# ECE 320 - Homework #4

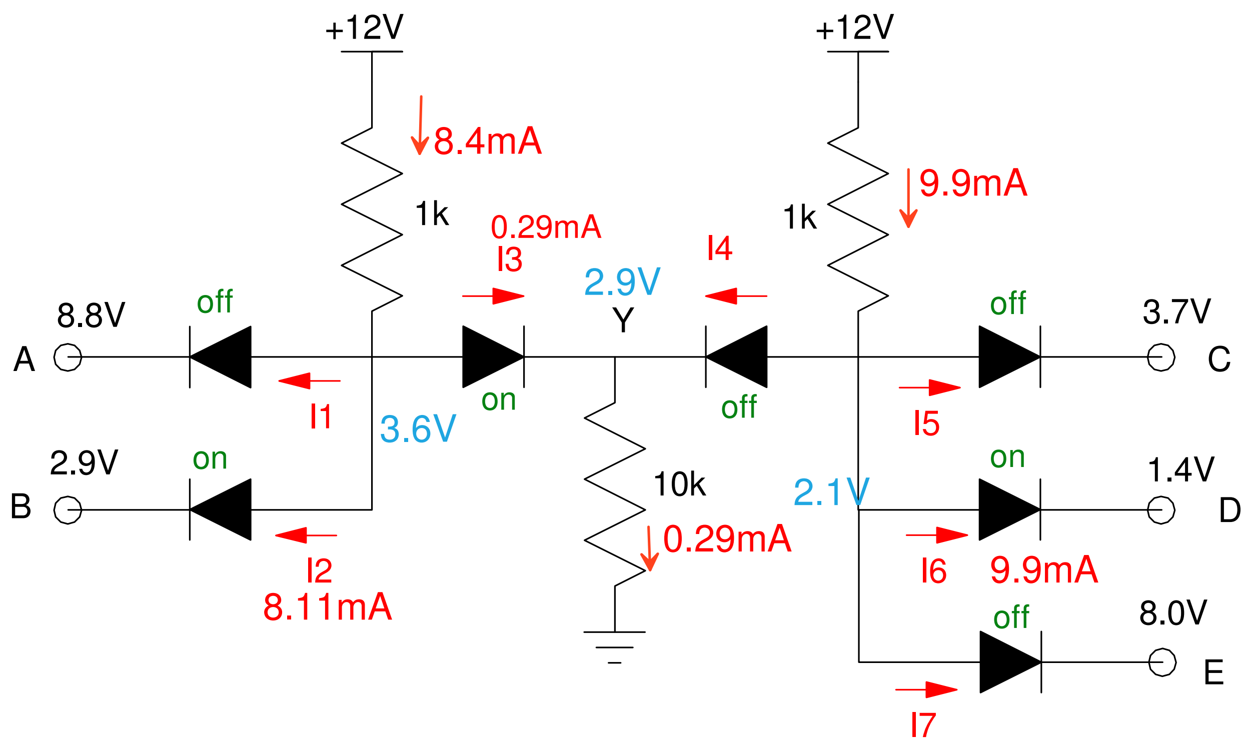
Max/Min Circuits, Clipper Circuits, Transistor Theory. Due Monday, February 6th
Please submit as a hard copy or submit on BlackBoard

### 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)

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

$$Y = AB + CDE$$

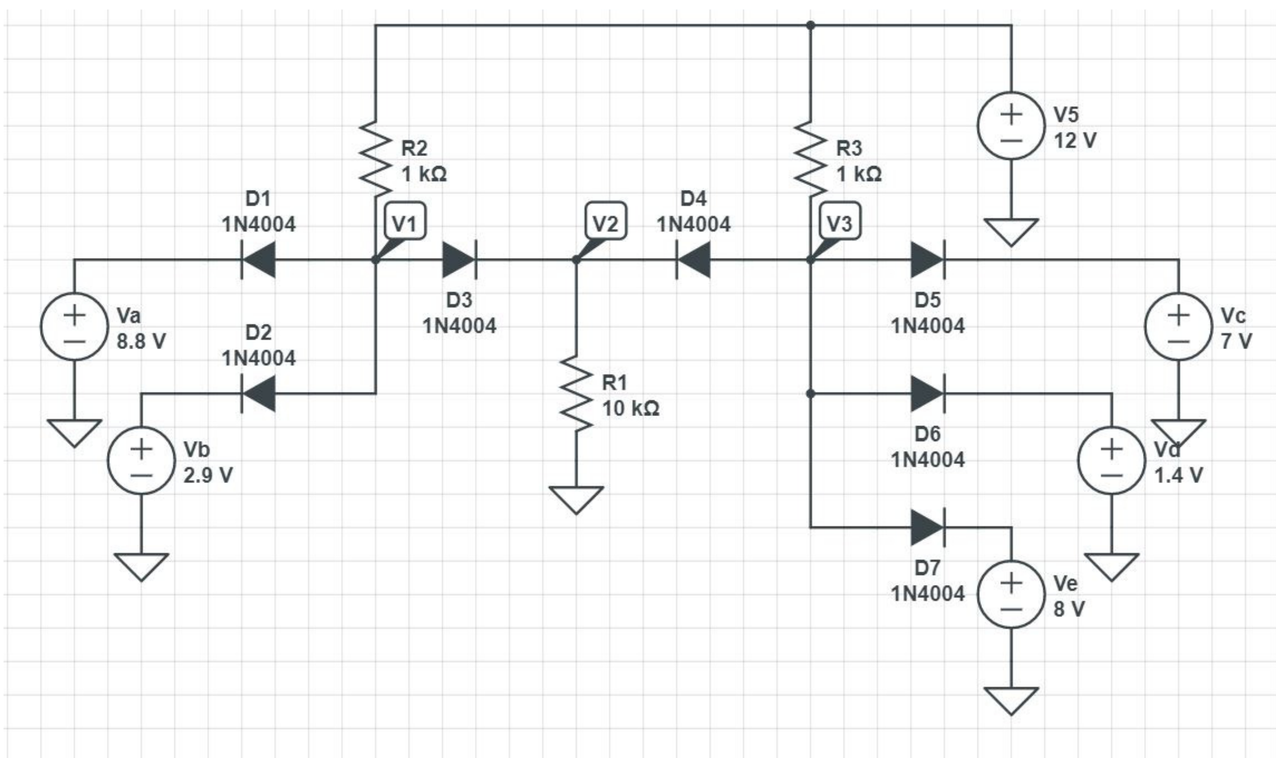



Problem 1-2.

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 |

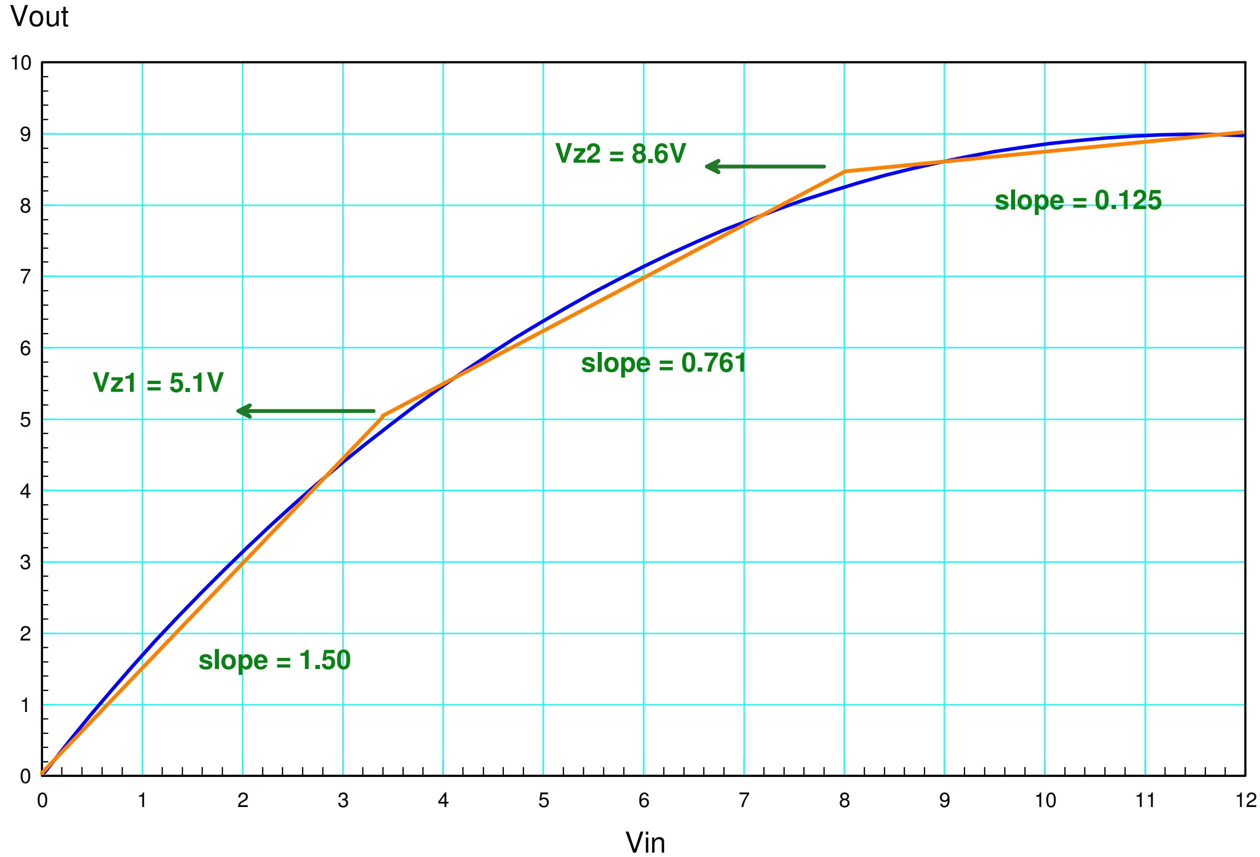



| | |
|---|---|
| V(V1) | 3.589 V |
| V(V2) | 3.023 V |
| V(V3) | 2.096 V |
| I(D1.nA) | -76.90 pA |
| I(D2.nA) | 8.109 mA |
| I(D3.nA) | 302.3 μA |
| I(D4.nA) | -76.90 pA |
| I(D5.nA) | -76.90 pA |
| I(D6.nA) | 9.904 mA |
| I(D7.nA) | -76.90 pA |

## 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

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

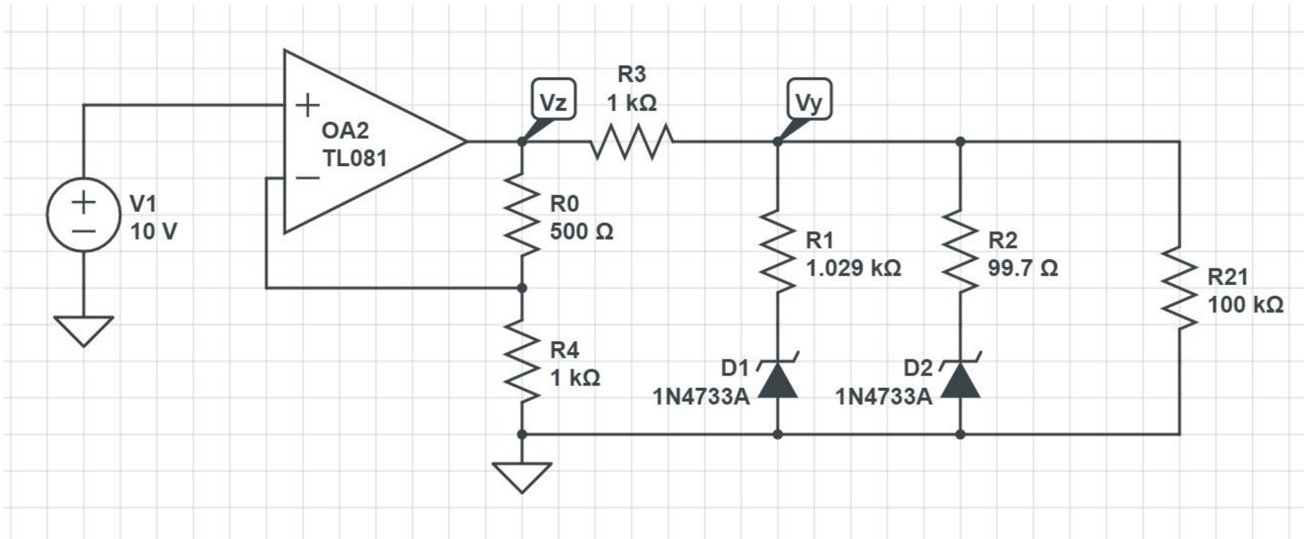
$$R_1 = \left(\frac{0.507}{1-0.507}\right) 1k = 1029.77$$

R2: Slope = 0.125

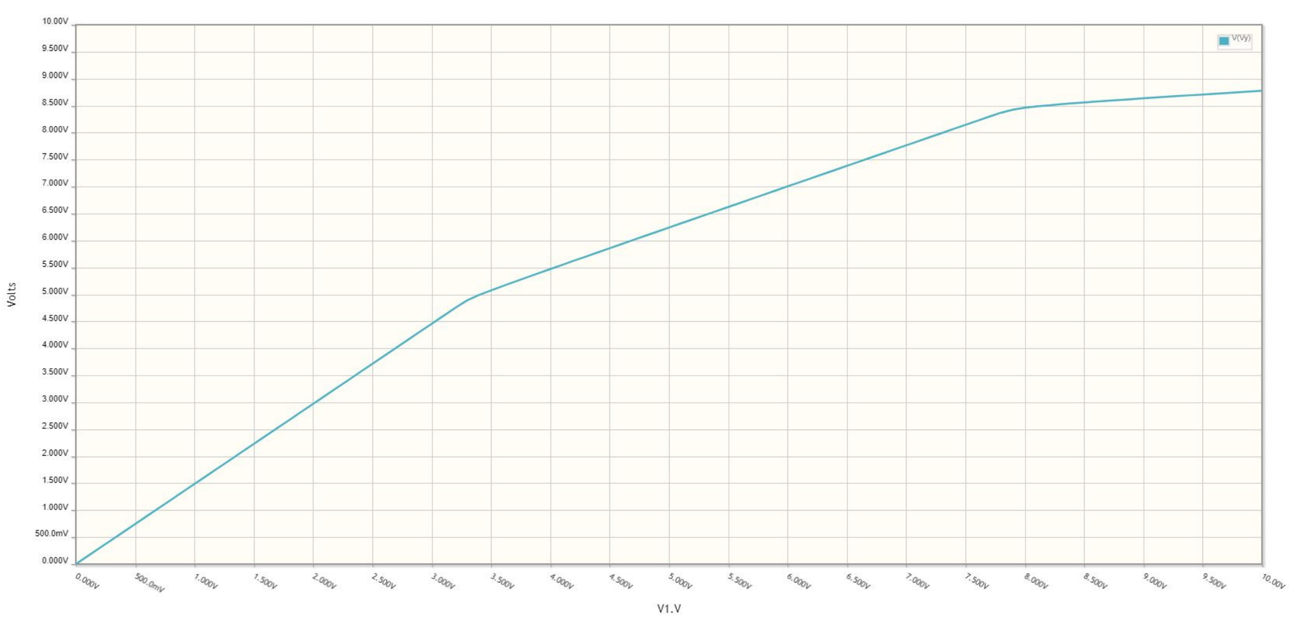
$$1.5 \cdot \left(\frac{R_{12}}{R_{12}+1000}\right) = 0.125$$

$$R_{12} = R_1 || R_2 = \left(\frac{0.0833}{1-0.0833}\right) 1000 = 90.9\Omega$$

$$R_2 = 99.7\Omega$$




4) Check your design in CircuitLab



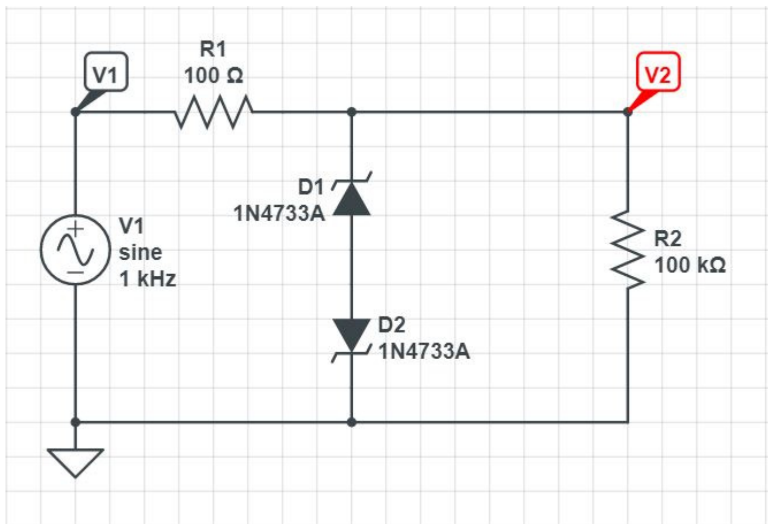
5) Design a circuit which meets the following requirements:

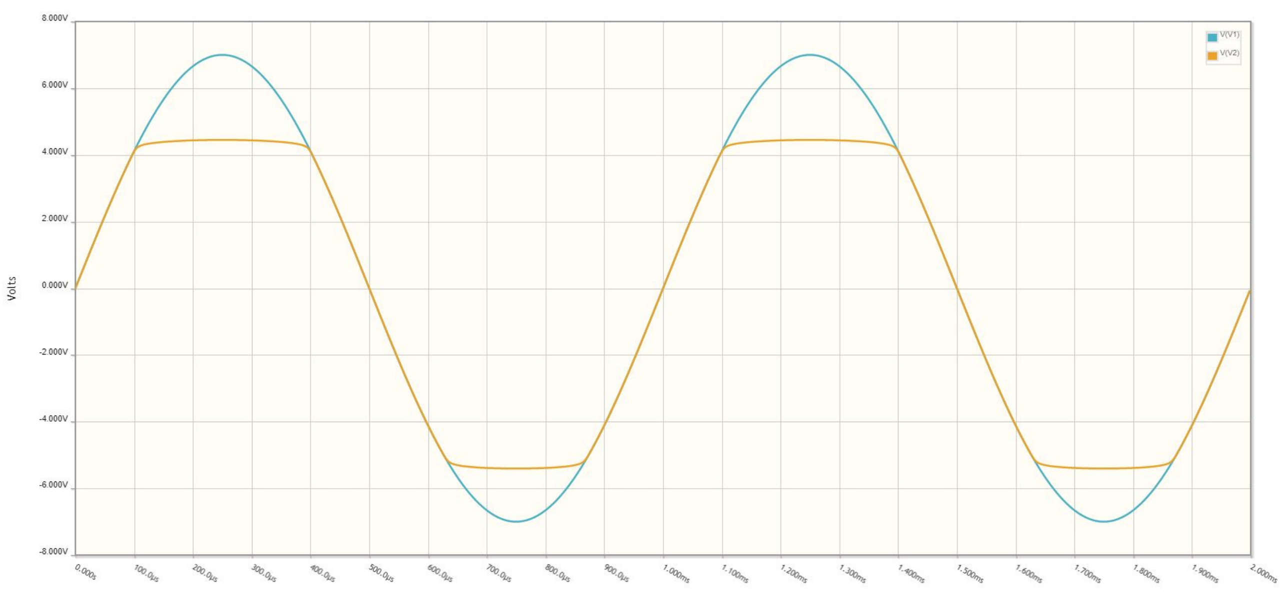
- Input: -10 .. +10V, capable of 100mA
- Output: 1k resistor
- Relationship:

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

D1: 3.8V zener

D2: 4.8V zener



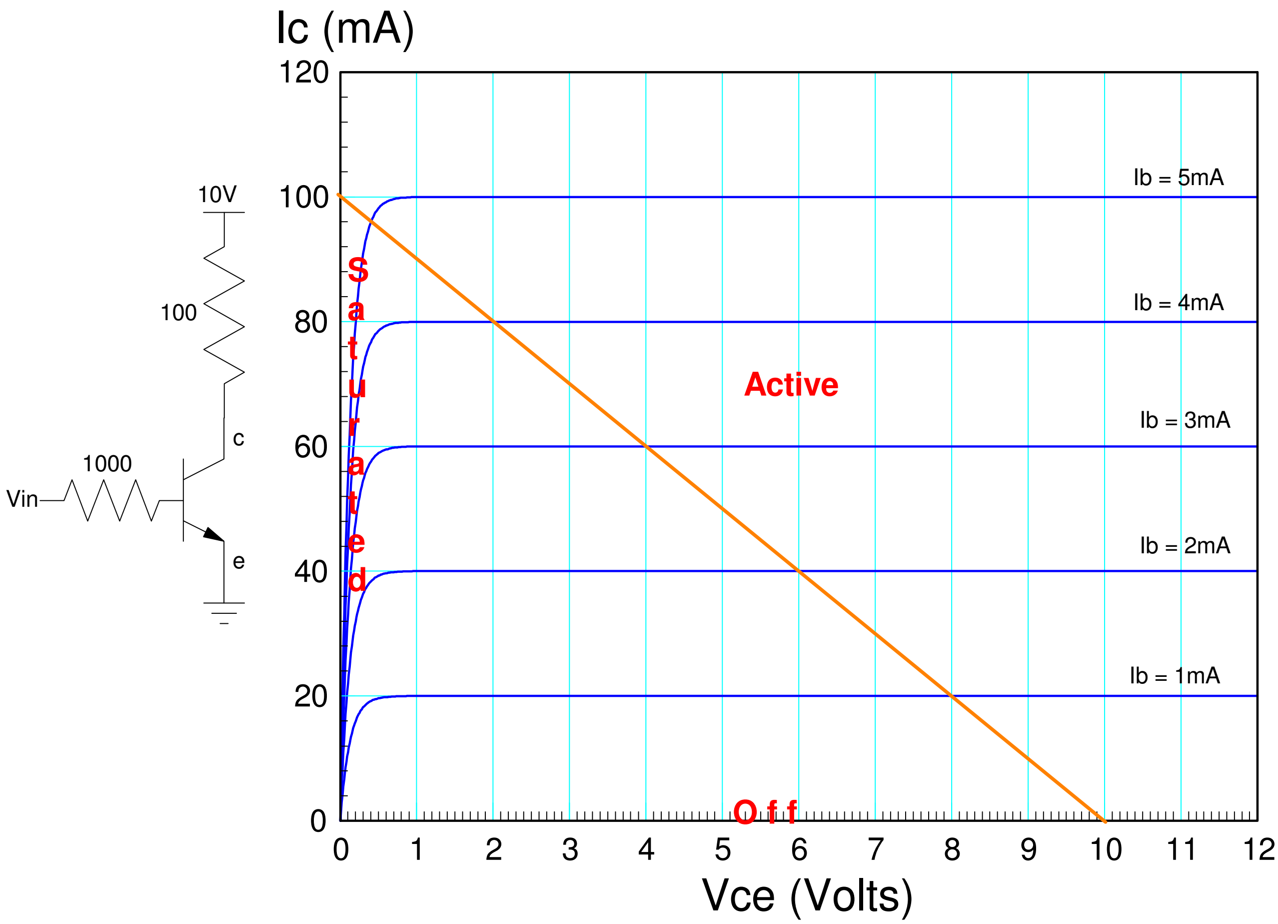



### Transistors

6) Determine the current gain, $\beta$, 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

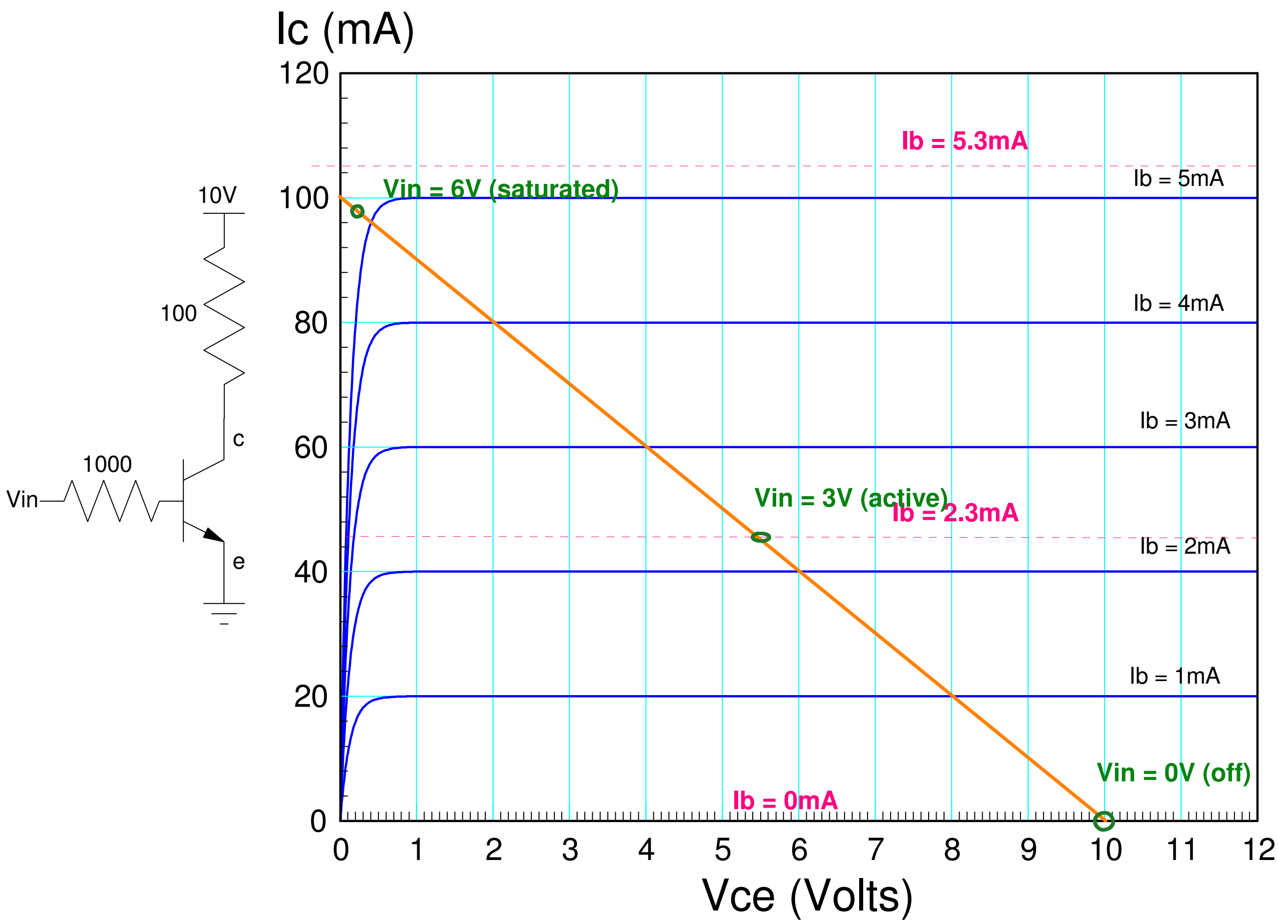
$$I_c = \beta I_b = 106mA$$

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

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

$$V_{ce} = 0.2V$$

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



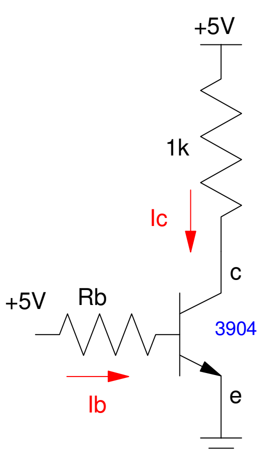
Ic (mA)
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Vce (Volts)
Ib = 5.3mA
Ib = 5mA
Vin = 6V (saturated)
Ib = 4mA
Ib = 3mA
Vin = 3V (active)
Ib = 2.3mA
Ib = 2mA
Ib = 1mA
Vin = 0V (off)
Ib = 0mA
10V
100
1000
Vin
c
e

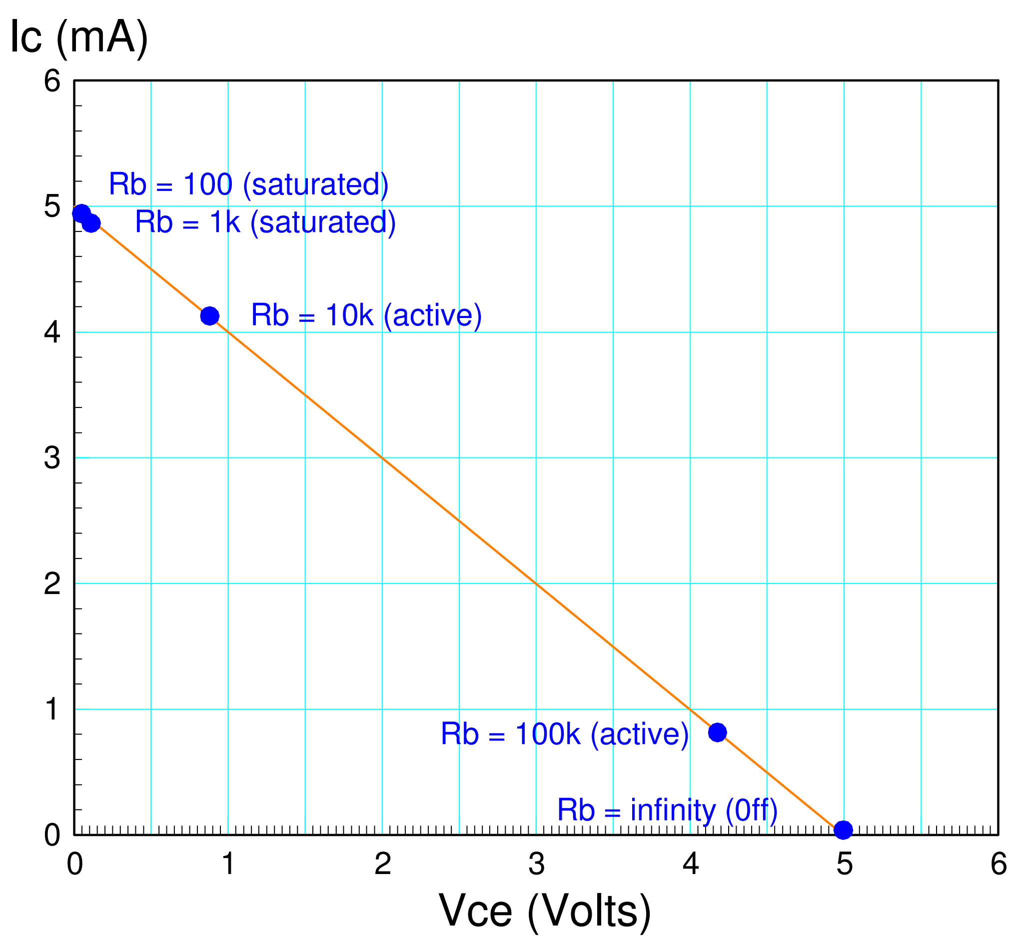
**Lab: Please include a photo of your circuit to receive credit for problems 8-10**

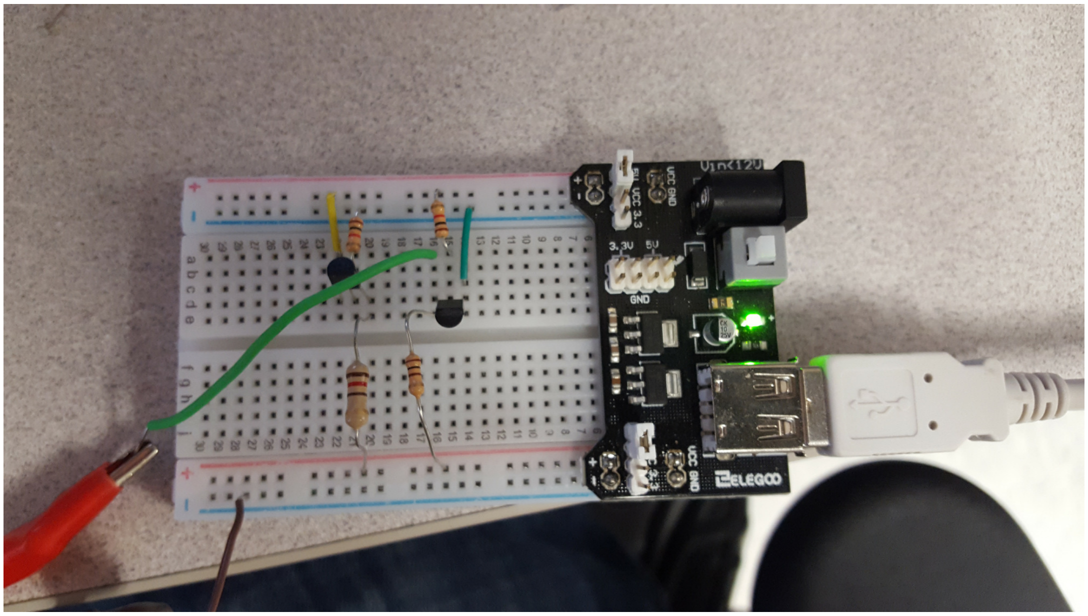
8-10) Build the following circuit with your electronics kit.

- 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 |




3.3V
5V
GND
ELEGOO