ECE 320 - Homework #9

MOSFET Switches, CMOS logic. Due Monday, March 21st

MOSFETs

1) The VI characteristics for an n-channel MOSFET are shown below.
   - Label the off / ohmic / and saturated regions
   - Determine the transconductance gain, kn. Assume Vth = 1.00V

Pick a point in the saturated region

Vgs = 7V, Ids = 290mA, Vds = 10V

Solve for kn

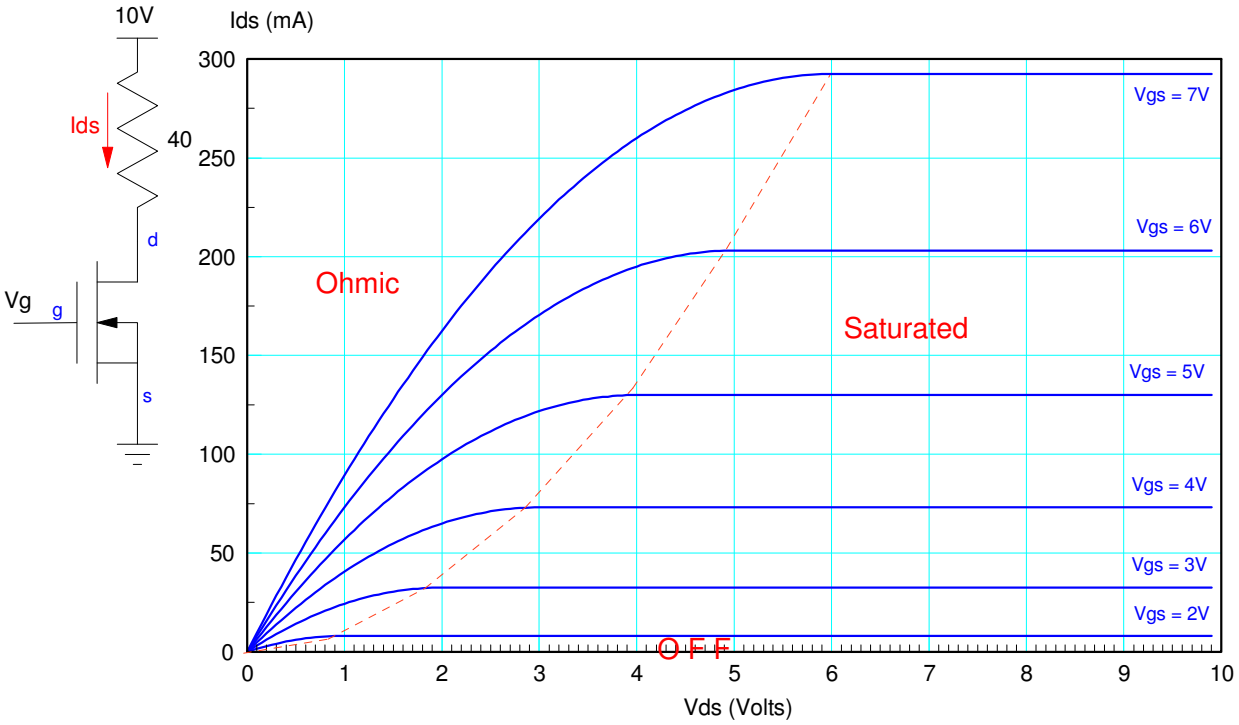
$$I_{ds} = \left(\frac{k_n}{2}\right)(V_{gs} - V_{th})^2$$

$$290mA = \left(\frac{k_n}{2}\right)(7V - 1V)^2$$

$$k_n = 0.0161\frac{A}{V^2}$$

If you pick a point in the ohmic region, you'll get the same result - just use the ohmic-region equation

$$I_{ds} = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$



2) Draw the load-line for the circuit below. From the load line, determine the Q-point (Vds, Ids) when

Vg = 0V

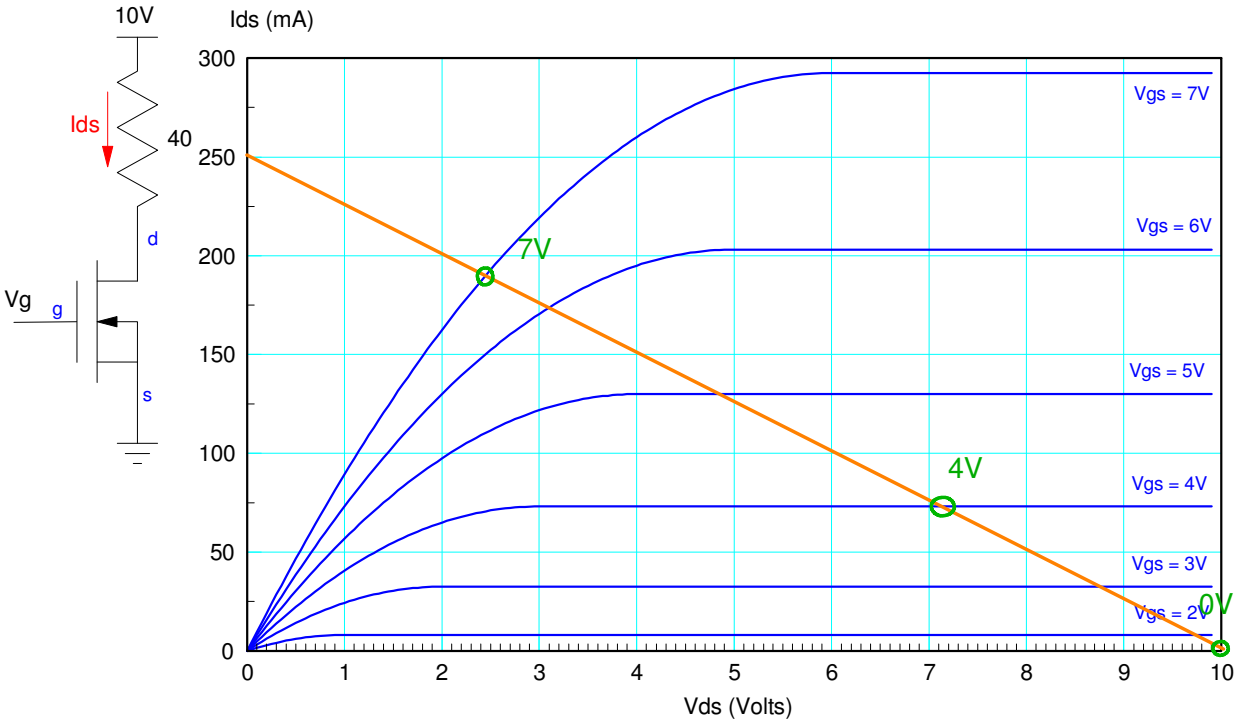
- Vds = 10V
- Ids = 0mA
- Off region

Vg = 4V

- Vds = 7.2V
- Ids = 60mA
- Saturated region

Vg = 7V

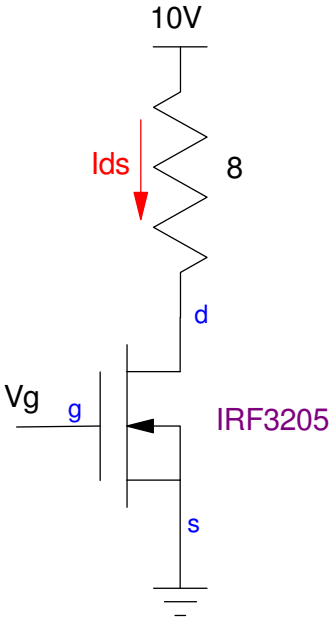
- Vds = 2.4V
- Ids = 190mA
- Ohmic region



MOSFET Switch

The characteristics for a IRF3205 MOSFET are

- Max Current = 110A continuous
- Rds = 0.008 Ohms @ Ids = 62A @ Vgs = 10V
- Vth = 4.00V (max)



3) Determine the transconductance gain, kn

In the ohmic region

$$I_{ds} = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

From the data

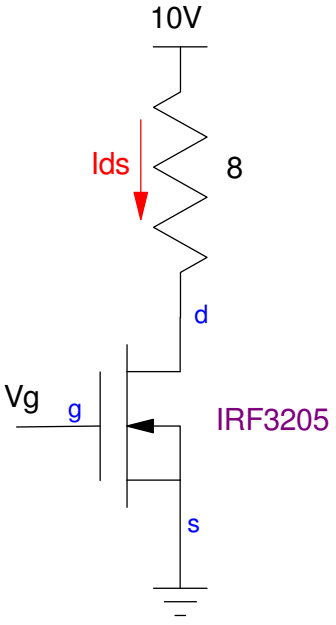
$$V_{ds} = 0.008\Omega \cdot 62A = 0.496V$$

Plugging in numbers

$$62A = k_n\left(10V - 4V - \frac{0.496V}{2}\right) \cdot 0.496V$$

$$k_n = 21.732\frac{A}{V^2}$$

4) Determine the voltages for the following circuit for



Vin = Vg = 0V

Off region

Vds = 10V, Ids = 0

Vin = Vg = 5V

Assume saturated region

$$I_{ds} = \left(\frac{k_n}{2}\right)(V_{gs} - V_{th})^2$$

$$I_{ds} = \left(\frac{21.732}{2}\right)(5V - 4V)^2$$

$$I_{ds} = 10.86A$$

$$V_{ds} = 10 - 8I_{ds} = -76.9V$$

That can't be, so assume ohmic region

$$I_{ds} = 21.732\left(5V - 4V - \frac{V_{ds}}{2}\right)V_{ds}$$

$$10 = 8I_{ds} + V_{ds}$$

Solving two equations for two unknowns

Vds = 0.0589V, Ids = 1.2427 Amps

Rds = Vds / Ids = 0.0474 Ohms

Vin = Vg = 10V

Assume Ohmic region

$$I_{ds} = 21.732\left(10V - 4V - \frac{V_{ds}}{2}\right)V_{ds}$$

$$10 = 8I_{ds} + V_{ds}$$

Solving

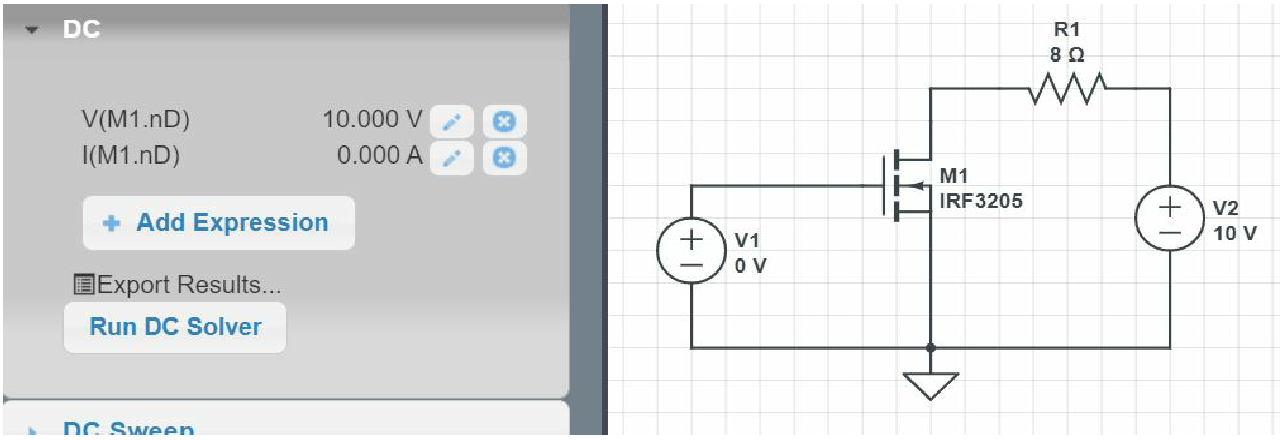
Vds = 0.0096V

Ids = 1.2488A

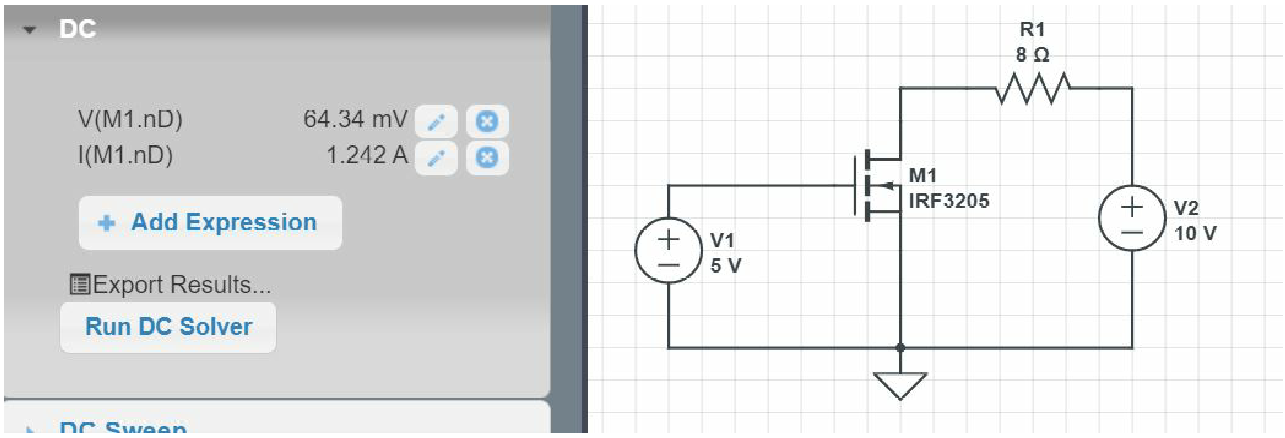
Rds = Vds / Ids = 0.0077 Ohms

5) Simulate this circuit in CircuitLab using an IRF3205 MOSFET. (you may need to adjust the parameters to match your calculations for kn and Vth). Determine the voltages and currents when

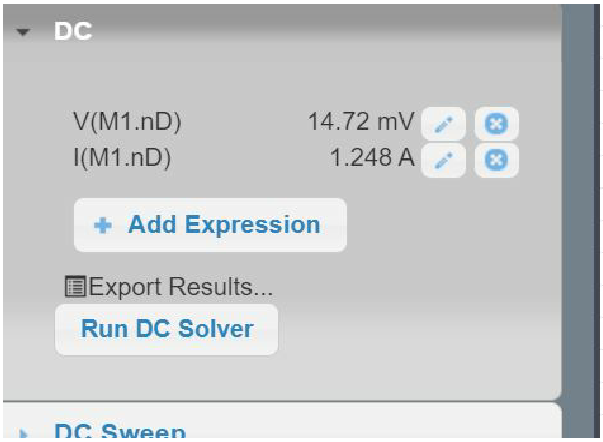
Vin = Vg = 0V

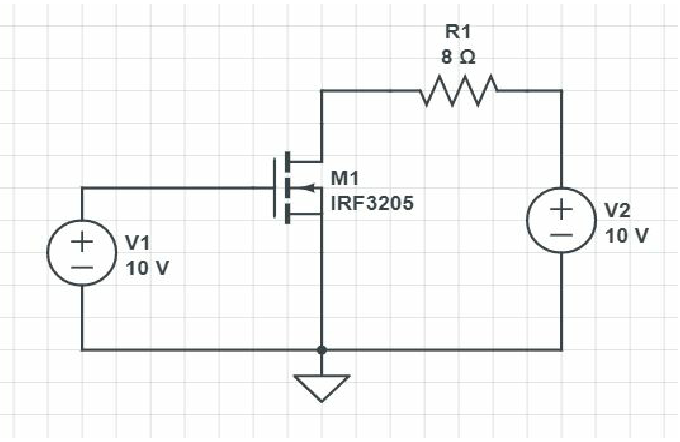


Vin = Vg = 5V



Vin = Vg = 10V





	Vg = 0V		Vg = 5V		Vg = 10V	
	Vds	Ids	Vds	Ids	Vds	Ids
calculated	10V	0A	58.9mV	1.2427A	9.6mV	1.2488A
simulated	10V	0A	64.34mV	1.242A	14.72mV	1.248A

CMOS Logic

6) Design a CMOS gate to implement the function: Y(A, B, C, D)

Circle the zeros (ones also work)

Y(A,B,C,D)	CD			
AB	00	01	11	10
00	1	1	1	x
01	0	0	0	1
11	1	x	1	0
10	x	1	x	0

$$\overline{Y} = \overline{A}B\overline{C} + \overline{A}BD + AC\overline{D}$$

From DeMorgan's law

$$Y = \left(A + \overline{B} + C\right)\left(A + \overline{B} + \overline{D}\right)\left(\overline{A} + \overline{C} + D\right)$$