ECE 320 - Homework #4

Max/Min Circuits, Clipper Circuits, Transistor Theory. Due Monday, February 6th

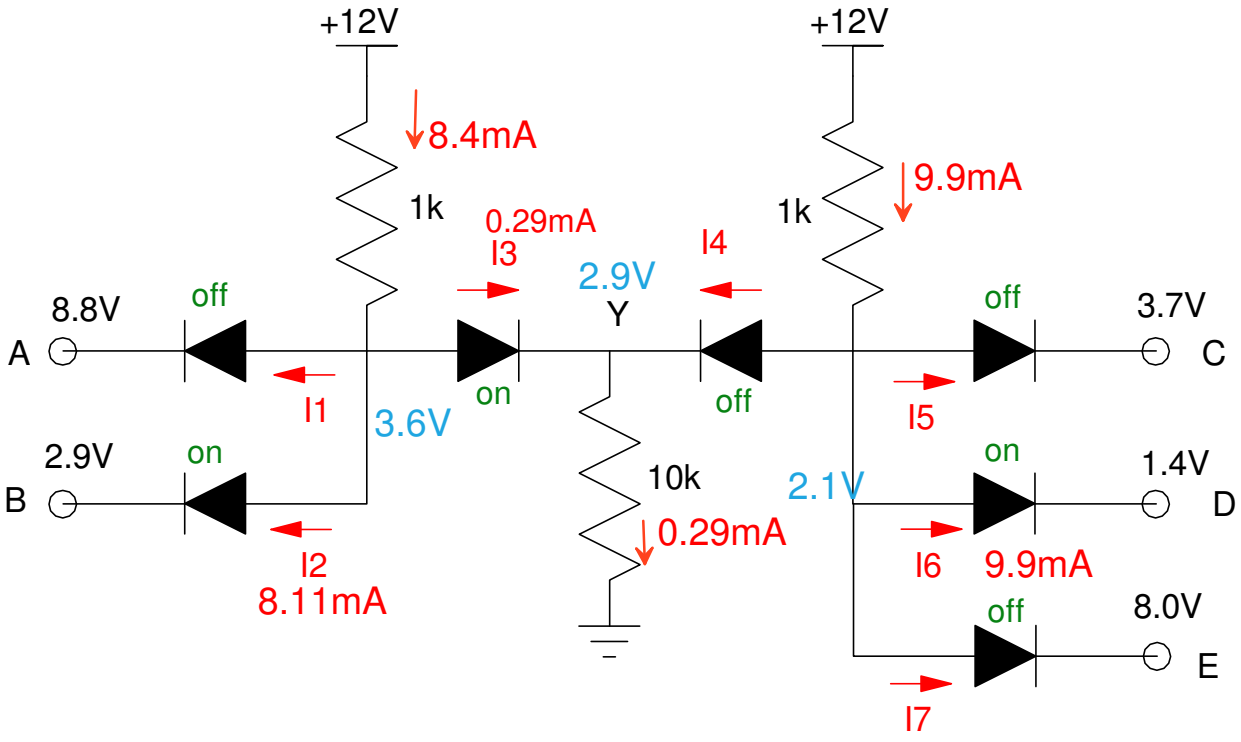
Please submit as a hard copy or submit on BlackBoard

Max/Min:

1) Determine the voltages and currents for the following max/min circuit. What function does this circuit implement? Y = f(A, B, C, D)

$$Y = \max(\min(A, B), \min(C, D, E))$$

$$Y = AB + CDE$$

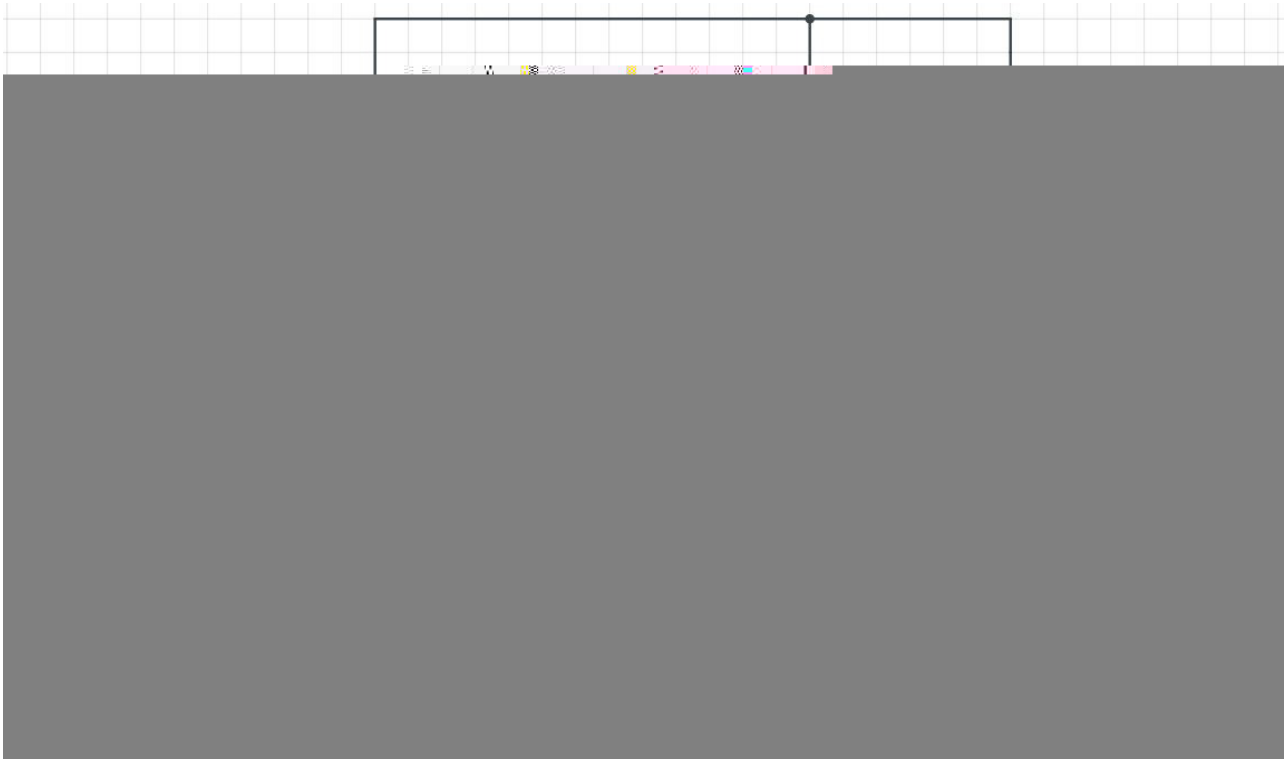


Problem 1-2.

2) Check your results in CircuitLab (or similar program) using 1N4004 diodes

	V1	V2	V3
Calculated	3.6V	2.9V	2.1V
Simulated	3.589V	3.023V	2.096V

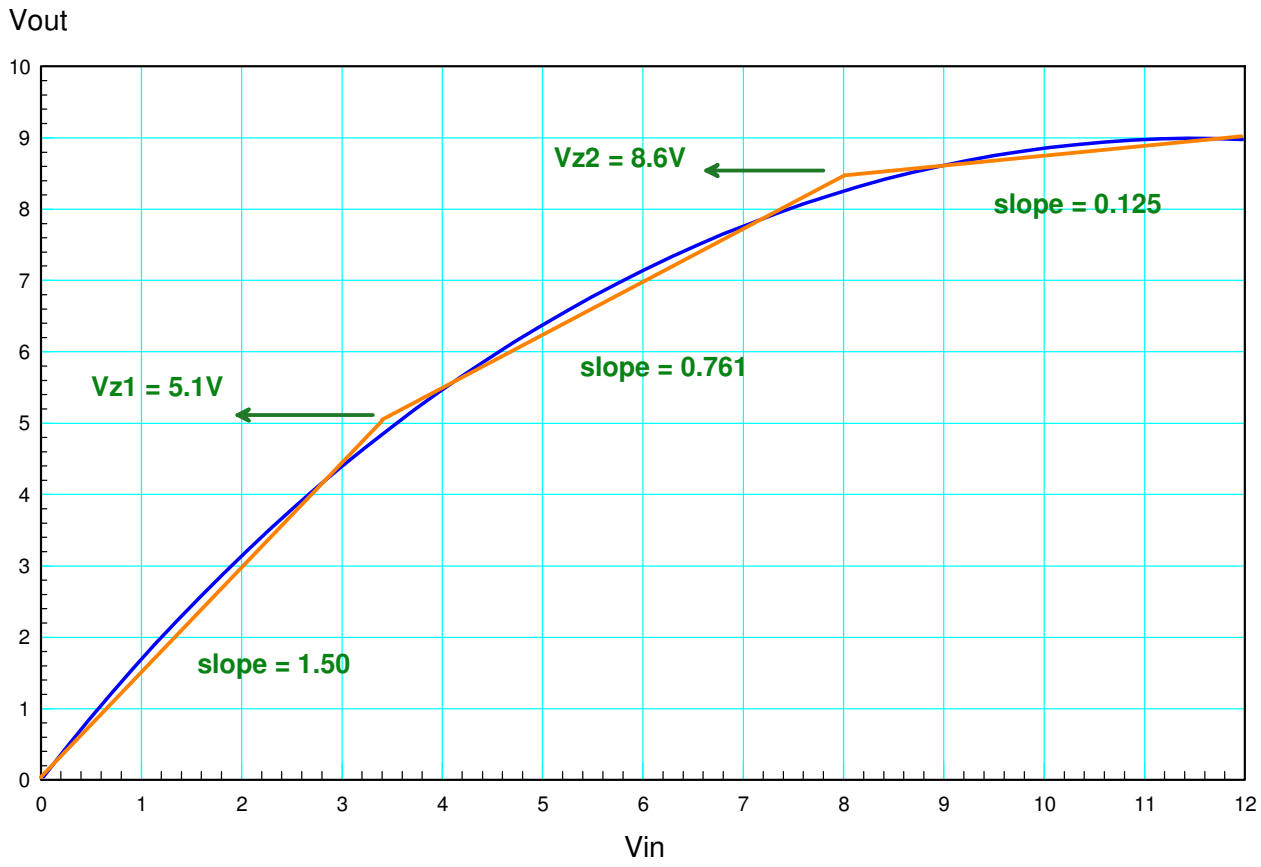
	Id1	Id2	Id3	Id4	Id5	Id6	Id7
Calcuated	0	8.11mA	0.29mA	0	0	9.9mA	0
Simlated	-76pA	8.109mA	0.302mA	-76pA	-76pA	9.904mA	-76pA



Clipper Circuits:

3) Design a circuit to approximate the following function subject to the following requirements:

- Input: 0 .. 10V, capable of 100mA
- Output: 100k resistor
- Relationship: Graph below, +/- 500mV



R0: Slope = 1.50

$$1 + \frac{R_0}{1k} = 1.5$$

$$R_0 = 500$$

R1: Slope = 0.761

$$1.5 \cdot \left(\frac{R_1}{R_1 + 1000} \right) = 0.761$$

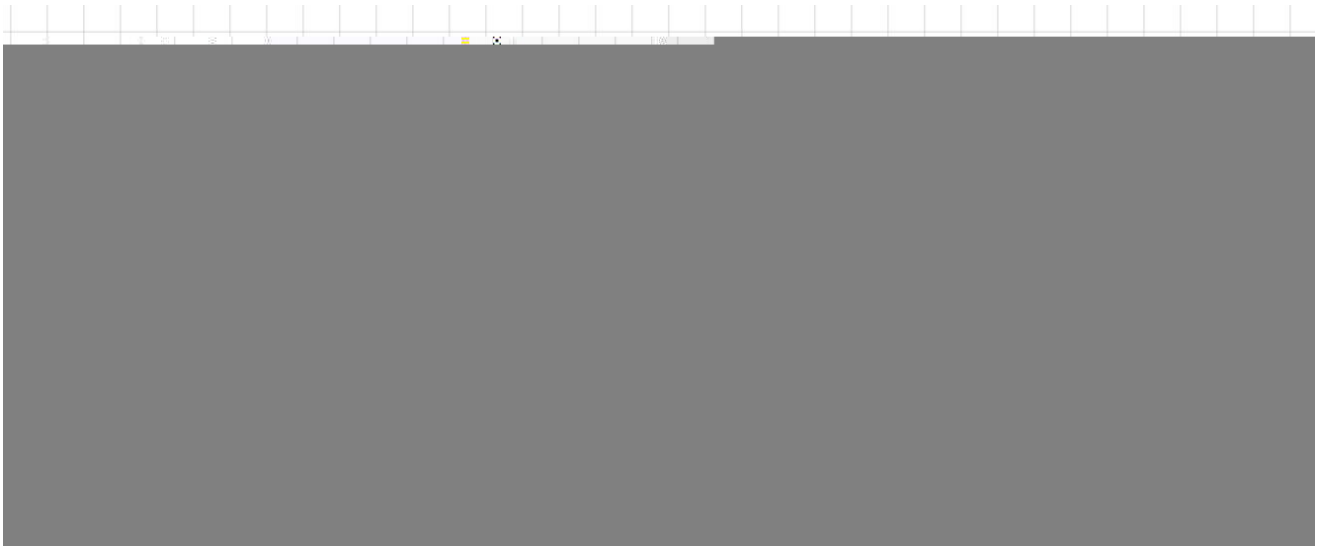
$$R_1 = \left(\frac{0.507}{1 - 0.507} \right) 1k = 1029.77$$

R2: Slope = 0.125

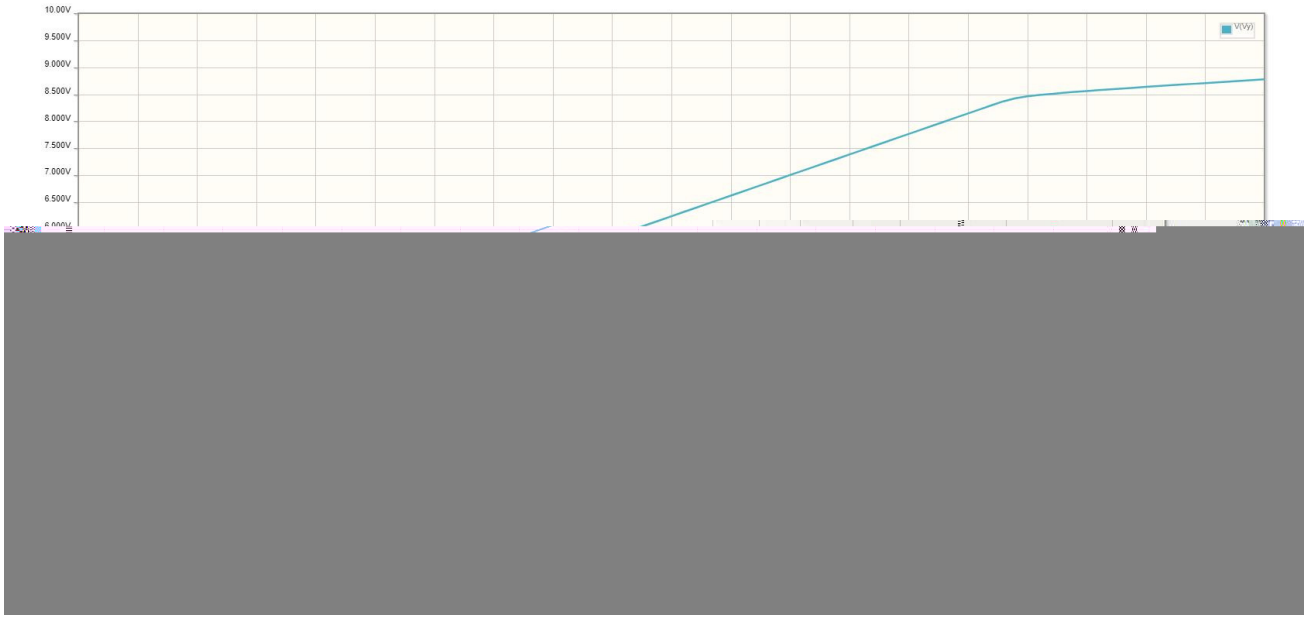
$$1.5 \cdot \frac{R_{12}}{R_{12}+1000} = 0.125$$

$$R_{12} = R_1 || R_2 = \frac{0.0833}{1-0.0833} \; 1000 = 90.9\Omega$$

$$R_2 = 99.7\Omega$$



4) Check your design in CircuitLab



5) Design a circuit which meets the following requirements:

- Input: -10 .. +10V, capable of 100mA
- Output: 1k resistor
- Relationship:

$$V_{out} = \begin{cases} +4.5V & V_{in} > +4.5V \\ V_{in} & otherwise \\ -5.5V & V_{in} < -5.5V \end{cases}$$

D1: 3.8V zener

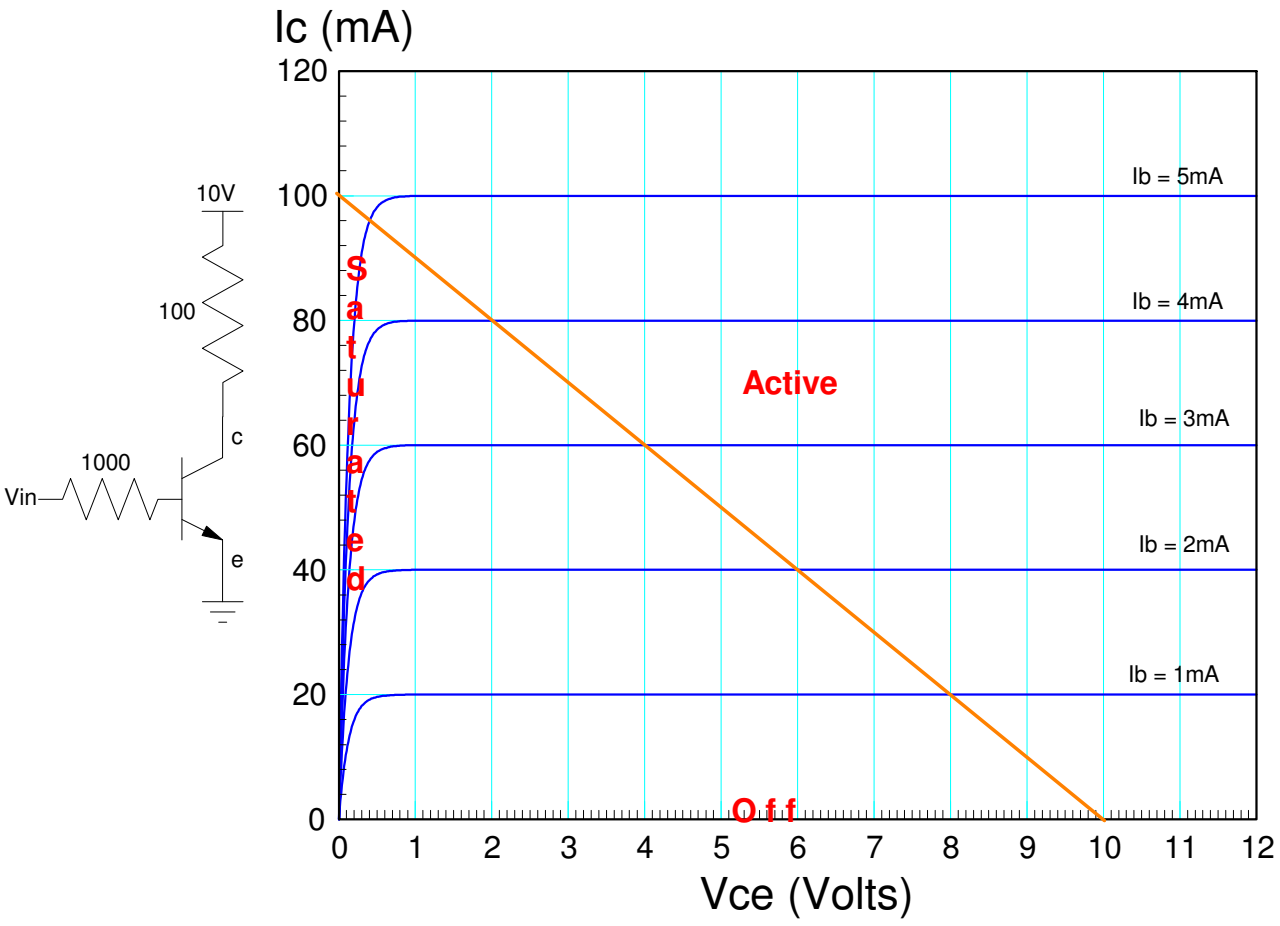
D2: 4.8V zener

Transistors

6) Determine the current gain, β, for the transistor show below. Also label the off, active, and saturated regions.

5mA in (Ib) produces 100mA out (Ic)

$$\beta = \left(\frac{100mA}{5mA}\right) = 20$$



7) Draw the load-line and determine the Q-point for

- Vin = 0V
- Vin = 3V
- Vin = 6V

Vin = 0 (off region)

Ib = 0

Ic = 20Ib = 0

Vce = 10 - 100Ic = 10V

Vin = 3V (active region)

$$I_b = \left(\frac{3V - 0.7V}{1k}\right) = 2.3mA$$

$$I_c = \beta I_b = 20 I_b = 46mA$$

$$V_{ce} = 10 - 100 I_c = 5.4V$$

Vin = 6V (saturated region)

$$I_b = \left(\frac{6V - 0.7V}{1k}\right) = 5.3mA$$

assuming active region

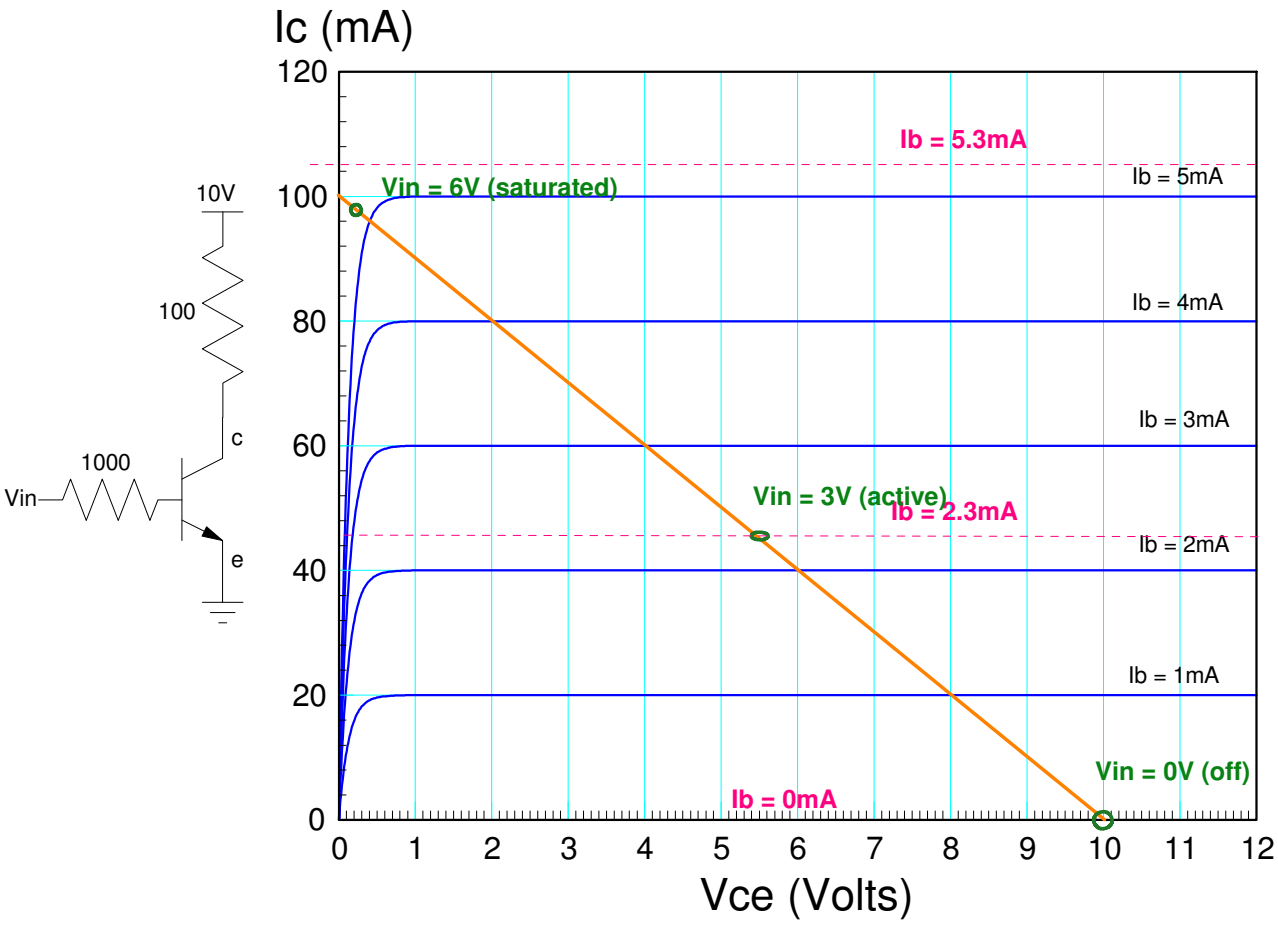
$$I_c = \beta I_b = 106mA$$

$$V_{ce} = 10 - 100 I_c = -0.6V$$

That can't happen: you can't have a negative voltage. This tells you that the assumption that we're in the active region is wrong. Instead, we're in the saturated region

$$V_{ce} = 0.2V$$

$$I_c = \left(\frac{10V - 0.2V}{100}\right) = 98mA$$


Ic (mA)
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Vce (Volts)
Ib = 5.3mA
Ib = 5mA
Ib = 4mA
Ib = 3mA
Ib = 2.3mA
Ib = 2mA
Ib = 1mA
Ib = 0mA
Vin = 6V (saturated)
Vin = 3V (active)
Vin = 0V (off)
10V
100
c
1000
Vin
e

Lab: Please include a photo of your circuit to receive credit for problems 8-10

8-10) Build the following circuit with your electronics kit.

- Measure Vce and Ic for 100 < Rb < infinity.
- Determine the operating point for each conidition and the current gain for your 3904 transistor
- Draw the load line on the graph below and mark each point you measured

Rb	Vb (Volts)	Vc (Volts)	Ib	Ic	Current Gain (Ic/Ib)	Operating Region (off / active / saturated)
1k br - bl - re	0.856V	0.157V	4.144mA	48.43mA	11.69	saturated
10k br - bl - or	0.819V	0.879V	418uA	41.21mA	98.56	active
100k br - bl - ye	0.736V	4.230V	67.9uA	7.70mA	113.3	active
1M br - bl - gr	0.716V	4.507V	4.28uA	492uA	115.1	active
infinity	0	5.03V	0	0	n/a	off