(1) (a) By definition, \( g_m = \frac{\Delta I_g}{\Delta V_{gs}} \). We can find this graphically by looking around point A, and keeping \( V_{gs} \) constant.

At point A: \( I_o = 20 \mu A, V_{ds} = 1.6 V, V_{gs} = 1.8 V \)

\[ g_m = \frac{\Delta I_g}{\Delta V_{gs}} = \frac{20 \mu A}{0.2 V} = \frac{20 \mu A}{0.2 V} = 100 \mu A/V \]

To find \( r_o \): by definition, \( r_o = \left( \frac{\Delta V_{gs}}{\Delta I_g} \right)^{-1} \)

At point A, extrapolate a straight (tangent) line though it, and it crosses these points:

First point: \( I_o = 20 \mu A, V_{ds} = 1.6 V, V_{gs} = 1.8 V \)

Another point: \( I_o = 21.7 \mu A, V_{ds} = 2.5 V, V_{gs} = 1.6 V \)

\[ r_o = \frac{\Delta V_{gs}}{\Delta I_o} = \frac{1.5 V}{1.7 \mu A} = \frac{1.5 V}{1.7 \mu A} = 882 \Omega \]

(b) At point B: same idea...

For \( g_m \): \( I_o = 5 \mu A, V_{ds} = 1.5 V, V_{gs} = 0.85 V \)

On the curve above B: \( I_o = 10 \mu A, V_{ds} = 1.5 V, V_{gs} = 1.1 V \)

\[ g_m = \frac{\Delta I_g}{\Delta V_{gs}} = \frac{5 \mu A}{0.45 V} = \frac{5 \mu A}{0.45 V} = 11 \mu A/V \]

For \( r_o \): again, extrapolate a straight line to find another point at:

\( V_{ds} = 2.5 V, V_{gs} = 0.85 V, I_o = 5.5 \mu A \)

\[ r_o = \frac{\Delta V_{gs}}{\Delta I_o} = \frac{1 V}{0.5 \mu A} = \frac{1 V}{0.5 \mu A} = 2000 \Omega \]

*Note: For this problem, answers may vary; it's the method that really matters.*

(2) (a) \( I_o = 10 e^{V_{gs}/4} + 20 (V_{ds} - 3)^2 \)

\[ I_o = 10 e^{V_{gs}/4} + 20 (4 - 3)^2 = \frac{31.33}{A} \]

\[ I_{oq} = 12 V_o V_{oq} = (12)(2.5)(4) = 24 A \]

(b) \[ i = \frac{\Delta I}{\Delta V} V_1 + \frac{\Delta V}{\Delta V} V_2 \]

\[ i = \frac{10 e^{V_{gs}/4}}{V_1} + 60 (V_{ds} - 3)^2 V_2 \]

\[ i = 2.83 \times 10^6 V_1 + 60 V_2 \]

but, a current source dependent on the voltage across it is simply a resistor.

\[ i = \frac{\Delta I}{\Delta V} V_1 + \frac{\Delta V}{\Delta V} V_2 \]

\[ i = \frac{10 e^{V_{gs}/4}}{V_1} + 60 (V_{ds} - 3)^2 V_2 \]

\[ i = 2.83 \times 10^6 V_1 + 60 V_2 \]

but, again this can be modeled as a resistor.
The equations governing the large-signal operation of a NMOS in triode are as follows:

\[ I_{DS} = \mu C_{ox} \left( \frac{W}{L} \right) \left[ \left( V_{GS} - V_T \right) V_{DS} - \frac{V_{TH}^2}{2} \right] \]

\[ V_T = \frac{V_{GS} + \gamma \left( \sqrt{2V_{DS} + V_{GS}} - \sqrt{2V_{GS}} \right) = V_{GS} + \gamma \left( \frac{V_{GS} + V_{DS}}{2} \right) \]

\[ g_m \equiv \left. \frac{\partial I_{DS}}{\partial V_{GS}} \right|_{V_{DS}} = \mu C_{ox} \left( \frac{W}{L} \right) V_{GS} \]

\[ g_{ds} \equiv \left. \frac{\partial I_{DS}}{\partial V_{DS}} \right|_{V_{GS}} = \gamma \frac{\left( V_{GS} - V_T \right)}{2} \left( \frac{V_{GS} + V_{DS}}{2} \right) \]

\[ g_{mb} \equiv \left. \frac{\partial I_{DS}}{\partial V_{TH}} \right|_{V_{DS}} = -\mu C_{ox} \left( \frac{W}{L} \right) V_{GS} \frac{V_{TH}}{2 \sqrt{2V_{DS} + V_{GS}}} \]

(b) The \( g_m \) for a NMOS in saturation is \( \mu C_{ox} \left( \frac{W}{L} \right) \left( V_{GS} - V_T \right) \)

Note that the transconductance in triode is dependent on \( V_{GS} \). In other words, it acts like a resistor.

(c) See next page for SPICE verification. Note the good agreement between SPICE and hand calculations.