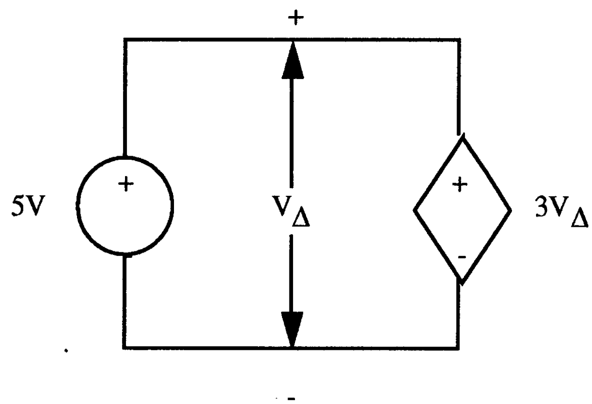
INS TCP/IP PrintServer 20

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	1
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	Quiz_1.ps.732464623
Submitted at:	Thu Mar 18 09:52:43 199350 199320:41 1993
Printed at:	Thu Mar 18 09:52:43 1993

flm@util
Quiz_1.ps.732464623

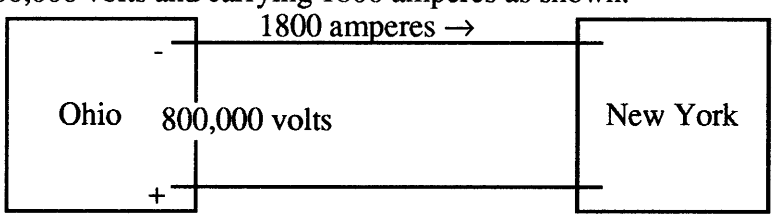
Quiz #1 SOLUTIONS
EEAP 244 January 22, 1993

1. Is the following circuit a valid circuit? Explain why or why not using the definitions of ideal voltage and current sources.



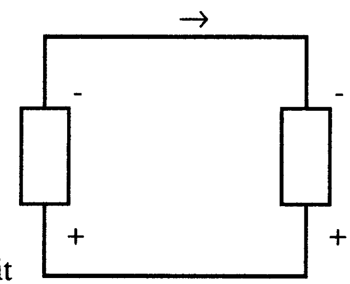
Answer: The circuit is invalid because the voltage source causes V_Δ to be 5V. This in turn causes the dependent (controlled) voltage source to force V_Δ to $3V_\Delta$=15 volts. V_Δ cannot be both +5 and +15 and the circuit is invalid because there is no common solution of the ideal voltage source v-i curves.
Misinterpreted source as a current source -10 points.

2. A high-voltage direct current transmission line between Ohio and New York is operating at 800,000 volts and carrying 1800 amperes as shown.



(a) What is the power at the New York end?

Answer: $-1.44\text{x}10^9$ watts.

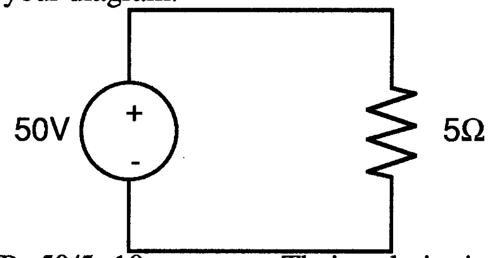
Redrawing the circuit


we see that New York is opposite to the passive sign convention. The power is then $p=-vi=-(8\text{x}10^5 \text{ volts})(1.8\text{x}10^3 \text{ amps}) =$ $-14.4\text{x}10^8$ watts. Since this is a negative quantity New York is generating power.
-3 points for sign loss.

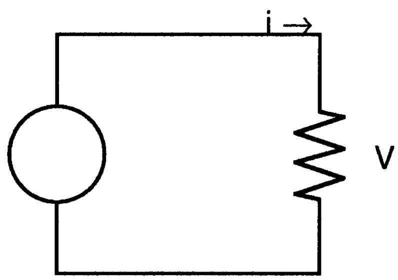
(b) Is Ohio absorbing or generating power? Explain your answer.

Ohio is absorbing power since it obeys the passive sign convention and p=vi>0 for Ohio.

3. (a) Calculate the values of v and i across the resistor. Be sure to label their directions and polarity on your diagram.



Answer: v=50 volts. i=v/R=50/5=10 amperes. Their polarity is as shown below. You lost -5 points for using the wrong form of Ohm's Law. -6 points for voltage polarity and current direction.



(b) What is the power dissipated in the resistor?
Answer: P=vi=(50 volts)(10 amperes) = 500 watts

INS TCP/IP PrintServer 20

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_2.ps.732547312
Submitted at:	Fri Mar 19 08:31:52 19931993
Printed at:	Fri Mar 19 08:31:53 1993

flm@util
quiz_2.ps.732547312

Name: ____________________ SSN:______________________

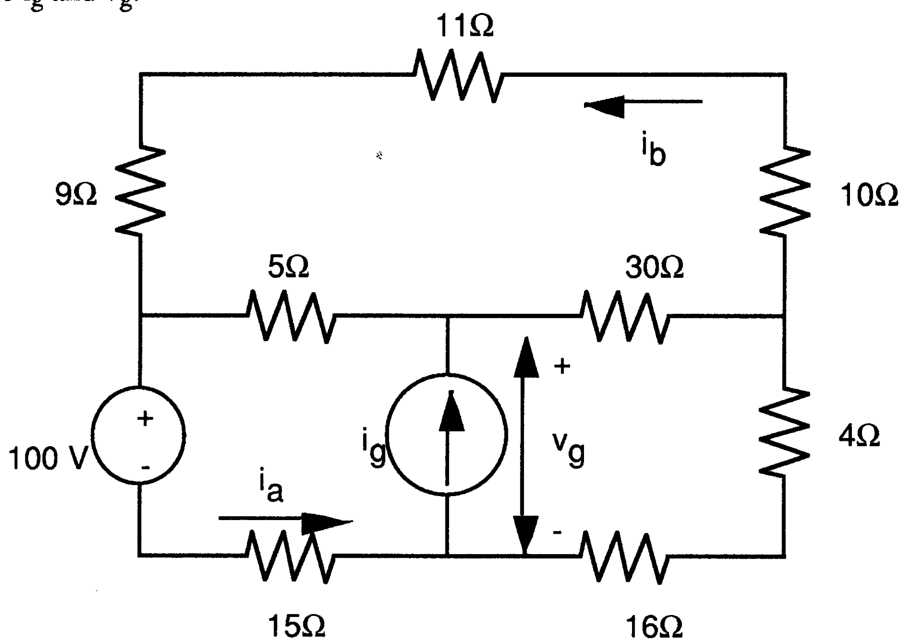
Quiz #2
EEAP 244 January 27, 1993

Topics on quiz:

- definitions of nodes, branches, loops, etc.
- ability to find currents, voltages and powers in simple resistive circuits
- validity of circuits due to current and voltage source constraints
- ability to determine currents, voltages and powers in multi-branch resistive circuits with independent and dependent sources
- circuit modeling and simple equivalent circuits
- simple KCL and KVL principles
- equivalent resistance of series and parallel connections and power delivered to resistance networks
- calculation of currents, voltages and powers developed in multi-branch circuits using KCL and KVL
- voltage and current divider circuits
- inductor voltages, currents and powers as a function of time
- capacitor voltages, currents and powers as a function of time

Quiz #2 SOLUTIONS
EEAP 244 January 27, 1993

1. The currents i_a and i_b in the circuit shown below are 4A and -2A respectively. Determine i_g and v_g.



Answer: Solve the problem using loop mesh analysis. Use loops in the directions of ia and ib. Use a clockwise loop for i_c which includes the 30, 4 and 16Ω resistors as well as the current source. The resulting loop equations are:

loop 1: $+i_b(9+10+11) + 5(i_b - i_a) + 30(i_b + i_c) = 0$

loop 2: $-v_g + 5(i_a - i_b) + 100 + 15i_a = 0$

loop 3: $+v_g + 30(i_c - i_b) + i_c(16+4) = 0$

plus the constraint equation:

eqn 4: $i_g = i_a + i_c$

Since i_a and i_b are known I can use the loop 1 equation to find i_c

$+(-2)(30) + 5(-2-4) + 30(-2+i_c) = 0$

which gives i_c=5 amperes

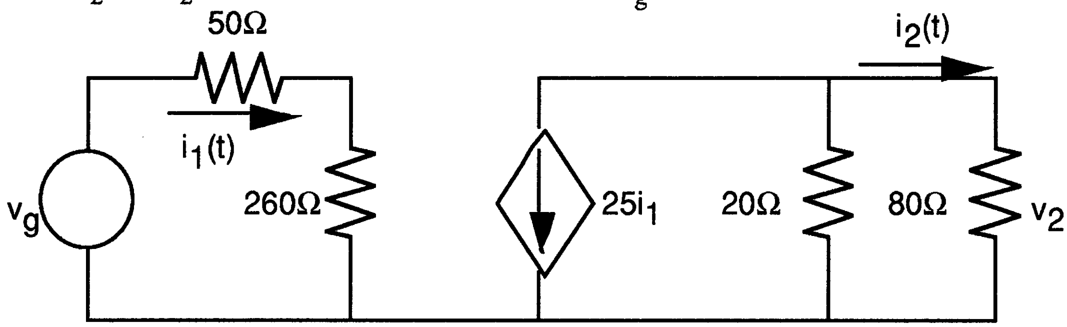
This, also tells me i_g since $i_g = i_a + i_c = +4+5 = +9$ amperes

Now, using the equation for loop 2 I can solve for v_g:

$-v_g + 5(4-(-2)) + 100 + 15(4) = 0$

or, v_g=+190 volts.

2. Find i_2 and v_2 in the circuit shown below when v_g= 5 volts.



Answer:
Using Ohm's Law at the input loop:

$$i_1 = \frac{v_g}{50+260} = \frac{5}{310} = 16.13 \text{ mA}$$

Now, evaluating the current controlled current source

$$25i_1 = \frac{25(5)}{310} = 0.403 \text{ A}$$

The current i_2 is found from the current source current by using a current divider:

$$i_2 = -\frac{20}{20+80}(0.403 \text{ A}) = -80.6 \text{ mA}$$

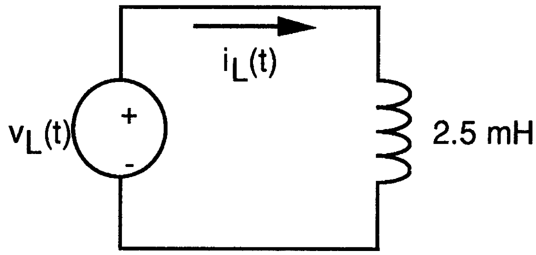
Use Ohm's Law to get the output voltage:

$$v_2 = iR = (-0.806\text{A})(80\Omega) = -6.45 \text{ volts}$$

3. The <u>current</u> through the 2.5-mH inductor in the circuit shown below is 1 ampere for $t \leq 0$. The voltage across the inductor for $t \geq 0$ is given by

$$v_L(t) = \begin{cases} 3e^{-4t}\ \text{mV},\ 0^+ \leq t < 2 \text{ seconds} \\ -3e^{-4(t-2)}\ \text{mV},\ 2^+ \leq t < \infty \end{cases}$$

Determine $i_L(t)$. Sketch your result.



Answer: Since $v_L(t) = L\frac{di_L(t)}{dt}$ we must find the current by integrating the voltage. For $0 \leq t < 2$ seconds we have

$$i_L(t) = \frac{1}{L}\int_{-\infty}^{t} v_L(x)dx = \frac{1}{L}\int_{-\infty}^{0} v_L(x)dx + \frac{1}{L}\int_{0}^{t} v_L(x)dx$$

$$= 1 \text{ Ampere} + \frac{1}{2.5\times10^{-3}}\int_{0}^{t} 3\times10^{-3}e^{-4x}dx$$

$$= 1\text{ A} + 1.2\left.\frac{e^{-4x}}{-4}\right|_{0}^{t} = 1 - 0.3e^{-4t} + 0.3\text{A}$$

$= 1.3 - 0.3e^{-4t}$ A for $0 \leq t \leq 2$ seconds

Note that we used the fact that the current was 1Ampere for $t \leq 0$

The analysis for $t > 2$ seconds is identical in form except for the initial condition which is $i_L(2) = 1.3 - 0.3e^{-4(2)}\text{ A} = 1.3 - 0.0003354 \approx 1.3$ Amperes

giving

$$i_L(t) = \frac{1}{L}\int_{-\infty}^{t} v_L(x)dx = \frac{1}{L}\int_{-\infty}^{2} v_L(x)dx + \frac{1}{L}\int_{2}^{t} v_L(x)dx$$

$$= 1.3 \text{ Ampere} + \frac{1}{2.5\times10^{-3}}\int_{2}^{t} -3\times10^{-3}e^{-4(x-2)}dx$$

$$= 1.3 - 1.2\left.\frac{e^{-4(x-2)}}{-4}\right|_{2}^{t} = 1.3 + 0.3e^{-4(t-2)} - 0.3\text{A}$$

$= 1.0 + 0.3e^{-4(t-2)}$ A for $2 \leq t$ seconds

INS TCP/IP PrintServer 20

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_2_new.ps.732547322
Submitted at:	Fri Mar 19 08:33:59 1993
Printed at:	Fri Mar 19 08:34:00 1993

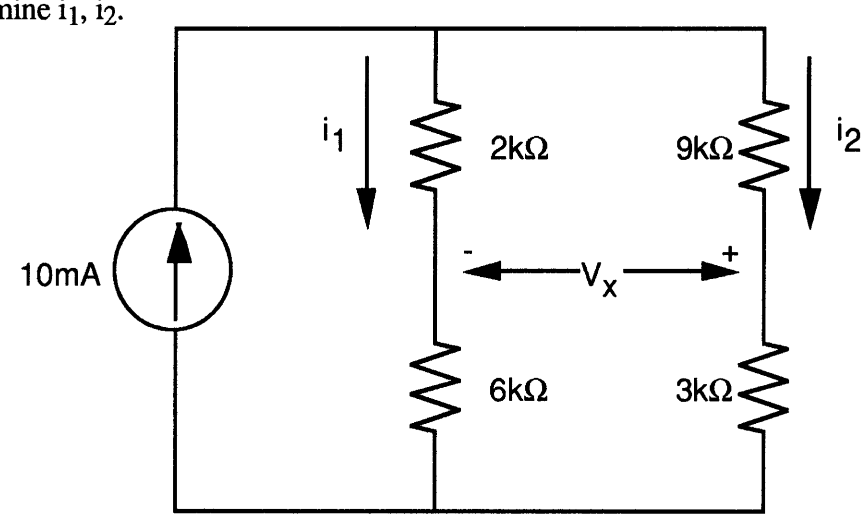
flm@util
quiz_2_new.ps.732547322

Name: ____________________ SSN: ________________________

Quiz #2 SOLUTIONS
EEAP 244

February 2, 1993

1. Determine i_1, i_2.

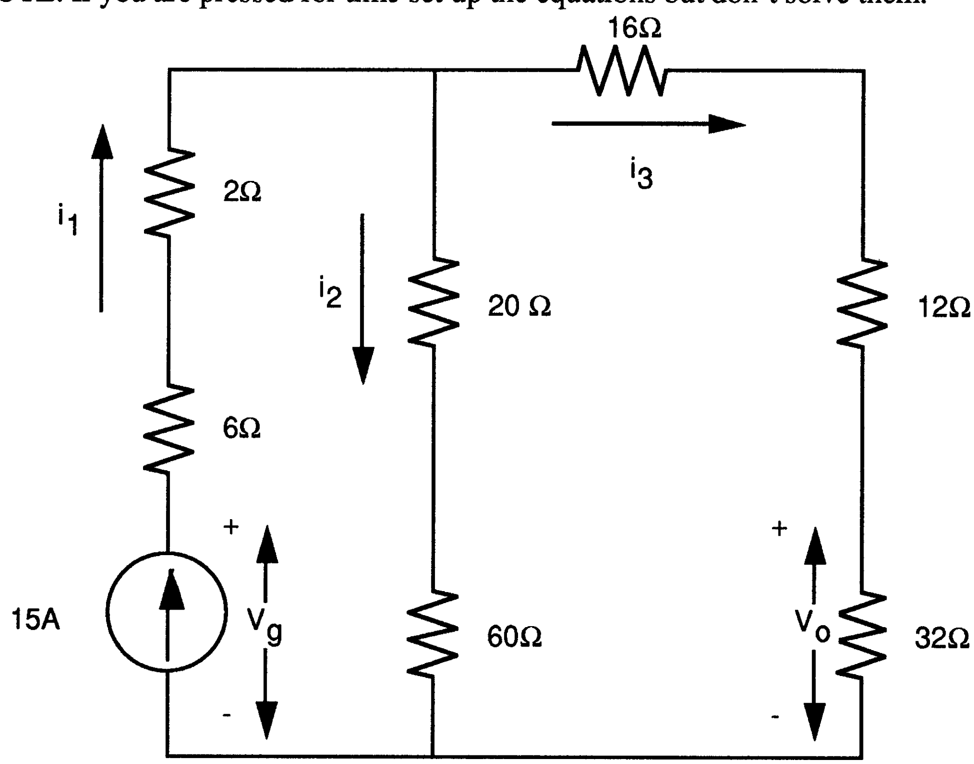


Answer: This problem can be done most efficiently using voltage and current dividers.

$$i_1 = \frac{R_{branch\,2}}{R_{branch\,1}+R_{branch\,2}}\, i = \frac{(9k + 3k)}{(2k + 6k)+(9k + 3k)} 10mA = \frac{12k}{8k+12k} 10mA = \frac{12k}{20k} 10mA = 6\ mA$$

Since KCL applies at the upper node, i_2=10mA-i_1=10-6 = 4 mA

2. For the circuit shown below: (a) Determine i_1, i_2 and i_3; (b) determine V_o and V_g.
NOTE: If you are pressed for time set up the equations but don't solve them.



Name: ____________________ SSN: ______________________

Answer:
(a)
You have to use one KCL equation (since there are two nodes), one source constraint, and one KVL equation.
Using KCL at node 1 with + in: $i_1 - i_2 - i_3 = 0$
The source provides: $i_1 = +15A$
KVL around the right hand loop (you can't go across the current source) gives:
$-60i_2 - 20i_2 + 16i_3 + 12i_3 + 32i_3 = 0$

These can be solved simultaneously:

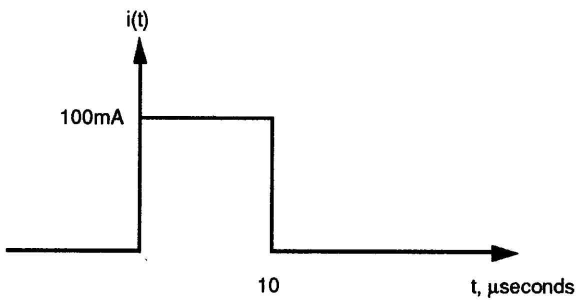
$$15 - i_2 - i_3 = 0$$
$$-80i_2 + 60i_3 = 0$$

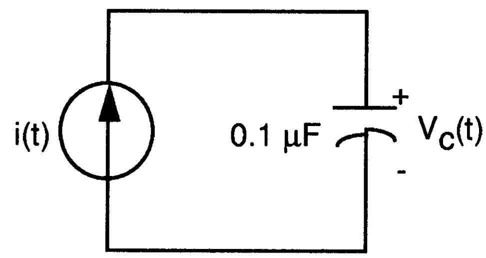
to give $i_1 = +15A$, $i_2 = 45/7 = 6.4$ A, $i_3 = 4/3(i_2) = 60/7 = 8.6$ A
(b) Solving for Vo is simple:

$$V_o = 32i_3 = 32\left(\frac{60}{7}\right) = \frac{1920}{7} \cong 274 \text{ volts}$$

Solving for Vg is more complicated. You have to determine V at node 1 or do KVL around the loop containing the current source.
$-V_g + 6i_1 + 2i_1 + 20i_2 + 60i_2 = 0$
Using the above expressions for the currents we get:
$V_g = +6(15) + 2(15) + 20(6.4) + 60(6.4) = 90 + 30 + 128 + 384 = 632$ volts

3. The current pulse shown at the left below is applied to the circuit shown at the right below. The capacitor is initially charged to Vc(t)= - 5 volts for t<0 seconds. Determine Vc(t) as a function of time. Sketch your answer.





Answer:

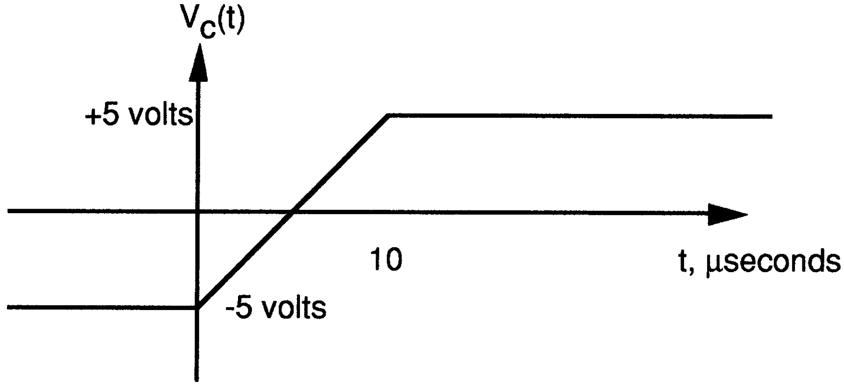
Solving for $0 \le t \le 10\mu$seconds

$$V_c(t) = \frac{1}{C}\int_{-\infty}^{t} i(x)dx = \frac{1}{0.1\times10^{-6}}\int_{-\infty}^{t} 100\times10^{-3}dx$$

$$= \frac{100\times10^{-3}}{0.1\times10^{-6}}\Bigg|_0^t - 5 = 10^6 t - 5 \text{ for } 0 \le t \le 10\mu \text{ seconds}$$

Name: ____________________ SSN:________________________

By inspection, Vc(t) = -5 for t<0 and Vc(t) = Vc(10μseconds) = +5 volts for t>10 μseconds



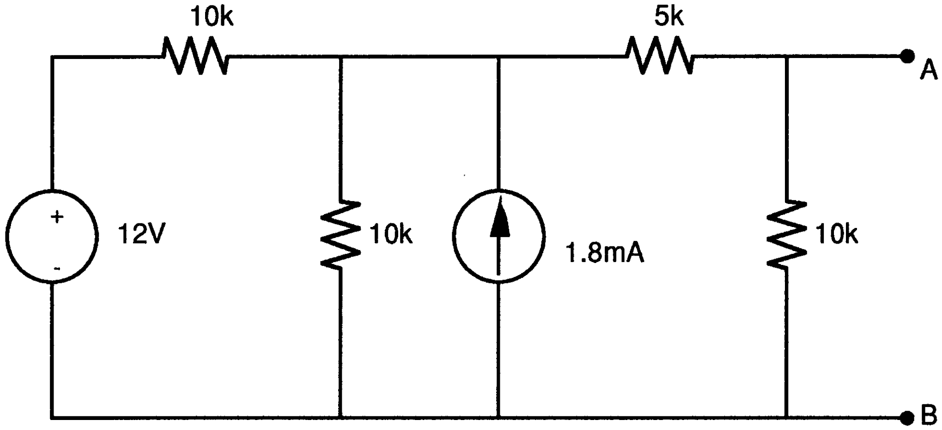
Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_3.ps.732547303
Submitted at:	Fri Mar 19 08:35:35 19931993
Printed at:	Fri Mar 19 08:35:36 1993

flm@util
quiz_3.ps.732547303

Name: ____________________ SSN: ______________________

Quiz #3 SOLUTIONS
EEAP 244 February 8, 1993

1. Determine the open circuit voltage, the short circuit current, and the thevenin equivalent resistance for the circuit shown below.



Answer:

For the open circuit voltage this problem can be done by assigning node 1 to the junction of the 10k resistors and the current source and node 2 to the junction at the output, i.e. A.

At node 1, with + representing current into the node,

$$+\frac{12-V_1}{10}-\frac{V_1}{10}+1.8\text{ mA}+\frac{V_2-V_1}{5}=0$$

At node 2, with + representing current into the node,

$$-\frac{V_2-V_1}{5}-\frac{V_2}{10}=0$$

These equations can be readily solved:

$12-V_1-V_1+18+2V_2-2V_1=0$

$-2V_2+2V_1-V_2=0$

Simplifying and re-arranging these equations:

$-2V_1+2V_2=-30$ volts

$2V_1-3V_2=0$

which has solution $V_2=+7.5$ volts.

For the short-circuit current, the output short bypasses the 10k resistor between A and B. Keeping the same node assignments KCL at node 1 can be writted as:

$$+\frac{12-V_1}{10}-\frac{V_1}{10}+1.8\text{ mA}-\frac{V_1}{5}=0$$

which is a single equation in only V_1. Solving for V_1 gives $V_1=+7.5$ volts. The short circuit current is then

$$i_{sc}=\frac{7.5\text{ V}}{5\text{ k}\Omega}=1.5\text{ mA}$$

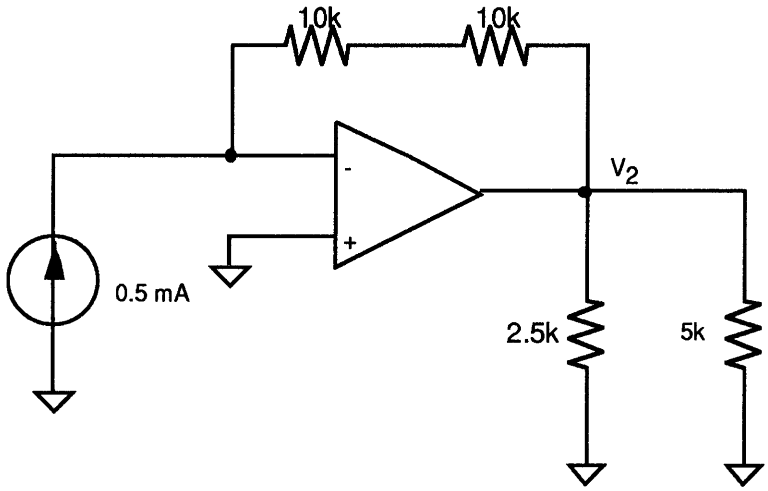
and the Thevenin resistance is

2. (a) For the circuit as shown below determine V_2. NOTE: State any assumptions.

Name: ________________ SSN:___________________

(b) If you place a short from V_2 to ground, what is the short circuit output current? Is there any current going through the op-amp output terminal?

(c) What is the Thevenin equivalent circuit for the op-amp at the output terminal, i.e. at V_2.



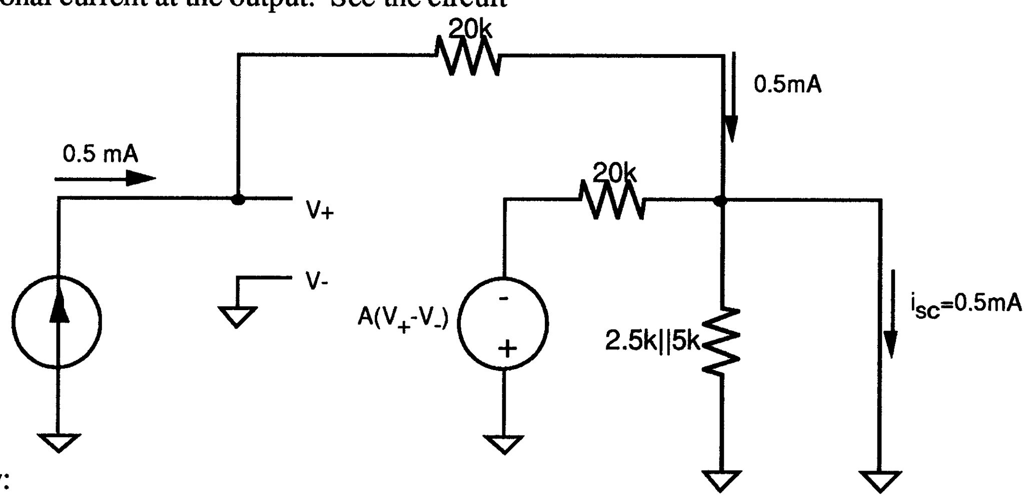
Answer:

(a) The important asumption is the virtual ground assumption (e.g., the virtual short) at the input. Using KCL at the - (i.e., inverting) input of the op-amp:

$$\frac{V_2 - 0}{20k} = 0.5 \text{ mA}$$

Solving for V_2 gives V_2=10 volts.

(b) By inspection, the short circuit current is the 0.5 ma coming from the input current source. Reasoning: the short bypasses the 2.5k and 5k load resistors. The only place any other current could come from is the op-amp itself. Since the voltage input is zero, the voltage source (in its equivalent circuit) is not producing any voltage and, thus, there is no additional current at the output. See the circuit



below:

As an aside, if you throw aside the ideal op-amp assumptions you will have some current from the op-amp. Problems 6.34 and 6.35 show this. For example, in 6.34 there is a 500k input resistance to the op-amp (between the V_+ and V_- terminals). This allows an input current into the op-amp input (you must use KCL at the V_- input to solve the problem), voltage across the input terminals (i.e., the virtual short assumption is not applicable if you have an input resistance), and you would have a current output from the op-amp if it were used in this problem. By the way, 6.34 was an assigned problem. Have a TA show you how to do it. If you want a similar problem to try do 6.35.

(c) No current goes through the op-amp because of the short. R_T is then given by 10volts/0.5ma=20kΩ

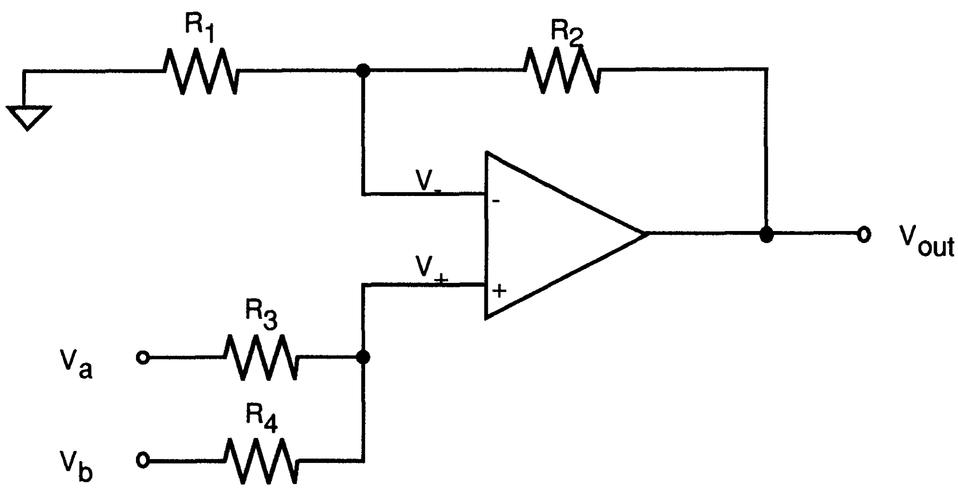
Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_4.ps.732547293
Submitted at:	Fri Mar 19 08:37:07 19931993
Printed at:	Fri Mar 19 08:37:07 1993

flm@util
quiz_4.ps.732547293

Name: ____________________ SSN:______________________

Quiz #4 SOLUTIONS
EEAP 244 February 15, 1993

1. You are given that R_1=5kΩ, R_2=10kΩ, R_3=47kΩ, and R_4=33kΩ for the op-amp circuit shown below. Assuming that the op-amp is ideal, what is vout if v_a=5 volts and v_b=3 volts?



Solution:
The formulas for this op-amp are relatively straight forward. Using KCL (+ in) at the + input of the op-amp:

$$\frac{v_a - V_+}{R_3} + \frac{v_b - V_+}{R_4} = 0$$

$$\frac{5 - V_+}{47k} + \frac{3 - V_+}{33k} = 0$$

And, solving for V_+,

$$165 - 33v_+ + 141 - 47v_+ = 0$$

giving

$$v_+ = 3.825 \text{ volts}$$

Since $V_- = V_+$ (the virtual short assumption) we proceed to the voltage divider at the inverting input to get

$$v_- = v_{out}\frac{R_1}{R_1 + R_2}$$

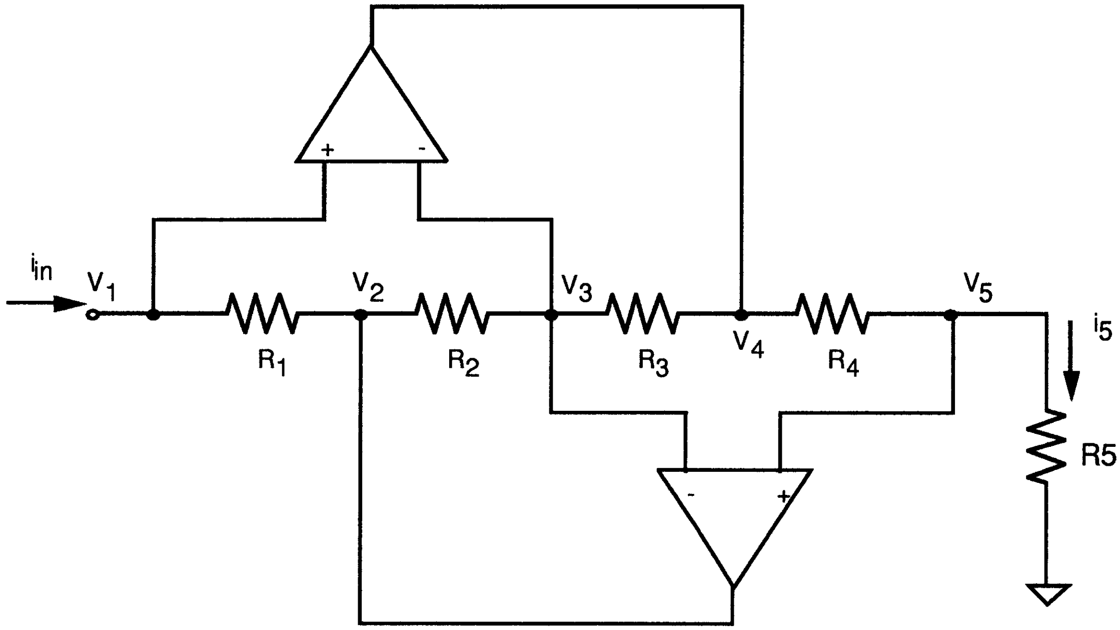
and, substituting,

$$v_{out} = v_-\frac{R_1 + R_2}{R_1} = 3.825\frac{5+10}{5} = 11.475 \text{ volts}$$

One of the biggest problems on this problem was PSC (Passive sign convention); the seconds biggest was units (dealing with kΩ).

Name: ____________________ SSN:________________________

2. <u>This is a tough problem.</u> You are given the following circuit which contains only ideal, identical op-amps and told i_5=1A. What is the value of i_{IN}, V_1, and $R_T=V_1/i_{IN}$?



Answer: Since the op-amps are ideal they must satisify the virtual short assumption, i.e. that V+=V- for each op-amp. This means that V1=V3=V5=1(R5)=R5 (assuming that i_5=1amp). I know V1 and the only problem left is to determine the currents. The current through R4 must also be 1A since no current can enter the op-amp. This means that V4=1(R4)+V5=R4+R5. The current through R3 is then given by KVL.

$$i_3=\frac{V_3-V_4}{R3}=\frac{V_5-V_4}{R3}=\frac{R5-(R4+R5)}{R3}=\frac{R5-(R4+R5)}{R3}=\frac{-R4}{R3}$$

The voltage at V3 is known. The voltage at V2 is then given by

$$V_2=i_2R2+R5=\frac{-R4}{R3}R2+R5=\frac{-R2R4+R3R5}{R3}$$

The input current is then given by

$$i_{in}=\frac{1(R5)-V_2}{R1}=\frac{1(R5)+\frac{R2R4-R3R5}{R3}}{R1}=\frac{R2R4}{R1R3}$$

The input resistance is then

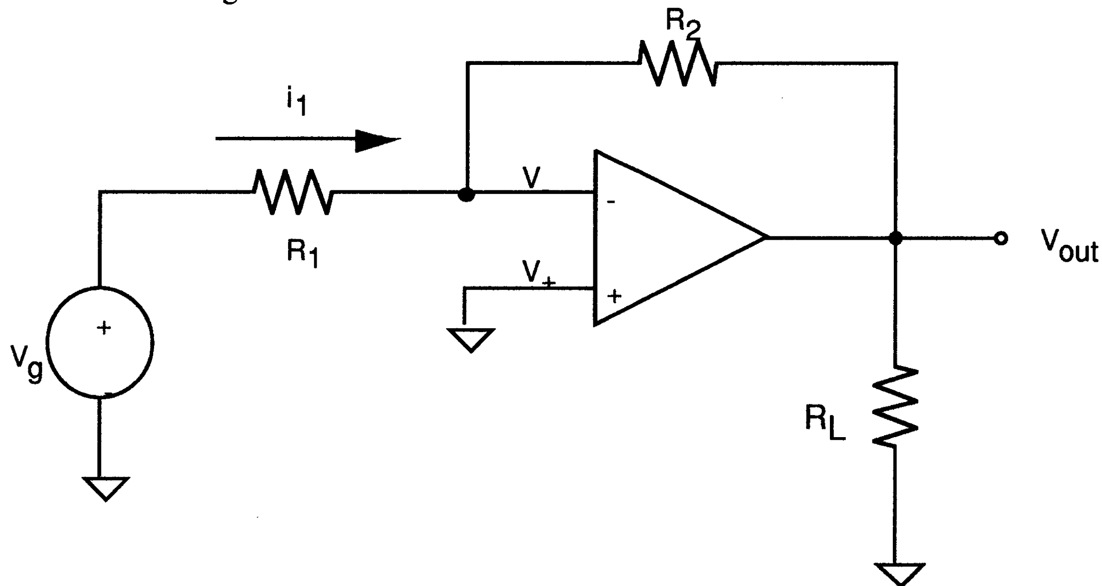
$$R_T=\frac{V_5}{i_{in}}=\frac{R5}{\frac{R2R4}{R1R3}}=\frac{R1R3R5}{R2R4}$$

In grading, I basically looked for the virtual short assumption (e.g., V5=V3=V1). I then looked for use of KCL at nodes 2 and 4. Finally, I checked to see if you included an op-amp output current in your calculations. Each of these was worth approximately 10 points.

Name: ____________________ SSN:______________________

3. This is a long problem. You are given the following circuit values for the circuit shown below.

R1=2KΩ;
R2=180kΩ;
RL=1600Ω
Vg=100mV



(a) Assuming an ideal op-amp, determine the values of v_{out}, i_1 and the Thevenin input resistance $R_T=V_g/i_1$.

The operational amplifier is no longer ideal. It has an open loop gain of 250,000, an input resistance of 500kΩ, and an output resistance of 5kΩ.

(b) Draw the new circuit explicitly showing the non-ideal model for the op-amp.
(c) Determine the voltages v_- and v_{out}.
(d) What is the new value of the Thevenin resistance?

Answer:
(a) Since the amplifier is ideal you can use the virtual ground assumption for V-. The input current is then given by

$$i_1 = \frac{V_g - V_-}{R1} = \frac{0.1-0}{2000} = 50\times10^{-6}\text{Amps}$$

This is also the current through R2 and the output voltage Vo can be found to be

$V_o = -i_1R_2 = -(50\times10^{-6})(180\times10^{3}) = -9$ volts

Rt is, quite simply,

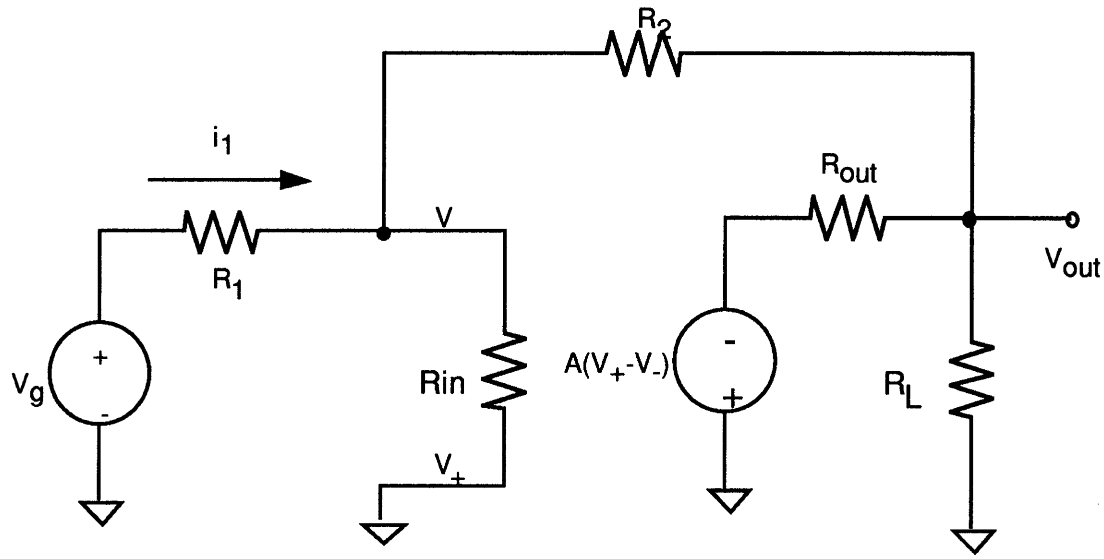
$$R_T = \frac{V_g}{i_1} = \frac{0.1\,\text{volts}}{50\mu A} = 2000\Omega$$

I took points off for the sign of the output voltage. A number of people got the amount of current wrong or attempted to calculate Thevenin output resistance.

(b) The complete non-ideal equivalent circuit is:

below:

Name: ____________________ SSN:________________________



I looked for the sign of the op-amp voltage source and took points off for it.

(c) The non-ideal op-amp can only be solved by setting up KCL at the input and output nodes of the op-amp as follows:

$$\frac{V_g - V_-}{R1} - \frac{V_-}{Rin} + \frac{V_0 - V_-}{R2} = 0$$

$$-\frac{V_o - V_-}{R2} - \frac{V_0 + AV_-}{Rout} - \frac{V_0}{RL} = 0$$

Many people did not get these equations right. The biggest mistake was PSC (passive sign convention). The second biggest mistake was combining voltages and currents.

Now, after substitution,

$$\frac{V_g - V_-}{2k} - \frac{V_-}{500k} + \frac{V_0 - V_-}{180k} = 0$$

$$-\frac{V_o - V_-}{180k} - \frac{V_0 + AV_-}{5k} - \frac{V_0}{1600} = 0$$

and re-arranging,

$$\left(-\frac{1}{2k} - \frac{1}{500k} - \frac{1}{180k}\right)V_- + \left(\frac{1}{180k}\right)V_o = -\frac{V_g}{2k}$$

$$\left(\frac{1}{180k} - \frac{A}{5k}\right)V_- + \left(\frac{1}{180k} - \frac{1}{5k} - \frac{1}{1.6k}\right)V_o = 0$$

These equations are solved to give V-=0.001473 volt and Vo=-8.987

(d) The input impedance is given quite simply as

$$R_T = \frac{V_g}{i_g} = \frac{V_g}{\frac{V_g - V_-}{R1}} = \frac{0.1}{\frac{0.1 - 0.0014}{2k}} = 2003\Omega$$

Name: ____________________ SSN:________________________

A lot of people calculated the Thevenin output resistance. The input was asked for in the problem and a circuit such as the one in this problem can have an output AND an input Thenevin resistance.

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_5.ps.732547286
Submitted at:	Fri Mar 19 08:39:23 19931993
Printed at:	Fri Mar 19 08:39:24 1993

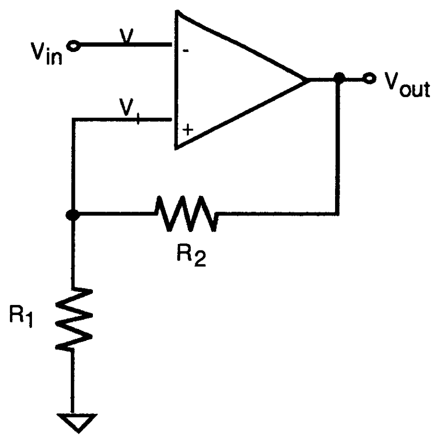
flm@util
quiz_5.ps.732547286

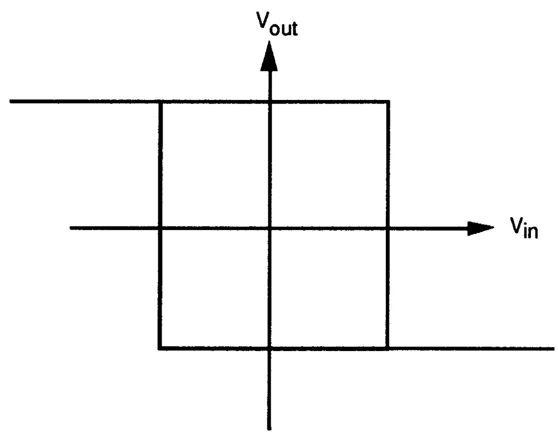
Name: ___________________ SSN: ______________________

Quiz #5 SOLUTIONS
EEAP 244

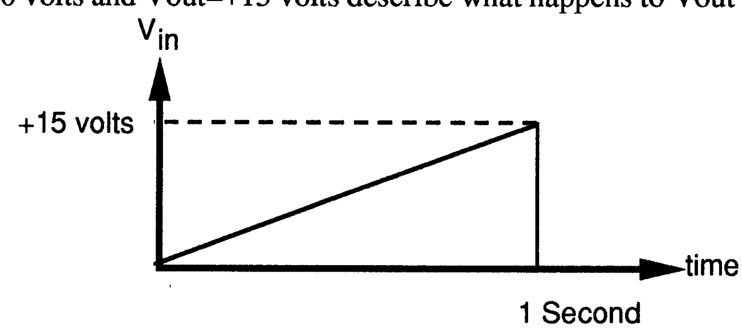
February 22, 1993

1. Answer the following questions about the Schmitt trigger circuit shown below.





(a) If Vin=0 volts and Vout=+15 volts describe what happens to Vout if Vin(t) is:



Answer: The output voltage will remain constant at +15 as Vin increases to the trip voltage (determined by R1 and R2). When Vin reaches this trip voltage, the V- input of the op-amp will dominate the V+ input and the output will change to -15 volts and will remain there.

(b) Using the input/output diagram at the above right, explain hysteresis as it applies to a Schmitt trigger. How can you change it in the given circuit.

Answer: Hysteresis is the difference between the upper and lower trip points. Basically, the circuit will trip at different voltages depending upon the current output voltage and the direction of the voltage, i.e. is it increasing or descreasing. The trip voltage is determined by the voltage divider relationship

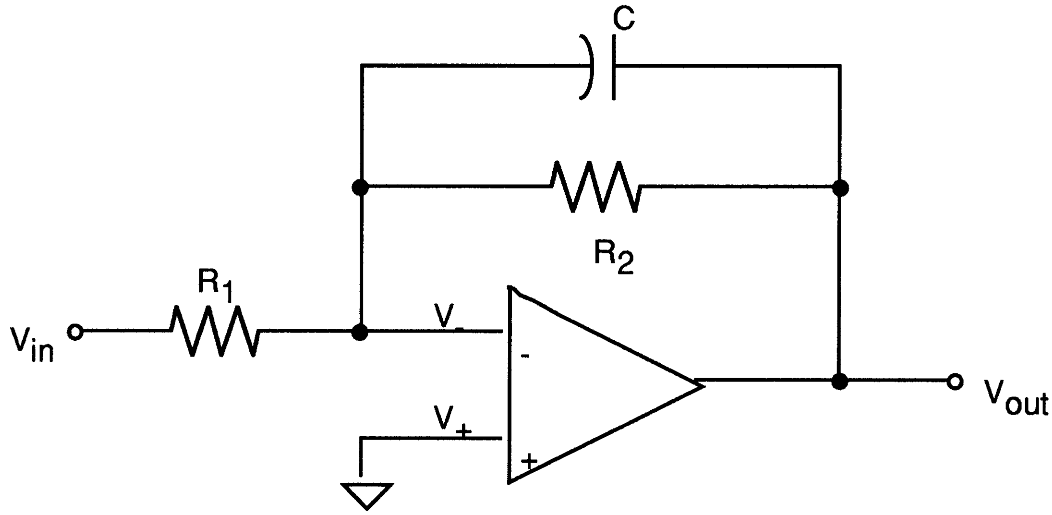
(c) How could you modify the above circuit so that the circuit operation is no longer centered about zero.

Name: ____________________ SSN:______________________

Answer: By connecting a voltage source through a resistance to the non-inverting input, or, alternatively, by connecting a battery to the grounded end of R1.

Name: ____________________ SSN: ______________________

2. The figure below is a circuit for an inverting amplifier designed to be used as a filter. The input is the complex signal $V_{in}(t)=\text{Re}\{V_i e^{jwt}\}$.



You are to:

(a) determine the response, $V_{out}(t)=\text{Re}\{V_o e^{jwt}\}$.

Answer:

Use KCl at the inverting node to get $\frac{V_{in}-0}{R_1}+\frac{V_{out}-0}{Z}=0$ where

$$Z = R_2 || \frac{1}{j\omega C} = \frac{R_2\frac{1}{j\omega C}}{R_2+\frac{1}{j\omega C}} = \frac{R_2}{j\omega C R_2+1} = \frac{R_2}{1+j\omega R_2 C}.$$ Solving for V_{out} gives

$V_{out} = -\frac{Z}{R_1}V_{in}$ which is the same formula we have derived before except that when we worked with resistive circuits we had $V_{out} = -\frac{R_2}{R_1}V_{in}$.

Using our expression for Z in our expression for V_{out} we get

$$V_{out} = -\frac{\frac{R_2}{1+j\omega R_2 C}}{R_1}V_{in} = \frac{-\frac{R_2}{R_1}}{1+j\omega R_2 C}V_{in} = \frac{-\frac{R_2}{R_1}}{\sqrt{1+(\omega R_2 C)^2}\,e^{j\theta}}V_{in}$$

$$= \frac{-\frac{R_2}{R_1}}{\sqrt{1+(\omega R_2 C)^2}}e^{-j\theta}V_{in} = \frac{-\frac{R_2}{R_1}}{\sqrt{1+(\omega R_2 C)^2}}e^{-j\theta}V_i e^{j\omega t}$$

$$= \frac{-\frac{R_2}{R_1}}{\sqrt{1+(\omega R_2 C)^2}}e^{-j\theta}V_i e^{j\omega t} = \frac{-\frac{R_2}{R_1}}{\sqrt{1+(\omega R_2 C)^2}}V_i e^{j(\omega t-\theta)}$$

Taking the real part, the solution is

Name: ____________________ SSN: ______________________

$$V_{out}(t) = \frac{-\frac{R_2}{R_1}}{\sqrt{1 + (\omega R_2 C)^2}} V_i \cos(\omega t - \theta)$$

(a) determine the magnitude of the response V_o.

Answer: Already done in the above answer.

INS TCP/IP PrintServer 20

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	28
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_6.ps.732547278
Submitted at:	Fri Mar 19 08:40:51 19931993
Printed at:	Fri Mar 19 08:40:51 1993

flm@util
quiz_6.ps.732547278

digital

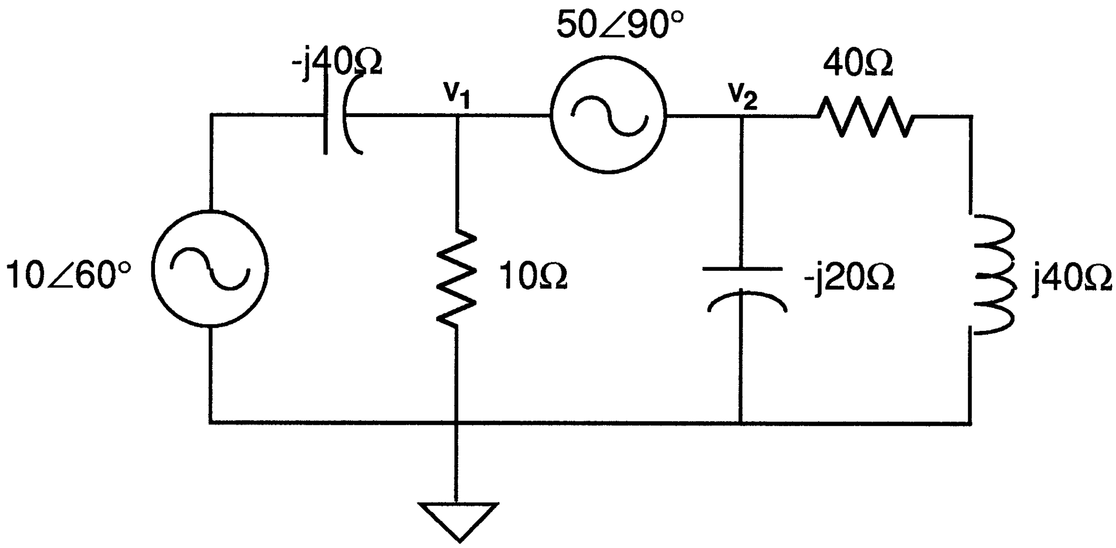
Name: ____________________ SSN: ______________________

Quiz #6 SOLUTIONS
EEAP 244

March 1, 1993

1. Solve for node voltages V1 and V2 in the circuit shown below. Define any circuit variables you use on the circuit drawing.

WARNING: The math in this problem can easily get out of hand. Set up the equations, reduce the problem to two equations in two unknowns, and leave the answer in that form.



HINT: The 50∠90° voltage source defines a constraint between V1 and V2. Define a new circuit variable as the current through the 50∠90° voltage source and solve the resulting set of equations.

Answer:
Using KCL at V1:

$$-\frac{10\angle 60^\circ - V_1}{-j40} + \frac{V_1}{10} + I_s = 0$$

Using KCL at V1:

$$-I_s + \frac{V_2}{-j20} + \frac{V_2}{40+j40} = 0$$

Now, adding the constraint,

$$V_1 = 50\angle 90^\circ + V_2$$

This defines three equations in three unknowns which can be solved.

The resulting KCL equations are then:

$$\left(\frac{1}{-j40} + \frac{1}{10}\right)V_1 + I_s = \frac{10\angle 60^\circ}{j40} = 0.25\angle -30^\circ$$

$$\left(\frac{1}{-j20} + \frac{1}{40+j40}\right)V_2 - I_s = 0$$

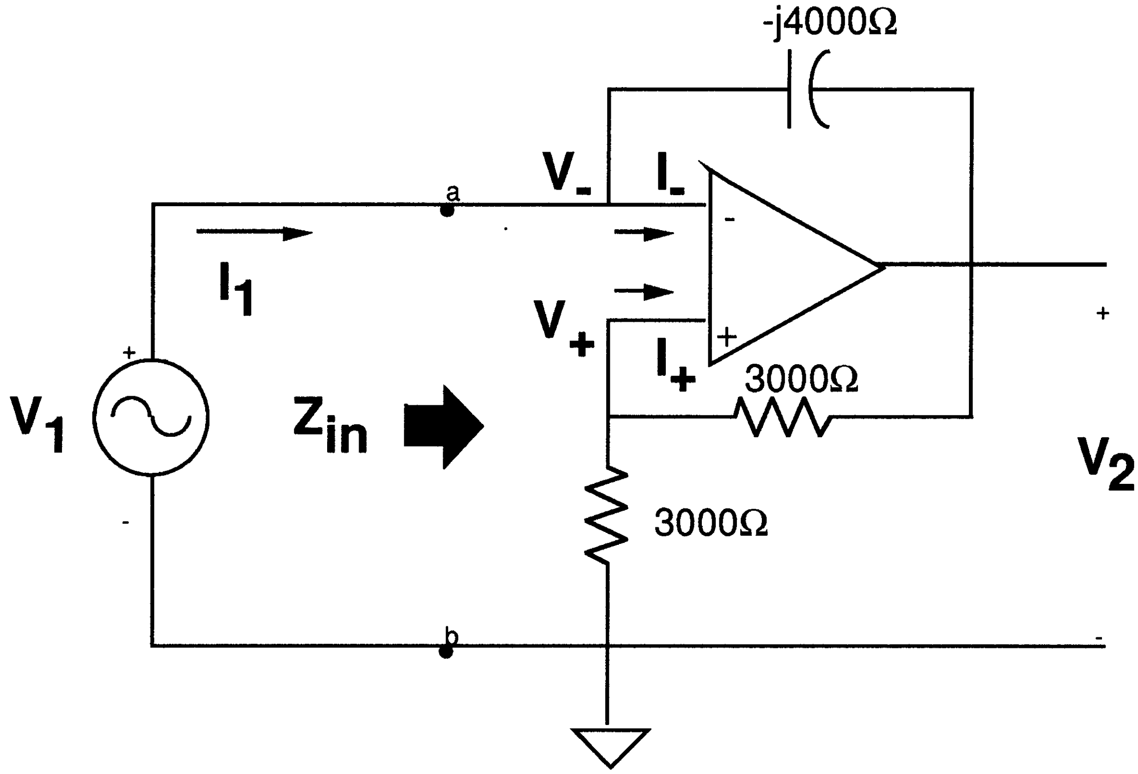
Name: ____________________ SSN:______________________

You can eliminate I_s by adding the two equations to get:
$(0.1+j0.025)V_1 - (0.0125+j0.0375)V_2 = 0.25\angle{-30^\circ}$
which, when combined with the constraint equation
$V_1 - V_2 = 50\angle 90^\circ$
gives two equations in two unknowns. Your answer should have been
$(0.1+j0.025)V_1 - (0.0125+j0.0375)V_2 = 0.25\angle{-30^\circ}$
$V_1 - V_2 = 50\angle 90^\circ$

This system can be solved (I did it on my HP-48) to give
$V_1=25.1\angle{-11.6^\circ}$ volts and $V_2=60.3\angle{-65.9^\circ}$ volts

Name: ____________________ SSN: ______________________

2. Your overall task in this problem is to determine the input impedance $\mathbf{Z_{in}}$ seen at terminals a-b. You are given that $\mathbf{V_1}=0.1\angle 70°$.



(a) The op-amp is ideal. What is is voltage $\mathbf{V_-}$ at the (-) input of the op-amp? What is the current $\mathbf{I_-}$ entering the (-) input of the op-amp? Why?

Answer: Because the op-amp is ideal I_- is zero. Furthermore, since the voltage source is directly connected to the inverting (-) input, $V_-=0.1\angle 70°$ volts.

(b) What is the voltage $\mathbf{V_+}$ at the (+) input of the op-amp? What is the current $\mathbf{I_+}$ entering the (+) input of the op-amp?

Answer: Because the op-amp is ideal you use the virtual short assumption to realize that $V_+=V_-=0.1\angle 70°$ Furthermore, since both inputs are ideal $I_+=0$.

(c) What is the output voltage $\mathbf{V_2}$?

Name: ____________________ SSN: ______________________

Answer: This now requires that you use KCL at the non-inverting input of the op-amp just as you did in the Schmitt trigger. The current through the 3000Ω resistor to ground is then

$$I = \frac{V_+}{3000\Omega} = \frac{0.1\angle 70°}{3000\Omega} = 33.6\angle 70° \ \mu\text{amps}$$

The output voltage V_2 is then

$$V_2 = (33.6\times 10^{-6}\angle 70°)3000\Omega + 0.1\angle 70° = 0.2\angle 70° \text{ volts}$$

Knowing V_- and V_2 you can calculate the current through the feedback resistor as

$$I_1 = \frac{V_2 - V_-}{-j4000} = \frac{0.2\angle 70° - 0.1\angle 70°}{-j4000} = 25\times 10^{-6}\angle 160° \text{ amps}$$

(d) What is the input impedance defined as $\mathbf{Z_{in}=V_1/I_1}$?

Answer:

The input impedance is simply

$$Z_{in} = \frac{V_1}{I_1} = \frac{0.1\angle 70°}{25\times 10^{-6}\angle 160°} = 2000\angle{-90°} \text{ ohms}$$

Name: ____________________ SSN: ______________________

Quiz #7 SOLUTIONS
EEAP 244

March 25, 1993

1. (40 points) Determine f(t) for the following expressions:

(a) $F(s) = \frac{12}{s^2 + 8s + 12}$

Answer:

$F(s) = \frac{12}{s^2 + 8s + 12} = \frac{12}{(s+2)(s+6)} = \frac{a}{s+2} + \frac{b}{s+6}$

Multiplying out and equating coefficients of s:

$a(s+6) + b(s+2) = s(a+b) + (6a+2b) = 12$

This gives two equations in two unknowns:

$a + b = 0$

$3a + b = 6$

which can be solved to give a=3 and b=-3.

$F(s) = \frac{3}{s+2} - \frac{3}{s+6}$

Inverse transforming,

$f(t) = 3e^{-2t}u(t) - 3e^{-6t}u(t)$

(b) $F(s) = \frac{300}{s(s+10)^2}$

Answer: This was assigned problem 15.24(a).

$F(s) = \frac{300}{s(s+10)^2} = \frac{a}{s} + \frac{b}{(s+10)^2} + \frac{c}{s+10}$

Multiplying out and equating coefficients of s:

$a(s+10)^2 + bs + c(s+10) = s^2(a+c) + s(20a+b+10c)+(100a) = 300$

By inspection, a=3. It then follows that c=-3 and b=-30

The partial fraction expansion is then:

$F(s) = \frac{3}{s} - \frac{30}{(s+10)^2} - \frac{3}{s+10}$

The inverse transform of this expression is then:

$f(t) = 3u(t) - 30te^{-10t}u(t) - 3e^{-10t}u(t)$

You lost 10 points if you did not have the $\frac{c}{s+10}$ term present in your expression.

Name: ____________________ SSN:______________________

2. (30 points) A student has arrived at the following integro-differential equation in analyzing a RLC circuit. Determine V(s) for this equation. Assume $v(0^-)=0$.

$$\frac{dv(t)}{dt} + 6v(t) + 9\int_0^t v(z)dz = 24(t-2)u(t-2)$$

Answer:
Transforming term by term

$$sV(s) - v(0^-) + 6V(s) + 9\frac{V(s)}{s} = 24e^{-2s}\frac{1}{s}$$

Since the initial condition was zero this reduces to

$$sV(s) + 6V(s) + 9\frac{V(s)}{s} = 24e^{-2s}\frac{1}{s}$$

Solving for V(s)

$$V(s)\left[s + 6 + \frac{9}{s}\right] = 24\frac{e^{-2s}}{s}$$

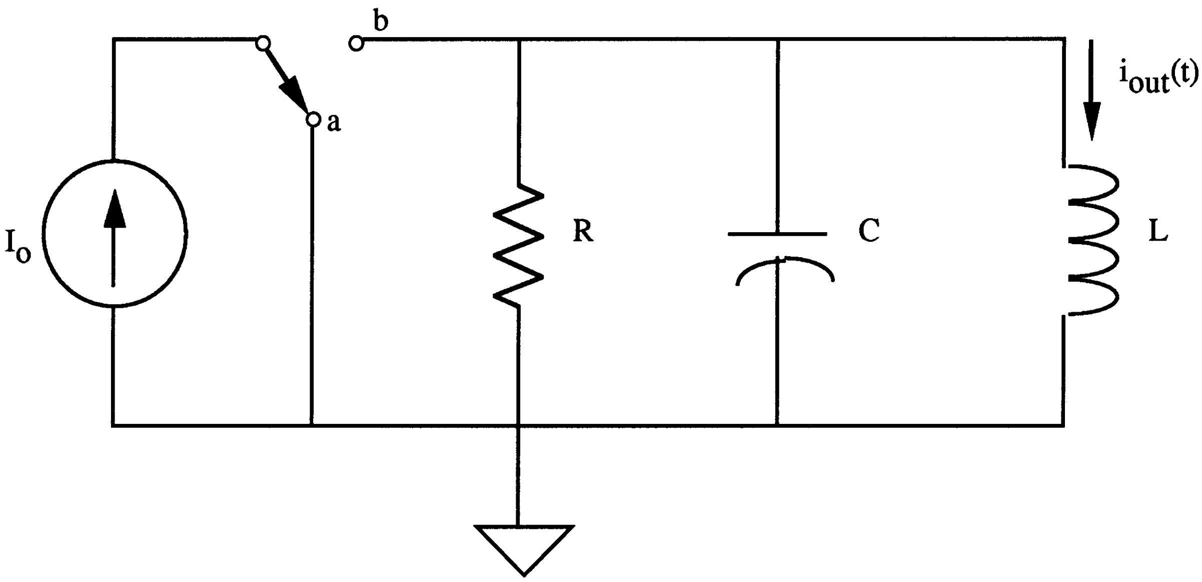
$$V(s)\left[\frac{s^2 + 6s + 9}{s}\right] = 24\frac{e^{-2s}}{s}$$

$$V(s) = 24\frac{e^{-2s}}{s^2 + 6s + 9}$$

You lost 15 points for not properly Laplace transforming the right side of the equation. The same number of points was alloted for the left hand side and everything else.

Name: ___________________ SSN:______________________

3. (30 points) Determine an expression for $I_{out}(s)$ if the switch moves from a to b at t=0. I_o is a constant. Assume all initial conditions are zero.



Answer: This was assigned problem 15.21
You can solve for the output current by any of a number of techniques. I will use KCL at the node connected to B. The source looks like a current source with a unit step. The short at a is necessary since an ideal current source ALWAYS puts out the same current irregardless of the load.

$$\frac{I_o}{s} = \frac{V_b}{R} + \frac{V_b}{\frac{1}{sC}} + \frac{V_b}{sL} = V_b\left(\frac{1}{R} + sC + \frac{1}{sL}\right)$$

$$V_b = \frac{\frac{I_o}{s}}{\left(\frac{1}{R} + sC + \frac{1}{sL}\right)}$$

$$I_{out}(s) = \frac{V_b}{sL} = \frac{\frac{1}{sL}\frac{I_o}{s}}{\frac{1}{R} + sC + \frac{1}{sL}} = I_o\frac{\frac{1}{LC}}{s\left(s^2 + \frac{s}{RC} + \frac{1}{LC}\right)}$$

-5 points for not properly representing the source with a unit step
-8 points for not relating the voltage at node B and i_{out}, i.e. Ohm's Law

EEAP 244 Electrical Circuits, Signals and Systems

An Abbreviated List of Laplace Transform Pairs

f(t) (t>0-)	TYPE	F(s)
$d(t)$	(impulse)	1
$u(t)$	(step)	$\frac{1}{s}$
t	(ramp)	$\frac{1}{s^2}$
e^{-at}	(exponential)	$\frac{1}{s+a}$
$\sin(\omega t)$	(sine)	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	(cosine)	$\frac{s}{s^2+\omega^2}$
te^{-at}	(damped ramp)	$\frac{1}{(s+a)^2}$
$e^{-at}\sin(\omega t)$	(damped sine)	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos(\omega t)$	(damped cosine)	$\frac{s+a}{(s+a)^2+\omega^2}$

An Abbreviated List of Operational Transforms

f(t)	F(s)
$Kf(t)$	$KF(s)$
$f_1(t)+f_2(t)-f_3(t)+\ldots$	$F_1(s)+F_2(s)-F_3(s)+\ldots$
$\frac{df(t)}{dt}$	$sF(s)-f(0^-)$
$\frac{d^2f(t)}{dt^2}$	$s^2F(s)-sf(0^-)-\frac{df(0^-)}{dt}$
$\frac{d^nf(t)}{dt^n}$	$s^nF(s)-s^{n-1}f(0^-)-s^{n-2}\frac{df(0^-)}{dt}-s^{n-3}\frac{d^2f(0^-)}{dt^2}-\ldots-\frac{d^{n-1}f(0^-)}{dt^{n-1}}$
$\int_0^t f(x)dx$	$\frac{F(s)}{s}$
$f(t-a)u(t-a)$, $a>0$	$e^{-as}F(s)$
$e^{-at}f(t)$	$F(s+a)$
$f(at)$, $a>0$	$\frac{1}{a}f(\frac{s}{a})$
$tf(t)$	$-\frac{dF(s)}{ds}$
$t^nf(t)$	$(-1)^n\frac{d^nF(s)}{ds^n}$
$\frac{f(t)}{t}$	$\int_s^\infty F(u)du$

Name: ____________________ SSN: ________________________

Quiz #7 SOLUTIONS
EEAP 244

March 25, 1993

1. Determine f(t) for the following expressions:

(a) $F(s) = \frac{12}{s^2 + 8s + 12}$

Answer:

$$F(s) = \frac{12}{s^2 + 8s + 12} = \frac{12}{(s+2)(s+6)} = \frac{a}{s+2} + \frac{b}{s+6}$$

Multiplying out and equating coefficients of s:

$a(s+6) + b(s+2) = s(a+b) + (6a+2b) = 12$

This gives two equations in two unknowns:

$a + b = 0$

$3a + b = 6$

which can be solved to give a=3 and b=-3.

$$F(s) = \frac{3}{s+2} - \frac{3}{s+6}$$

Inverse transforming,

$f(t) = 3e^{-2t}u(t) - 3e^{-6t}u(t)$

(b) $F(s) = \frac{300}{s(s+10)^2}$

Answer: This was assigned problem 15.24(a).

$$F(s) = \frac{300}{s(s+10)^2} = \frac{a}{s} + \frac{b}{(s+10)^2} + \frac{c}{s+10}$$

Multiplying out and equating coefficients of s:

$a(s+10)^2 + bs + c(s+10) = s^2(a+c) + s(20a+b+10c)+(100a) = 300$

By inspection, a=3. It then follows that c=-3 and b=-30

The partial fraction expansion is then:

$$F(s) = \frac{3}{s} - \frac{30}{(s+10)^2} - \frac{3}{s+10}$$

The inverse transform of this expression is then:

$f(t) = 3u(t) - 30te^{-10t}u(t) - 3e^{-10t}u(t)$

You lost 10 points if you did not have the $\frac{c}{s+10}$ term present in your expression.

Name: ____________________ SSN: ________________________

2. (30 points) A student has arrived at the following integro-differential equation in analyzing a RLC circuit. Determine V(s) for this equation. Assume $v(0^-)=0$.

$$\frac{dv(t)}{dt} + 6v(t) + 9\int_0^t v(z)dz = 24(t-2)u(t-2)$$

Answer:
Transforming term by term

$$sV(s) - v(0^-) + 6V(s) + 9\frac{V(s)}{s} = 24e^{-2s}\frac{1}{s^2}$$

Since the initial condition was zero this reduces to

$$sV(s) + 6V(s) + 9\frac{V(s)}{s} = 24e^{-2s}\frac{1}{s^2}$$

Solving for V(s)

$$V(s)\left[s + 6 + \frac{9}{s}\right] = 24\frac{e^{-2s}}{s^2}$$

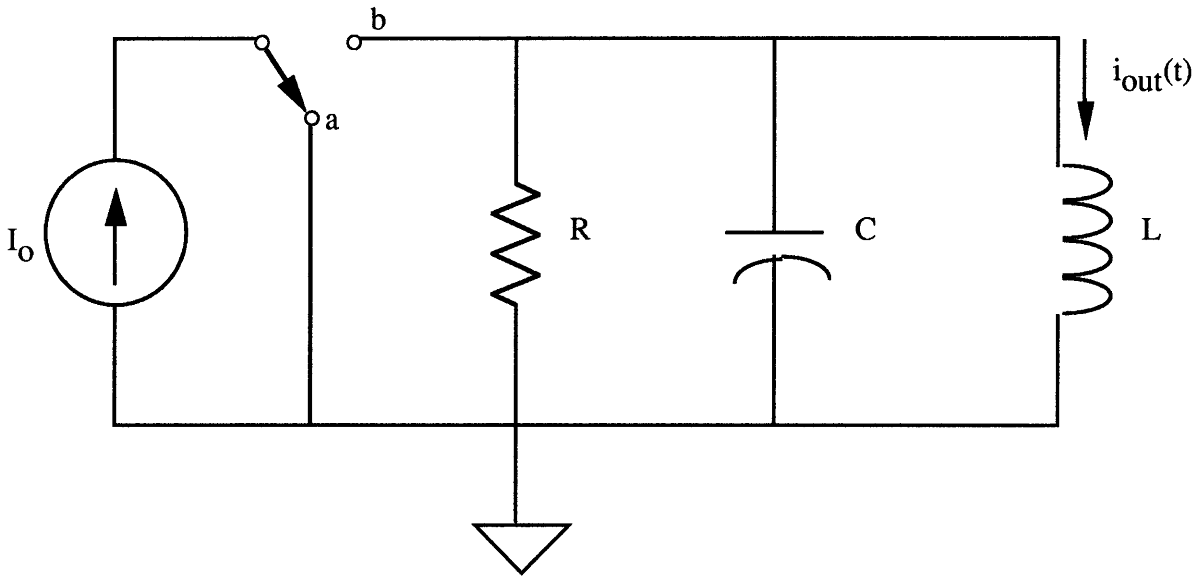
$$V(s)\left[\frac{s^2 + 6s + 9}{s}\right] = 24\frac{e^{-2s}}{s^2}$$

$$V(s) = 24\frac{e^{-2s}}{s\,(s^2 + 6s + 9)}$$

You lost 15 points for not properly Laplace transforming the right side of the equation. The same number of points was alloted for the left hand side and everything else.

Name: ____________________ SSN: ________________________

3. (30 points) Determine an expression for $I_{out}(s)$ if the switch moves from a to b at t=0. I_o is a constant. Assume all initial conditions are zero.



Answer: This was assigned problem 15.21
You can solve for the output current by any of a number of techniques. I will use KCL at the node connected to B. The source looks like a current source with a unit step. The short at a is necessary since an ideal current source ALWAYS puts out the same current irregardless of the load.

$$\frac{I_o}{s} = \frac{V_b}{R} + \frac{V_b}{\frac{1}{sC}} + \frac{V_b}{sL} = V_b\left(\frac{1}{R} + sC + \frac{1}{sL}\right)$$

$$V_b = \frac{\frac{I_o}{s}}{\left(\frac{1}{R} + sC + \frac{1}{sL}\right)}$$

$$I_{out}(s) = \frac{V_b}{sL} = \frac{\frac{1}{sL}\frac{I_o}{s}}{\frac{1}{R} + sC + \frac{1}{sL}} = I_o \frac{\frac{1}{LC}}{s\left(s^2 + \frac{s}{RC} + \frac{1}{LC}\right)}$$

-5 points for not properly representing the source with a unit step
-8 points for not relating the voltage at node B and i_{out}, i.e. Ohm's Law

An Abbreviated List of Laplace Transform Pairs

f(t) (t>0-)	TYPE	F(s)
d(t)	(impulse)	1
u(t)	(step)	$\frac{1}{s}$
t	(ramp)	$\frac{1}{s^2}$
e^{-at}	(exponential)	$\frac{1}{s+a}$
$\sin(\omega t)$	(sine)	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	(cosine)	$\frac{s}{s^2+\omega^2}$
te^{-at}	(damped ramp)	$\frac{1}{(s+a)^2}$
$e^{-at}\sin(\omega t)$	(damped sine)	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos(\omega t)$	(damped cosine)	$\frac{s+a}{(s+a)^2+\omega^2}$

An Abbreviated List of Operational Transforms

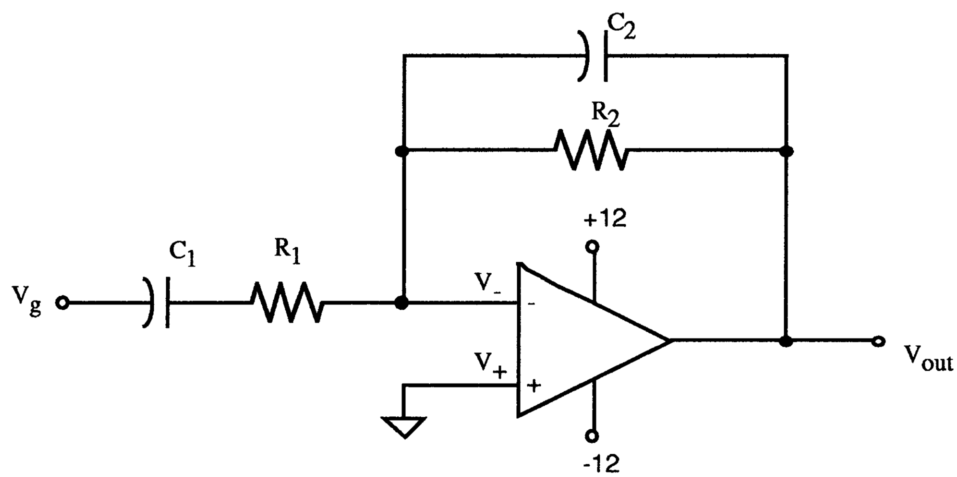
f(t)	F(s)
$Kf(t)$	$KF(s)$
$f_1(t)+f_2(t)-f_3(t)+\ldots$	$F_1(s)+F_2(s)-F_3(s)+\ldots$
$\frac{df(t)}{dt}$	$sF(s)-f(0^-)$
$\frac{d^2f(t)}{dt^2}$	$s^2F(s)-sf(0^-)-\frac{df(0^-)}{dt}$
$\frac{d^nf(t)}{dt^n}$	$s^nF(s)-s^{n-1}f(0^-)-s^{n-2}\frac{df(0^-)}{dt}-s^{n-3}\frac{d^2f(0^-)}{dt^2}-\ldots-\frac{d^{n-1}f(0^-)}{dt^{n-1}}$
$\int_0^t f(x)dx$	$\frac{F(s)}{s}$
$f(t-a)u(t-a)$, $a>0$	$e^{-as}F(s)$
$e^{-at}f(t)$	$F(s+a)$
$f(at)$, $a>0$	$\frac{1}{a}f\left(\frac{s}{a}\right)$
$tf(t)$	$-\frac{dF(s)}{ds}$
$t^nf(t)$	$(-1)^n\frac{d^nF(s)}{ds^n}$
$\frac{f(t)}{t}$	$\int_s^\infty F(u)du$

Name: ___________________ SSN:______________________

Quiz #8
EEAP 244

March 29, 1993

1. (60 points) The operational amplifier shown in the circuit below is ideal. There is no energy stored in the circuit at the time it is energized, i.e. the initial conditions for all capacitors is zero.



(a) What is the transfer function of the amplifier in the s-domain. You can leave your answer in terms of R_1, R_2, C_1 and C_2.

$$v_o = -\frac{Z_f}{Z_i} v_g$$

$$Z_f = R_2 \| \frac{1}{sC_2} = \frac{R_2 \frac{1}{sC_2}}{R_2 + \frac{1}{sC_2}} = \frac{R_2}{1 + sR_2C_2}$$

$$v_o = -\frac{Z_f}{Z_i} v_g = -\frac{\frac{R_2}{1 + sR_2C_2}}{\frac{1 + sR_1C_1}{sC_1}} v_g = -\frac{sR_2C_1}{(1 + sR_2C_2)(1 + sR_1C_1)} v_g$$

(b) the Laplace transform of the input $v_g(t)=tu(t)$ volts,

Name: ____________________ SSN:________________________

(c) Suppose the transfer function of the amplifier is $\frac{V_o(s)}{V_g(s)} = -\frac{200}{s}$, what is $v_o(t)$ for the input $v_g(t)=tu(t)$ volts? HINT: You may need to use the list of operational transforms provided.

(d) Suppose $v_o(t) = [-15 + 30e^{-1000t} - 15e^{-2000t}]u(t)$ volts . Will the operational amplifier saturate and, if so, when will it saturate?

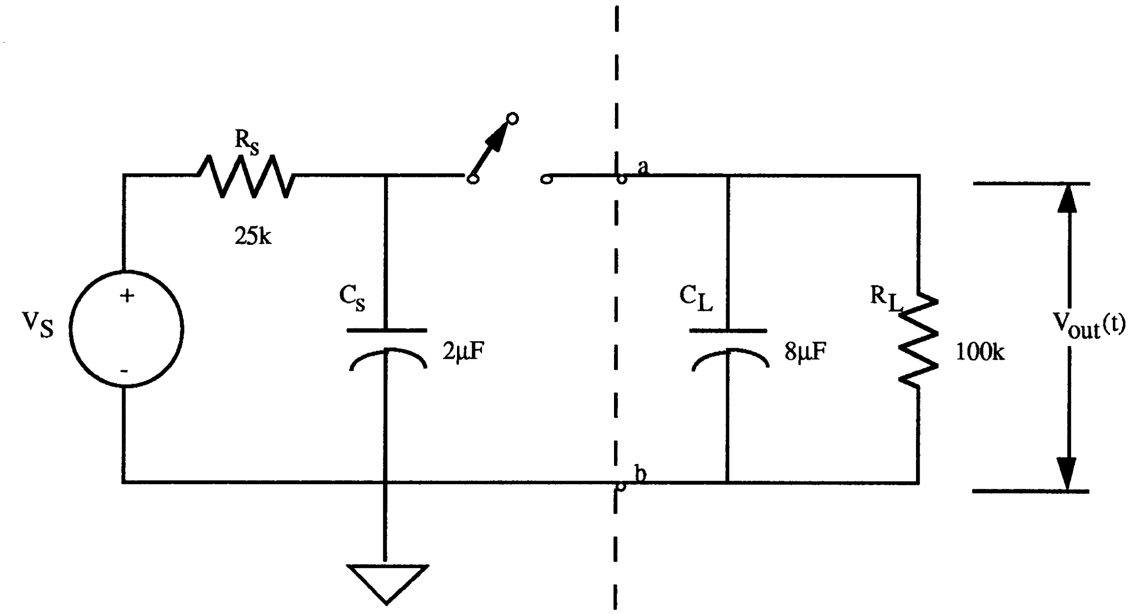
$-15 + 30e^{-1000t} - 15e^{-2000t} = -12$

$x = e^{-1000t}$ $15x^2 - 30x + 3 = 0$

$t = -\frac{\ln\left(1 - \sqrt{4/5}\right)}{1000} \approx 2.25 \text{ mS}$

Name: ____________________ SSN: ______________________

2. (40 points) Determine the s-domain Thevenin equivalent of the circuit to the left of the terminals a,b.



$$V_{thevenin} = \frac{50}{s}\,\frac{\frac{5\times10^5}{s}}{25\ 10^3 + \frac{5\times10^5}{s}} = \frac{50}{s}\,\frac{500}{25s+500} = \frac{50}{s}\,\frac{20}{s+20} = \frac{50}{s}\,\frac{20}{s+20} = \frac{1000}{s(s+20)}$$

$$Z_{thevenin} = \frac{(25\times10^3)\frac{5\times10^5}{s}}{25\ 10^3 + \frac{5\times10^5}{s}} = (25\times10^3)\,\frac{20}{s+20} = \frac{5\times10^5}{s+20}\ \text{ohms}$$

An Abbreviated List of Laplace Transform Pairs

$f(t)$ $(t>0^-)$	TYPE	$F(s)$
$d(t)$	(impulse)	1
$u(t)$	(step)	$\frac{1}{s}$
t	(ramp)	$\frac{1}{s^2}$
e^{-at}	(exponential)	$\frac{1}{s+a}$
$\sin(\omega t)$	(sine)	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	(cosine)	$\frac{s}{s^2+\omega^2}$
te^{-at}	(damped ramp)	$\frac{1}{(s+a)^2}$
$e^{-at}\sin(\omega t)$	(damped sine)	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos(\omega t)$	(damped cosine)	$\frac{s+a}{(s+a)^2+\omega^2}$

An Abbreviated List of Operational Transforms

$f(t)$	$F(s)$
$Kf(t)$	$KF(s)$
$f_1(t)+f_2(t)-f_3(t)+\ldots$	$F_1(s)+F_2(s)-F_3(s)+\ldots$
$\frac{df(t)}{dt}$	$sF(s)-f(0^-)$
$\frac{d^2f(t)}{dt^2}$	$s^2F(s)-sf(0^-)-\frac{df(0^-)}{dt}$
$\frac{d^nf(t)}{dt^n}$	$s^nF(s)-s^{n-1}f(0^-)-s^{n-2}\frac{df(0^-)}{dt}-s^{n-3}\frac{d^2f(0^-)}{dt^2}-\ldots-\frac{d^{n-1}f(0^-)}{dt^{n-1}}$
$\int_0^t f(x)dx$	$\frac{F(s)}{s}$
$f(t-a)u(t-a)$, $a>0$	$e^{-as}F(s)$
$e^{-at}f(t)$	$F(s+a)$
$f(at)$, $a>0$	$\frac{1}{a}f\left(\frac{s}{a}\right)$
$tf(t)$	$-\frac{dF(s)}{ds}$
$t^nf(t)$	$(-1)^n\frac{d^nF(s)}{ds^n}$
$\frac{f(t)}{t}$	$\int_s^\infty F(u)du$

Name: ____________________ SSN:________________________

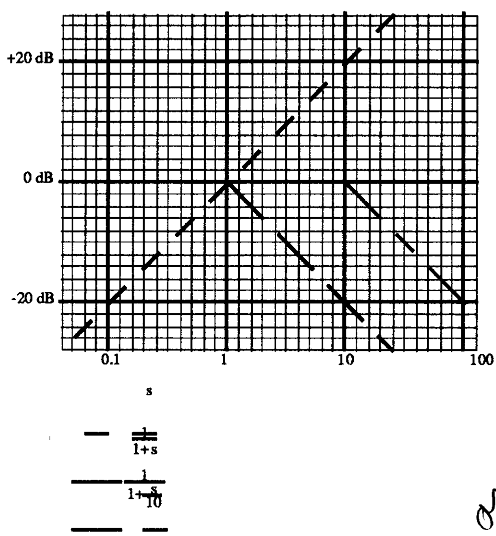
Quiz #9 SOLUTIONS
EEAP 244

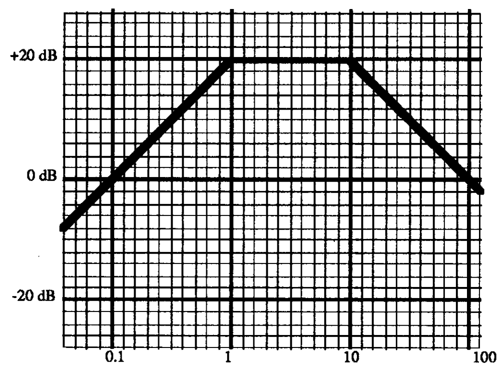
April 5, 1993

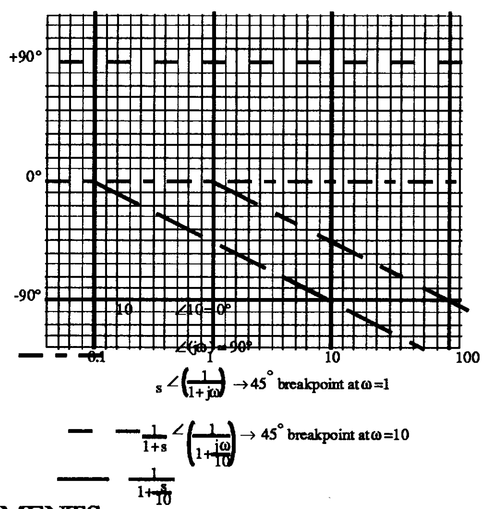
1. 60 points. Plot $|H(j\omega)|$ and $\angle H(j\omega)$, given that

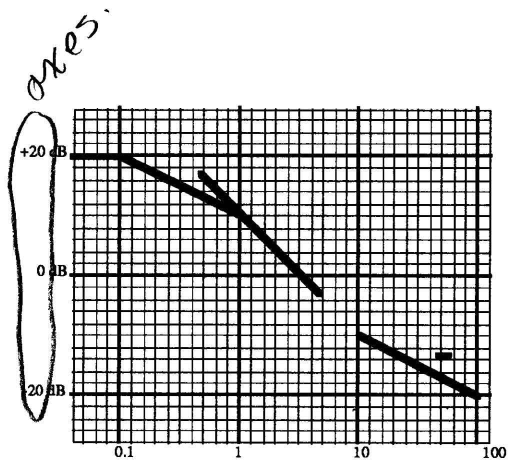
$$H(s) = \frac{10s}{(1+s)(1+\frac{s}{10})}$$

SOLUTIONS:









COMMENTS:
You lost 5 points for not labeling your graph, i.e. horizontal or vertical units.
You lost 5 points for not properly computing the overall phase response.
You lost 5 points for missing terms in each expression.

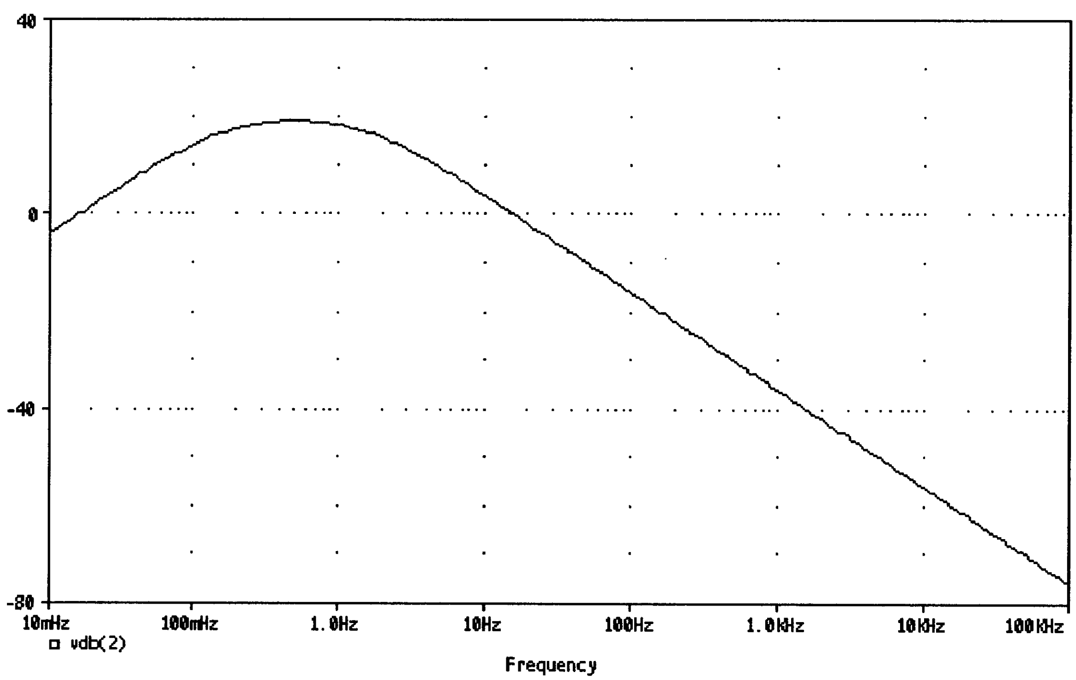
Name: ___________________ SSN:______________________

You lost 5 points for forgetting the $\angle 10\omega$ term.
You lost 10 points for using square phase response, i.e. constant phase. READ YOUR TEXTBOOK about this. The response is ±45° each side of the breakpoint.
You lost 20 points if you had some equations appropriate to the response but you did not plot them. The question explicitly told you the plot the responses.

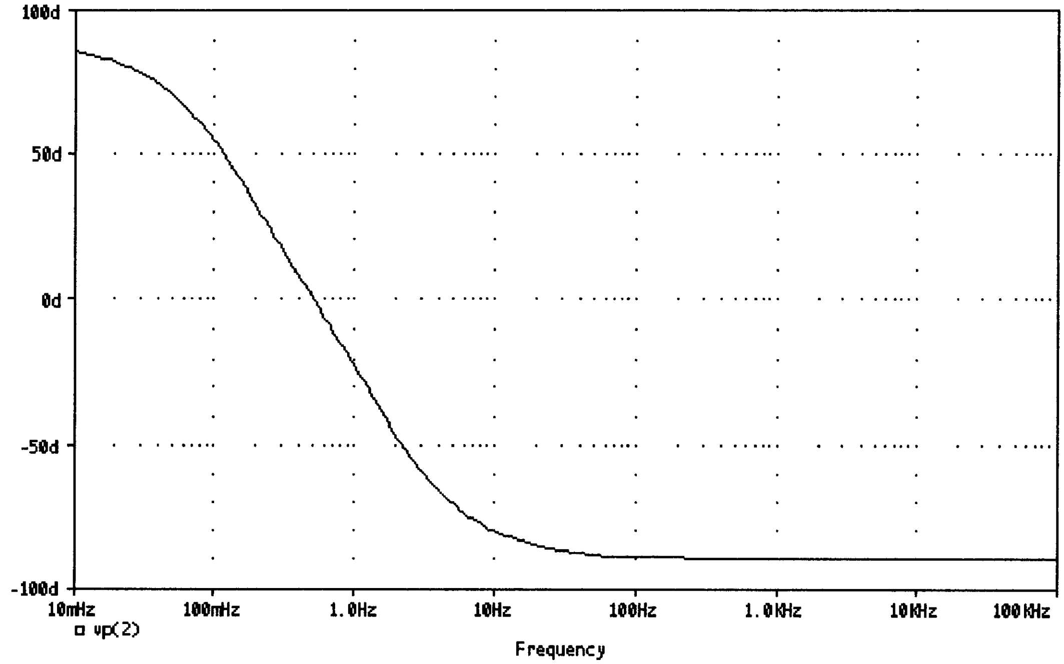
For interested people, here is the PSpice simulation of the circuit response:

```
Quiz 9 problem 1
Vin 1 0 ac 1
Rin 1 0 1
E1 2 0 laplace {v(1)}={10*s/((1+s)*(1+s/10))}
R1 2 0 1
.ac dec 40 .01 100K
.probe
.end
```

Plot of solutions

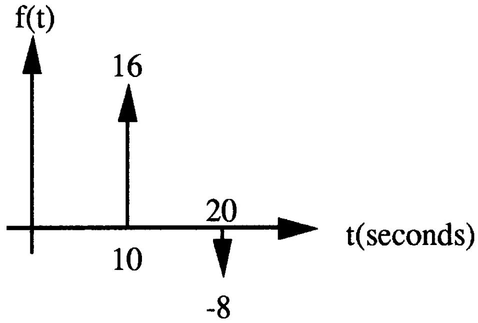


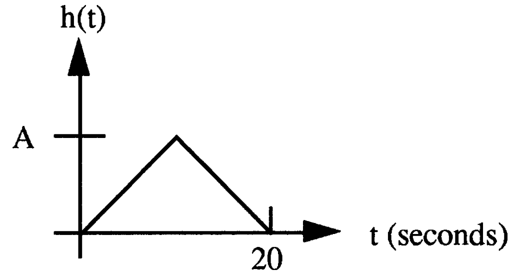
Name: ____________________ SSN: ______________________

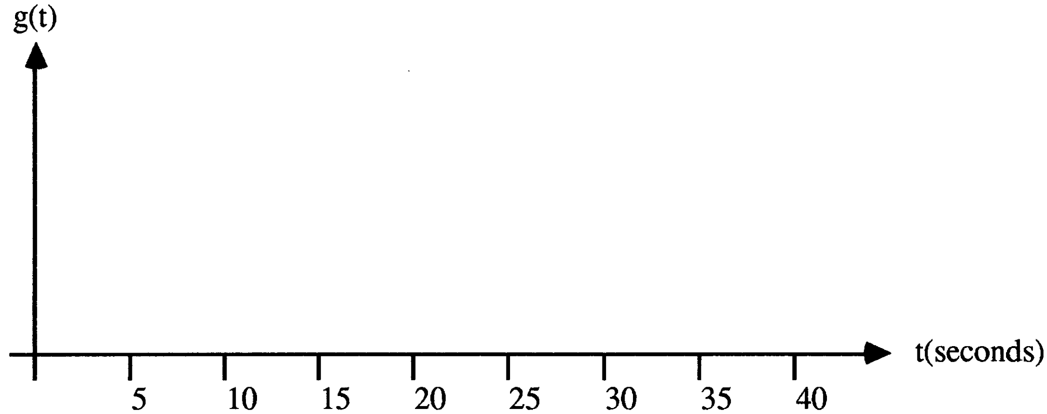

100d
50d
0d
-50d
-100d
10mHz
100mHz
1.0Hz
10Hz
100Hz
1.0KHz
10KHz
100KHz
vp(2)
Frequency

Name: ____________________ SSN: ______________________

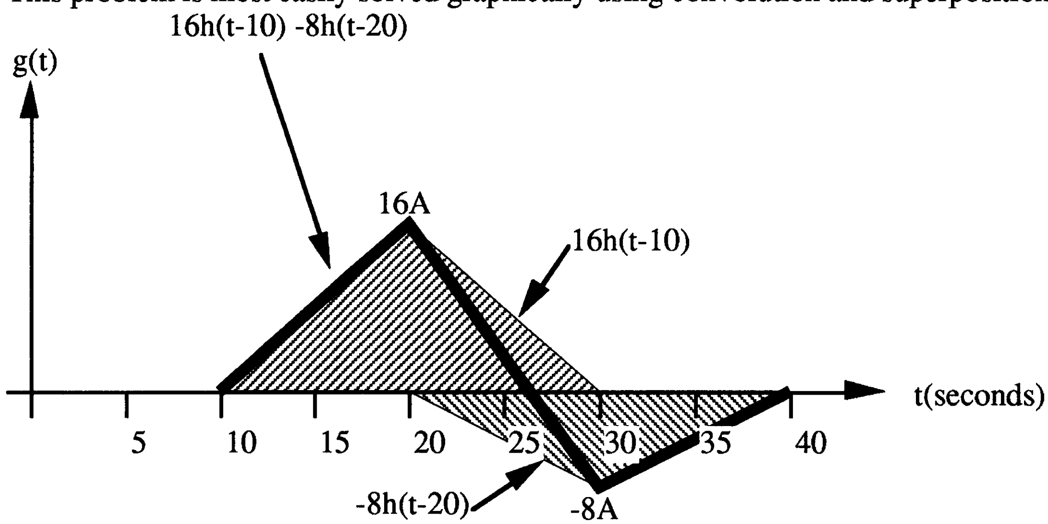
2. The signal f(t) shown below is the input to a linear system whose impulse response is given by h(t). Sketch the output g(t) of the filter for $0 \le t \le 40$ seconds. HINT: You can do your answer mathematically or graphically, <u>but</u> the answer must be sketched below.







Solution:
This problem is most easily solved graphically using convolution and superposition.



COMMENTS: You gained 10 points for representing the output as a convolution integral; you got 5 points for using the impulses correctly; you lost 10 points for not using the time-shifting property of impulses; you lost 20 points if there was no mention of or any comprehension of convolution either graphically or mathematically. The most common error (-10 points) was not using a delta function and/or not time shifting the the response functions.

An Abbreviated List of Laplace Transform Pairs

$f(t)$ $(t>0^-)$	TYPE	$F(s)$
$d(t)$	(impulse)	1
$u(t)$	(step)	$\frac{1}{s}$
t	(ramp)	$\frac{1}{s^2}$
e^{-at}	(exponential)	$\frac{1}{s+a}$
$\sin(\omega t)$	(sine)	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	(cosine)	$\frac{s}{s^2+\omega^2}$
te^{-at}	(damped ramp)	$\frac{1}{(s+a)^2}$
$e^{-at}\sin(\omega t)$	(damped sine)	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos(\omega t)$	(damped cosine)	$\frac{s+a}{(s+a)^2+\omega^2}$

An Abbreviated List of Operational Transforms

$f(t)$	$F(s)$
$Kf(t)$	$KF(s)$
$f_1(t)+f_2(t)-f_3(t)+\ldots$	$F_1(s)+F_2(s)-F_3(s)+\ldots$
$\frac{df(t)}{dt}$	$sF(s)-f(0^-)$
$\frac{d^2f(t)}{dt^2}$	$s^2F(s)-sf(0^-)-\frac{df(0^-)}{dt}$
$\frac{d^nf(t)}{dt^n}$	$s^nF(s)-s^{n-1}f(0^-)-s^{n-2}\frac{df(0^-)}{dt}-s^{n-3}\frac{d^2f(0^-)}{dt^2}-\ldots-\frac{d^{n-1}f(0^-)}{dt^{n-1}}$
$\int_0^t f(x)dx$	$\frac{F(s)}{s}$
$f(t-a)u(t-a)$, $a>0$	$e^{-as}F(s)$
$e^{-at}f(t)$	$F(s+a)$
$f(at)$, $a>0$	$\frac{1}{a}f(\frac{s}{a})$
$tf(t)$	$-\frac{dF(s)}{ds}$
$t^nf(t)$	$(-1)^n\frac{d^nF(s)}{ds^n}$
$\frac{f(t)}{t}$	$\int_s^\infty F(u)du$

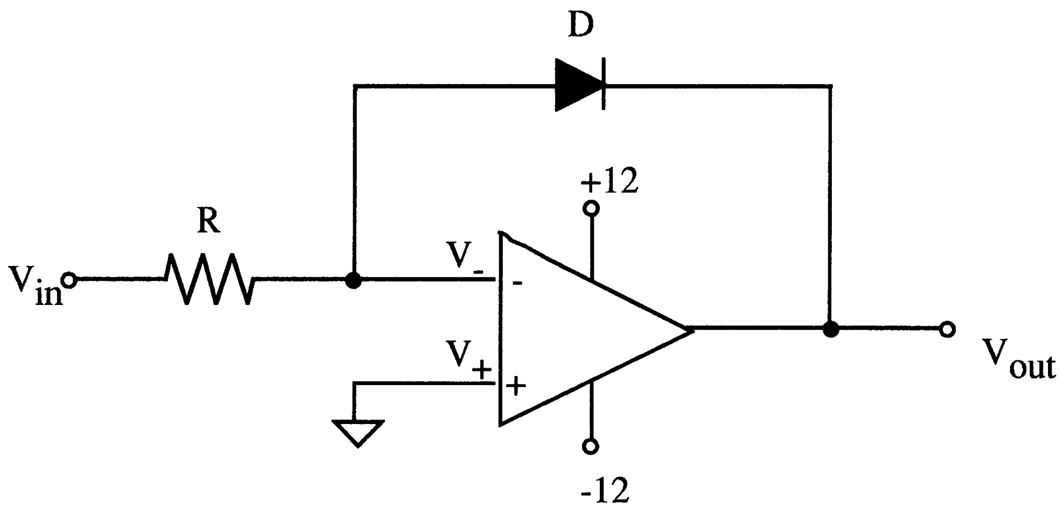
INS TCP/IP PrintServer 20

Print engine name:	PrintServer 20
Print engine version:	17
Printer firmware version:	32
Server Adobe PostScript version:	48.3
Server software version:	V2.0
Server network node:	crawford
Server name:	crawford
Server job number:	86
Client software version:	WRL-1.0
Client network node:	util
Client name:	flm
Client job name:	quiz_10.ps.735168728
Submitted at:	Sun Apr 18 17:57:00 19939933X
Printed at:	Sun Apr 18 17:57:00 1993

flm@util
quiz_10.ps.735168728

Quiz #10 SOLUTIONS 59 took exam
EEAP 244 April 11, 1993

1. (50 points) Problem 8.1-6 of your textbook. The operational amplifier shown in the circuit below is ideal. The diode is at room temperature. Determine V_{out} as a function of V_{in}. Use $R=1k\Omega$ and I_o (for the diode) = $1\mu A$ in your answer.



ANSWER:
The basic equation for the resistor is Ohm's Law

$$i_1 = \frac{V_{in}}{R}$$

The diode is governed by the diode equation at room temperature, i.e.

$$i_2 = I_o(e^{-40V_{out}}-1)$$

Applying KCL at the inverting input of the op-amp

$$i_1 - i_2 = 0$$

Or, after substitution,

$$\frac{V_{in}}{R} - I_o(e^{-40V_{out}}-1) = 0$$

Rearranging

$$(e^{-40V_{out}}-1) = \frac{V_{in}}{I_oR}$$

and, assuming the 1 can be neglected on the left hand side, we get

$$e^{-40V_{out}} \approx \frac{V_{in}}{I_oR}$$

After taking the natural log of both sides this becomes

$$-40V_{out} \approx -\frac{1}{40}\ln\left(\frac{V_{in}}{I_oR}\right)$$

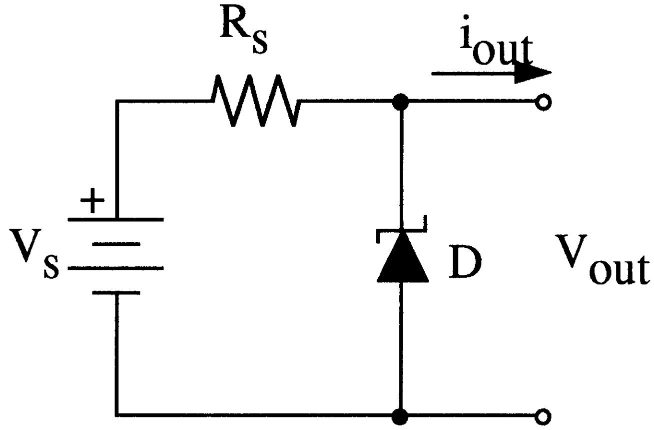
The final answer is

$$V_{out} \approx -\frac{1}{40}\ln\left(\frac{V_{in}}{(1\mu A)(1k\Omega)}\right) = -\frac{1}{40}\ln\left(1000V_{in}\right)$$

$$V_{out} \approx -0.025\ln\left(1000V_{in}\right) = -0.025\ln\left(1000\right) + 0.025\ln\left(V_{in}\right) = -0.17269 - 0.025\ln\left(V_{in}\right)$$

COMMENTS: You lost 5 points for not recognizing that the diode was reverse biased. You lost 5-10 points for reversing the input and output of the circuit.

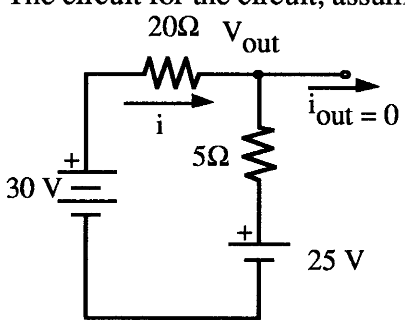
2. (50 points) Problem 8.2-11 of your textbook. Answer the following questions about the zener diode voltage regulator circuit shown below.



Use the circuit parameters: V_S=30 volts, R_S=20 ohms, V_Z=25 volts and R_Z=5 ohms for all parts of this problem.

(a) Determine V_{out} for i_{out}=0 amperes.

ANSWER:
The circuit for the circuit, assuming conduction of the zerer diode, is:



The current in the circuit is determined by Ohm's Law

$$i = \frac{30-25}{20+5} = \frac{5}{25} = 0.2 \text{ Amps}$$

The output voltage is then

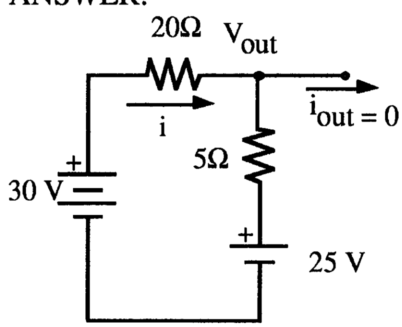
V_{out}= 30 – (0.2A)(20Ω) = 30 – 4 = 26 volts

The output voltage is greater than V_Z so the diode is conducting and our assumption is correct.

COMMENT: You lost 10 points for the wrong voltage.

(b) Determine V_{out} for i_{out}=0.5 amperes.

ANSWER:



Since there is a non-zero i_{out} use KCL at the output terminal:

$$+\frac{30 - V_{out}}{20\ \Omega} - \frac{V_{out} - 25}{5\ \Omega} - 0.5 = 0$$

Eliminating fractions,

$$30 - V_{out} - 4V_{out} + 100 - 10 = 0$$

which yields

$$120 - 5V_{out} = 0$$

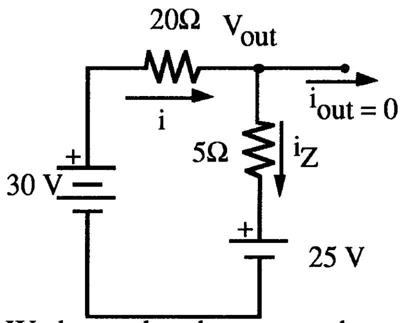
or $V_{out} = 24$ volts . Obviously the diode is not conducting and our assumption was wrong. Using Ohm's Law and ignoring the non-conducting diode

$$V_{out} = 30 - (20\Omega)(0.5\text{ Amps}) = 30 - 10 = 20\text{ volts}$$

COMMENT: You lost 15 points if you did not notice that the zener was OFF, said nothing about it being OFF, and did not compute the output voltage for it being OFF. You only lost 5-10 points if you noticed it was OFF and/or calculated the voltage for it being OFF.

(c) At what value of i_{out} does the zener diode stop conducting?

ANSWER:

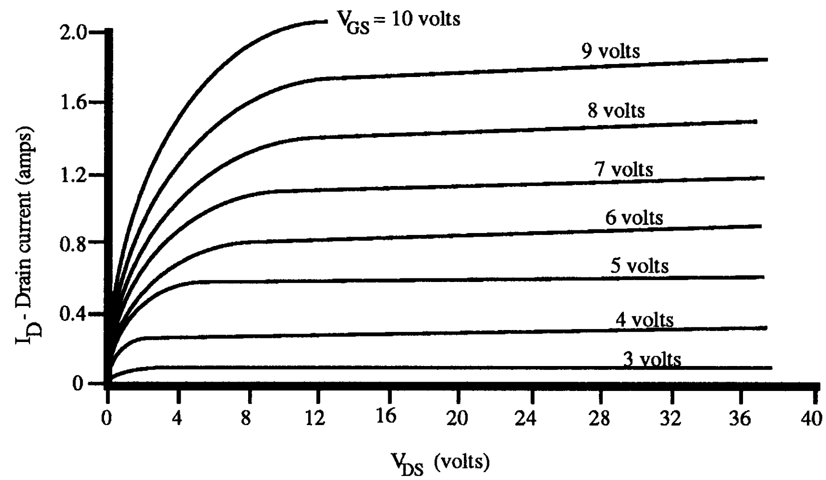


We know that the current through the zener diode must be zero when the diode just stops/starts conducting. Therefore, use i_Z=0 and, consequently, V_{out}=25 volts. For this situation

$$i_{out,max} = \frac{30 - 25 \text{ volts}}{20\ \Omega} = \frac{5}{20} = 0.25 \text{ ampere}$$

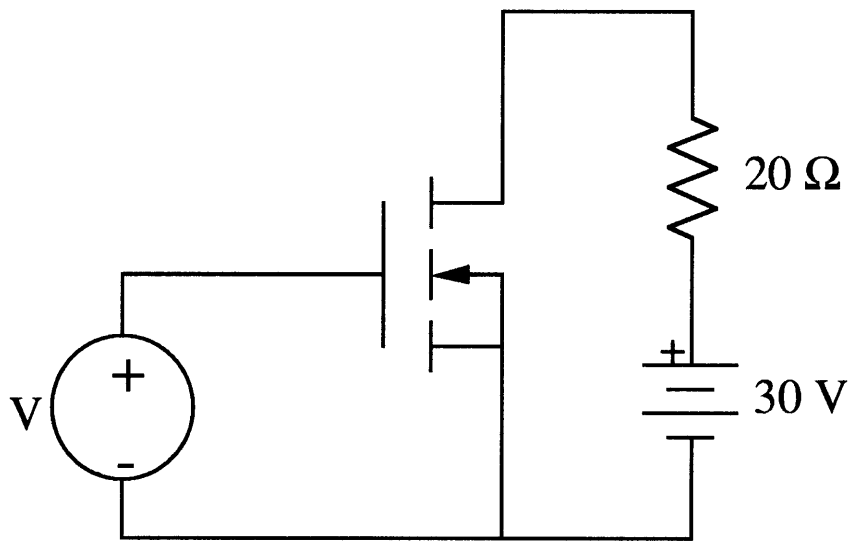
Quiz #11 SOLUTIONS
EEAP 244 April 19, 1993

1. (50 points) The following questions refer to the measured characteristics (shown below) of a 2N5447 MOSFET. The data was taken with a Tektronix 575 curve tracer.



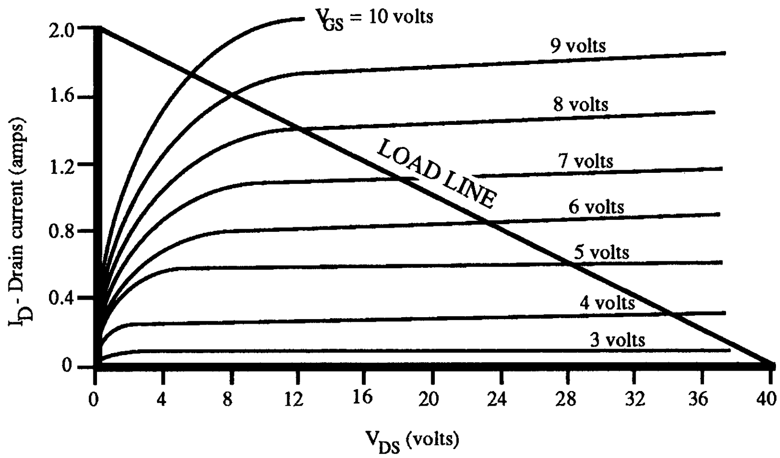
(a) Estimate the threshold voltage (V_T) of the MOSFET from the data.
ANSWER: By inspection the threshold voltage must be smaller than 3 volts. Good answers would be 2-3 volts.

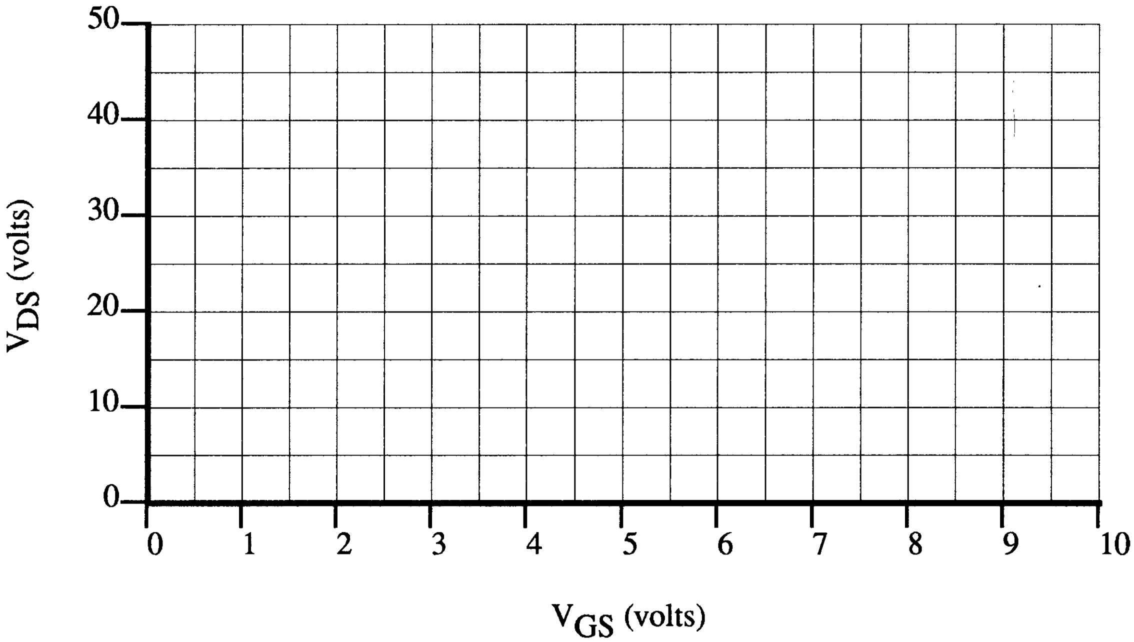
(b) The MOSFET is connected in the circuit shown below. For V=6 volts, determine the operating point of the MOSFET using a load line analysis.



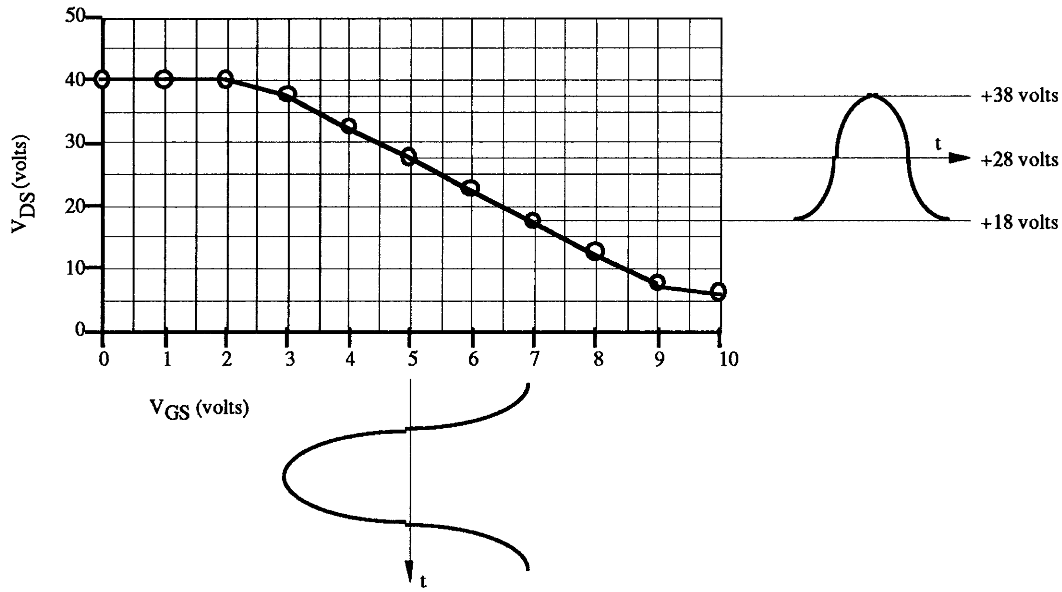
ANSWER: The x-intercept of the load line is 30 volts. The y-intercept of the load line is given by $i_D = \frac{30 \text{ volts}}{20\ \Omega} = 1.5$ amps . Drawing this line and estimating its intersection with the curve for V_{GS}=6 volts gives (12 volts, 0.8 amps) for the operating point.

(c) Assuming the operation of the MOSFET circuit is described by the characteristic data/load line shown below, plot V_{DS} as a function of V_{GS} for V_{GS} ranging from 0 to 10 volts. If V_{GS}= 6 volts + 2cosωt, determine the change in V_{DS} as a function of V_{GS}. Do you think this MOSFET would make a good amplifier?



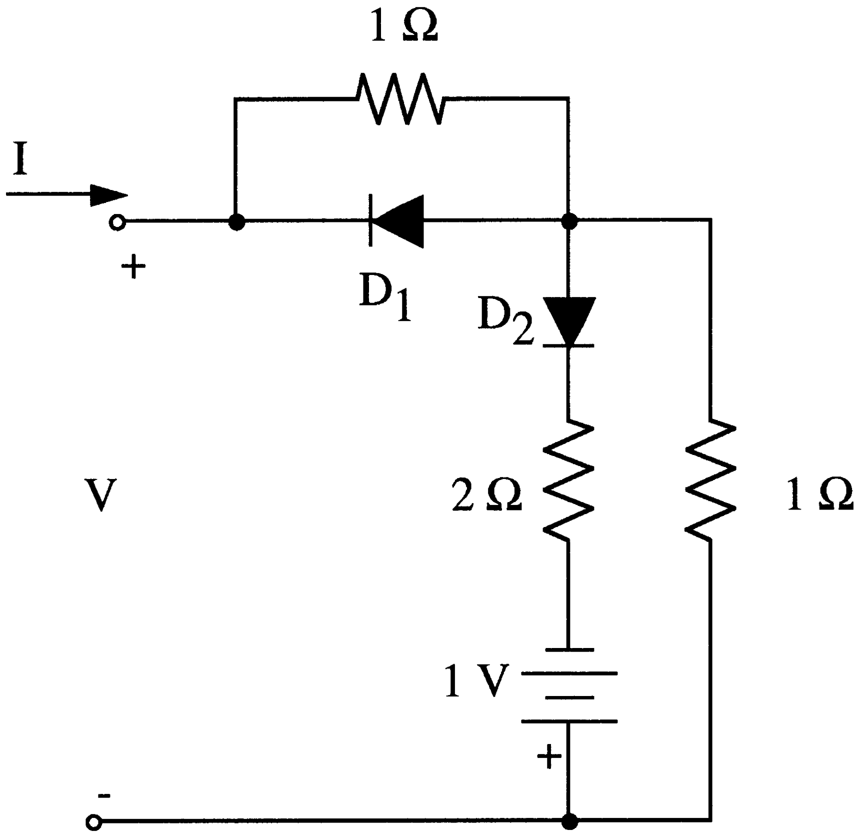


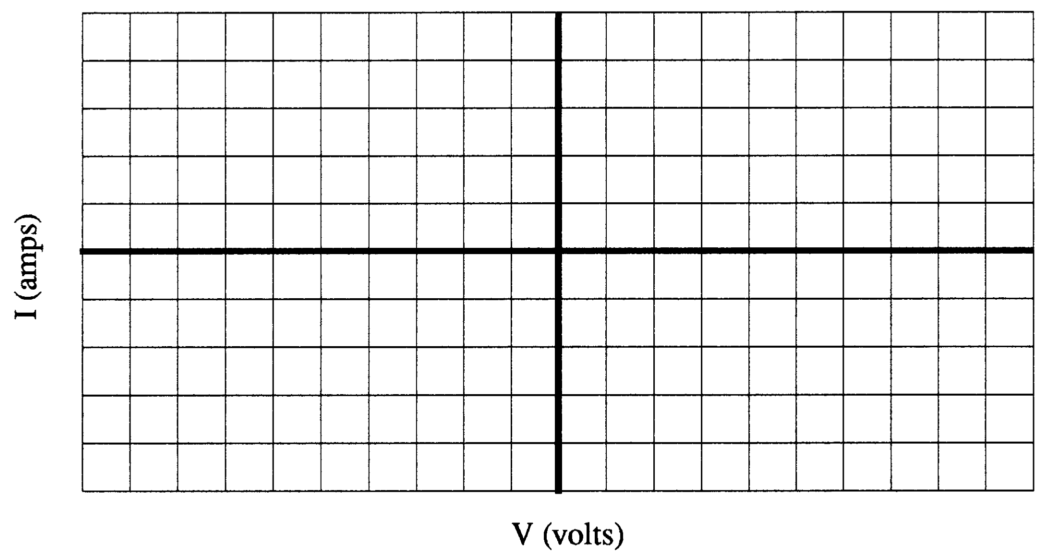
ANSWER:



This circuit would make an excellent amplifier. It has a nice, long transfer curve and the input signal is approximately in the middle of the region resulting in undistorted output with a gain of approximately 5.

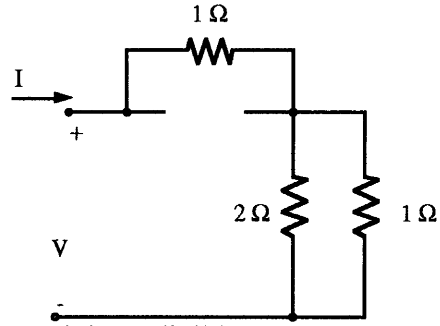
2. (50 points). For the circuit shown below, determine the two breakpoints and sketch I vs. V.





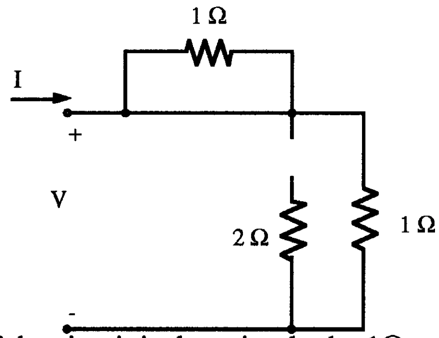
ANSWER:
There are four cases.

1. As V→+∞ D1 must be OFF and D2 is ON. The circuit then looks like



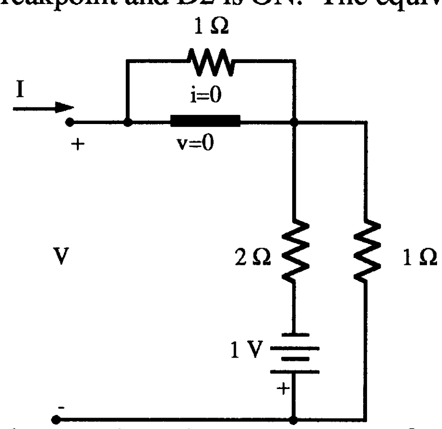
The battery is neglected because it is negligible compared to ∞. The equivalent resistance of the circuit is then 1+ 2||1 = 1 + 2/3 = 5/3 Ω. The slope of the I-V curve is then 3/5.

2. As V→-∞ D1 must be ON and D2 is OFF. The circuit then looks like



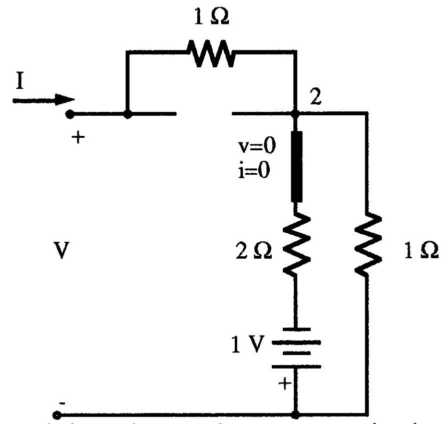
The equivalent resistance of the circuit is then simple the 1Ω resistance and the slope of the I-V curve is 1.

3. Assume D1 is at a breakpoint and D2 is ON. The equivalent circuit is

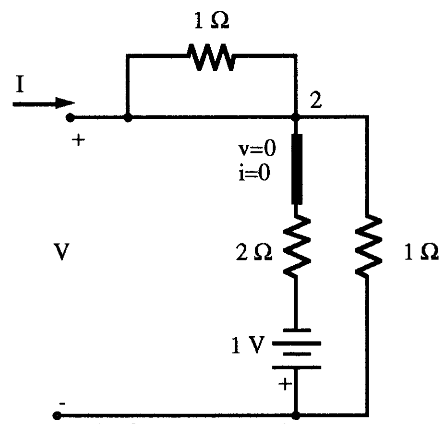


Since the voltage across D1 is zero, the voltage across the 1Ω resistor is also zero and the current through it is also zero. This means immediately that I=0. The voltage at the junction of the diodes is determined by the 1 volt battery. The current flows from + to - meaning it flows through the 1Ω 2Ω battery loop in a counterclockwise direction. The magnitude of this current is i=1 volt/3Ω = 1/3 amp. The voltage at the node is then the battery voltage PLUS the voltage drop across the 2Ω resistor, i.e. -1 + (2Ω)(1/3 A) = -1/3 volt. Since there is no voltage drop across D1, the voltage at the input must be -1/3 volt. The first breakpoint is at (-1/3 volt, 0 amps).

4. Now assume D2 is at the breakpoint and let's assume D1 is OFF. The circuit is as shown below

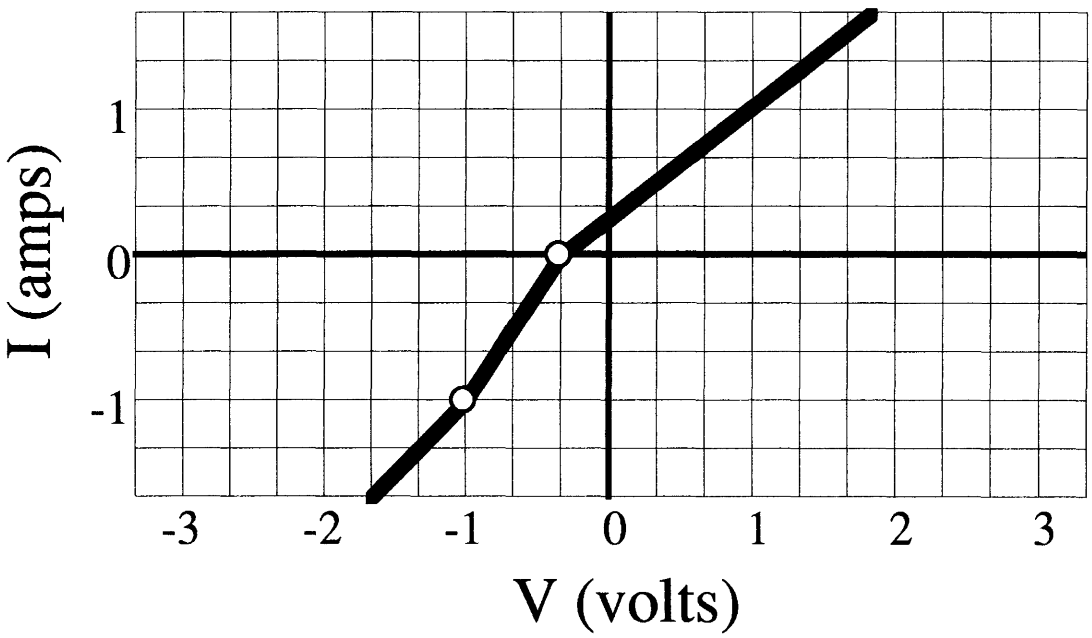


Since D2 has no current through it and no voltage across it, the voltage at node 2 must be -1 volts. This means that there is 1 amp of current flowing into node 2 from the 1Ω resistor to the right. Since there is no current through D2 this current must also be flowing through the 1Ω resistor across D1. This means that there is a positive voltage across D1 and D1 must be ON, not OFF as we assumed. Let's try again assuming at D1 is ON and D2 is at the breakpoint. This new circuit is



The analysis is exactly the same as before except that we can now see that for this situation V=-1 volt and I=-1 amp. Note that the current is negative, not positive.

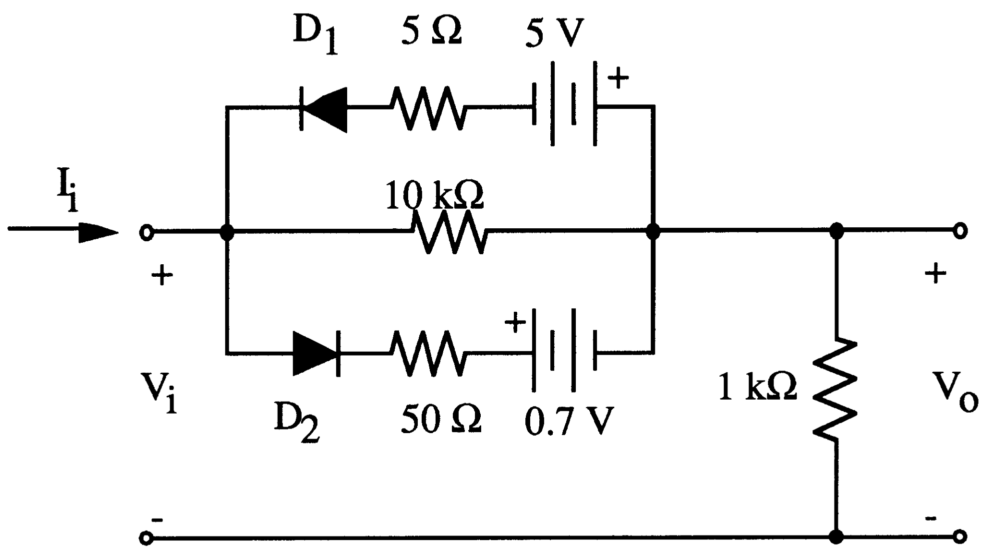
The resulting V-I characteristic is shown below.

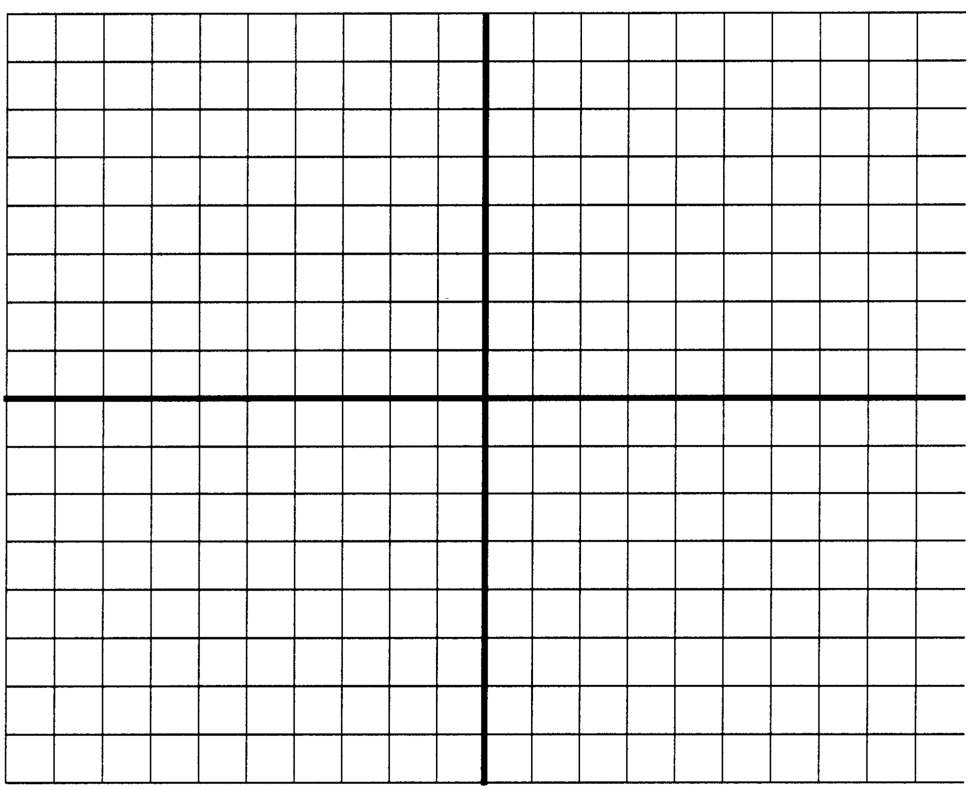


I (amps)
1
0
-1
-3
-2
-1
0
1
2
3
V (volts)

Quiz #12 SOLUTIONS (BONUS)
EEAP 244 April 27, 1993

1. (50 points). For the circuit shown below, sketch the voltage transfer function V_o vs. V_i. Identify how many breakpoints and their values the circuit has.





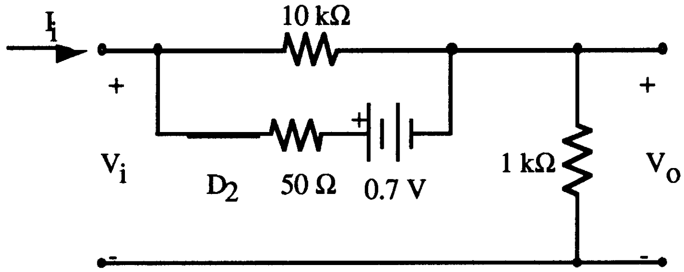
Vo (volts)

Vi (volts)

ANSWER:

There are four cases.

1. As V→+∞ D1 must be OFF and D2 is ON. The circuit then looks like



I will solve the circuit exactly using KCL at the output node. Note that since V_i is positive the current I_i is also positive, i.e. in the direction shown.

$$\frac{V_i - V_o}{10k\,\Omega} + \frac{V_i - (V_o + 0.7)}{50\,\Omega} - \frac{V_o}{1k\,\Omega} = 0$$

Rationalizing and re-writing the equation:

$$V_i - V_o + 200(V_i - V_o - 0.7) - 10V_o = 0$$

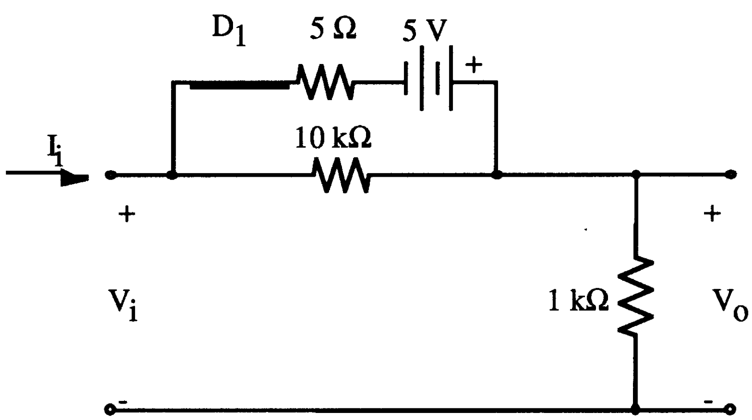
which gives

$$201V_i - 211V_o - 140 = 0$$

$$V_o = \frac{201}{211}V_i - \frac{140}{211} = 0.953V_i + 0.663$$

This is the equation of a line with a slope nearly one.

2. As V→-∞ D1 must be ON and D2 is OFF. The circuit then looks like



I will solve the circuit exactly using KCL at the output node. Note that since Vi is negative the current is also negative, i.e. opposite to the direction shown. Using + to indicate a current into the node:

$$\frac{V_o - V_i}{10k\,\Omega} + \frac{(V_o - 5) - V_i}{5\,\Omega} + \frac{V_o}{1k\,\Omega} = 0$$

Rationalizing and re-writing the equation:

$$V_o - V_i + 2000(V_o - 5 - V_i) + 10V_o = 0$$

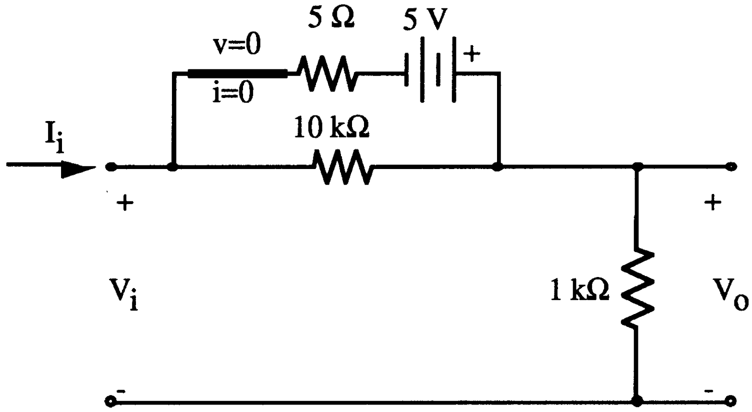
which gives

$$2011V_o - 2001V_i - 10000 = 0$$

$$V_o = \frac{2001}{2011}V_i - \frac{10000}{2011} = 0.995V_i - 4.973$$

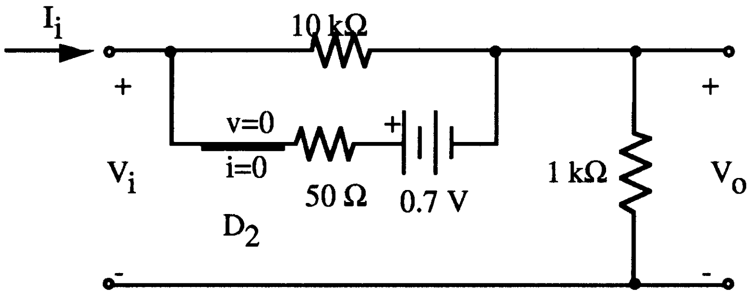
This is also the equation of a line with a slope nearly one.

3. Assume D1 is at a breakpoint. By inspection I will assume that D2 is OFF since the battery voltage across it is a reverse bias. Let's assume it is off and analyze the equivalent circuit:



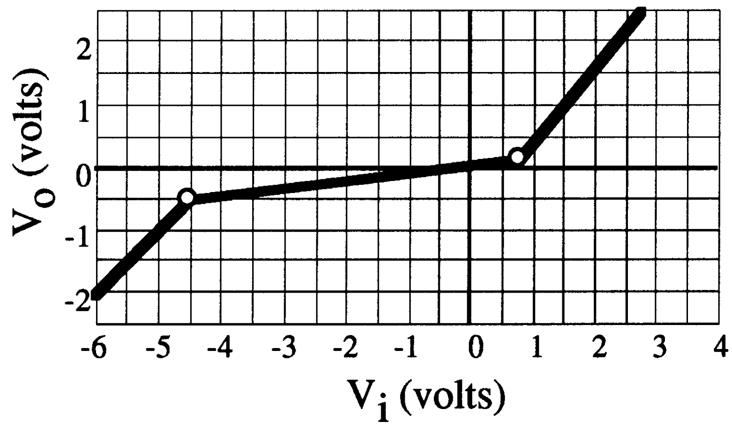
Since the current thru D1 is zero, the voltage across the 5Ω resistor is also zero and the voltage across the 10k Ω resistor is 5 volts. This means immediately that I_i=-5V/10k = -0.5 mA. Note that the current is in the negative direction because of the battery direction. The corresponding voltage across the 1kΩ output resistor is then V_o = (-0.5mA)(1kΩ) = -0.5 volts. The battery voltage relates the input and output voltages, i.e. $V_o=V_i+5$. The input voltage is then Vi = Vo-5 = -0.5 - 5 = -5.5 volts. The breakpoint occurs at (-5.5, -0.5) volts.

4. Now assume D2 is at the breakpoint and let's assume D1 is OFF. This is reasonable as the battery voltages would reverse bias D1. The equivalent circuit is:



The analysis is exactly the same as for D1. Since the current thru D2 is zero, the voltage across the 50Ω resistor is also zero and the voltage across the 10k Ω resistor is 0.7 volts. This means immediately that I_i=0.7V/10k = +0.07 mA. Note that the current is now in the positive direction because of the battery direction. The corresponding voltage across the 1kΩ output resistor is then V_o = (0.07mA)(1kΩ) = +0.07 volts. The battery voltage relates the input and output voltages, i.e. $V_i=V_o+0.7$. The input voltage is then V_i = 0.07 + 0.7 = 0.77 volts. The breakpoint then occurs at (0.77, 0.07) volts.

The resulting transfer characteristic is shown below.



COMMENTS ON GRADING:

$V_i \rightarrow +\infty$	10 points
$V_i \rightarrow -\infty$	10 points
D1 breakpoint	13 points
D2 breakpoint	13 points
graph	4 points

The number one cause of mistakes in the breakpoint analysis was thinking that the batteries forced the output voltage to 0.7 or 5 volts. The batteries CANNOT do this. At a breakpoint the current through the diode/resistor/battery combination is zero. Since the current through the resistor is zero the voltage drop across it is zero. The voltage drop across the diode is zero because it is at a breakpoint. This means that the voltage across the entire diode/resistor/battery combination is the battery voltage which then appears across the 10kΩ resistor, NOT at the output terminal.

2. (50 points, This is basically problem 9.2-1, an assigned problem, with the numbers changed.) The transistor shown in Figure 1 below has the static charactristics shown in Figure 2. R_k=0.5kΩ, R_D=1kΩ, and V_{DD}=18 volts.

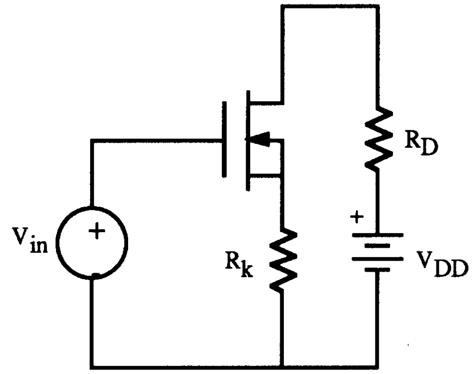


Figure 1 - Transistor Circuit

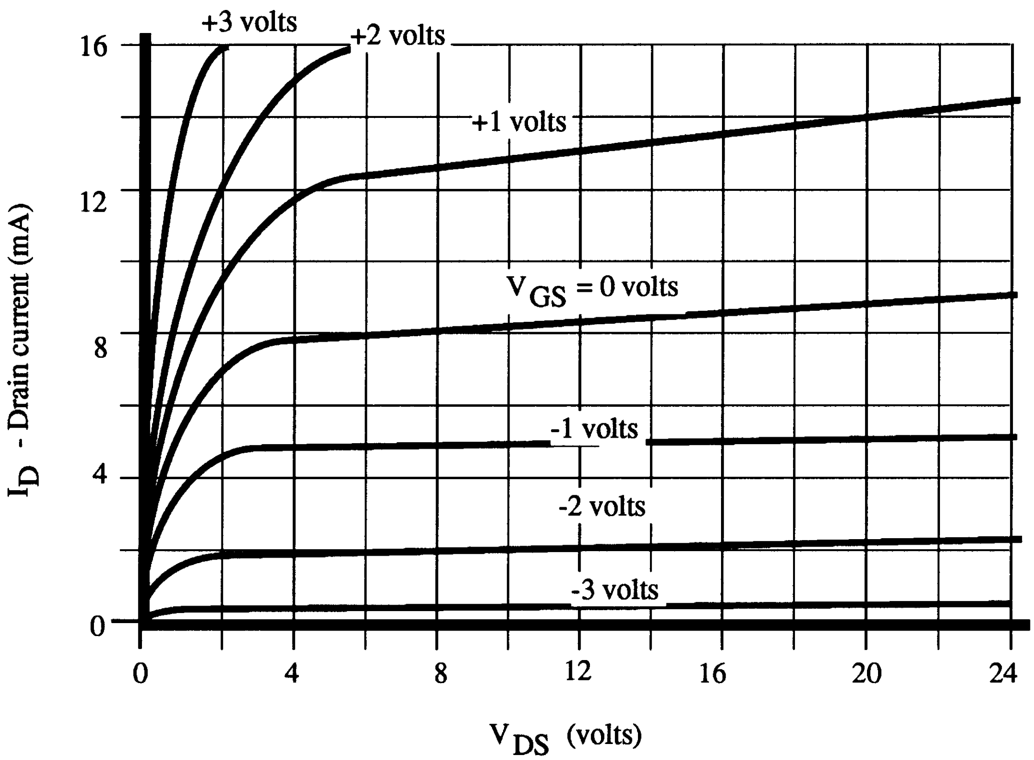


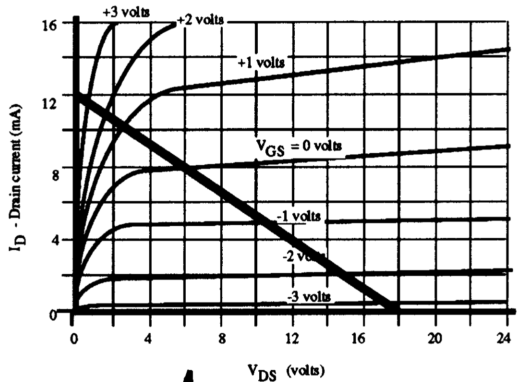
Figure 2 - Static Characteristics

(a) What type of transistor is this?
ANSWER: The circuit symbol AND the static characteristics indicate that the transistor is a depletion mode n-channel MOSFET.
(10 points)

(b) Using a load line, estimate the value of v_{in} that yields V_k=+3 volts for the given circuit parameters. NOTE: V_k is the voltage at the source of the transistor.

ANSWER: The load line is given by its x-intercept [18 volts] and its y-intercept [18/(1+0.5k) = 12mA]. Since R_k=0.5kΩ, we have $I_D = V_k/R_k$=3 volts/0.5kΩ =

6mA. Using the load line below we quickly find that this operating point [I_D=6mA] corresponds to a V_{GS} of approximately -0.6 volts. Thus, $V_{in} = V_{GS}+v_k = -0.6+3 = +2.4$ volts.



(20 points. You lost 8-10 points for no graphical analysis depending upon what you did. You lost 5 points for each end of the load line if it was wrong.)

(c) The transistor in the circuit of Figure 1 is now described by the transistor parameters V_P=5 volts and I_{DSS}=2.5 mA. THIS IS NO LONGER THE TRANSISTOR DESCRIBED IN FIGURE 2. What is V_{GS} if V_{in}=0?

ANSWER:

The gate-source voltage is described by
$V_{GS} = V_G - V_{GS} = 0 - I_D R$

Solving for I_D and equating this to the transistor characteristic curve

$$I_D = -\frac{V_{GS}}{R_k} = I_{DSS}\left(1 + \frac{V_{GS}}{V_P}\right)^2$$

Rearranging and expanding the function:

$$-\frac{V_{GS}}{I_{DSS}R_k} = 1 + 2\frac{V_{GS}}{V_P} + \frac{V_{GS}^2}{V_P^2}$$

Substituting values

$$-\frac{V_{GS}}{(2.5\text{volt})(0.5\text{k}\Omega)} = 1 + 2\frac{V_{GS}}{5\text{ volts}} + \frac{V_{GS}^2}{25\text{ volts}^2}$$

Rearranging
$V_{GS}^2 + 30V_{GS} + 25 = 0$

Solving,

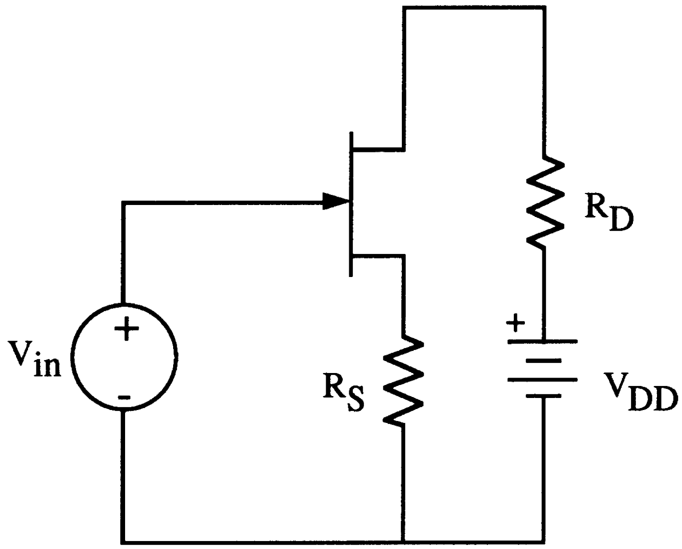
$$V_{GS} = \frac{-30 \pm \sqrt{(30)^2 - 4(25)}}{2} = -15 \pm 14.1 = -29.1, -0.9 \text{ volts}$$

The answer is -0.9 volts since the other value would be beyond pinchoff.

(20 points. The most common error was not using the term $I_D = -\frac{V_{GS}}{R_K}$ for which you lost 10 points)

Quiz #13 SOLUTIONS
EEAP 244 May 3, 1993

1. (50 points) Consider the JFET transistor in the circuit shown. The circuit parameters are V_{DD}=20 volts, R_D=3kΩ and R_S=2kΩ.



(a) (35 points) If V_{in}=0 volts determine the operating point (i.e. V_{DS}, V_{GS} and I_D) for the JFET. The transistor parameters are I_{DSS}=18mA and V_P=6volts.

ANSWER:
This problem is very similar to problem 9.2-4 in your textbook. From the transistor characteristics

$$I_D = \frac{I_{DSS}}{V_P^2}(V_{GS} + V_P)^2$$

For the self-biased amplifier with V_G=V_{IN}=0:

$$V_S = I_D R_S \text{ , or}$$

$$I_D = +\frac{V_S}{R_S} = -\frac{V_{GS}}{R_S}$$

Combining these equations

$$-\frac{V_{GS}}{R_S} = \frac{I_{DSS}}{V_P^2}(V_{GS} + V_P)^2$$

Using numerical values the equation becomes:

$$-\frac{V_{GS}}{2} = \frac{18}{(6)^2}(V_{GS} + 6)^2$$

which can be re-arranged into the standard form

$$0.5V_{GS}^2 + 6.5V_{GS} + 18 = 0$$

with the solutions

$$V_{GS} = -4, -9 \text{ volts}$$

The -9 volt solution can be ignored since it is beyond V_P and no transistor operation is possible for such values. Using V_{GS}=-4 volts

$I_D = \frac{18}{(6)^2}(-4+6)^2 = 2mA$

With these values V_{DS} can be computed using KVL for the transistor drain-source circuit:

$V_{DS} = V_{DD} - I_D R_D - I_D R_S = 20 - (2mA)(3k) - (2mA)(2k) = 20 - 6 - 4 = 10$ volts

The complete operating point is then:

V_{GS}=-4 volts,
I_D=2mA, and
V_{DS}=10 volts.

A detailed numerical analysis using an Excel spreadsheet is:

Problem 9.2-4 Analysis of a self-biased JFET amplifier

Circuit parameters:			
Power supply voltage	VDD	20 volts	
Load resistance	RD	3 kΩ	
Source resistance	RS	2 kΩ	
JFETparameters:			
	IDSS	18 mA	
	VP	6 volts	
A. Determine Q-point of amplifier			
VGS	a	0.5	
	b	6.5	
	c	18	
	VGS1	-4 volts	
	VGS2	-9 volts	
	0≥VGS≥	-6 volts	
Pick operational value	VGS=	-4 volts	<<<CHECK
2. Calculate drain current ID		ID= 2 mA	
3. Calculate VDS using KVL		VDS= 10 volts	
Condition for active operation:			
	VDS>VGS+VP	2 volts	
or	VDD>VGS+VP+VDS*(RD+RS)	12 volts	

GRADING SUMMARY:

-15	starting with VDS to determine VGS
-15	using a RD-RS voltage divider to find VDS
-10	forgetting the term ID=-VGS/RS in computing VGS
-30	only showing some rlevant formulas; no calculations
-35	no answer whatsoever
-10	no coupling between the calculations for ID and VDS
-10	saying VGS=VDS since VIN=0

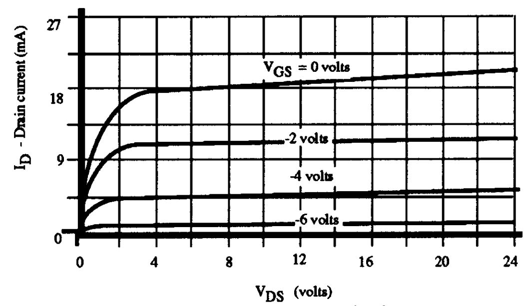
(b) (15 points) Using the static and active transfer characteristics shown below for the transistor used in part (a), explain the basis for the following "conditions for active operation" used by the textbook, i.e. why does the book say

$$v_{DS} > v_{GS} + V_P \qquad (1)$$

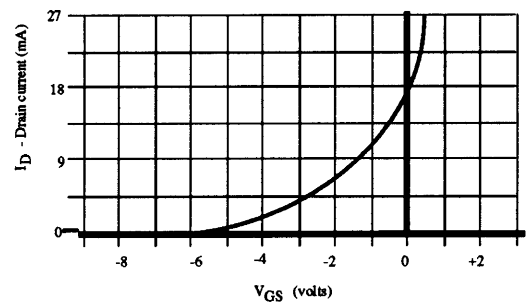
and

$$v_{GS} > -V_P \qquad (2)$$

are required for active operation of a JFET amplifier?



(a) static characteristics



(b) active transfer characteristics

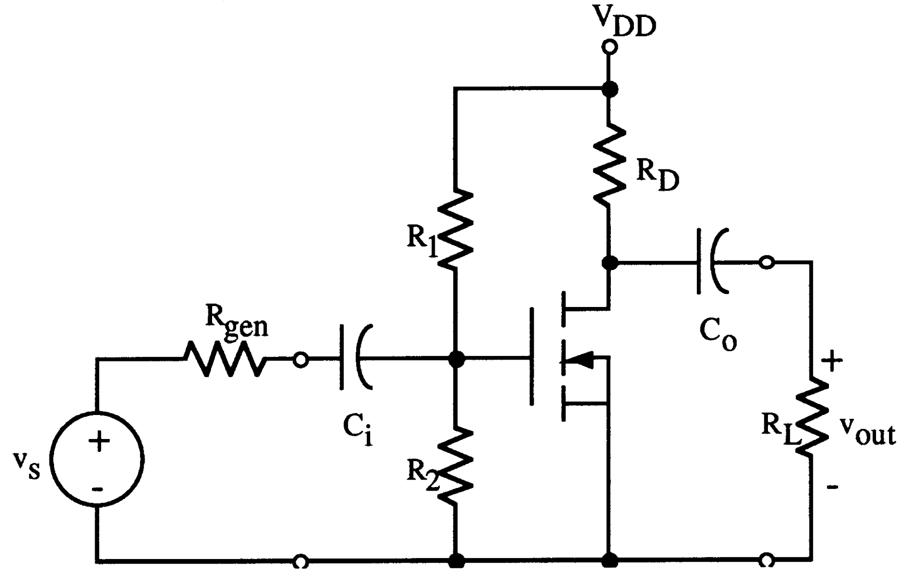
ANSWER:

The first equation, (1), simply indicates that the transistor should be operating in the active region of the transistor static characteristics which begins at $v_{GS}+V_P$. In the figure (a), this is the point at which the characteristric curve stops following a curve (actually a parabola) and becomes a straight line. Amplifiers should operate in this "straight line" region of the static characteristic curve.

The second equation, (2), indicates that the transistor should be operating in the region where $0>V_{GS}>V_P$. In (a) this means that the transistor must operate in the region below the V_{GS}=0 curve and above the V_{GS}=-6 volts curve. Anything outside of this region is not appropriate for amplifier operation. The curve (b) simply amplifies this fact.

GRADING SUMMARY:
This part of the problem was worth 15 points. For Eqn.(1) and Figure (a) you needed to mention operating in the linear region of the curve. Also, acceptable was saying that you did NOT want to operate in the ohmic part of the curve. Depending upon how your answer was worded you lost 2-7 points for not mentioning these points. For Eqn.(2) and Fig.(b) you needed to mention that the transistor needed to be active.

2. For the MOSFET amplifier circuit shown below:



(a) (20 points) Using the values R_{gen}= 10kΩ, V_{DD}=18V, R_1=3.3MΩ, R_2=1.2MΩ, R_D=2kΩ, and R_L=5kΩ determine the DC operating point of the transistor, i.e. determine I_D, V_{DS}, and V_{GS}. The MOSFET is characterized by I_{DSS}=6mA and V_T=2.5 volts.

ANSWER:
This problem is very similar to problem 11.1-3 with some of the numbers changed. The detailed analysis procedure is as follows:

There is no voltage at the source as it is connected directly to ground. V_{GS} is determined only by V_G which is set by the R_1-R_2 voltage divider.

$$V_{GS} = \frac{R_2}{R_1 + R_2} V_{DD} = \frac{1.2M\Omega}{1.2M\Omega + 3.3M\Omega}(18V) = (0.27)(18V) = 4.8V$$

Since the transistor is an enhancement mode MOSFET we will switch to the convention of using k to describe the transistor where

$$k = \frac{I_{DSS}}{V_T^2} = \frac{6mA}{(2.5V)^2} = 0.96\,\frac{mA}{V^2}$$

With the transistor parameter k AND V_{GS} we can calculate the drain current as:

$$I_D = k\,(V_{GS} - V_T)^2 = 0.96\,\frac{mA}{V^2}(4.8V - 2.5)^2 = 5.08mA$$

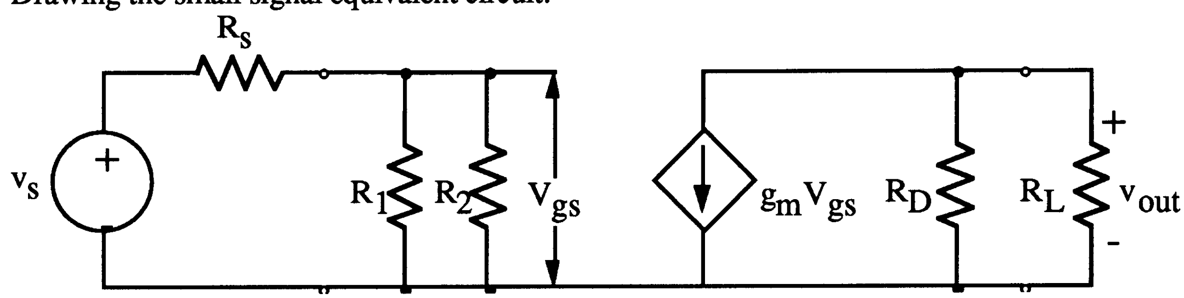
Once the drain current is known we can apply KVL to the loop from ground through the transistor, through R_D, and through the power supply to ground to get:

$$V_{DS} = V_{DD} - R_D I_D = 7.84V$$

COMMENTS: V_{GS},I_D and V_{DS} were worth approximately 5 points apiece plus some points for the equations to get them.

(b) Draw the small signal equivalent circuit of the amplifier.

ANSWER:
Drawing the small signal equivalent circuit:



GRADING COMMENTS: The most common error was not replacing the power supply connection to ground. That lost 3-5 points depending upon how bad the error was. You also forgot to include the load resistance R_L in your circuits. That cost 3-8 points depending upon the rest of the circuit.

(c) (15 points) Using this small signal model determine A_v and R_{in} for this amplifier.

ANSWER:
For the ac analysis (i.e., voltage gain) we need to compute the transistor small signal parameter g_m:

$$g_m = 2k(V_{GS} - V_T) = 2\left(0.96\ \frac{mA}{V^2}\right)(4.8V - 2.5V) = 4.416\ mS$$

This can be used to determine the small signal gain. The ac input impedance of the amplifier is determined primarily by the bias resistors:

$$R_i = R_1 || R_2 = \frac{R_1 R_2}{R_1 + R_2} = \frac{(3.3M\Omega)(1.2M\Omega)}{3.3M\Omega + 1.2M\Omega} = 880k\Omega \gg R_s$$

Since $R_1||R_2 \gg R_s$, basically the entire input voltage appears as V_{gs} and $V_{gs}=V_s$. The output voltage is then $-g_m V_{gs}(R_1||R_2)$. The ratio of the output voltage to the input voltage becomes $-g_m V_s(R_1||R_2)$ divided by V_s giving

$$A_v = -g_m(R_D||R_L) = -g_m\frac{R_D R_L}{R_D + R_L} = -(4.416\ mS)\frac{(2k\Omega)(5k\Omega)}{2k\Omega + 5k\Omega} = -6.31$$

The problem was solved using an Excel spreadsheet:

Problem 9.2-3 — Analysis of an enhancement MOSFET amplifier

Circuit parameters:

Power supply voltage	VDD	18 volts
Generator resistance	Rgen	10 kΩ
Drain resistance	RD	2 kΩ
Load resistance	RL	5 kΩ
Bias resistors	R1 (upper)	3300 kΩ
	R2 (lower)	1200 kΩ

Enhancement MOSFETparameters:

	IDSS	6 mA
	VT	2.5 volts

(a)

1. Calculate transistor param		k= 0.96 mA/volt^2
2. Calculate VGS	VGS=	4.8 volts
3. Calculate drain current	ID=	5.0784 mA
4. Calculate VDS	VDS=	7.8432 volts

(c)

5. Calculate gm	gm=	4.416 mS
6. Calculate Rin	Rin=	880 kΩ
7. Calculate voltage gain	Av=	-6.308571429

GRADING COMMENTS: R_i and A_v were worth 8 points each with one extra point for the problem setup.