

# Homework 4 - ECE 1238 Rayan Hassan (4511021)

① (a) Here,  $V_{DS} \geq V_{GS}$ , the NMOS will be in saturation

$$\frac{I_{D(4th\ row)}}{I_{D(2^{nd}\ row)}} = \frac{\frac{k}{2} (V_{GS} - V_{T0})^2 (1 + \lambda V_{DS(4)})}{\frac{k}{2} (V_{GS} - V_{T0})^2 (1 + \lambda V_{DS(2)})}$$

Because we know  $V_{GS(2)} = V_{GS(4)} = 0.8V$  (Table)

$$\Rightarrow \frac{I_{D(4)}}{I_{D(2)}} = \frac{1 + \lambda V_{DS(4)}}{1 + \lambda V_{DS(2)}}$$

$$\Rightarrow \frac{60}{59} = \frac{1 + \lambda \times 1}{1 + \lambda \times 0.8} \Rightarrow 59(1 + \lambda) = 60(1 + 0.8\lambda)$$

$$\Rightarrow 59 + 59\lambda = 60 + 48\lambda$$

$$\Rightarrow 11\lambda = 1 \Rightarrow \boxed{\lambda = 0.0909\ V^{-1}}$$

(b) Now to find  $V_{T0}$ , we want to eliminate the  $(1 + \lambda V_{DS})$  part of the equation and use the ratio of currents. So let's take row 1 and row 2, where  $V_{DS(1)} = V_{DS(2)} = 0.8V$ .

$$\frac{I_{D(2)}}{I_{D(1)}} = \frac{\frac{k}{2} (V_{GS(2)} - V_{T0})^2 (1 + \lambda V_{DS(2)})}{\frac{k}{2} (V_{GS(1)} - V_{T0})^2 (1 + \lambda V_{DS(1)})} = \frac{(V_{GS(2)} - V_{T0})^2}{(V_{GS(1)} - V_{T0})^2}$$

$$\Rightarrow \frac{59}{8} = \frac{(0.8 - V_{T0})^2}{(0.6 - V_{T0})^2} \Rightarrow \sqrt{\frac{59}{8}} = \frac{0.8 - V_{T0}}{0.6 - V_{T0}}$$

$$\Rightarrow 2.7156 = \frac{0.8 - V_{T0}}{0.6 - V_{T0}}$$

$$2.7156(0.6 - V_{T0}) = 0.8 - V_{T0}$$

$$\Rightarrow 1.63 - 2.7156 V_{T0} = 0.8 - V_{T0}$$

$$\Rightarrow 1.7156 V_{T0} = 0.83$$

$$\Rightarrow \boxed{V_{T0} \approx 0.484 \text{ V}}$$

(6) For  $k$ , use any row, (let's use row 1)

$$I_{D(sat,1)} = \frac{k}{2} (V_{GS(1)} - V_{T0})^2 (1 + \lambda V_{DS(1)})$$

$$8 = \frac{k}{2} (0.6 - 0.484)^2 (1 + 0.0909 \times 0.8)$$

$$k = \frac{8}{\frac{1}{2} (0.116)^2 (1.07272)}$$

$$\Rightarrow \boxed{k \approx 1.1 \text{ mA/V}^2}$$

(d) To find  $\gamma$  let's take row 3

$$37 \times 10^{-6} = \frac{1.1 \times 10^{-3}}{2} (0.8 - V_T)^2 (1 + 0.0909 \times 0.8)$$

$$\Rightarrow (0.8 - V_T)^2 = \frac{37 \times 10^{-6}}{\frac{1.1 \times 10^{-3}}{2} (1 + 0.0909 \times 0.8)}$$

$$\Rightarrow (0.8 - V_T)^2 = 62.7123 \times 10^{-3}$$

$$\Rightarrow 0.8 - V_T = 0.2504$$

$$\Rightarrow V_T = 0.5496 \text{ V}$$

So now:  $V_T = V_{T0} + \gamma (\sqrt{|-2\phi_F + V_{SB}|} - \sqrt{|2\phi_F|})$

$$\Rightarrow \gamma = \frac{V_T - V_{T0}}{\sqrt{|-2\phi_F + V_{SB}|} - \sqrt{|2\phi_F|}}$$

$$\Rightarrow \gamma = \frac{0.5496 - 0.484}{\sqrt{|-1.1 - 0.3|} - \sqrt{|-1.1|}} = \frac{0.0656}{\sqrt{1.4} - \sqrt{1.1}}$$

$$\Rightarrow \boxed{\gamma \approx 0.443 \text{ V}^{1/2}}$$

$$(e) \quad k = k' \frac{w}{L}$$

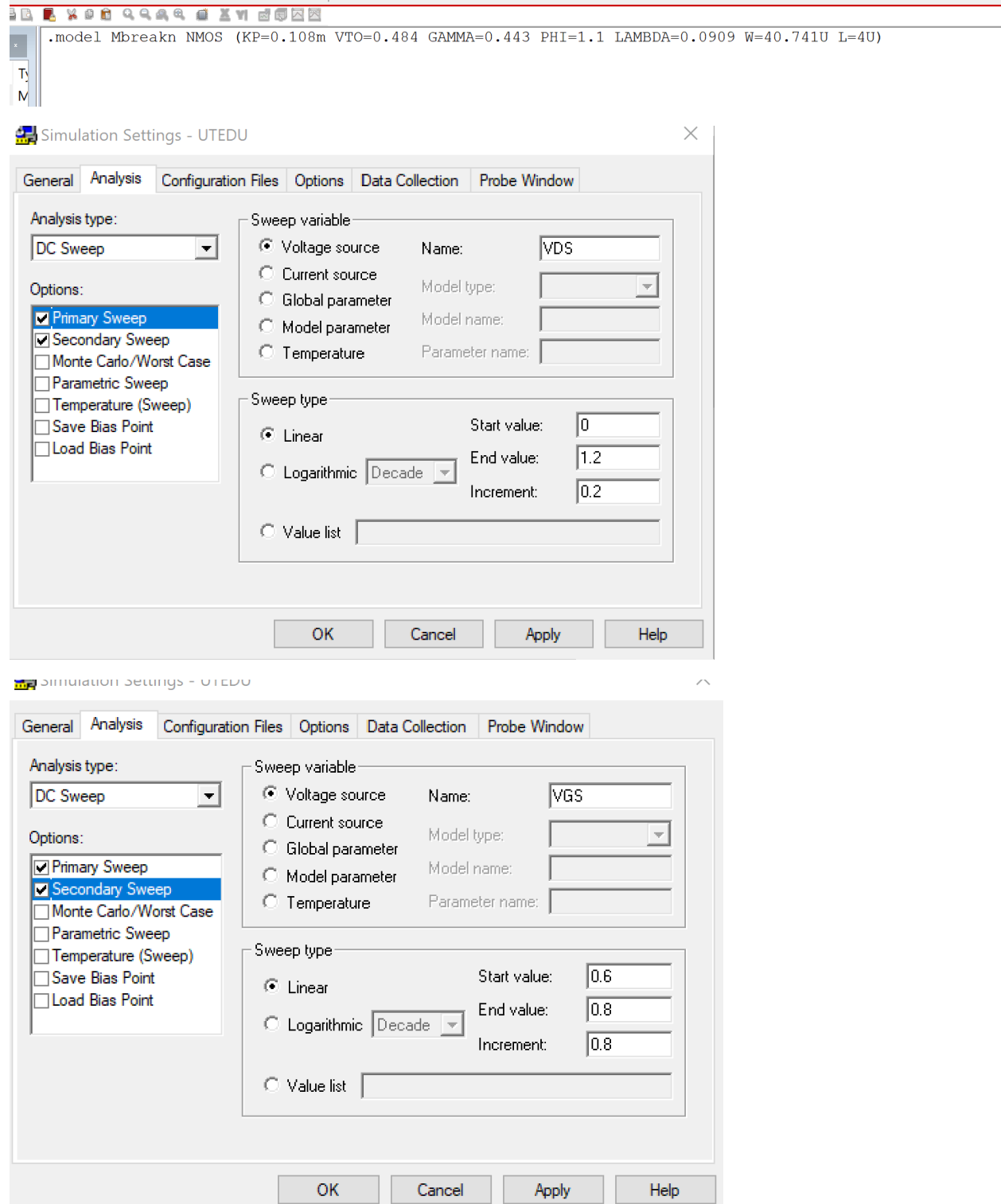
$$\Rightarrow w = \frac{kL}{k'} = \frac{1.1 \times 4}{0.108}$$

$$\Rightarrow \boxed{w \approx 40.741 \mu\text{m}}$$

## Homework 4 – ECE 1238

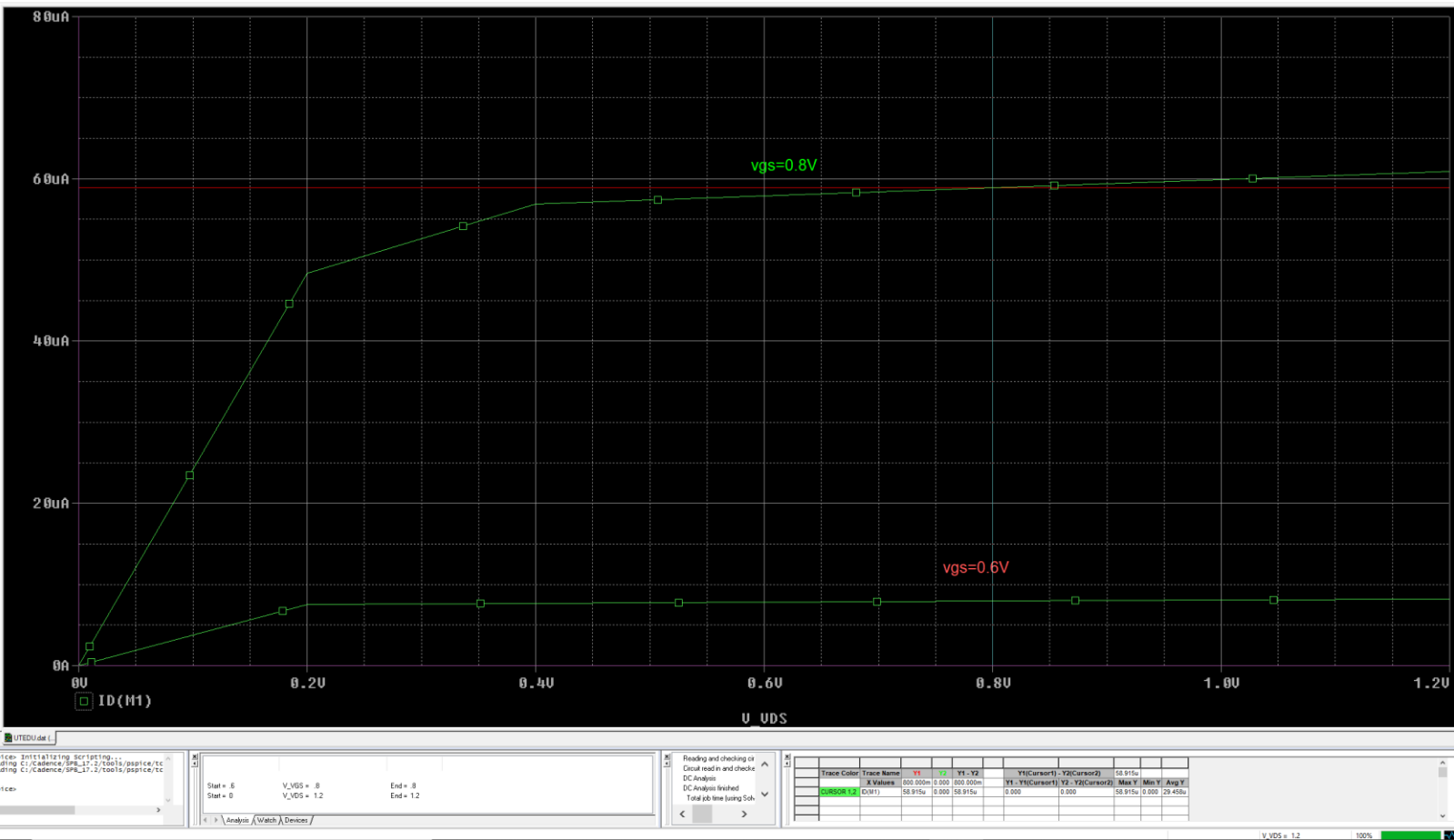
Rayan Hassan

### SPICE



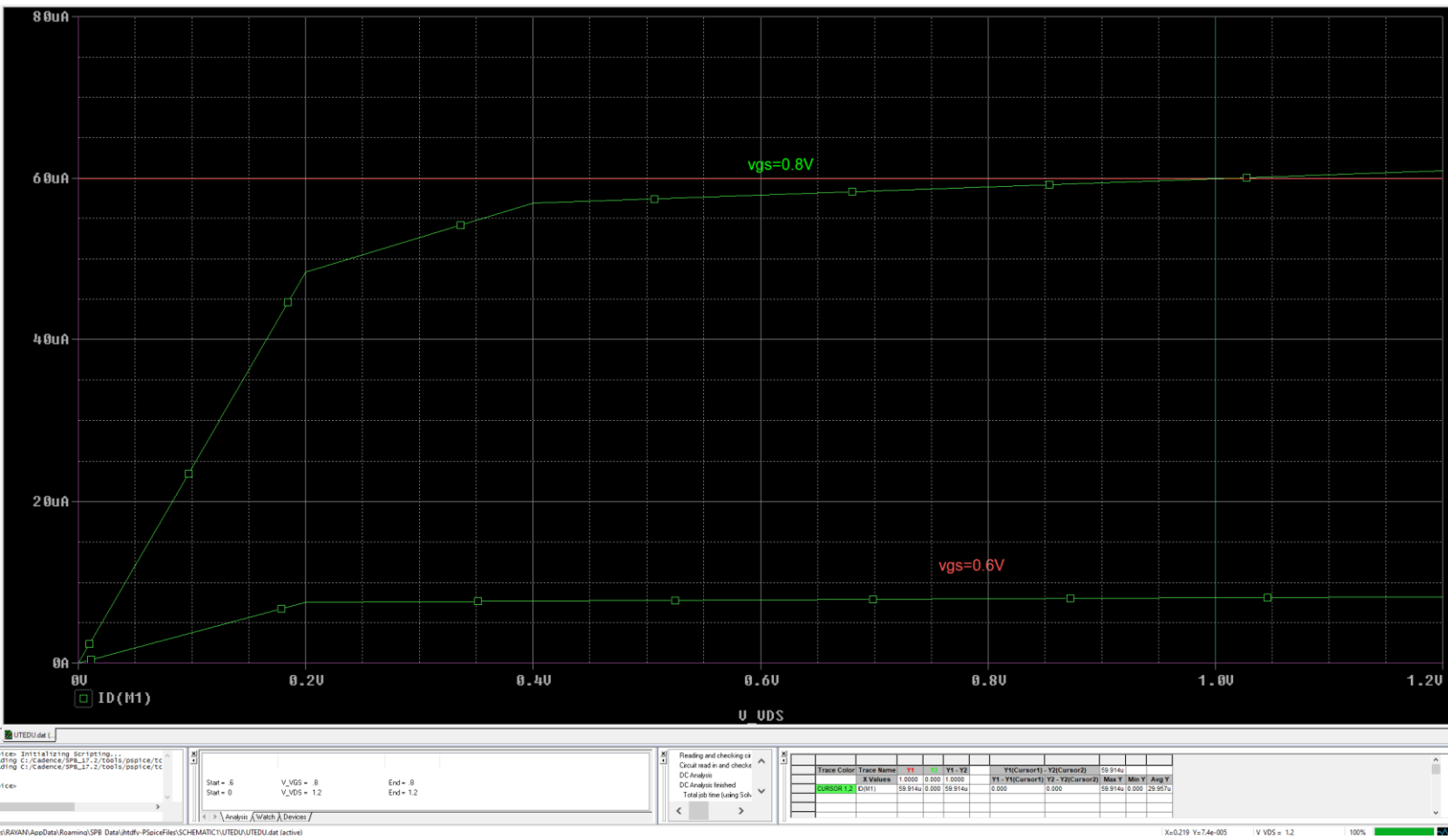
Results:

Vgs = 0.8 V and Vds = 0.8 V



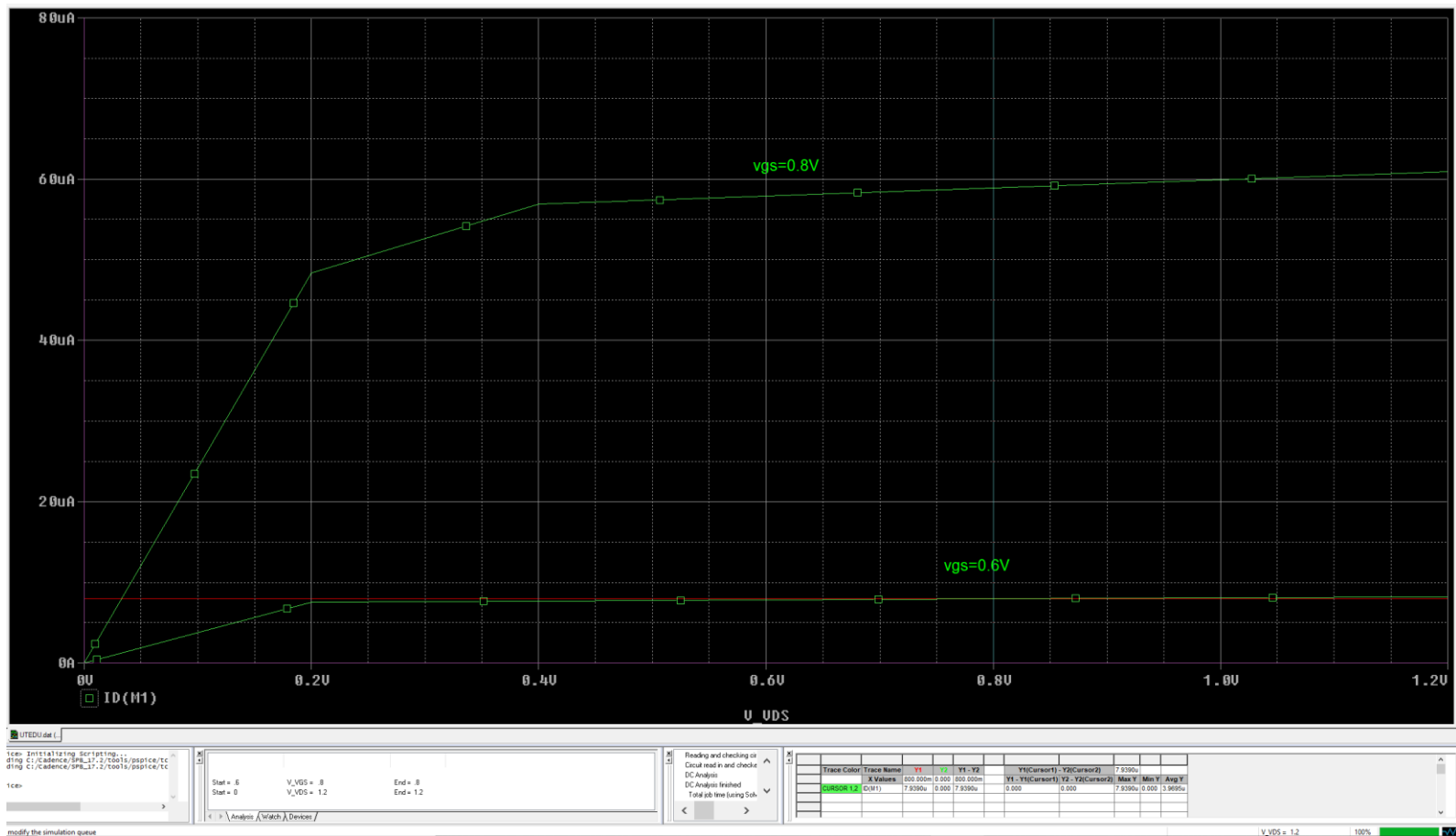
With cursor ON, we can see in the table at the bottom of the simulation window that  $I(d) = 58.91 \mu A$  which is almost the same as  $59 \mu A$  (the value in the given table row 2)

**$V_{gs} = 0.8 \text{ V}$  and  $V_{ds} = 1 \text{ V}$**



Here, I got  $I(D) = 59.91 \mu A$  which is almost equal to  $60 \mu A \rightarrow$  corresponds to value in given table at row 4

$V_{gs} = 0.6 \text{ V}$  and  $V_{ds} = 0.8 \text{ V}$



Here, I got  $I(D) = 7.939 \text{ uA}$ , which is also almost equal to  $8 \text{ uA} \rightarrow$  corresponds to value in row 1 of given table

**NB.** Please note that I didn't get the exact same results because I took approximations when I did my calculations of the device parameters. However, I got very close values which validates the results in the given table.



## Report

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1174 ** Creating circuit file "UTEDU.cir"
1175 ** WARNING: THIS AUTOMATICALLY GENERATED FILE MAY BE OVERWRITTEN BY SUBSEQUENT SIMULATIONS
1176
1177 *Libraries:
1178 * Profile Libraries :
1179 * Local Libraries
1180 * LIB "C:\Users\RAYAN\Desktop\JHTDFY.lib"
1181 * From [PSpice NETLIST] section of C:\Users\RAYAN\AppData\Roaming\SPB_Data\cdssetup\OrCAD_PSpice\17.2.0\PSpice.ini file:
1182 * lib "nomd.lib"
1183
1184 *Analysis directives:
1185 DC LIN V VDS 0 1.2 0.2
1186 * LIN V VGS 0 6 0.8 0.2
1187 OPTIONS ADWCONV
1188 PROBE64 V(alias(*)) I(alias(*)) V(alias(*)) D(alias(*)) NOISE(alias(*))
1189 INC "..\SCHEMATIC1.net"
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1193 **** INCLUDING SCHEMATIC1.net ****
1194 * source JHTDFY
1195 M_M1 N00098 N00091 0 0 Mbreakn
1196 V_VGS N00091 0 0.8Vdc
1197 V_VDS N00098 0 1.2Vdc
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1199 **** RESUMING UTEDU.cir ****
1200 .END
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1203 **** 10/03/21 19:55:15 ***** PSpice Lite (March 2016) ***** ID# 10813 ****
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1205 ** Profile: "SCHEMATIC1-UTEDU" [ C:\Users\RAYAN\AppData\Roaming\SPB_Data\jhtdfy-PSpiceFiles\SCHEMATIC1\UTEDU.sim ]
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1207 **** MOSFET MODEL PARAMETERS
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