UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE40
Summer 09

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MIDTERM EXAMINATION #1
Time allotted: 90 minutes

NAME: SOLUTIONS
(print) Last First

STUDENT ID#: _____

DISCUSSION SECTION: _____ / _____
Day / Time

LAB SECTION: _____ / _____
Days / Time

INSTRUCTIONS:

1. **SHOW YOUR WORK. Partial credit will be given only if your methods are clear to the grader.**
2. **Clearly mark (BOX or UNDERLINE) your answers.**
3. **Specify the units on answers whenever appropriate. Points will be deducted for missing units.**
4. **Closed book, closed notes. You are allowed ONE 8.5" x 11" sheet of notes.**
5. **Calculators are allowed.**

I acknowledge that the UC rules on academic honesty apply. _____
Signature

SCORE: 1 _____ / 15

2 _____ / 20

3 _____ / 24

4 _____ / 20

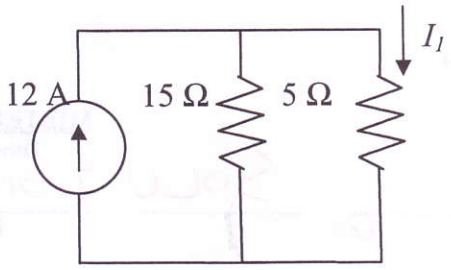
5 _____ / 16 **TOTAL:** _____ / 95

SOLUTIONS

Problem 1 [15 points]: Circuit Basics

a) Multiple Choice Questions. Select only ONE choice. No credit will be given to multiple answers. **[5 pts each]**

1) What is the current in I_1?



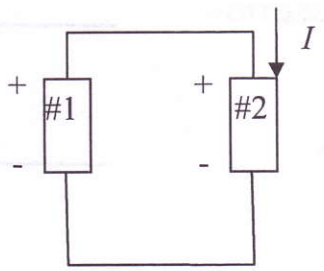
a) 3 A

b) 6 A

c) 9 A

d) 12 A

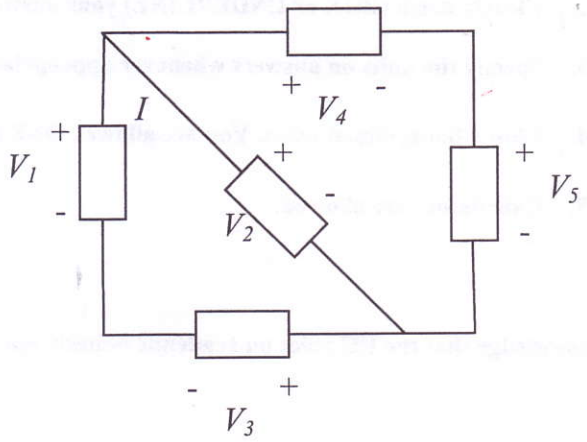
2) Which element is absorbing power?



a) #1

b) #2

3) If $V_1 = 2$ V, $V_2 = -3$ V, $V_3 = 5$ V, $V_4 = 5$ V, what is V_5?



a) 8 V

b) 2 V

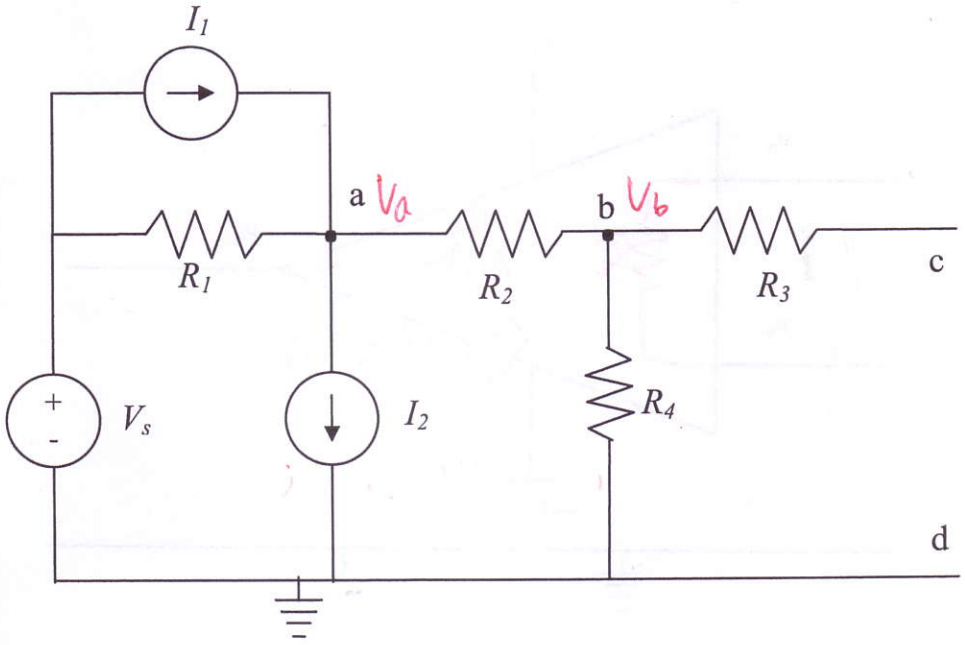
c) -8 V

d) -2 V

SOLUTIONS

Problem 2 [20 points]: Circuit Basics

1) Consider the circuit below:



a) Write a KCL expression for node *a*. Be sure to label any new variables you create on the circuit diagram above. **[5 pts]**

$$\frac{V_a - V_s}{R_1} + \frac{V_a - V_b}{R_2} + I_2 - I_1 = 0$$

flipped signs = −1 each (max −2)

omit a voltage in a term = −1 each

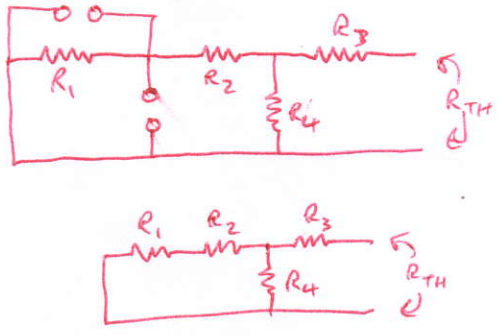
b) Write a KCL expression for node *b*. Be sure to label any new variables you create on the circuit diagram above. **[5 pts]**

$$0 = \frac{V_b - V_a}{R_2} + \frac{V_b}{R_4}$$

include R_3 term = −1

Flip sign = −1

c) What is R_{TH} between nodes *c* and *d*? **[5 pts]**



$$R_{TH} = (R_1 + R_2) \| R_4 + R_3$$

$$= \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_4}} + R_3$$

$$= \frac{(R_1 + R_2) R_4}{R_1 + R_2 + R_4} + R_3$$

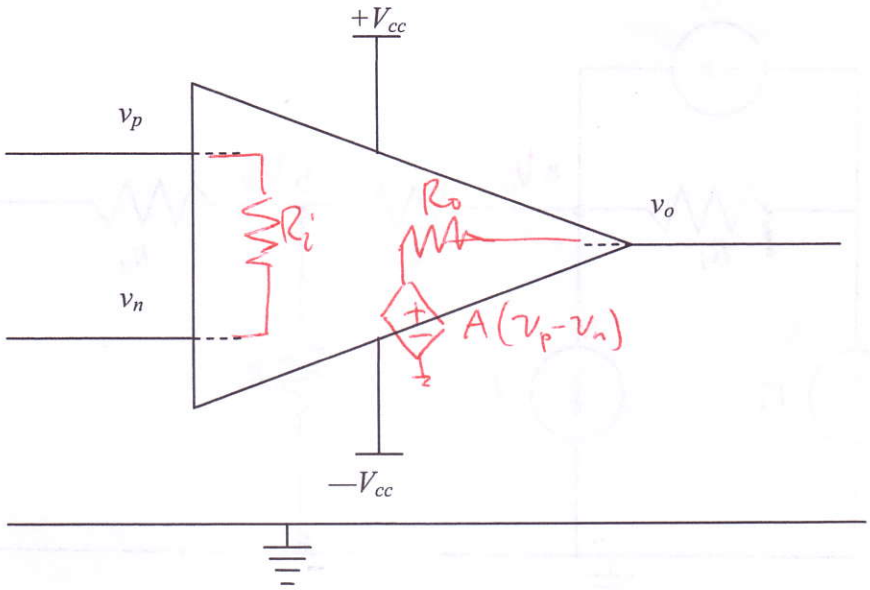
miss reciprocal = −1 each

open all supplies = 0

miss R_3 = −1

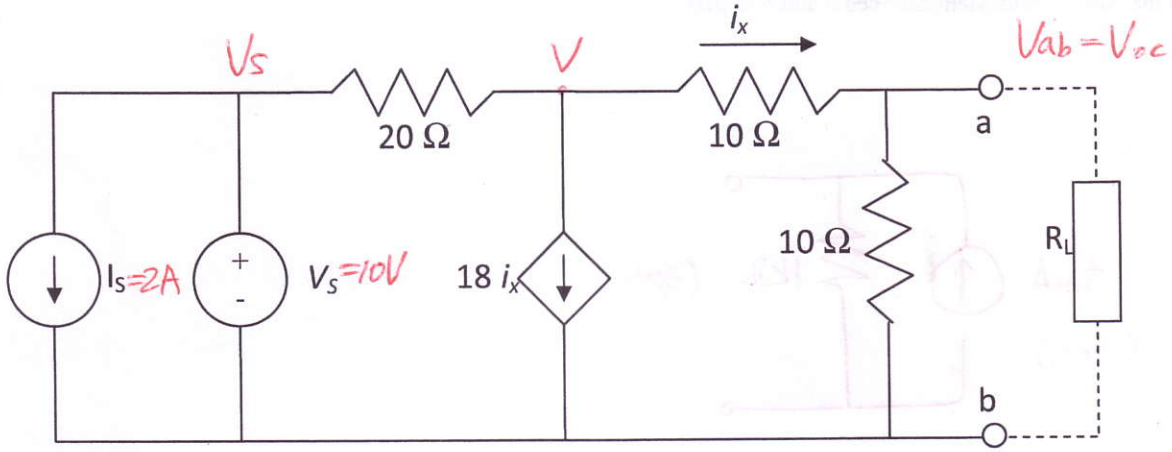
SOLUTIONS

2.) Draw the equivalent circuit model of an op amp in the linear range: **[5 pts]**
Be sure to label all the elements.



SOLUTIONS

Problem 3 [24 points]: Maximum Power Transfer
Consider the circuit below:



a.) Find the Thévenin equivalent between *a* and *b* **[12 pts]**

For V_{Th}

KCL

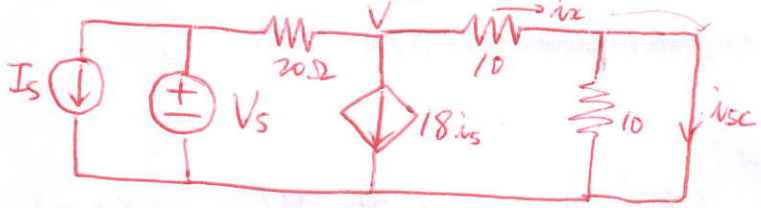
$$\frac{V-V_s}{20} + 18i_x + \frac{V}{10+10} = 0 \quad (2\text{pts})$$

$$i_x = \frac{V}{10+10} = \frac{V}{20} \quad (1.5\text{pts})$$

$$\therefore V = \frac{V_s}{20}, \quad V_{Th} = V_{oc} = \frac{10}{10+10} V = \frac{1}{2}\frac{V_s}{20} = \frac{1}{40}V_s \quad (2\text{pts})$$

$$= 0.25\ V$$

For R_{Th}, we can use short-circuit method.

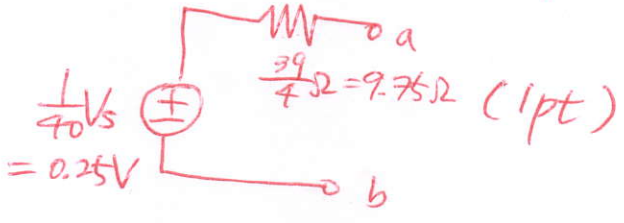


KCL $\quad \frac{V-V_s}{20} + \frac{V}{10} + 18\frac{V}{10} = 0 \quad (2\text{pts})$

$$i_x = \frac{V}{10} = i_{sc} \quad (1.5\text{pts})$$

$$\therefore V = \frac{V_s}{39}, \quad i_{sc} = \frac{V_s}{390} = \frac{1}{39} \quad R_{Th} = \frac{V_{Th}}{i_{sc}} = \frac{\frac{1}{40}V_s}{\frac{1}{390}V_s} = \frac{39}{4}\Omega \quad (2\text{pts})$$

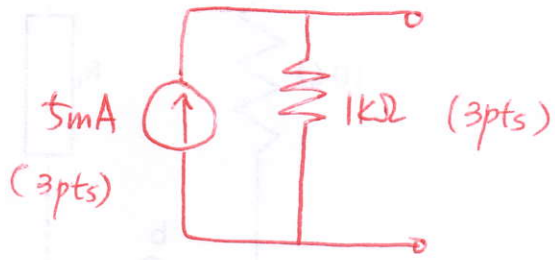
$$= 9.75\Omega$$



SOLUTIONS

For parts (b) to (d), please use the values $V_{TH} = 5$ V and $R_{TH} = 1\text{k}\Omega$ INSTEAD of the values you found in part (a).

b.) Find the Norton equivalent between a and b **[6 pts]**



c.) Based on your answer in part (b), find the optimal R_L such that the power delivered to R_L is maximized. **[3 pts]**

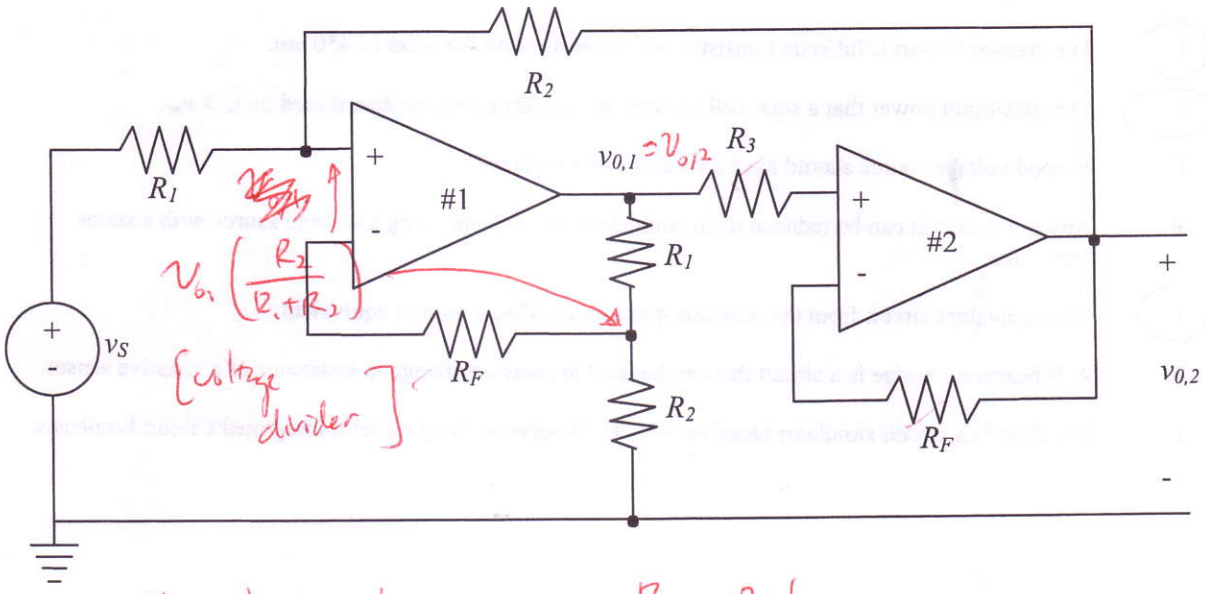
$R_L = R_{Th} = 1\text{k}\Omega$ (3pts)

d.) Based on your answer to part (c), what power is dissipated by R_L? **[3 pts]**

$P = I^2R = \left(\frac{5}{2k}\right)^2 \cdot 1k = 6.25\text{mW}$ (3pts)

SOLUTIONS

Problem 4 [20 points]: Op Amp Circuit
Consider the circuit below. Assume that both op-amps are ideal.



No voltage drop across R_3, R_F!

-2 pts for extra terms in KCL

a) Write the KCL expression at the non-inverting input of op-amp #1. Be sure to label any new variables you create on the circuit diagram above. **[8 pts]**

$$\frac{v_S - v_{0,1}\left(\frac{R_2}{R_1+R_2}\right)}{R_1} + \frac{v_{0,2} - v_{0,1}\left(\frac{R_2}{R_1+R_2}\right)}{R_2} = 0 \quad \text{(A)}$$

+4 pts for each correct term KCL

$$\Rightarrow R_2\left[v_S - v_{0,1}(A)\right] + R_1\left[v_{0,2} - v_{0,1}(A)\right] = 0$$

+4 pts for voltage divider or KCL @ right node

b) Find the expression for the overall gain, $G = v_{o,2}/v_s$ in terms of the listed parameters. **[12 pts]**

+4 for $v_{0,2} = v_{0,1}$

$$v_{0,1} = v_{0,2}$$

$$\Rightarrow R_2\left[v_S - v_{0,2}(A)\right] + R_1\left[v_{0,2} - v_{0,2}(A)\right] = 0$$

$$v_{0,2}\left[\underbrace{A(R_2+R_1)}_{R_2} - R_1\right] = R_2 v_S$$

+4 for correct expression

$$\Rightarrow \boxed{\frac{v_{0,2}}{v_S} = \frac{R_2}{R_2 - R_1} = 1 - \frac{R_2}{R_1}}$$

SOLUTIONS

Problem 5 [16 points]: EE Technology and Circuit Basics
True or False Questions. Select only ONE answer. **[2 pts each]**

T	F	Moore's Law describes the phenomenon where the number of transistors on a computer chip doubles every 1.5 to 2 years.
T	F	The state-of-the-art solid-state transistor has dimensions on the order of 450 μm.
T	F	The maximum power that a solar cell can deliver in practice can be determined by i_{sc} x v_{oc}.
T	F	A good voltage source should have a small series resistance.
T	F	Any linear circuit can be reduced to an equivalent circuit comprising a voltage source with a series resistance.
T	F	The equivalent circuit from the previous question is called a Norton equivalent
T	F	A Wheatstone bridge is a circuit that can be used to measure change in resistance of a resistive sensor.
T	F	Multisim is a circuit simulator based on SPICE: Simulation Program with Integrated Circuit Emphasis.