<File: Exam #1 S'02>

EECS 245 - SPRING 2002

EXAM#1 – 2/18/02

NAME: _________________ CWRUnet e-mail address:_____________

Solutions

IMPORTANT INFORMATION:

1. All questions are worth the same.
2. Exam is closed book, closed notes. Calculators are allowed.

		Possible
1.		25
2.		25
3.		25
4.		25
SCORE		100

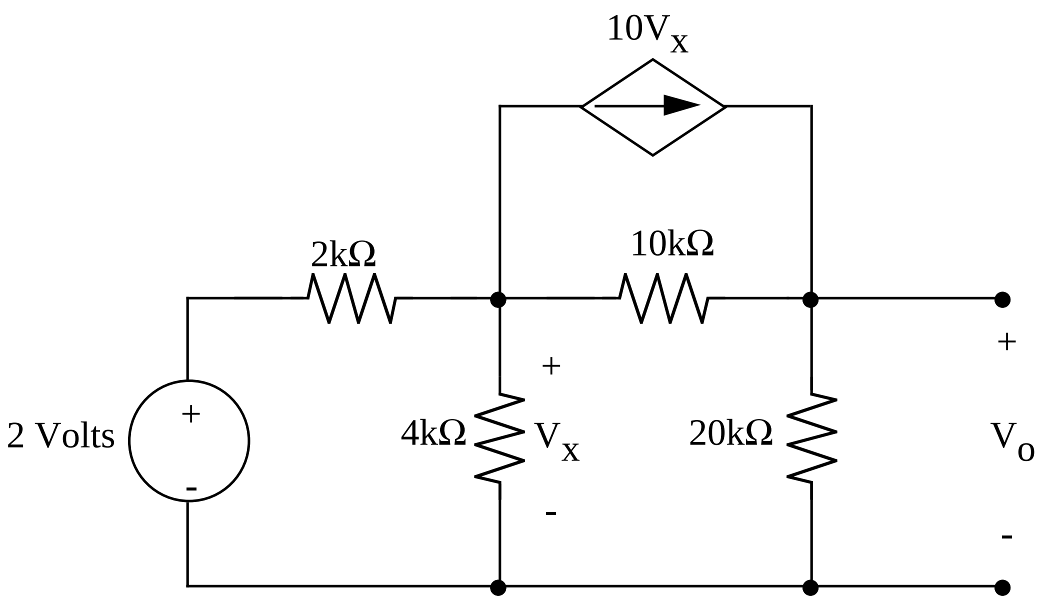
NOTE: Problems 1 and 2 may involve some time-consuming calculations. I would recommend setting up the equations and simply stating any assumptions if you are running short of time. You might also consider starting with problems 3 and 4.

Name: ____________________ e-mail: ______________________

EECS 245: Exam #1 February 18, 2002

DEPENDENT SOURCES

1. Consider the following circuit with a dependent current source.
   (a) Determine the open circuit output voltage.
   V_{OC}=__________ANSWER: 20 Volts
   (b) Determine the short circuit output current.
   I_{SC}=__________ANSWER: 0.93 mA



ANSWER:

The following shows how to solve the problem using KCL. You could use KCL if you were careful about how to handle the loop with the 10Vx current source.

At node1 (the input node) we have the simple result that $V_1 = 2\ volts$

At node2 (the interior node) we use KCL to write

$$\frac{V_1 - V_2}{2k\Omega} - \frac{V_2}{4k\Omega} - \frac{V_2 - V_3}{10k\Omega} - 10V_2 = 0$$

At node3 (the output node) we can also use KCL to write

$$+10V_2 + \frac{V_2 - V_3}{10k\Omega} - \frac{V_3}{20k\Omega} = 0$$

Re-arranging these equations into a standard matrix form to solve gives:

$$\begin{aligned} V_1 & & &= 2\ volts \\ 10V_1 &- 200{,}017V_2 &+ 2V_3 &= 0 \\ &+ 200{,}002V_2 &- 3V_3 &= 0 \end{aligned}$$

The solution of these equations is quite straightforward although you can make many numerical simplifications. Using the value for V_1 (2 volts) from the first equation and for V_3 ($\frac{200{,}002}{3}V_2$) from the last equation in the middle equation gives

$$10(2\ volts)\ - 200{,}017V_2\ + 2\left(\frac{200{,}002}{3}V_2\right) = 0$$

which can be solved for V_2 to give $V_2 = 3\times 10^{-4}\ volts$. This then gives

$$V_o = V_3 = \frac{200{,}002}{3}(V_2) = \frac{200{,}002}{3}\left(3\times 10^{-4}\right) = 20\ volts \quad .$$

I also simulated this circuit in Electronics Workbench and got the mysterious result that the current through the 20kΩ output resistor was 1mA with a voltage of 19.6 volts across it!

The answer for part (b) is much simpler to calculate. Since the output node is shorted there is only one unknown voltage, e.g., V_x. I would use KCL to find V_x and then compute the short circuit current. Specifically, using KCL at the output node gives

$$\sum_{+in} i = 0 = \frac{2-V_x}{2} - \frac{V_x}{4} - \frac{V_x}{10} - 10V_x$$

$$1 = \frac{V_x}{2} + \frac{V_x}{4} + \frac{V_x}{10} + 10V_x$$

$$1 = 10.85V_x$$

$$V_x = 0.09216589\text{volts}$$

The output short circuit current is then given by

$$I_{SC} = \frac{V_x}{10} + 10V_x = 10.1V_x = 10.1(0.09216589) = 0.93mA$$

The Electronics Workbench simulation gave 1mA for the short circuit current which indicates I might have a small math error in my solution. However, as long as you were numerically close to the correct answer and started from a correct equation you received full credit.

GRADING NOTES:

(a) The problem required that you use KCL and KVL to develop an appropriate set of equations to solve for the requested variables. KCL gave the simplest equations and you should always start with KCL when there is a current source in the problem. If you used KCL there were three equations with three unknown voltages (one of these was the source voltage of 2 volts). If you used KVL there should have been at least three loop currents. You lost four points for each variable's equation which you failed to write or failed to correctly write. You lost three points for the correct evaluation of the circuit's system of equations.

(b) The short circuit current was worth 5 points. In this case you received 3 points for correctly setting up the equation for calculating the short circuit current and 2 points for correctly solving the equation.

NOTE:
Several people eliminated the voltage controlled current source. This completely changed the problem and cost you 15 points.

MOST COMMON ERRORS:
The most common error was to compute the current through the 2kΩ input resistor as 2volts/2kΩ=1mA totally ignoring the fact that the voltage at the other side of the 2kΩ resistor is NOT zero.
The second most common error was to short circuit the output and still have a current flowing through the 20kΩ load resistor.

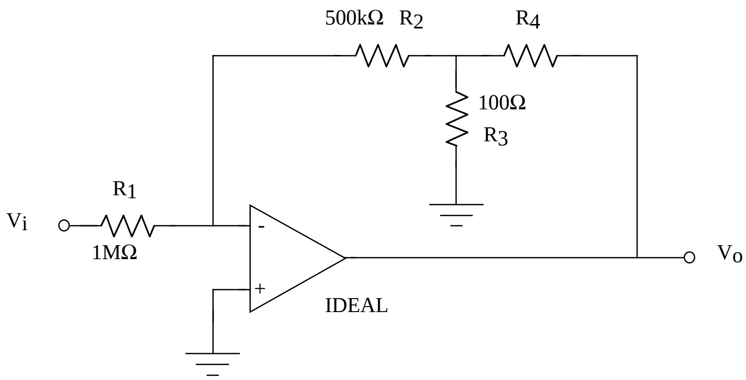
Name: ____________________ e-mail: ______________________

EECS 245: Exam #1 February 18, 2002

OPERATIONAL AMPLIFIERS

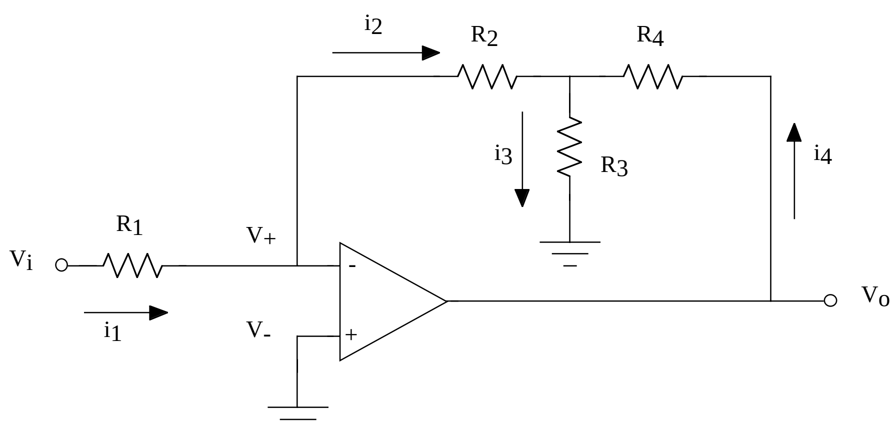
2. Determine the voltage gain V_o/V_i in the circuit shown below. Assume the operational amplifier is ideal. You may use R4=24kΩ.

V_o/V_i = ____________ ANSWER: -120.5



ANSWER:

There are multiple ways to solve the problem. The key is that by KCL and the virtual short assumption the voltage at the junction of R2, R3 and R4 is actually known. Once this is known Vo can be readily calculated using KCL.



Using the virtual short assumption, since v_{in-} is grounded v_{in+} is also at ground potential, i.e., $v_{in-} = 0$

Since $v_{in-} = 0$, the input current through R1 is given by $i_l=v_i/R_1$.

Using KCL at the – input of the op amp and recognizing that no current can flow into the op amp we have that $v_x=-i_2R_2$ where $i_2=i_1$ where v_x is the voltage at the node formed by R_2, R_3 and R_4.

Name: ____________________ e-mail: ______________________
EECS 245: Exam #1 February 18, 2002

If we know v_x we can write v_x=-i_3R_3 and v_x-v_o =-i_4R_4 . Using Kirchhoff's current law at this node we have $i_4 = i_2 + i_3$ which gives

$$\frac{v_x - v_o}{R_4} = \frac{-v_x}{R_2} + \frac{-v_x}{R_3} \qquad (1)$$

Substituting for the actual circuit values gives

$$\frac{v_x - v_o}{24{,}000\Omega} = \frac{-v_x}{500{,}000\Omega} + \frac{-v_x}{100\Omega}$$

We know v_x in terms of v_i from the input node where $\frac{v_i - v_+}{R_1} = \frac{v_+ - v_x}{R_2}$

And, using the given circuit values becomes $\frac{v_i - 0}{1{,}000{,}000\Omega} = \frac{0 - v_x}{500{,}000\Omega}$

which can be solved to give $v_x = -\frac{v_i}{2}$. Substituting this value into equation (1) gives

$$-\frac{v_i}{48{,}000} + \frac{-v_o}{24{,}000\Omega} = +\frac{v_i}{1{,}000{,}000} + \frac{v_i}{200}$$

Combining terms gives $\frac{-v_o}{24{,}000\Omega} = \frac{v_i}{199.13}$ or $\frac{v_o}{v_i} = -\frac{24{,}000}{199.13} = -120.52$

GRADING NOTES:
Just as in the first problem there were multiple ways to set up the equations to solve for the voltage gain.

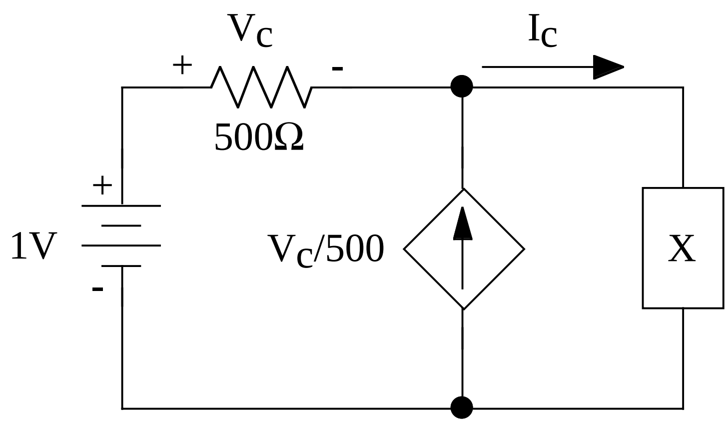
The problem really required two equations, that at the inverting input of the op amp and another at the junction of R2, R3 and R4. You lost 10 points for failing to set up either equation. Typically you lost 10 points for failing to identify the correct value of v_x and/or another 10 points for failing to relate v_x to v_o.

You lost 5 points if you failed to solve the equations you set up; however, math errors only lost you two points.

Name: ____________________ e-mail: ______________________
EECS 245: Exam #1 February 18, 2002

LOAD LINE ANALYSIS

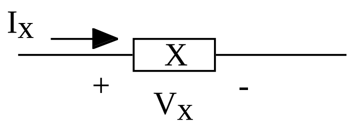
3. Use graphical load-line analysis to find Vc and Ic in the circuit shown below. The device characteristics are illustrated in the accompanying figure.

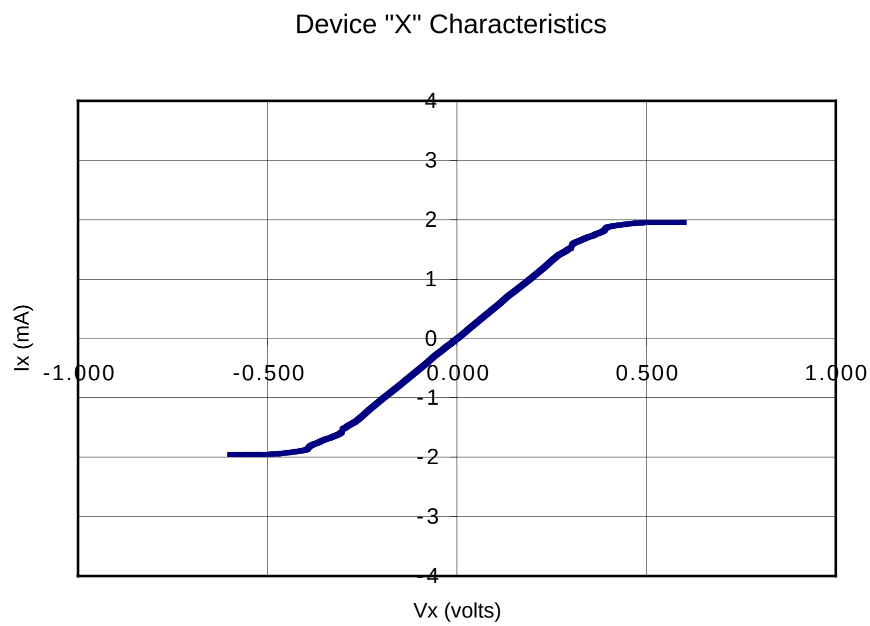


Vc = ______________
ANSWER: 0.055 volts

Ic = ______________
ANSWER: 0.22 mA

NOTE:

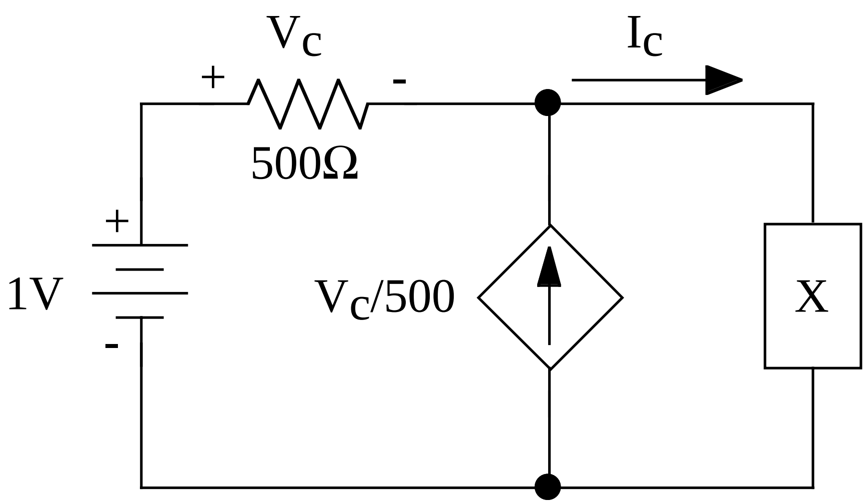




Solution:
This problem was a variation of a homework problem. It requires a load line analysis and there is a title to that effect at the top of this page. The characteristics for the device are given in the above figure. The scale should have been larger than that given in the original problem and I have modified it in this solution set.

Name: ___________________ e-mail: _____________________

EECS 245: Exam #1 February 18, 2002



To construct a load line for the circuit to the left of the load you need to determine the open circuit voltage and the short circuit current.

Let's first consider the open circuit situation, i.e. replace circuit element X by an open. In this open circuit situation there is no load current I_C. Because X has been replaced by an open circuit the current through the 500Ω resistor must be the same as that through the voltage controlled current source. If there is no load current then there should be no current through the 500Ω resistor due to the load, no voltage across the 500Ω resistor, and no corresponding current through the current source,. Consequently, we can conclude that there is no overall current through the 500Ω resistor and no voltage drop across the 500Ω resistor requiring that $V_{OC} = 1.0 volts$

The short circuit current can be computed by applying KCL at the output node to get

$$\sum_{+in} i = 0 = +\frac{V_C}{500} + \frac{V_C}{500} - I_C$$

or $I_C = \frac{V_C}{500} + \frac{V_C}{500} = \frac{V_C}{250}$. To finish computing this short circuit current we need a second equation. Consider using KVL on the outside loop when the output is shorted. Using this outer loop we get $\sum V = -1.0 + V_C + 0 = 0$ or $V_C = 1.0 volts$. This gives

$$I_C = \frac{V_C}{250} = \frac{1.0}{250} = 0.004 \text{ or } 4\text{mA}.$$

We then draw the load line with $V_{OC} = 1.0 volts$ and $I_{sc} = 4mA$.

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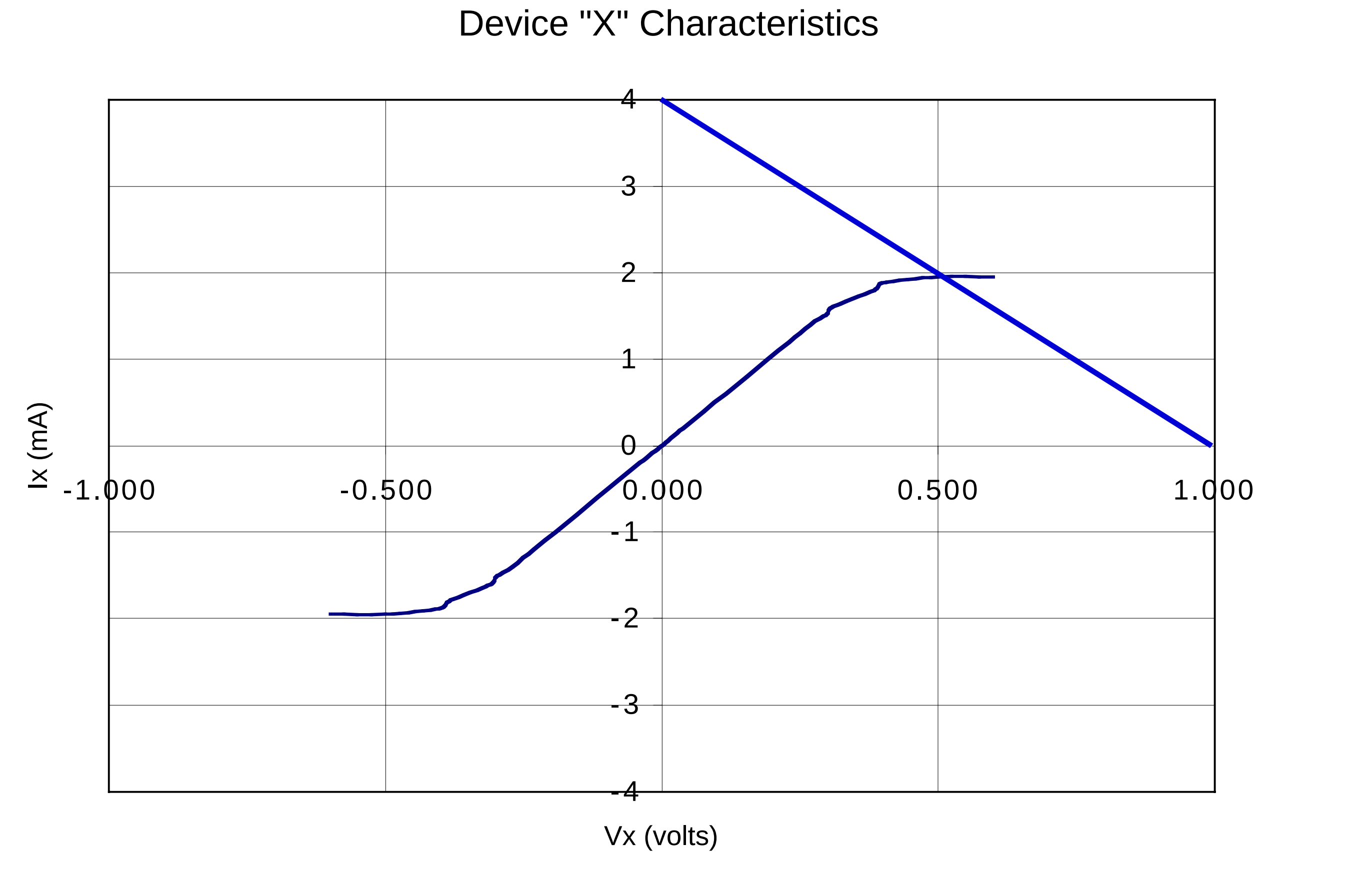


From the graph the approximate operating point is about 0.5 volts, 2mA. This tells us that $V_C = 1 - V_X = 1 - .5 = 0.5 volts$

GRADING NOTES:
This problem was a modification of a homework problem.

The fundamental concept was to use a load line to model the characteristics of the electrical network consisting of the 1V source, the 500Ω resistor, and the voltage controlled current source. The load line part of the problem was worth 20 points. You needed to determine the open circuit voltage and the short circuit current. You typically lost 5 points for failing to correctly find either one.

Intersecting the load line with the device characteristic curve to determine I_C and V_C was worth 5 points.

Name: ____________________ e-mail: ______________________

EECS 245: Exam #1 February 18, 2002

DIODE CIRCUITS

4. Assume that the diodes are ideal. Assuming that Vin=+8 volts find the values for I and Vout for the circuit shown below. Identify the status (ON or OFF) of all diodes in the circuit for this input and the current through them if they are ON.

I ______________ANSWER: 6mA

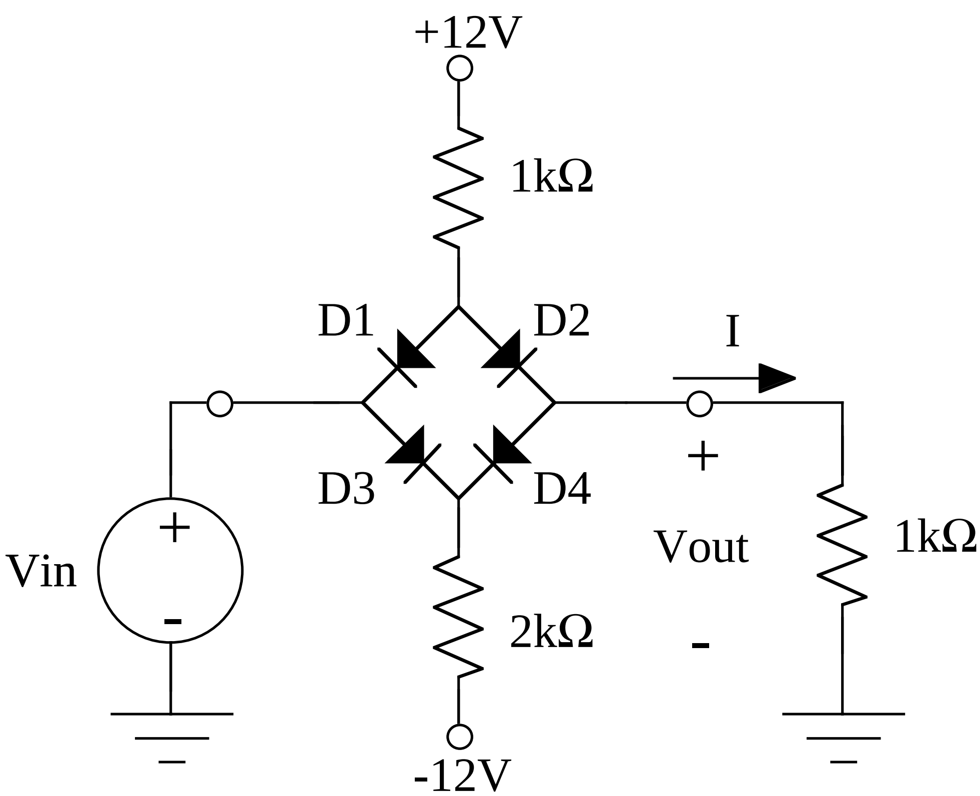
Vout ______________ANSWER: 6 volts

D1 ______________ANSWER: OFF

D2 ______________ANSWER: ON, 6mA

D3 ______________ANSWER: ON, 10mA

D4 ______________ ANSWER: OFF



Solution:

Assume first that D1 and D2 are both ON. If Vin=+8 volts this causes the D1-D2 junction and Vout to also be at 8 volts. If Vout=8 volts then I=8mA. Now look at the voltage drop across the upper 1kΩ resistor. If it is 12 volts at the top and 8 volts at the bottom then only 4mA can be supplied by this +12volt source. This is not enough for the value of I; nor can the extra current be supplied by the source through D1. D1 cannot supply the current because to have DC current going in the reverse direction would turn it off. According to this reasoning

D1 must then be OFF and D2 ON. If D2 is on then the 1kΩ resistors function as a voltage divider causing Vout=+6 volts. This means that I must be 1mA.

To consider the remaining diodes we see that D3 is forward biased by Vin. This would put the top of the 2kΩ resistor at +8 volts. Note that D4 will be OFF since it has +6 volts at the cathode and +8 volts at its anode. The current going through the 2kΩ resistor is then

$$I_{in} = \frac{V_{in} - (-12)}{2k\Omega} = \frac{8+12}{2k\Omega} = \frac{20}{2k\Omega} = 10mA$$

GRADING NOTES:
This problem was a modification of a homework problem, was discussed in class and was also covered in the review session.

It concentrated upon the simple case of determining when the diodes were ON and OFF when the input voltage was forcing current starvation.

The state of each diode was worth 4 points, the amount of current through each ON diode was worth 3 points, and the voltage and current of the output were worth 3 points each.