Homework#4

For 01205231 -Electronic Circuits & Systems I: sec 450

Name...

I.D. ....

Due Date: April 21, 2016: 11.59 AM (no late submission)!!

Problem#	Points
1	
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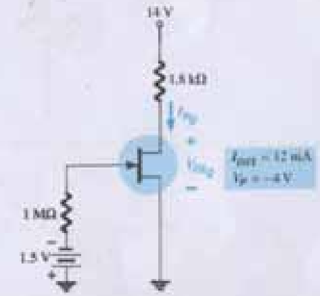
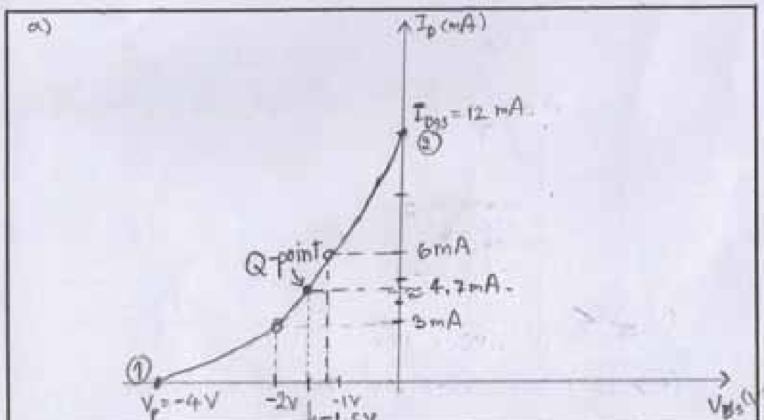
Homework # 4 due date April 21, 2016: 11.59 AM

1. For the fixed-bias configuration of Figure:

a. Sketch the transfer characteristics of the device.
b. Superimpose the network equation on the same graph.
c. Determine I_{D_Q} and V_{DS_Q}.
d. Using Shockley's equation, solve for I_{D_Q} and then find V_{DS_Q}. Compare with the solutions of part (c).



a)



(b) Use shorthand Method to find the point for plot graph.

① $V_{GS} = V_P = -4V$, $I_D = 0 mA$.

② $V_{GS} = 0V$, $I_D = I_{DSS} = 12 mA$

③ $V_{GS} = 0.5V_P = -2V$, $I_D = I_{DSS}/4 = 3 mA$

④ $V_{GS} = 0.3V_P = -1.2V$, $I_D = I_{DSS}/2 = 6 mA$

(c) From the circuit, there was constant $V_{GS} = -1.5V$

From graph $I_{DQ} \approx 4.7mA$.

$V_{DS} = V_{DD} - I_D R_D = 14 - (4.7m)(1.8K)$

$V_{DSQ} = 5.54V$.

(d) Shockley's equation

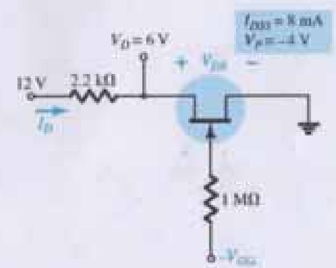
$I_{DQ} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = (12mA)\left(1 - \frac{1.5}{4}\right)^2 = 4.68 mA$.

$V_{DSQ} = V_{DD} - I_{DQ}R_D = 14 - (4.68m)(1.8K)$

$V_{DSQ} = 5.57 V$.

2. Given the measured value of V_D in Figure, determine;

**Please show methods, equivalent circuit and circle your answers with pen, then write your answer in the provided (red) box.



a) I_D = ...

b) V_{DS} = ...

c) V_{GG} = ...

a) $V_{DD} = V_D + I_D R_D$

$\therefore I_D = \frac{V_{DD} - V_D}{R_D} = \frac{12-6}{2.2K} = 2.73 mA$.

b) From circuit: $V_{DS} = V_D = 6V$.

c) $V_{GG} = V_{GS}$

Shockley's eq: $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$V_{GS} = \left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right)V_P$

$= \left(1 - \sqrt{\frac{2.73}{8}}\right)(-4)$

$= -1.66 V$.

$\therefore V_{GG} = -1.66 V$

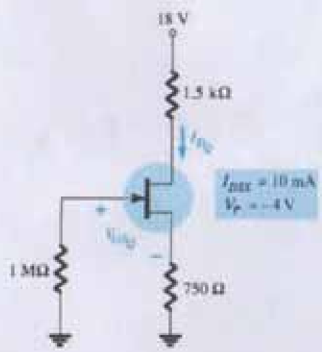
3. For the self-bias configuration of Figure:

a. Sketch the transfer curve for the device.

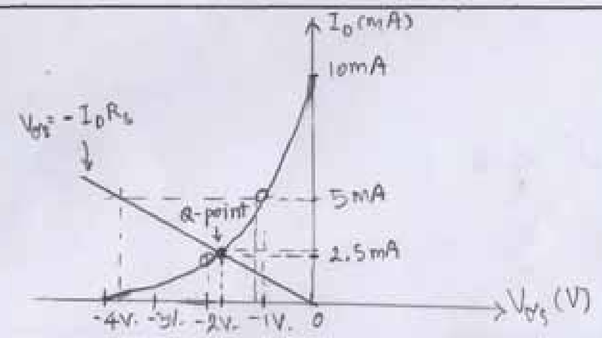
b. Superimpose the network equation on the same graph.

c. Determine I_{D_Q} and V_{GS_Q}.

d. Calculate V_{DS}, V_D, V_G, and V_S.



a)



(b) $V_{GS} = 0V$, $I_{DSS} = 10\ mA$ ✓

$V_{GS} = V_P = -4V$, $I_D = 0\ mA$. ✓

$V_{GS} = 0.5V_P = -2V$, $I_D = I_{DSS}/4 = 2.5\ mA$ ✓

$V_{GS} = 0.3V_P = -1.2V$, $I_D = I_{DSS}/2 = 5mA$ ✓

(c) $V_{GS} = -V_S = -I_D R_S$ — linear equation ✓

At $I_D = 5mA$: $V_{GS} = -(5m)(750) = -3.75\ V$ ✓

From the graph: $I_{DQ} \approx 2.7mA$ ✓

$V_{DSQ} = 18 - (2.7m)(1.5K + 0.75K)$.

$V_{DSQ} = 11.925\ V$ ✓

$V_{GSQ} = V_P\left(1 - \sqrt{\frac{I_{DQ}}{I_{DSS}}}\right)$

$V_{GSQ} = (-4)\left(1 - \sqrt{\frac{2.7}{10}}\right) = -1.92V$.

(d) $V_D = V_{DD} - I_D R_D = 18 - (2.7m)(1.5K) = 13.95V$. ✓

$V_G = 0V$ ✓

$V_S = I_D R_S = (2.7m)(750) = 2.025V$. ✓

$V_{DS} = V_D - V_S = 13.95 - 2.025 = 11.925V$. ✓

4. Determine I_{D_Q} for the network of Figure (Problems 3) using a purely mathematical approach. That is, establish a quadratic equation for I_D and choose the solution compatible with the network characteristics. Compare to the solution obtained in Problem 3.

From Shockley's eq: $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ — ①

$V_{GS} = V_G - V_S = -I_D R_S$ — ②

$\therefore \quad I_D = I_{DSS}\left(1 + \frac{I_D R_S}{V_P}\right)^2$

$I_D = I_{DSS}\left(1 + \frac{2 I_D R_S}{V_P} + \left(\frac{I_D R_S}{V_P}\right)^2\right)$

$I_D = I_{DSS} + \left(\frac{2 R_S I_{DSS}}{V_P}\right) I_D + \left(\frac{R_S}{V_P}\right)^2 I_{DSS} I_D^2$

$351.56 I_D^2 - 4.75 I_D + 10^{-2} = 0$

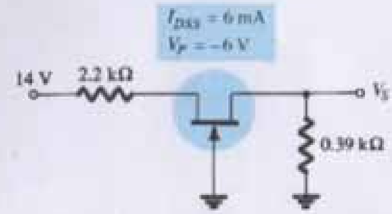
$I_D = 0.011, 0.0026$

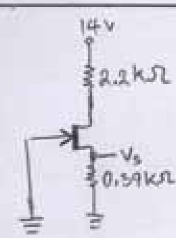
$= \cancel{11\,mA}, 2.6\,mA$ ✓

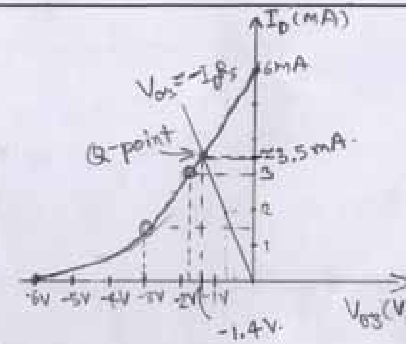
$\therefore I_{DQ} = 2.6\,mA$ ✓

$V_{GSQ} = -(2.6m)(750) = -1.95\,V.$

5. Find V_s for the network of Figure.







$V_{GS} = 0V,\ I_D = I_{DSS} = 6\,mA$

$V_{GS} = V_P = -6V,\ I_D = 0\,mA.$

$V_{GS} = 0.5 V_P = -3V,\ I_D = 0.25 I_{DSS} = 1.5\,mA$

$V_{GS} = 0.3 V_P = -1.8V,\ I_D = 0.5 I_{DSS} = 3\,mA$

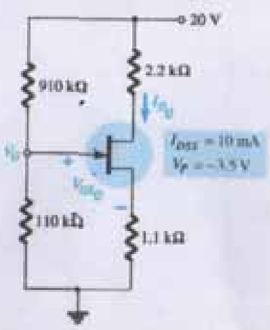
$\boxed{V_{GS} = -I_D R_S}$

From graph: $V_{GS_Q} \approx -1.4V,\ I_{D_Q} \approx 3.5\,mA$

$\therefore \quad V_S \approx -V_{GS} = 1.4V.$ ✓

6. For the network of Figure, determine:

**Please show methods, equivalent circuit and circle your answers with pen, then write your answer in the provided (red) box.



a) V_G = ...
b) I_{D_Q} = ...
c) V_{GS_Q} = ...
d) V_D = ...
e) V_S = ...
f) V_{DS_Q} = ...

a) $V_G = \left[\frac{110 k\Omega}{(110+910) k\Omega}\right] 20V = 2.16\ V.$ ✓

$V_{GS} = 0.3V_p = -1.05V$, $I_D = 0.5I_{DSS} = 5mA$

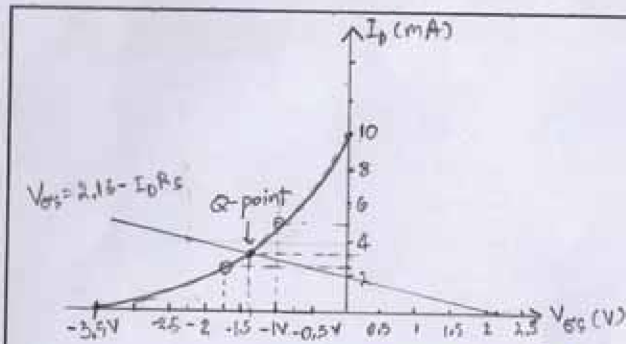
$V_{GS} = 0.5V_p = -1.75V$, $I_D = 0.25I_{DSS} = 2.5\ mA.$

$V_{GS} = V_p = -3.5V$, $I_D = 0\ mA.$

$V_{GS} = 0V$, $I_D = I_{DSS} = 10\ mA$

$V_{GS} = V_G - V_S = 2.16 - I_D R_S$

$\boxed{V_{GS} = 2.16 - I_D R_S}$ ✓



(b) $I_{DQ} \approx 3.2\ mA$ ✓ or $\approx 3.3\ mA$

(c) $V_{GSQ} \approx -1.36\ V$ or $\approx 1.5\ V$

(d) $V_D = 20 - (3.2m)(2.2K) = 12.96\ V$ or $\approx 12.74V$

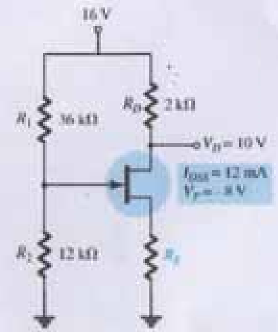
(e) $V_S = I_D R_S = (3.2m)(1.1K) = 3.52\ V$ or $\approx 3.63V$

(f) $V_{DSQ} = 20 - I_D(3.3K) = 20 - (3.2m)(3.3K)$

$V_{DSQ} = 9.44\ V$ or $\approx 9.11\ V$

$y = x - 4^v$

7. Determine the value of R_S for the network of Figure to establish $V_D = 10\ V$.



From Shockley's Equation

$$\boxed{I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2} \quad — ①$$

From circuit : $I_D = \dfrac{16 - V_D}{R_D} = \dfrac{16-10}{2k} = 3mA$ ✓

$V_G = \left[\dfrac{12k\Omega}{(36+12)k\Omega}\right](16) = 4\ V$ ✓

Eg. ① we have: $V_{GS} = \left(1 - \sqrt{\dfrac{I_D}{I_{DSS}}}\right)V_P = \left(1 - \sqrt{\dfrac{3}{12}}\right)(-8)$ ✓

$V_{GS} = -4V$ ✓

$\therefore V_S = V_G - V_{GS} = 4 - (-4) = 8\ V.$

So $R_S = \dfrac{V_S}{I_S} = \dfrac{8}{3m} = 2.67\ k\Omega \rightarrow R_S$ can vary.

✓

8. Given $V_{DS} = 4\ V$ for the network of Figure, determine:

**Please show methods, equivalent circuit and circle your answers with pen, then write your answer in the provided (red) box.

a) I_D = ...

b) V_D = ...

c) V_S = ...

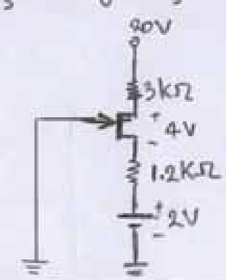
f) V_{GS} = ...

(a) $I_D = \dfrac{20 - 4 - 2}{(3+1.2)k} = \dfrac{14}{4.2K} \cong 3.33\ mA$ ✓

(b) $V_D = V_{DS} + V_S = 4 + 2 + (3.33m)(1.2K) \cong 10V$ ✓ or $V_D - I_D R_D \approx 10V$

(c) $V_S = V_D - V_{DS} = 10 - 4 = 6\ V$ ✓ or $I_D R_S + 2V \approx 5.96V$

(f) $V_{GS} = V_G - V_S = -V_S = -6V$ ✓



✓

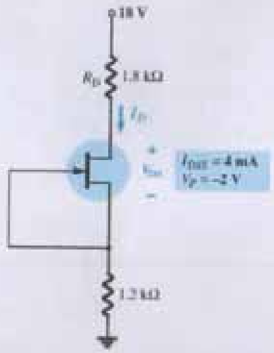
Special Case: $V_{GS_Q} = 0\ V$

9. For the network of Figure.

a. Find I_{D_Q}.

b. Determine V_{D_Q} and V_{DS_Q}.

c. Find the power supplied by the source and dissipated by the device.



(a) Because of $V_{GS_Q} = 0V$. So $I_{D_Q} = I_{DSS} = 4mA$

(b) $V_{DQ} = V_{DD} - I_D R_D = 18 - (4m)(1.8K) = 10.8\ V.$

$V_{DSQ} = V_{D_Q} - V_{S_Q} = 10.8 - I_D R_S = 10.8 - (4m)(1.2k)$

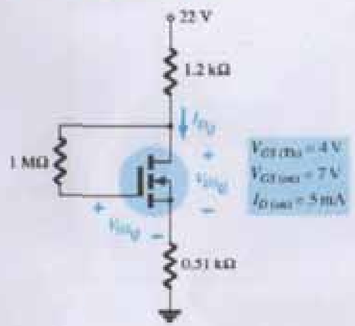
$\therefore V_{DSQ} = 6\ V$

(c) $P_{src} = I_D V_{DD} = (4m)(18) = 72\ mW$

$P_{device} = I_D V_{DS} = (4m)(6) = 24\ mW$

10. For the network of Figure, determine:

**Please show methods, equivalent circuit and circle your answers with pen, then write your answer in the provided (red) box.



a) I_{D_Q} = ...

b) V_{GS_Q} = ...

c) V_{DS_Q} = ...

d) V_D = ...

e) V_S = ...

f) V_{DS} = ...

(a) $I_{DQ} = k(V_{GS} - V_T)^2$

From $k = \dfrac{I_{D(on)}}{(V_{GS(on)} - V_T)^2} = \dfrac{5\,mA}{(7-4)^2 V^2} = 0.56 \times 10^{-3} \dfrac{A}{V^2}$ ✓

$\therefore \boxed{I_{DQ} = (0.56 \times 10^{-3})(V_{GS} - 4)^2}$ — The transfer Characteristics eq. ✓

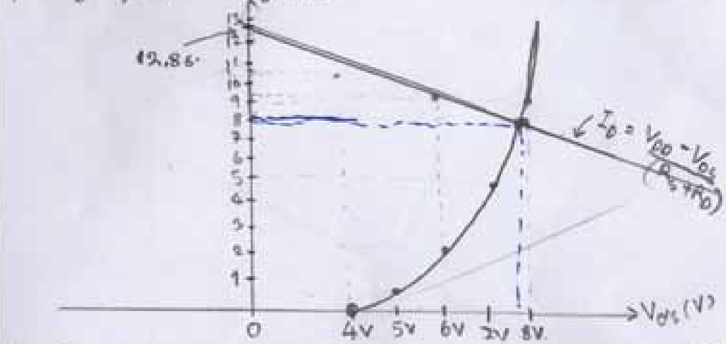
From circuit: $\boxed{V_{DD} = V_{DS} + I_D(R_S + R_D)}$ — linear eq.

① if $V_{DS} = 0$; $I_D = \dfrac{V_{DD}}{R_S + R_D} = \dfrac{22}{1.27\,k} = 12.86\,mA$ ✓

② $I_D = 0$; $V_{DS} = V_{DD} = 22\,V$ ✓

$V_{DG} = V_{DS} - V_{GS} \rightarrow V_{DS} = V_{GS}$; $V_{DG} = 0$

plot graph.



(b) Intersections point of curve and line.

$(0.56 \times 10^{-3})(V_{GSQ} - 4)^2 = \dfrac{V_{DD} - V_{GSQ}}{R_S + R_D}$

$(0.56 \times 10^{-3})V_{GSQ}^2 - (3.895 \times 10^{-3})V_{GSQ} - (8.9 \times 10^{-3}) = 0$

$V_{GSQ} = -\cancel{0.89}, 7.84\,V$ ✓

$\therefore I_{DQ} = \dfrac{22 - 7.84}{1.27\,K} = 8.28\,mA$ ✓

or from graph $I_{DQ} \approx 8.25\,mA$ ✓ $V_{GSQ} \approx 7.9\,V$ ✓

(c) $V_{DSQ} = V_{GSQ} = 7.84\,V$ ✓

$I_D \cdot R_D$

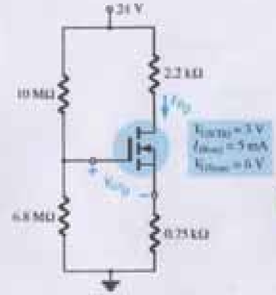
(d) $V_D = 22 - (8.28m)(1.2k) = 12.064\,V$ ✓ $\Rightarrow V_D = I_D \cdot R_D$

(e) $V_S = (8.28)(0.51) = 4.223\,V.$ ✓

(f) $V_{DS} = 12.064 - 4.223 = 7.84\,V.$ ✓

11. For the voltage-divider configuration of Figure, determine:

**Please show methods, equivalent circuit and circle your answers with pen, then write your answer in the provided (red) box.



a) I_{D_Q} = ...

b) V_{GS_Q} = ...

c) V_D = ...

d) V_S = ...

from problem.

a) From Eq. $I_D = k(V_{GS} - V_T)^2$

$$k = \frac{I_{D(on)}}{(V_{GS(on)} - V_T)^2} = \frac{5\,mA}{(6-3)^2} = (0.55 \times 10^{-3})$$

$$V_{GS_Q} = V_G - V_S = \frac{(6.8)24}{(16.8)} - I_D(0.75k)$$

$$V_{GS_Q} = 9.71 - 750 I_{DQ}$$

$$V_T = 3V$$

$$I_{DQ} = (0.55\times10^{-3})(6.71 - 750 I_{DQ})^2$$

$$509.375 I_{DQ}^2 - 5.53 I_{DQ} + 0.025 = 0$$

$$I_{DQ} = \cancel{16\,mA},\ 5\,mA$$

$I_{DQ} = 5\,mA$

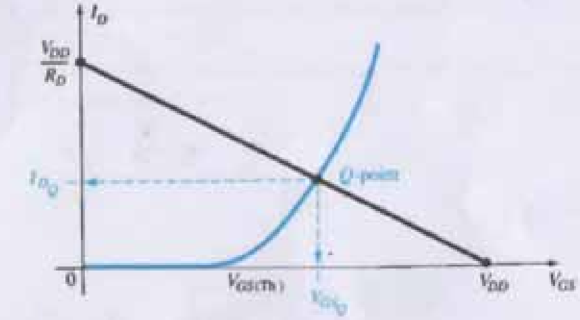
b) $V_{GS_Q} = 9.71 - (750)(5\times10^{-3}) = 5.96$ V

$V_{GS(on)} = 6V$

c) $V_D = 24 - (5)(2.2) = 13$ V

d) $V_S = (0.75)(5) = 3.75$ V.

12. Design a network such as appears in Figure using an enhancement-type MOSFET with $V_{GS(Th)} = 4\,V$ and $k = 0.5\times10^{-3}\,A/V^2$ to have a Q-point of $I_{D_Q} = 6\,mA$. Use a supply of 16 V and standard values.

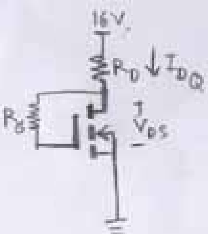


From eq: $I_{DQ} = k(V_{GSQ} - V_T)^2$

$$6\times10^{-3} = (0.5\times10^{-3})(V_{GSQ} - 4)^2$$

$$(0.5\times10^{-3})V_{GSQ}^2 - 4\times10^{-3}V_{GSQ} + 2\times10^{-3} = 0$$

$$V_{GSQ} = 7.46\text{ V},\ \cancel{0.54\text{ V}}$$



$\therefore V_{DD} = V_{DS} + I_D R_D$

$V_{DS} = V_{DD} - I_D R_D$

From $V_{DG} = V_{DS} - V_{GS}$

$0 = V_{DS} - V_{GS}$

$\therefore V_{GS} = V_{DS}$

$$\therefore R_D = \frac{V_{DD} - V_{GSQ}}{I_{DQ}} = \frac{16 - 7.46}{6m} = 1.42\,k\Omega$$

R_G should have very high value. such as $1\,M\Omega$. In order to limit the I_G.

no need

$I_D = k(V_{GS} - V_T)^2$

$\frac{I_D}{k} = (V_{GS} - V_T)^2$

$\sqrt{\frac{I_D}{k}} = V_{GS} - V_T$

$\therefore V_{GS_Q} = V_T + \sqrt{\frac{I_D}{k}} = 7.46V$

$R_D = \frac{V_{R_D}}{I_D} = \frac{V_{DD} - V_{DS_Q}}{I_D}$

$= \frac{V_{DD} - V_{GS_Q}}{I_D}$

$= 1.42\,k\Omega$