Problem 1 (5 points) For the following transistor, find the value of $V_S$ which produces the indicated $I_{DS}$ given: $W_n = 0.5 \ \mu m$, $L_n = 0.1 \ \mu m$, $V_{T,n} = 1 \ V$, $\mu_n C_{ox} = 0.5 \times 10^{-4} \ A/V^2$, $\lambda = 0$, $\gamma = 0$. Show all work to receive full credit.

\[
V_{DS} = 5V - V_S > 3.3V - V_S - V_{T,n} = 2.3V - V_S \Rightarrow \text{saturation} \quad (1 \ \text{pt.})
\]

\[
I_{DS} = \frac{k_n}{2} \frac{W}{L} \left( V_{GS} - V_{T,n} \right)^2 (1 + \gamma V_{DS}) \quad (1 \ \text{pt.})
\]

\[
V_{GS} = V_{T,n} + \sqrt{\frac{2I_{DS}}{k_n W/L}} = 1V + \sqrt{\frac{2 \times 10^{-6} \ A}{0.5 \times 10^{-4} \ A/V^2}} \quad (1 \ \text{pt.})
\]

\[
V_{GS} = 1.283V \quad (1 \ \text{pt.})
\]

\[
V_S = V_G - V_{OS} = 2.017V
\]

\[
V_S = 2.02V \quad (1 \ \text{pt.})
\]

Problem 2 (2 points) Suppose $\lambda = 0.1 \ V^{-1}$. What is the new current $I_{DS}$ for the $V_S$ you found above?

\[
I_{DS} = \frac{k_n}{2} \left( \frac{W}{L} \right) \left( V_{GS} - V_{T,n} \right)^2 (1 + \lambda V_{DS})
\]

\[
= 500 \mu A/V^2 \left( \frac{5}{1} \right) \left( 1.283V - 1V \right)^2 (1 + 0.1 V^{-1} (5 - 2.02V)) \quad (1 \ \text{pt.})
\]

\[
\text{New } I_{DS} = 13 \mu A \quad (1 \ \text{pt.})
\]