = 0.4V$, and $W/L = 50$.

1. Sketch the DC transfer function of $V_o$ vs. $V_i$ for the input range of 0 to 3V in the above space, and add proper voltage scales to mark the saturation range of the transistor.

\[
V_o = 3 - \frac{200 \times 10^{-6} \times 50 (V_i - 0.4)^2}{2} \times 1k = V_i - 0.4V \\
V_o = V_i - 0.4V = \frac{-l + \sqrt{l^2}}{5} = 0.6V \\
V_i = 1V
\]

2. What is the DC bias voltage $V_i$ to set the output DC voltage to be in the middle of the output saturation range?

\[
I_o = \frac{200 \times 10^{-6} \times 50 (V_i - 0.4)^2}{2} = 1.2mA \\
V_i = 0.4V + \sqrt{\frac{1.2}{5}} \approx 0.9V
\]

3. Estimate $V_o$ when $V_i = 3V$.

\[
V_{osat} = 3 - \frac{200 \times 10^{-6} \times 50 (3 - 0.4) V_{osat} \times 1k}{2} \\
V_{osat} = \frac{3}{27} \approx 0.11V
\]

4. Estimate the low-frequency small-signal voltage gain $v_o/v_i$ and the -3dB bandwidth.

\[
\frac{v_o}{v_i} = -9m1k = -\sqrt{2 \times 200 \times 10^{-6} \times 50 \times 1.2mA \times 1k} \approx -5 \\
\beta W = \frac{1}{1k \times 1pF} = 10^9 \text{rad/s}
\]