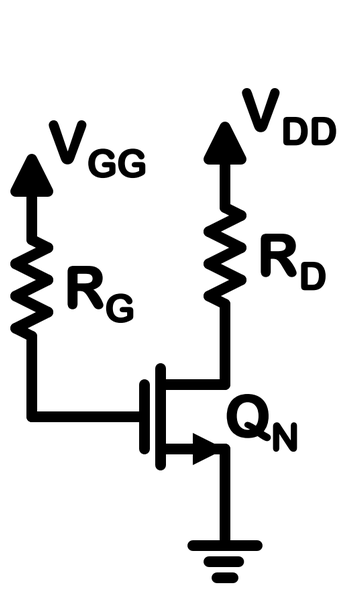
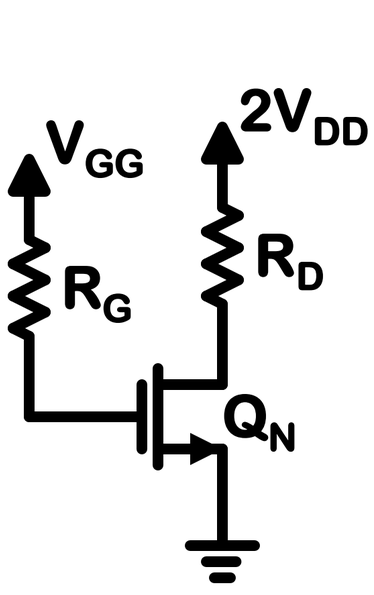
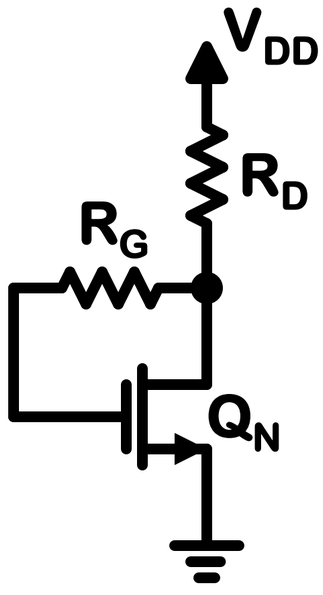
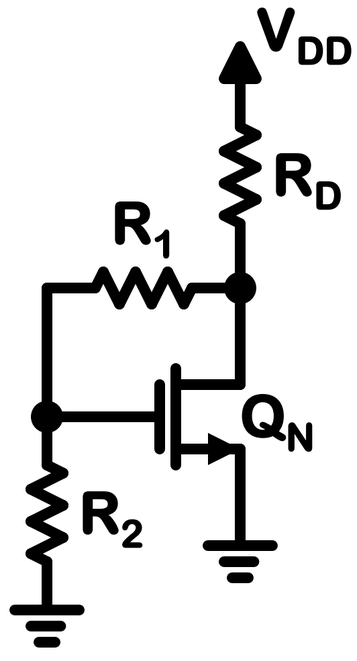
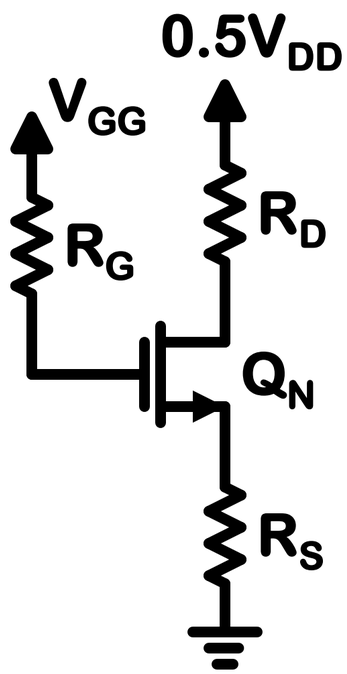


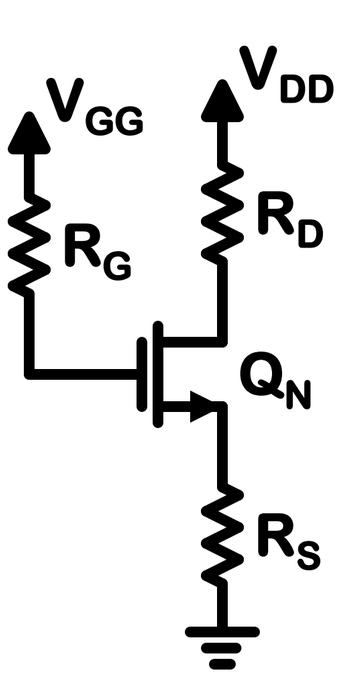



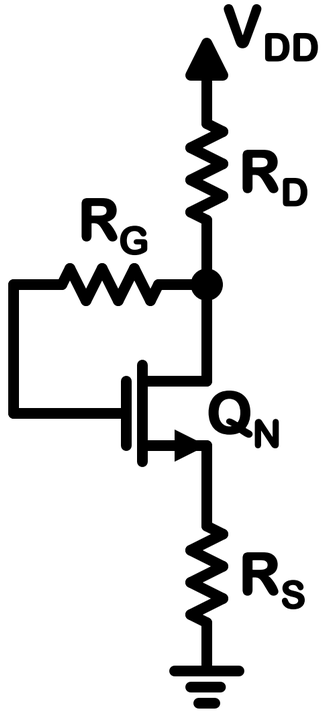



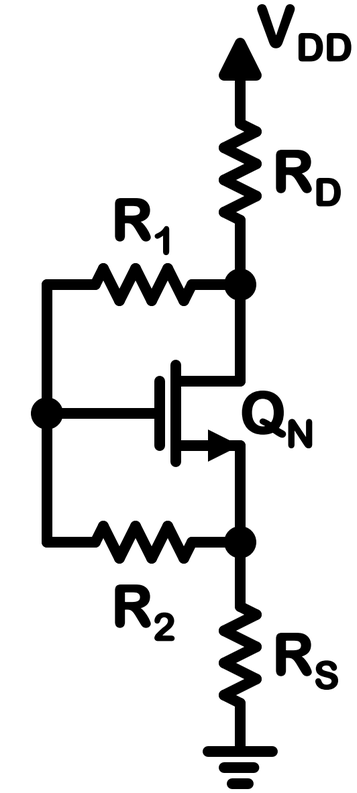



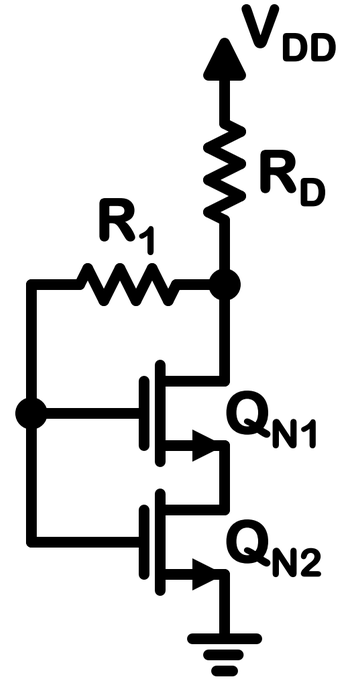

$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

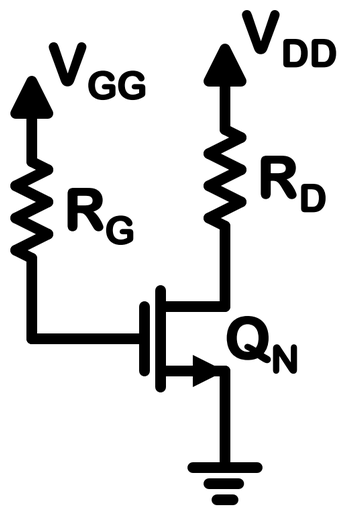





$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Triode**

**2. Enforce (device equation)**

$i_D = 0.002(v_{GS} - 1 - v_{DS}/2)v_{DS}$

**3. Solve**

**a. Circuit Equations**

$v_{GS} = 4V$

$i_D = (6 - v_{DS})/500$

**b. Solve**

$(6 - v_{DS})/500 = 0.002(4 - 1 - v_{DS}/2)v_{DS}$

$6 - v_{DS} = 3v_{DS} - 0.5v_{DS}^2$

$0.5v_{DS}^2 - 4v_{DS} + 6 = 0$

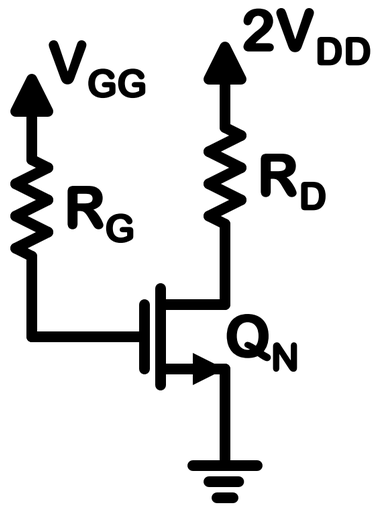
$v_{DS} = 4 +/- sqrt(16 - 12) = 6V \text{ or } 2V \ldots \text{Choose } 2V$

$i_D = (6 - 2)/500 = 4/500 = 8\ mA$

**4. Check**

$v_{GS} - V_{tn} > 0$, Yes

$v_{DS} < v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

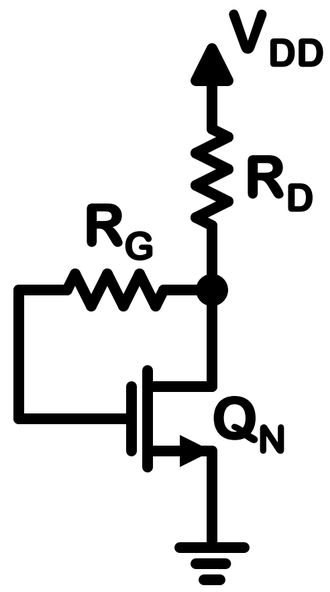
**1. Saturation**

**2. Enforce (device equation)**
$i_D = (0.5)0.002(v_{GS} - 1)^2$

**3. Solve**
**a. Circuit Equations**
$v_{GS} = 4V$
$i_D = .001(4-1)^2 = 9\ mA$

**b. Solve**
$v_{DS} = 12 - 500(0.009) = 7.5V$

**4. Check**
$v_{GS} - V_{tn} > 0$, Yes
$v_{DS} > v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Saturation**

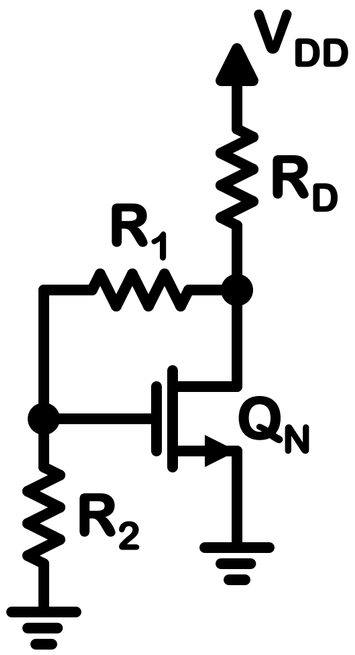
**2. Enforce (device equation)**
$i_D = (0.5)0.002(v_{GS} - 1)^2$

**3. Solve**
**a. Circuit Equations**
$v_{GS} = v_{DS}$
$i_D = (6 - v_{GS})/500$

**b. Solve**
$(6 - v_{GS})/500 = 0.001(v_{GS} - 1)^2$
$12 - 2v_{GS} = v_{GS}^2 - 2v_{GS} + 1$
$v_{GS}^2 - 11 = 0$

$v_{GS}$ = +/- sqrt(11) = +/- 3.32V … choose 3.32V
$i_D = 5.37\ mA$

**4. Check**
$v_{GS} - V_{tn} > 0$, Yes
$v_{DS} > v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Saturation**

**2. Enforce (device equation)**

$i_D = (0.5)0.002(v_{GS} - 1)^2$

**3. Solve**

**a. Circuit Equations**

$v_{GS} = 3v_{DS}/5$ or $v_{DS} = (5/3)v_{GS}$

$i_{RD} = i_D + i_{R1}$

$i_{RD} = (6 - (5/3)v_{GS})/500$

$i_{R1} = (5/3)v_{GS}/500$

**b. Solve**

$(6 - (5/3)v_{GS})/500 - (5/3)v_{GS}/500 = 0.001(v_{GS} - 1)^2$

$12 - (20/3)v_{GS} = v_{GS}^2 - (6/3)v_{GS} + 1$

$v_{GS}^2 + (14/3)v_{GS} - 11 = 0$

$v_{GS} = (-14/3 +/- sqrt((14/3)^2 + 44))/2 =$ choose 1.72V

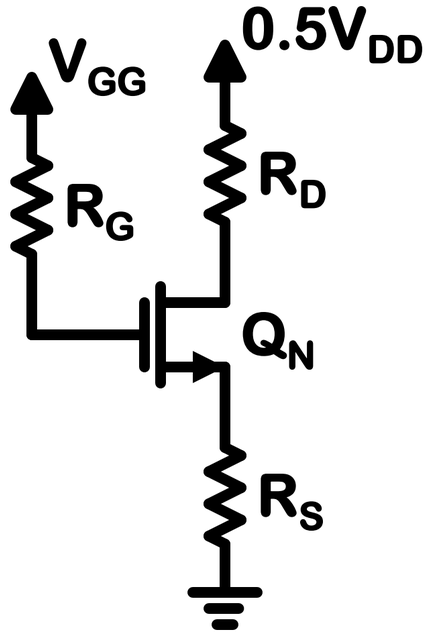
$v_{DS} = 2.87V$

$i_D = 0.518\ mA$

**4. Check**

$v_{GS} - V_{tn} > 0$, Yes

$v_{DS} > v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

1. Triode

2. Enforce (device equation)
$i_D = 0.002(v_{GS} - 1 - v_{DS}/2)v_{DS}$

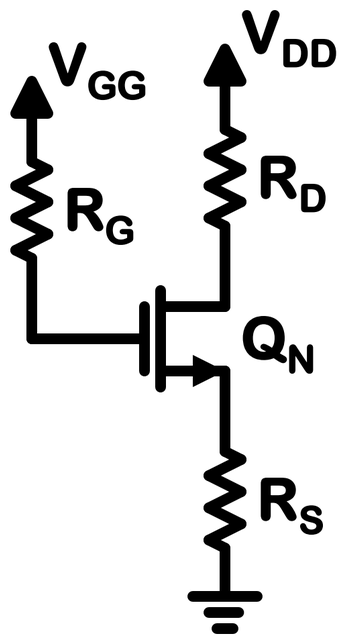
3. Solve
a. Circuit Equations
$v_{GS} = 4 - 200i_D$ or $i_D = (4 - v_{GS})/200$
$i_D = (3 - v_{DS})/700$

b. Solve
$(3 - v_{DS})/700 = (4 - v_{GS})/200$
$6 - 2v_{DS} = 28 - 7v_{GS}$ or $v_{GS} = (2v_{DS} + 22)/7$

$(3 - v_{DS})/700 = 0.002((2v_{DS} + 22)/7 - 1 - v_{DS}/2)v_{DS}$
$3 - v_{DS} = 1.4((2v_{DS} + 22)/7 - 1 - v_{DS}/2)v_{DS}$
$3 - v_{DS} = (.2(2v_{DS} + 22) - 1.4 - .7v_{DS})v_{DS}$
$3 - v_{DS} = ((.4v_{DS} + 4.4) - 1.4 - .7v_{DS})v_{DS}$
$3 - v_{DS} = 3v_{DS} - .3v_{DS}^2$
$0.3v_{DS}^2 - 4v_{DS} + 3 = 0$

$v_{DS} = (4 +/- sqrt(16 - 4*0.3*3))/.6 = 0.8V$ or $12.5V$
Choose $0.8V$
$v_{GS} = 3.37V$
$i_D = (3 - 0.8)/700 = 3.1\ mA$

4. Check
$v_{GS} - V_{tn} > 0$, Yes
$v_{DS} < v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Saturation**

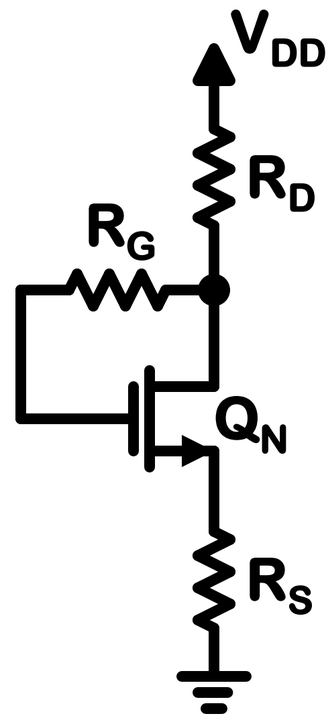
**2. Enforce (device equation)**
$i_D = 0.001(v_{GS} - V_{tn})^2$

**3. Solve**
**a. Circuit Equations**
$v_{GS} = 4 - 200i_D$ or $i_D = (4 - v_{GS})/200$

**b. Solve**
$(4 - v_{GS})/200 = 0.001(v_{GS} - 1)^2$
$20 - 5v_{GS} = v_{GS}^2 - 2v_{GS} + 1$
$v_{GS}^2 + 3v_{GS} - 19 = 0$

$v_{GS}$ = (-3 +/- sqrt(3*3 – -4*19))/2 = 3.11V or -6.11V … choose 3.11V
Choose 3.11V
$i_D = 0.001(3.11 - 1)^2 = 4.45\ mA$
$v_{DS} = 6 - 700i_D = 2.885V$

**4. Check**
$v_{GS} - V_{tn} > 0$, Yes
$v_{DS} > v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Saturation**

**2. Enforce (device equation)**

$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$

**3. Solve**

**a. Circuit Equations**

$v_{GS} = v_{DS}$

$i_D = (6 - v_{GS})/700$

**b. Solve**

$(6 - v_{GS})/700 = 0.001(v_{GS} - 1)^2$

$6 - v_{GS} = .7v_{GS}^2 - 1.4v_{GS} + .7$

$.7v_{GS}^2 - 0.4v_{GS} - 5.3 = 0$

$v_{GS} = (0.4+/- sqrt(0.16 + 4*.7*5.3))/1.4 = 3.05V$ or $-2.48V$

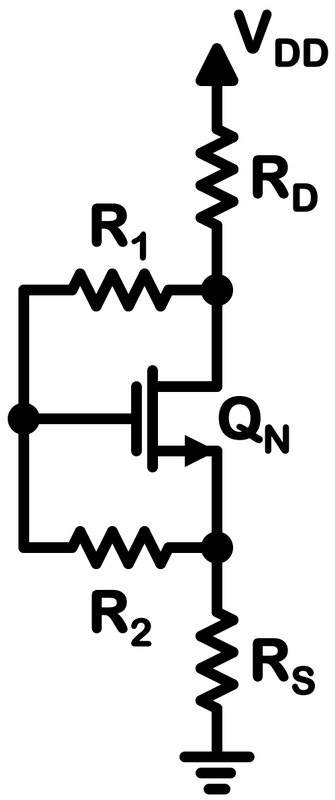
Choose 3.05V

$i_D = 4.2\ mA$

**4. Check**

$v_{GS} - V_{tn} > 0$, Yes

$v_{DS} > v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
$V_{GG} = 4V$
$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Saturation**

**2. Enforce (device equation)**

$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$

**3. Solve**

**a. Circuit Equations**

$v_{GS} = v_{DS}(300/500) = 0.6v_{DS}$

$i_D = (6 - v_{DS})/700 - v_{DS}/500$

**b. Solve**

$(6 - 1.67v_{GS})/700 - 1.67v_{GS}/500 = 0.001(v_{GS} - 1)^2$

$6 - 4v_{GS} = .7v_{GS}^2 - 1.4v_{GS} + .7$

$.7v_{GS}^2 + 2.6v_{GS} - 5.3 = 0$

$v_{GS} = (-2.6 +/- sqrt(2.6^2 + 4*.7*5.3))/1.4 = 1.46V \text{ or } -5.17V$

Choose 1.46V

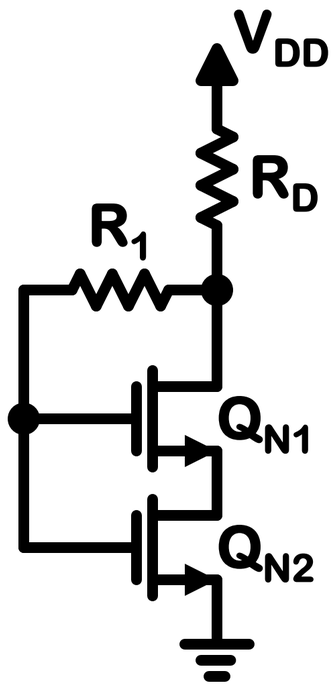
$v_{DS} = 2.43V$

$i_D = 0.206\ mA$

**4. Check**

$v_{GS} - V_{tn} > 0$, Yes

$v_{DS} > v_{GS} - V_{tn}$, Yes




$V_{DD} = 6V$
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$R_G = 10k\Omega$
$R_D = 500\Omega$
$R_S = 200\Omega$
$R_1 = 200\Omega$
$R_2 = 300\Omega$
$k_n = 2\ mA/V^2$
$V_{tn} = 1V$

**1. Saturation, Triode**

**2. Enforce (device equation)**

$i_{D1} = 0.001(v_{GS1} - V_{tn})^2$

$i_{D2} = 0.002(v_{GS2} - V_{tn} - 0.5v_{DS2})v_{DS2}$

**3. Solve**

**a. Circuit Equations**

$v_{GS1} = v_{DS1}$

$v_{GS2} = v_{DS1} + v_{DS2}$

$i_D = (6 - (v_{DS1} + v_{DS2}))/500$

**b. Solve**

**Use Matlab and 3D plot to find intersection**

$v_{GS1} = 3.1V$, $v_{DS1} = 3.1V$

$v_{GS2} = 3.9V$, $v_{DS2} = 0.8V$

$i_D = 4.2mA$

**4. Check**

$v_{GS} - V_{tn} > 0$, Yes

$v_{DS} > v_{GS} - V_{tn}$, Yes