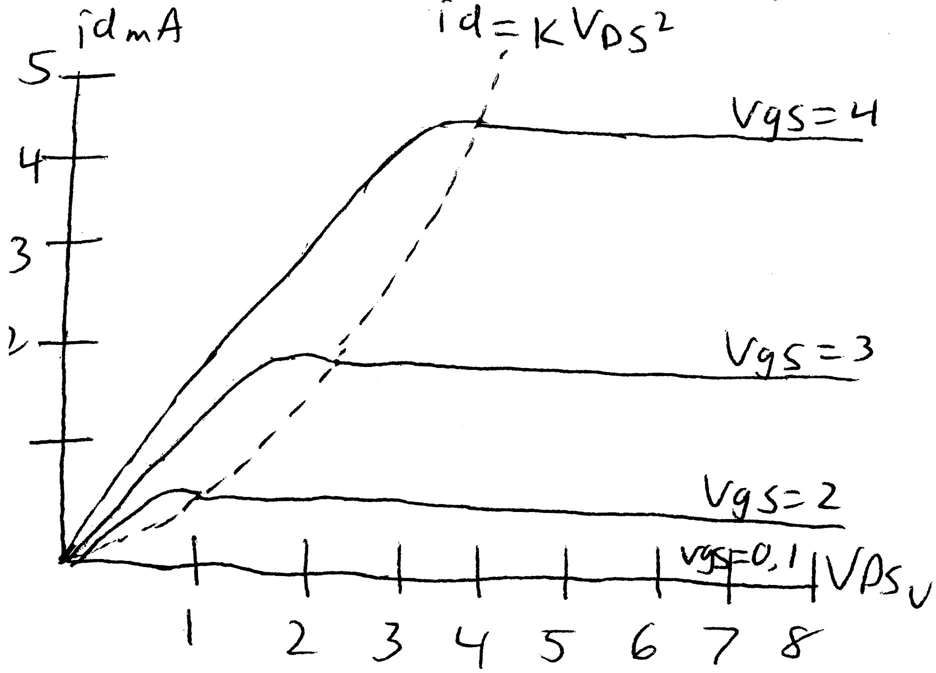
EECS 245 HMWK 6 Solution

5.5 In saturation, $id = K(V_{gs}-V_{TO})^2$ $K = \frac{50\times10^{-6}}{2}\left(\frac{w}{L}\right) = 5\times10^{-4}$



Vgs	id sat
2	0.5 mA
3	2 mA
4	4.5 mA

Now, for each Vgs, we start at the saturation current and $id = KV_{DS}^2$ intersection. To the right, a straight line; to the left, a ray to 0. For $V_{gs} < 2$, $id = 0$

See next page for PSPICE results. See Dr. Merat's NMOS notes for how to generate this graph.

5.13

In the triode region, $id = K[2(V_{gs}-V_{TO})V_{DS} - V_{DS}^2]$

If $V_{DS} \ll V_{gs}-V_{TO}$, this reduces to $id \approx 2K(V_{gs}-V_{TO})V_{DS}$

$rd = \frac{V_{DS}}{i_D}$ $\therefore$ $\underline{rd = \frac{1}{2K(V_{gs}-V_{TO})}}$ If $V_{gs} < V_{TO}$ (cutoff), rd is infinite because $id = 0$

Vgs (V)	rd (kΩ
0.5	∞
1.0	∞
1.5	4
2.0	2

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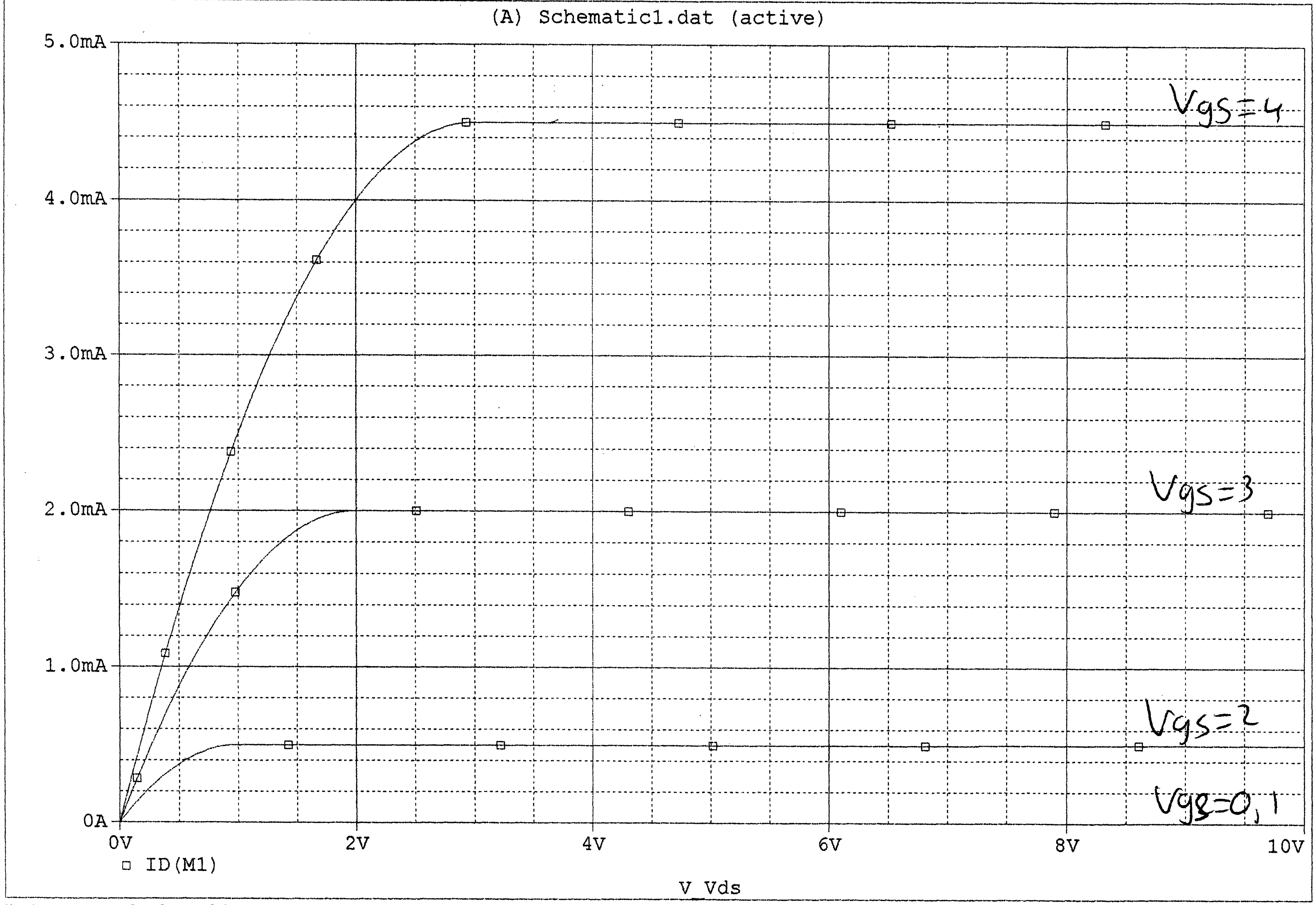

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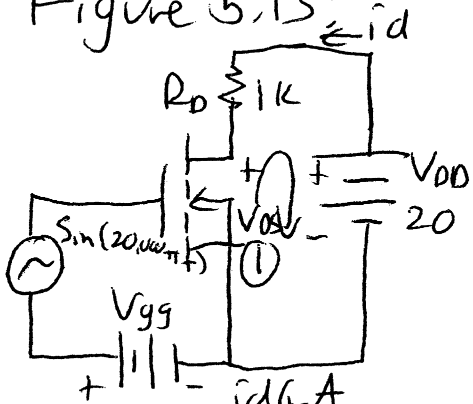
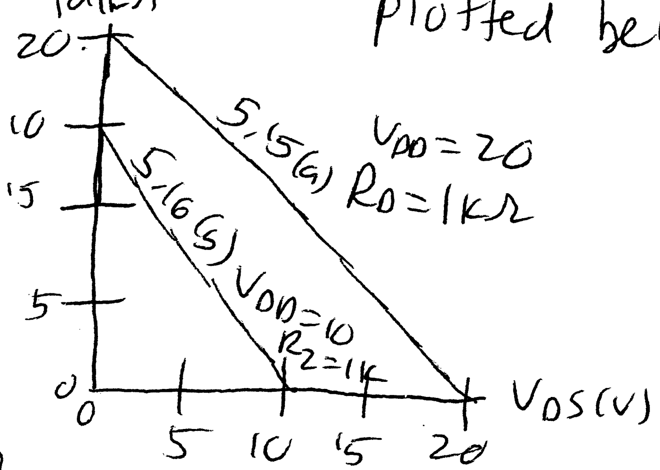
5.15 (a)

Figure 5.13:



Writing a loop equation around ① yields $-V_{DS} - i_D R_D + V_{DD} = 0$ or

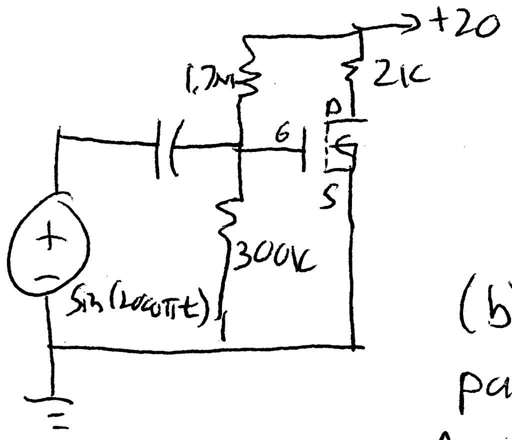
$V_{DD} = i_D R_D + V_{DS}$ This is our load line equation. Graph is plotted below for $V_{DD}=20$, $R_D = 1K\Omega$



5.16 (b)

Again, $V_{DD} = i_D R_D + V_{DS}$. Graph above for $V_{DD}=10$, $R_D = 1K\Omega$

5.18



(a) $V_{gs}(t) = \sin(2000\pi t) + V_{gsQ}$

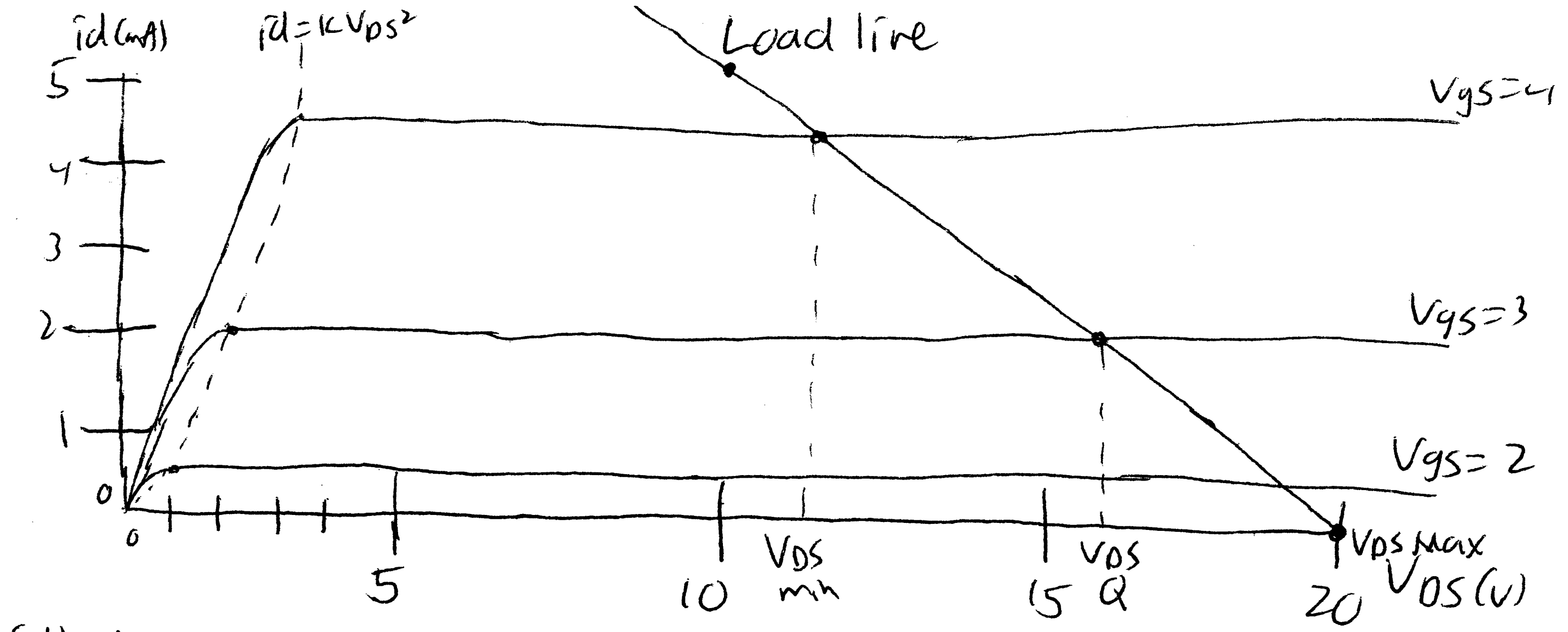
$V_{GSQ} = 20\left(\frac{300K}{1.7M + 300K}\right) = 3V \therefore$

$\boxed{V_{gs}(t) = \sin(2000\pi t) + 3}$

(b) $i_{dsat} = 0.5\times10^{-3}(V_{gs}-1)^2$ see next page for graph, see problem 5.5 for how to draw it. Actually, it's the same as 5.5!

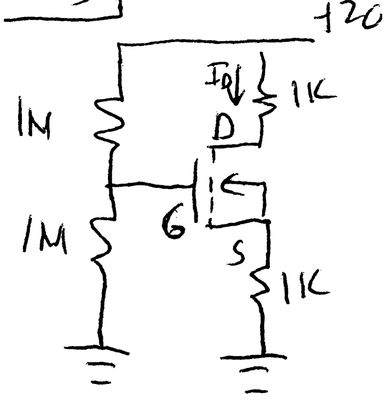
(c) Load line = $V_{DD} = i_D R_D + V_{DS}$: $20 = i_D(2K) + V_{DS}$

plotted on next page



(d) As can be seen from the above graph, $\boxed{V_{DS\,min} \approx 11V \quad V_{DS\,max} = 20V \quad V_{DSQ} \approx 16V}$

5.23



(a) $V_g = 20\left(\frac{1M}{1M+1M}\right) = 10V$

$V_S = I_S(1K) \quad I_D = I_S \therefore V_S = I_D(1K\Omega) \therefore$

① $V_{gs} = 10 - I_D(1K\Omega)$

we also know that in saturation,

$I_D = K(V_{gs} - V_{T0})^2$ substituting into ①,

$V_{gs} = 10 - (1K)(1\times10^{-3})(V_{gs}-4)^2 \longrightarrow V_{gs}^2 - 7V_{gs} + 6 = 0$

Solving yields $V_{gs} = 1, 6$ If $V_{gs}=1$, transistor is off $\therefore V_{gsQ} = 6$

From ①, $I_{DQ} = 4mA$ $\quad V_{DSQ} = 10 - (2K\Omega)(I_{DQ})$ $\boxed{V_{DSQ} = 12}$

Check: is $V_{DS} \geq V_{gs} - V_{T0}$? $12 \geq 6-4 \longrightarrow$ correct!

As with BJT's, assume saturation, then check your assumption

$V_{DS} \geq V_{gs} - V_{T0}$ for saturation.

(b) Same equations, different numbers

$V_{gs} = 10 - (1K)(2\times10^{-3})(V_{gs}-2)^2 \rightarrow V_{gs}^2 - 3.5V_{gs} - 1 = 0$

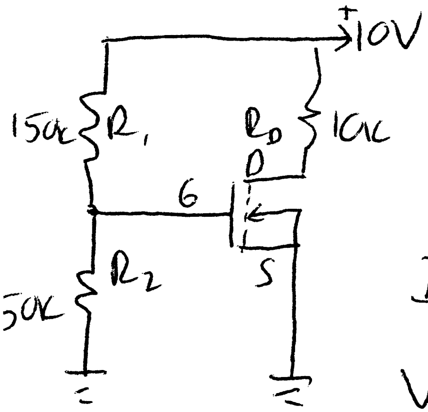
$V_{gsQ} = 3.765, -.265 \rightarrow V_{gsQ} = 3.765V$

$I_{DQ} = \frac{3.765-10}{-1K} = 6.235mA \quad V_{DSQ} = 20-(2K)(6.235mA)$

$\boxed{V_{DSQ} = 7.53V}$

$7.53 \geq 3.765 - 2 \rightarrow$ correct

$\boxed{5.26}$



$V_s = 0 \therefore V_{gs} = V_g$

$V_g = 10\left(\frac{50K}{50K+150K}\right) = 2.5V = V_{gs}$

Assume saturation: $I_{DQ} = K(V_{gsQ} - V_{TO})^2$

$I_{DQ} = (.25\times10^{-3})(2.5-1)^2 = .5625mA$

$V_{DSQ} = V_{DD} - R_D I_{DQ} = 10-(10K)(.5625mA)$

$\boxed{V_{DSQ} = 4.375V}$