ECE 305 HW 11.

1. a. when $V_{gs} = V_{ds} = V_{dd} = 1.8V$, $I_{on} = I_{ds} \doteq 110\ \mu A$

when $V_{gs} = 0$, $V_{ds} = V_{dd} = 1.8V$, $I_{off} = I_{ds} \doteq 0\ A$

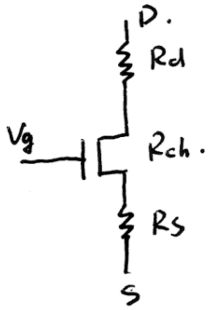
b. As subthreshold current is exponential, $V_{th\,(sat,\ linear)} \doteq 0.8\ V$, $I_{th(sat)} = 8 \times 10^{-6}\ A$

c. $Q_{inv} = C_{ox}(V_{gs} - V_{th}) = 3\ \mu F/cm^2 \times (1.8 - 0.8V) = 3\ \mu C/cm^2$. (negative)

or more precisely $Q_{inv} = C_{ox}(V_{gs} - V_{th} - I_d \cdot R_s) = 3\ \mu F/cm^2\ (1.8 - 0.8 - 110\mu A \cdot 1k\Omega)$

$\doteq 2.67\ \mu C/cm^2$ (negative)

2.



the effective $V_{gs}' = V_{gs} - I_d \cdot R_s$.

the effective $V_{ds}' = V_{ds} - I_d(R_s + R_d)$.

so just replace V_{gs} (or V_{ds}) with V_{gs}' (or V_{ds}') to correct the series resistance.

a. $I_{on} = W C_{ox} v (V_{gs} - V_{th})$ ideal case.

$I_{on} = W C_{ox} v (V_{gs}' - V_{th})$ real case

so $I_{on} = W C_{ox} v (V_{gs} - V_{th} - I_{on} \cdot R_s)$

$$v = \frac{I_{on}}{W C_{ox}(V_{gs} - V_{th} - I_{on} \cdot R_s)} = \frac{110\ \mu A}{1\mu m \cdot 3\mu F/cm^2 \cdot (1.8v - 0.8V - 110\mu A \cdot 1k\Omega)}$$

$$= 4.1 \times 10^7\ cm/s$$

b.

In the linear region, $I_{ds} \doteq 20\mu A$ whe $V_{gs} = 1.8V$, $V_{ds} = 0.1V$.

$$R_{total} = \frac{V_{ds}}{I_{ds}} = \frac{0.1V}{20\mu A} = 5k\Omega.$$

$$R_{ch} = R_{total} - R_s - R_d = 5k\Omega - 1k\Omega - 1k\Omega = 3k\Omega.$$

ideally $I_d(\text{linear}) = \mu C_{ox} \frac{W}{L} (V_g - V_{th}) \cdot V_d$,

$$\text{so } R_{ch} = \frac{V_d}{I_d} = \frac{1}{\mu C_{ox} \frac{W}{L}(V_g - V_{th})} = 3k\Omega.$$

$$\Rightarrow \mu = \frac{1}{R_{ch} C_{ox} \frac{W}{L} (V_g - V_{th})} = \frac{1}{3k\Omega \times 3\mu F/cm^2 \times \frac{1\mu m}{14nm} \times (1.8V - 0.8V)}$$

$$\doteq 1.56\ cm^2/V\cdot s.$$

c. The drain current is drift current:

$$I_d(y) = W\mu\, Q_n(y)\, E(y)$$

$$Q_n = -C_{ox}\left[V_g - V_{th} - V(y)\right]$$

So $I = W\mu Q_n E(y) = \frac{W\mu C_{ox}}{L}\left[(V_g - V_t)V_d - \frac{1}{2}V_d^2\right]$

$$\Rightarrow \quad E(y) = -\frac{1}{L}\,\frac{\left[(V_g - V_t)V_d - \frac{1}{2}V_d^2\right]}{\left[V_g - V_t - V(y)\right]}$$

For small V_d, we can ignore $(-\frac{1}{2}V_d^2)$, and $Q_n \approx -C_{ox}(V_g - V_t)$

So $E(y) \doteq -\frac{V_d}{L}$ for $V_d \ll V_G - V_T$.