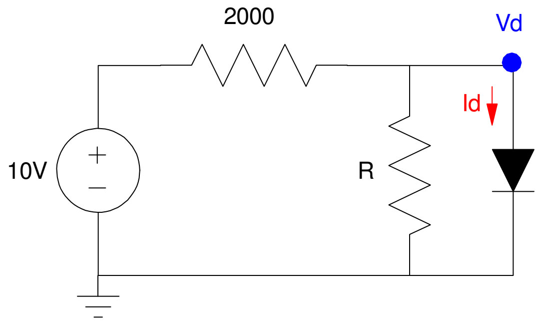
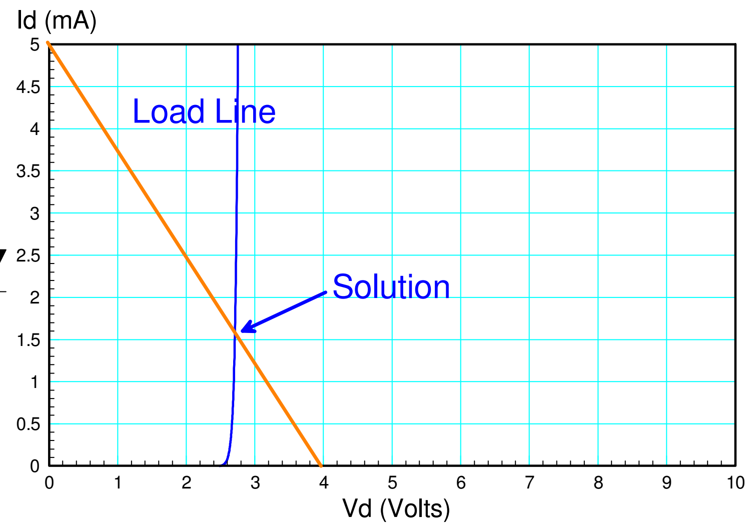
ECE 320 - Final (pt 1) - Name ____________________

Semiconductors & Diodes - Spring 2023

1) Load Lines: Assume the VI characteristics for the diode is as shown in the graph. Draw the load line for the following circuit and determine Id and Vd. Assume R = 800 + 100*(your birth month) + (your birth date).





R 800 + 100*mo + day	Load Line x-intercept (volts)	Load Line y-intercept (mA)	Vd Volts	Id mA
1314	**3.965V**	**5.00mA**	**2.7V**	**1.6mA**

Convert to a Thevenin equivalent:

$$V_{th} = \left(\frac{1314}{1314+2000}\right) 10V = 3.965V$$

$$R_{th} = 2000 || 1314 = 793.0\Omega$$

The load line is then

Xint = Vth = 3.965V

Yint = Vth / Rth = 5.00mA

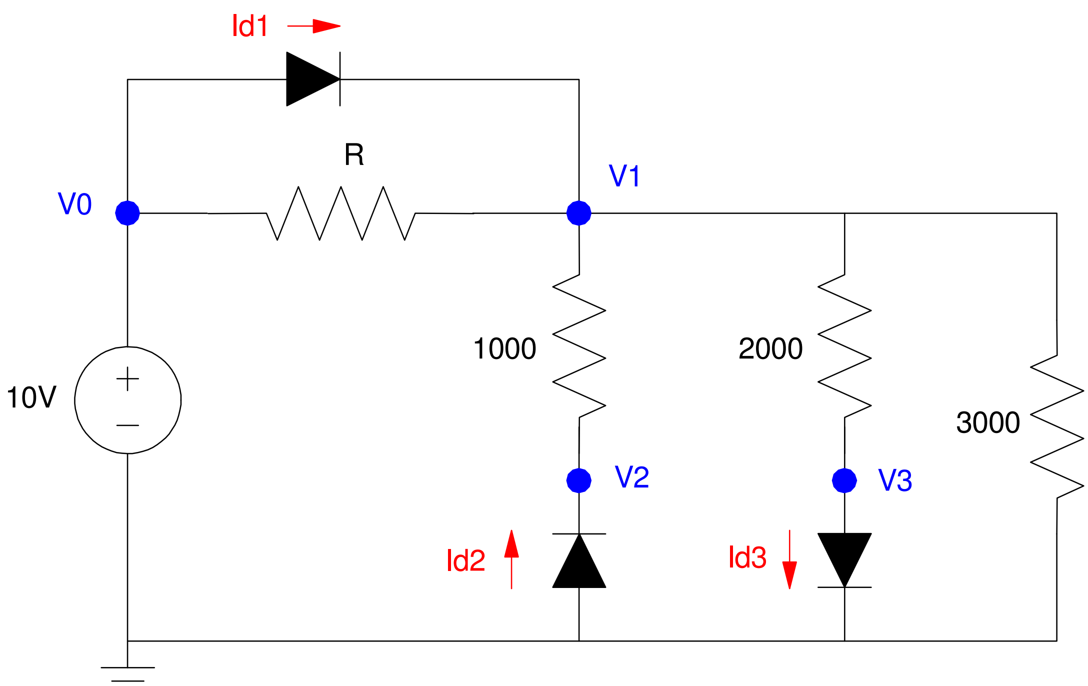
2) Nonlinear equations: Diode circuit

Assume the VI characteristics for the diodes shown below are

$$V_d = 0.038 \ln\left(10^{11} \cdot I_d + 1\right) \qquad I_d = 10^{-11} \cdot \left(\exp\left(\frac{V_d}{0.038}\right) - 1\right)$$

Write 6 equations to solve for 6 unknonws: {V1, V2, V3, V4, Id1, Id2, Id3}.

- Note: you do not need to solve.
- R = 800 + 100*(your birth month) + (birth date).



Start with the diode equations

$$I_{d1} = 10^{-11} \cdot \left(\exp\left(\frac{V_0 - V_1}{0.038}\right) - 1\right)$$

$$I_{d2} = 10^{-11} \cdot \left(\exp\left(\frac{0 - V_2}{0.038}\right) - 1\right)$$

$$I_{d3} = 10^{-11} \cdot \left(\exp\left(\frac{V_3 - 0}{0.038}\right) - 1\right)$$

$$V_0 = 10$$

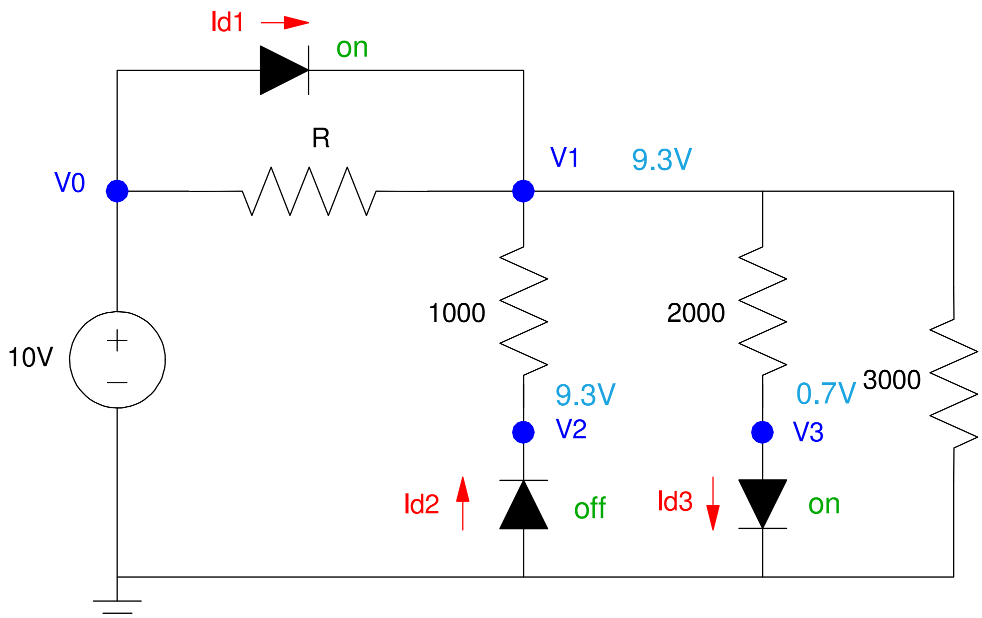
$$-I_{d1} + \left(\frac{V_1 - V_0}{1314}\right) + \left(\frac{V_1 - V_2}{1000}\right) + \left(\frac{V_1 - V_3}{2000}\right) + \left(\frac{V_1}{3000}\right) = 0$$

$$\left(\frac{V_2 - V_1}{1000}\right) - I_{d2} = 0$$

$$\left(\frac{V_3 - V_1}{2000}\right) + I_{d3} = 0$$

3) Ideal Silicon Diodes. Assume the diodes in this circuit are ideal silicon diodes:

- Vd = 0.7V   Id > 0
- Id = 0   Vd < 0.7V
- R = 800 + 100*(your birth month) + (birth date).



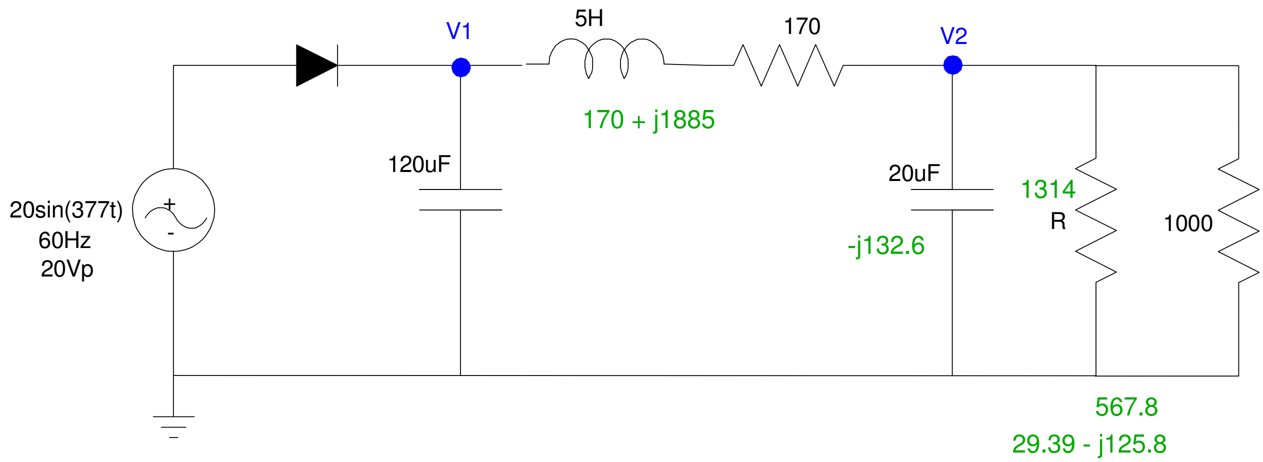
R 800 + 100*mo + day	Id1	Id2	Id3
1314	**6.867mA**	**0mA**	**4.30mA**
	V1	V2	V3
	9.30V	**9.30V**	**0.70V**

Id1: Current In = Current Out

$$I_{d1} = \left(\frac{V_1 - V_0}{1314}\right) + 0 + \left(\frac{V_1 - V_3}{2000}\right) + \left(\frac{V_1}{3000}\right)$$

$$I_{d1} = 6.867mA$$

4) AC to DC: Analysis: Determine V1 and V2 (both DC and AC) for the following AC to DC converter



R 800 + 100*mo + day	V1		V2	
	DC	AC	DC	AC
1314	**17.48V**	**3.633Vpp**	**13.46V**	**0.265Vpp**

$$I \approx \left(\frac{19.3V}{170+567.8}\right) = 26.16mA$$

$$I = C\frac{dV}{dt}$$

$$26.16mA = 120\mu F \cdot \frac{dV}{1/60s}$$

$$dV = V_1(AC) = 3.633V_{pp}$$

$$V_1(DC) = 19.3V - \tfrac{1}{2}V_{1pp} = 17.48V$$

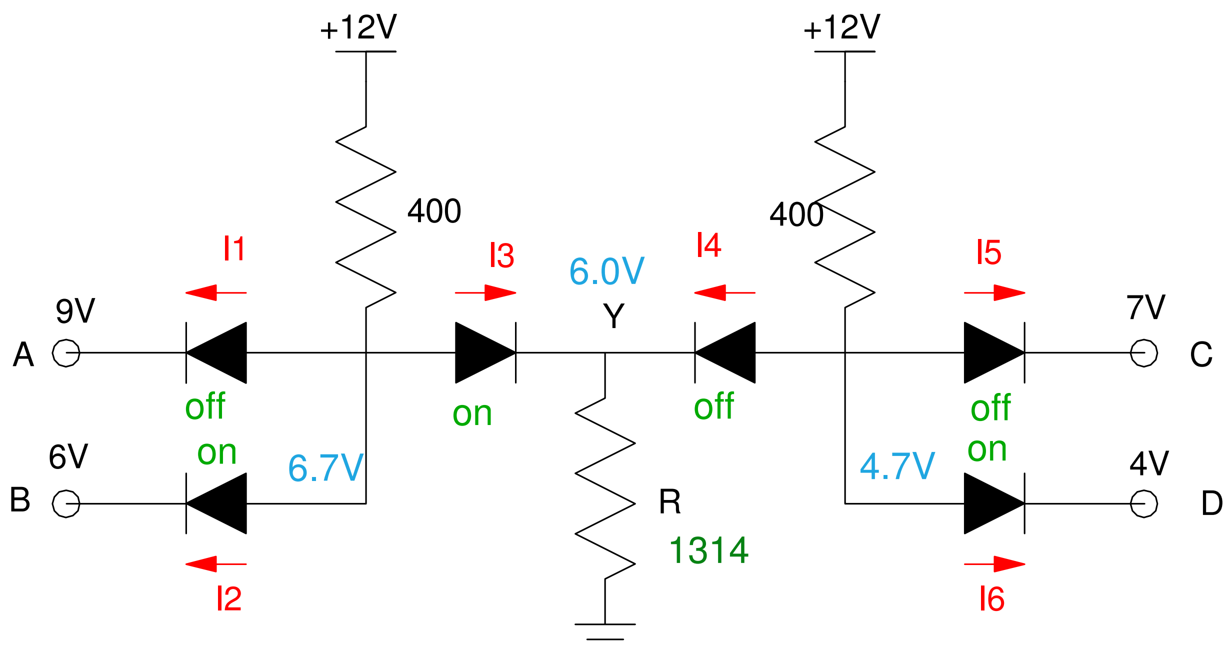
$$V_2(DC) = \left(\frac{567.8}{567.8+170}\right)V_1(DC) = 13.46V$$

$$V_2(AC) = \left(\frac{(29.39-j125.8)}{(29.39-j125.8)+(170+j1885)}\right)V_1(AC)$$

$$|V_1(AC)| = 0.265V_{pp}$$

5) Max/Min Circuits. Determine the currents I1 .. I6. Assume

- Ideal silicon diodes (Vf = 0.7V)
- R = 800 + 100*(your birth month) + (birth date)



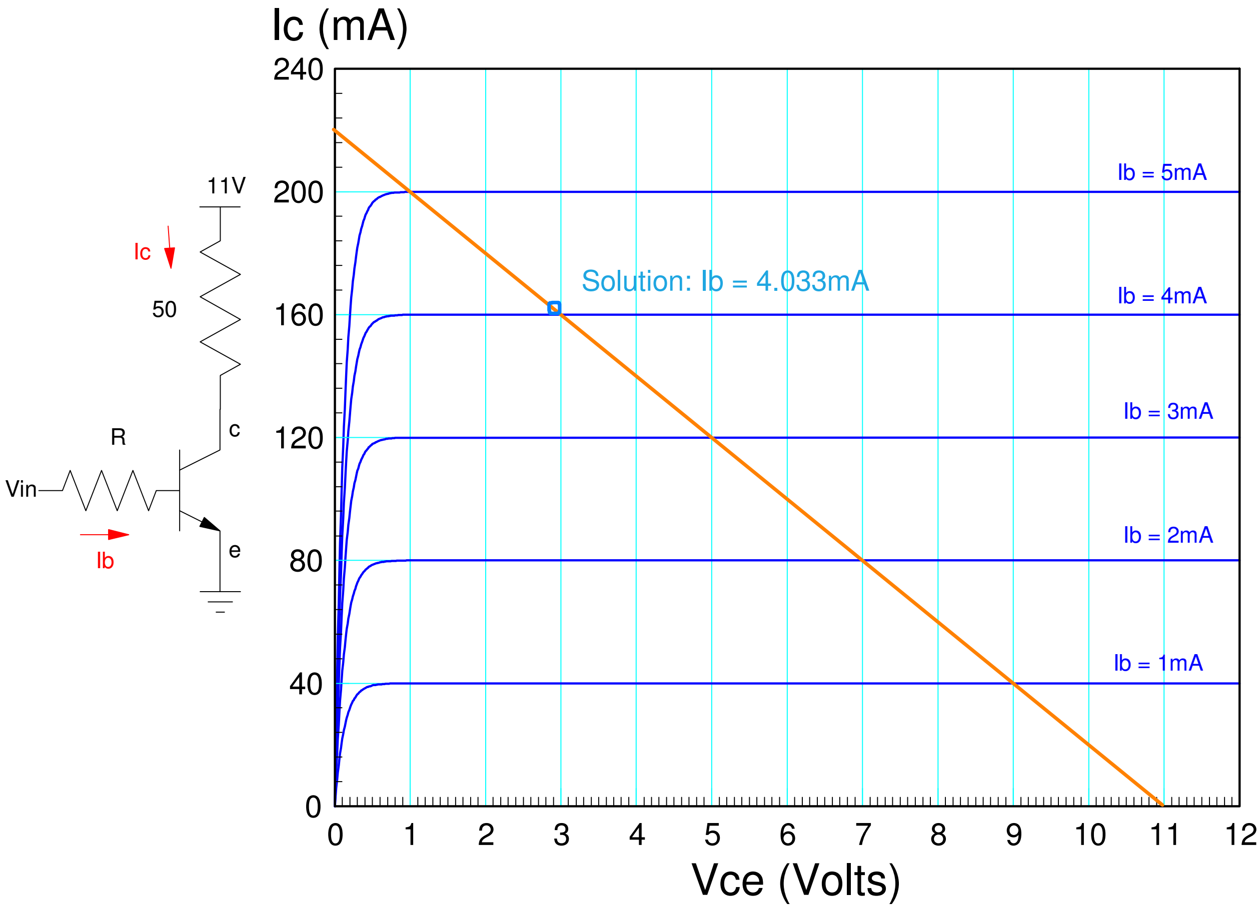
R 800 + 100*mo day	I1	I2	I3	I4	I5	I6
1314	**0mA**	**8.684mA**	**4.566mA**	**0mA**	**0mA**	**18.25mA**

$$I_6 = \left(\frac{12V - 4.7V}{400\Omega}\right) = 18.25mA$$

$$I_3 = \left(\frac{6V}{1314\Omega}\right) = 8.684mA$$

$$I_2 + I_3 = \left(\frac{12V - 6.7V}{400\Omega}\right) = 13.25mA$$

6) Determine the current gain, β. Also draw the load line and determine the operating point when Vin = 6V



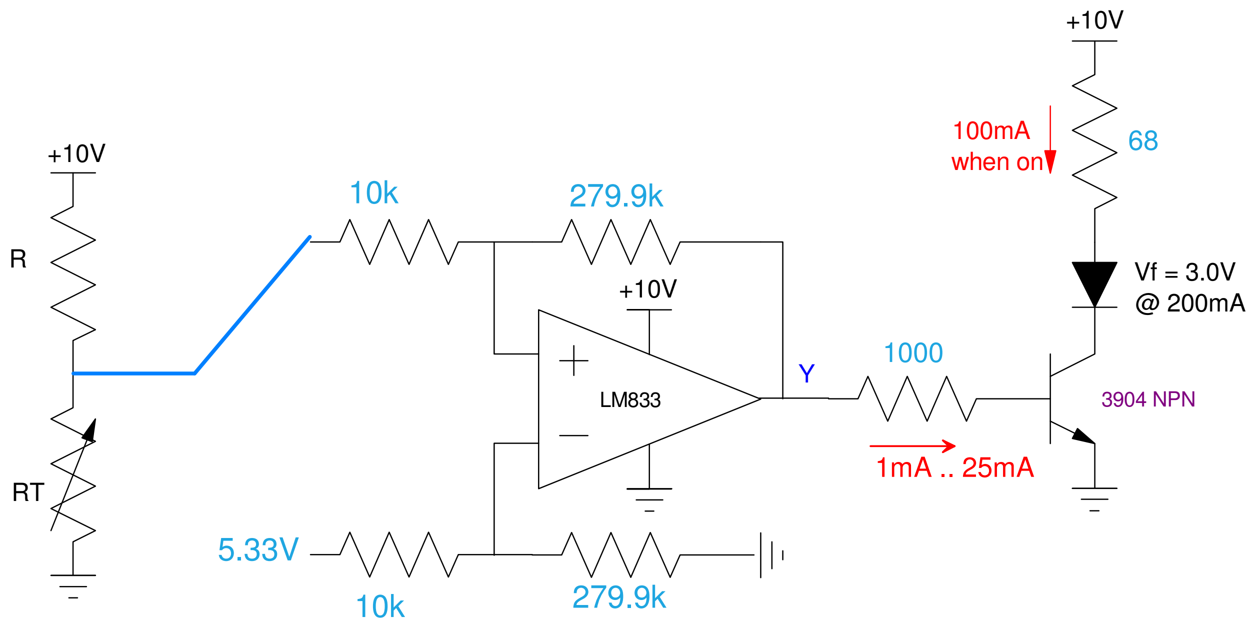
R 800 + 100*Mo + Day	Current Gain hfe = beta	Load Line x-intercept (Volts)	Load Line y-intercept (mA)	Vce Vin = 6V	Ic Vin = 6V
1314	**40**	**11V**	**220mA**	**2.933V**	**161.33mA**

7) Design a Schmitt Trigger & transistor switch so that

- Turns on the LED at 100mA when Rt > 1500 Ohms
- Turns off the LED when Rt < 1300 Ohms

Assume

- R = 800 + 100*(your birth month) + (your birth date)
- Vce(sat) = 0.2V
- Current gain (β) = 100



Rt = 1500 (on)

- $V_a = \left(\frac{1500}{1500+1314}\right) 10V = 5.33V$

Rt = 1300 (off)

- $V_a = \left(\frac{1300}{1300+1314}\right) 10V = 4.793V$

V(on) > V(off)

- connect to the plus input

V(on) = 5.33V

- offset = 5.33V

Gain:

$$gain = \left(\frac{10V-0V}{5.33V-4.793V}\right) = 27.99$$

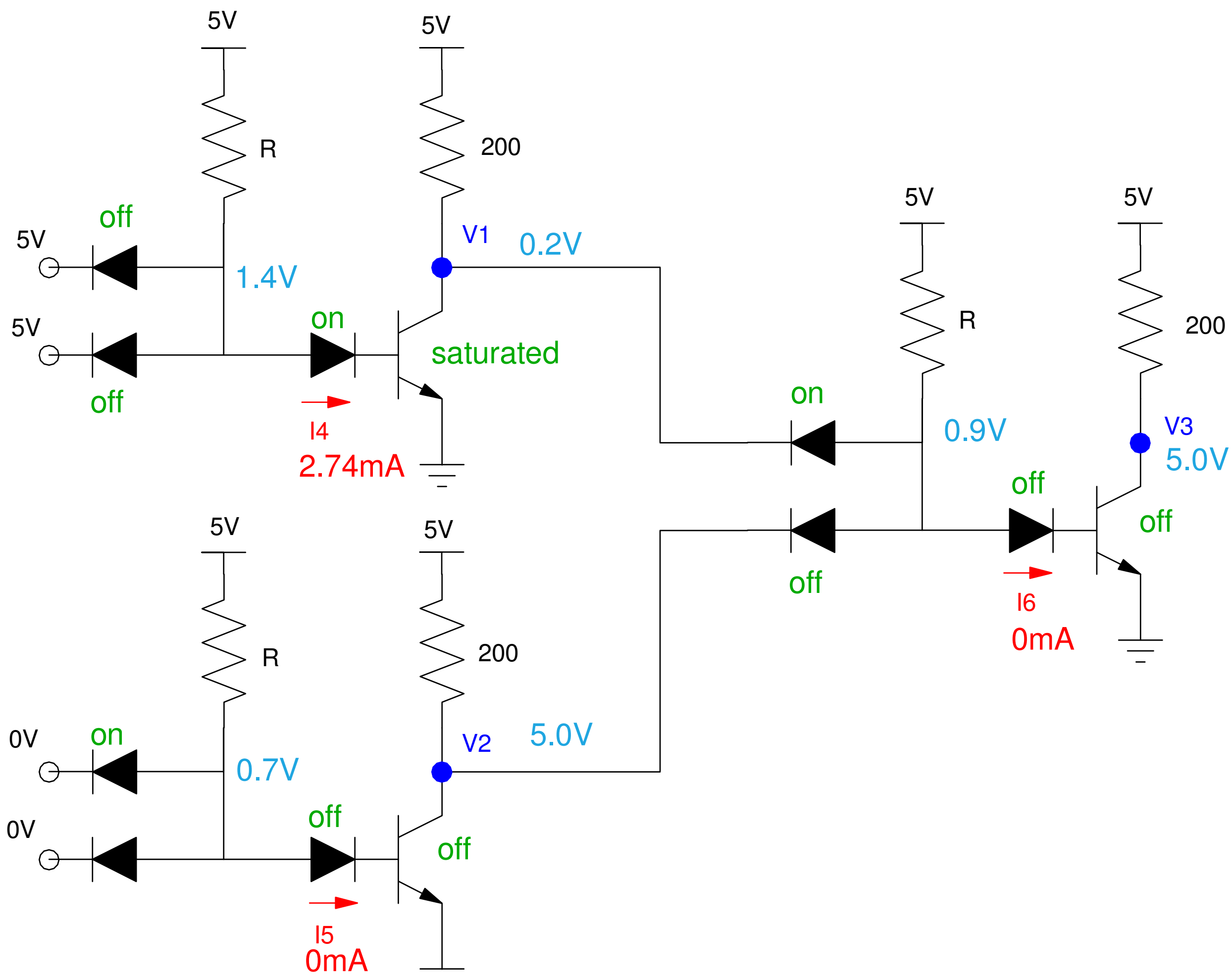
Rc:

$$I_c = 100mA = \left(\frac{10V-3.0V-0.2V}{R_c}\right)$$

$$R_c = 68\Omega$$

8) DTL Logic: Determine the voltages and currents for the following DTL logic gage. Assume

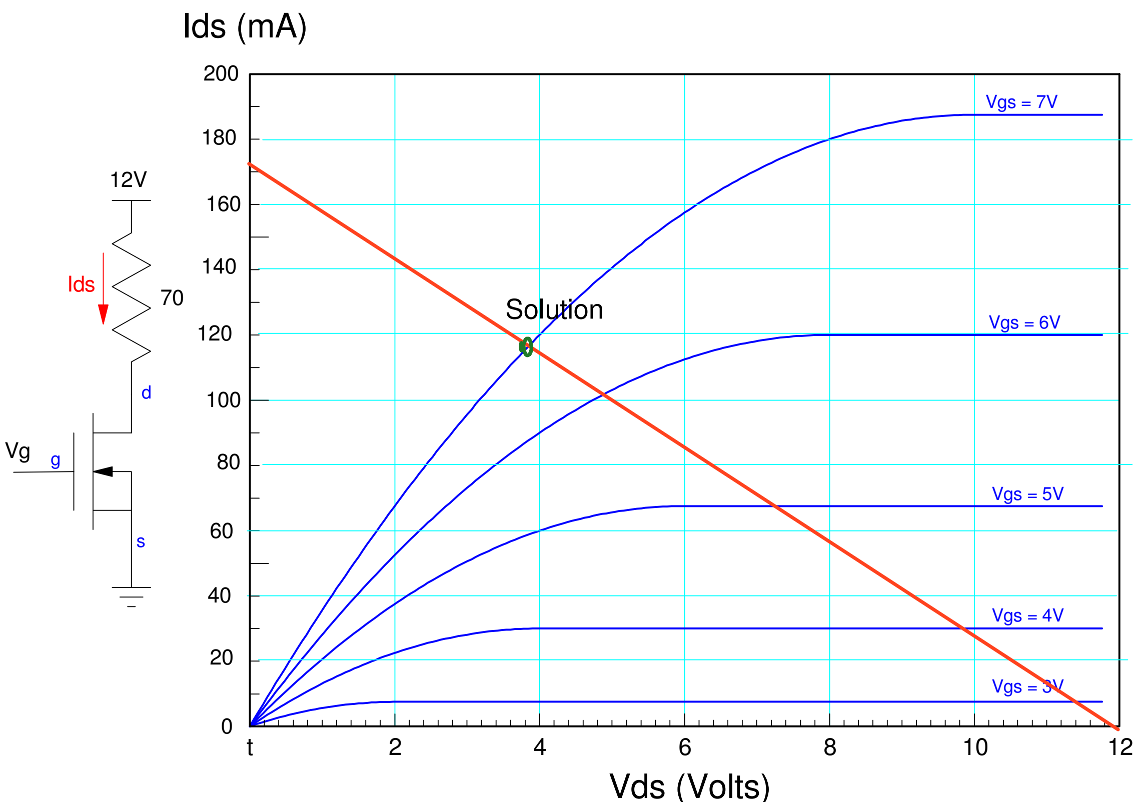
- R = 800 + 100*(your birth month) + (birth day)
- Ideal silicon diodes (Vf = 0.7V), and
- Ideal 3904 transistors (Vbe = 0.7V, Vce(sat) = 0.2V, β=100)



R 800 + 100*mo + da	V1	V2	V3	I4	I5	I6
1314	**0.2V**	**5.0V**	**5.0V**	**2.74mA**	**0mA**	**0mA**

9) MOSFET Load Line: For the following MOSFET circuit

- Determine the transconductance gain, kn,
- Draw the load line (x and y intercept), and
- Determine {Vds, Ids} when Vg = 7V. (note: Vth = 2V)



kn transconductance gain	Load Line x=intercept	Load Line y intercept	Vds Vg = 7V	Ids Vg = 7V	Operating Region off / active / ohmic
15.2 mA/V2	**12V**	**171mA**	**3.8V**	**115mA**	**Ohmic**

In the saturated region

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

$$190mA = \frac{k_n}{2}(7V - 2V)^2$$

$$k_n = 15.2\frac{mA}{V^2}$$

10) CMOS Logic

Design a CMOS logic gate to implement Y=f(A,B,C,D)

AB \ CD	00	01	11	10
00	1	0	1	1
01	x	0	x	1
11	1	0	0	x
10	1	1	0	0

Circle the zeros:

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

Using DeMorgan's Law

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