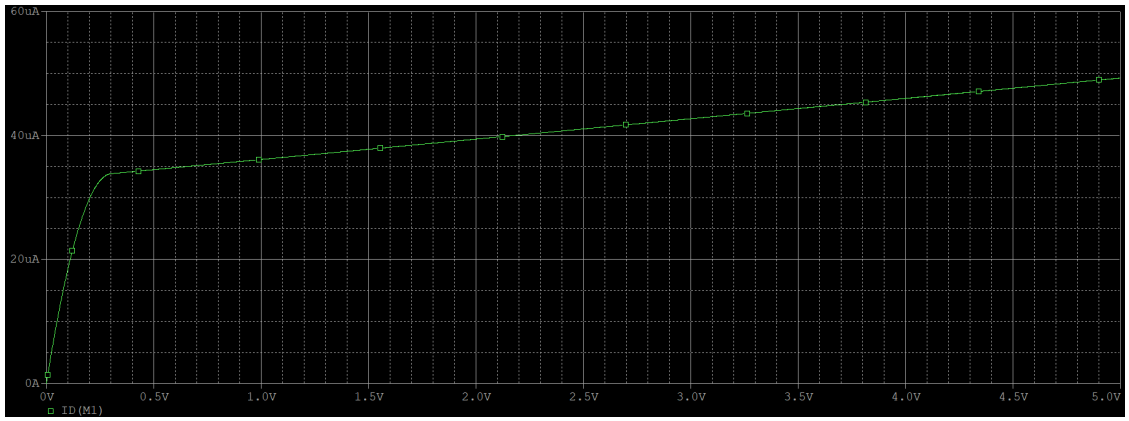
1 Problem 2

1.1 (a)

1.1.1 (i)

When $V_{gs} = 1V$, we get the figure



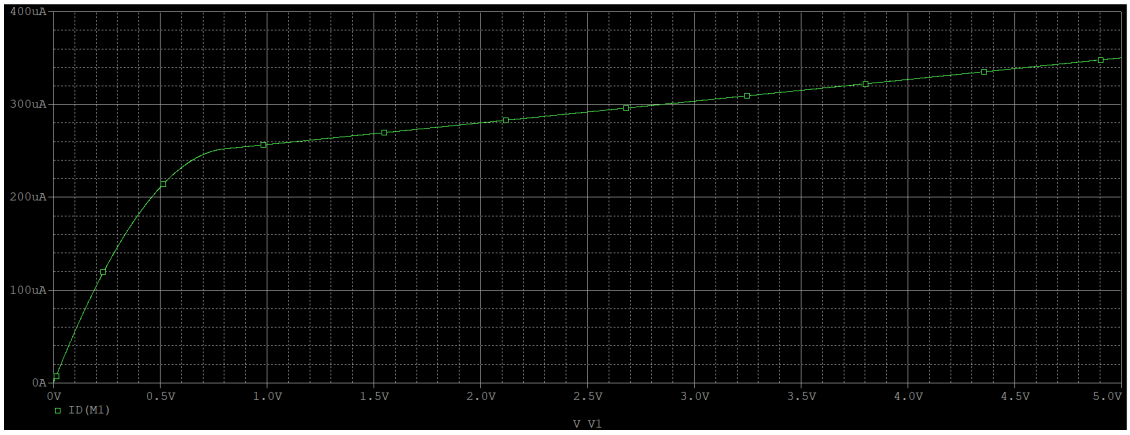
From the figure we know that when $V_d < 0.3V$, it's in triode region and when $V_d > 0.3V$, its' in saturation region. The slope is $\frac{15.15 \cdot 10^{-6}}{4.6} = 3.27 \cdot 10^{-6}$, so $R_0 = \frac{1}{slope} = 3.06 \cdot 10^6 \Omega$

$$I_d = 0.5\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH})^2 = 0.5 * 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * \frac{10}{2 - 2 * 0.08} * (1 - 0.7)^2 = 3.26 \cdot 10^{-5}$$

$$r_0 = \frac{1}{I_d * \lambda} = \frac{1}{3.26 \cdot 10^{-6}} = 306667\Omega$$

1.1.2 (ii)

When $V_{gs} = 1.5V$, we get the figure



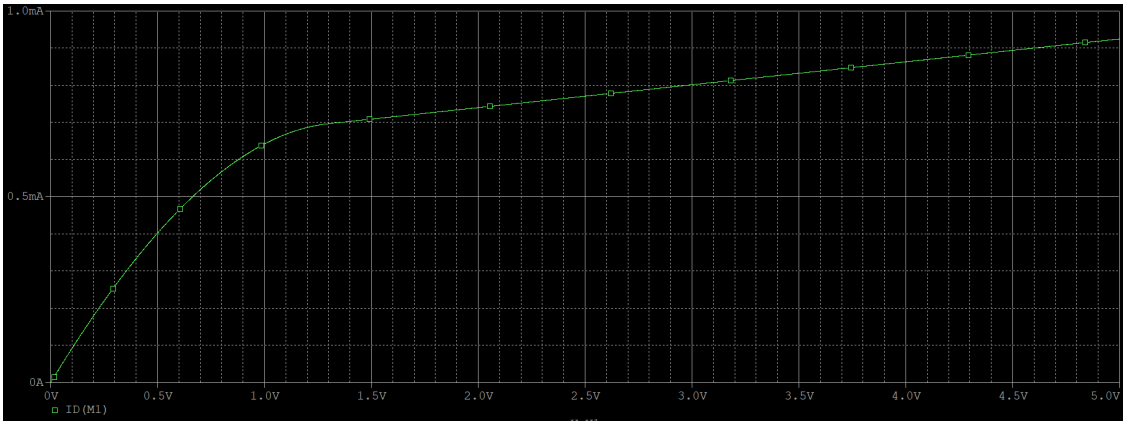
From the figure we know that when $V_d < 0.8V$, it's in triode region and when $V_d > 0.8V$, its' in saturation region. The slope is $\frac{97.8 \cdot 10^{-6}}{4.1} = 2.39 \cdot 10^{-5}$, so $R_0 = \frac{1}{slope} = 4.19 \cdot 10^4 \Omega$

$$I_d = 0.5\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH})^2 = 0.5 * 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * \frac{10}{2 - 2 * 0.08} * (1.5 - 0.7)^2 = 2.32 \cdot 10^{-4}$$

$$r_0 = \frac{1}{I_d * \lambda} = \frac{1}{2.32 \cdot 10^{-5}} = 43192\Omega$$

1.1.3 (iii)

When $V_{gs} = 2V$, we get the figure



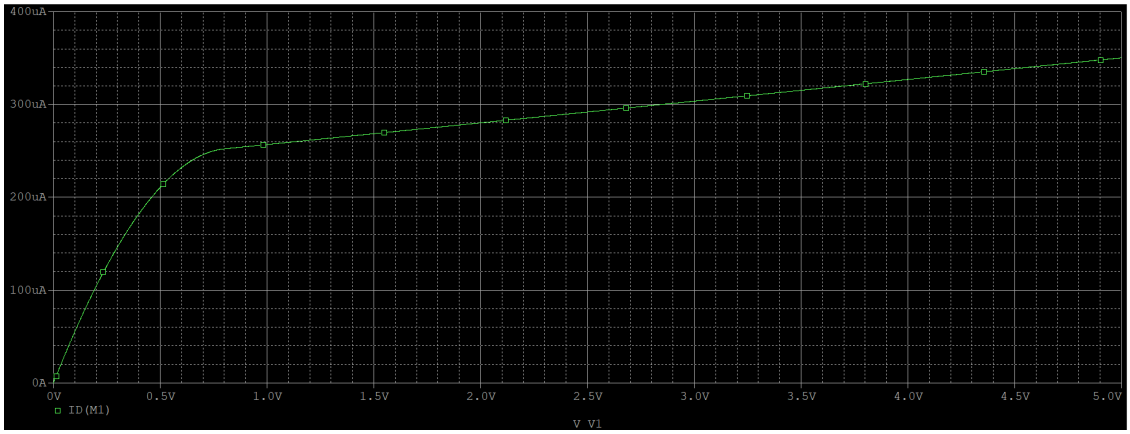
From the figure we know that when $V_d < 0.8V$, it's in triode region and when $V_d > 0.8V$, its' in saturation region. The slope is $\frac{227.7 \cdot 10^{-6}}{3.7} = 6.15 \cdot 10^{-5}$, so $R_0 = \frac{1}{slope} = 1.62 \cdot 10^4 \Omega$

$$I_d = 0.5\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH})^2 = 0.5 * 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * \frac{10}{2 - 2 * 0.08} * (2 - 0.7)^2 = 6.16 \cdot 10^{-4}$$

$$r_0 = \frac{1}{I_d * \lambda} = \frac{1}{6.16 \cdot 10^{-5}} = 16226\Omega$$

All my calculated r_o are a little bigger than the simulated one.

1.2 (b)



The slope is $\frac{30 \cdot 10^{-6}}{20 \cdot 10^{-3}} = 1.5 \cdot 10^{-3}$

$$gm = \mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH}) * (1 + \lambda V_{DS}) = 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * 5 * (2 - 0.7) * (1 + 0.1 * 5) = 1.3 \cdot 10^{-3} (\Omega^{-1})$$

My calculated value is a bit smaller than the simulated value.