Exam 2a  
November 13, 2002  

ECE 221: Electric Circuits  
Dr. McNames  

- Write the first letter in your last name, your 6-digit identification number, and your student identification number below.  
- Do not begin the exam or look at the problems until instructed to do so.  
- You have 100 minutes to complete the exam.  
- Do not use separate scratch paper. If you need more space, use the backs of the exam pages.  
- If you have extra time, double check your answers. If you run out of time, write a note describing your strategy and equations that can be used to help solve the problem.  

Problem 1: _____ / 15  
Problem 2: _____ / 17  
Problem 3: _____ / 18  

Total: _____ / 50  

First Letter in Last Name: ____________  
6-Digit Identification Number: ____________  
Student Identification Number: ____________
1. Thevenin Equivalents, Norton Equivalents, and Superposition (15 pts)
Use the circuit below to answer the following questions. For partial credit, draw the appropriate circuit for each question.

![Circuit Diagram]

a. (2 pts) Use superposition to find the current that flows from terminal $a$ to $b$ when the terminals are connected (short-circuit) due to the voltage source acting alone.

$I_{scv} =$

b. (2 pts) Use superposition to find the current that flows from terminal $a$ to $b$ when the terminals are connected (short-circuit) due to the current source acting alone.

$I_{sci} =$

c. (1 pt) Find the Norton equivalent current.

$I_N = $

d. (1 pt) If the current source produced twice as much current as shown, what would the Norton equivalent current be? Hint: linearity.

$I_{N,2C} =$

e. (1 pt) If the polarity of the voltage source was reversed, what would the Norton equivalent current be?

$I_{N,-V} =$

f. (2 pts) Find the Thevenin/Norton equivalent resistance of the circuit.

$R_{eq} =$
1. Thevenin Equivalents, Norton Equivalents, and Superposition Continued (15 pts)
The circuit on the previous page is repeated below for your convenience.

\[ V_{Th} = \text{__________} \]

h. (2 pts) Draw both the Thevenin and Norton equivalents of the circuit as seen from the nodes \( a \) and \( b \). Clearly label these nodes.

i. (1 pt) Suppose a resistor \( R_L \) is connected to the nodes \( a \) and \( b \). What value of \( R_L \) will maximize the power delivered to \( R_L \)?

\[ R_L = \text{__________} \]

j. (1 pt) Suppose a resistor \( R_L \) is connected to the nodes \( a \) and \( b \). What is the maximum power that can be delivered to \( R_L \)?

\[ P_L = \text{__________} \]

k. (1 pt) Is this equal to half of the power produced by the voltage source and current source in the original circuit? (Circle)

Yes \hspace{1cm} No
2. Mesh Current Method (17 points)

\[ i_a \quad i_b \quad i_c \quad i_d \]

a. (12 pts) Use the mesh-current method to write four independent equations in terms of the currents \( i_a, i_b, i_c, \) and \( i_d \). Do not use any other variables in your equations. If appropriate, use the supermesh technique. You do not need to simplify your equations.

Equation 1:

Equation 2:

Equation 3:

Equation 4:

b. (4 pts) Solve for the currents \( i_a, i_b, i_c, \) and \( i_d \).

\[ i_a = \quad i_b = \quad i_c = \quad i_d = \]

c. (1 pt) How many independent equations would be necessary to solve for the node voltages using the node-voltage technique?

\[ n = \]
3. **Operational Amplifiers (18 points)**

Use the circuit below to answer the following questions. The op amp is ideal.

![Operational Amplifier Circuit](image)

a. (1 pt) Does this op amp have negative feedback? (Circle)
   - Yes  
   - No

b. (1 pt) Find $i_3$.
   
   $i_3 = \underline{___________}$

c. (1 pt) Write an expression for the voltage at the inverting terminal of the op amp in terms of the appropriate resistances and $v_s$.
   
   $v_- = \underline{___________}$

d. (1 pt) Write an expression for $v_o$ in terms of the appropriate resistances and $v_s$.
   
   $v_o = \underline{___________}$

e. (1 pt) Which resistors affect the relationship of $v_o$ and $v_s$?
   
   $R_1$  $R_2$  $R_3$  $R_4$

f. (1 pt) If we used the real model of an op amp, which resistors would affect the relationship of $v_o$ and $v_s$?
   
   $R_1$  $R_2$  $R_3$  $R_4$

g. (1 pt) If we used the real model of an op amp and $R_4 = 0$, what would $v_o$ be?
   
   $v_o = \underline{___________}$
3. Operational Amplifiers Continued (18 points)
Use the circuit below to answer the following questions. The op amps in the circuit are ideal. The questions are intended to be answered in the order listed. For partial credit, include algebraic expressions for each answer next to the corresponding question. Each expression may include variables listed in earlier questions.

![Circuit Diagram]

h. (1 pt) Find \( v_b \).

\[ v_b = \]

i. (1 pt) Find \( v_d \).

\[ v_d = \]

j. (1 pt) Find \( i_c \).

\[ i_c = \]

k. (1 pt) Find \( i_d \).

\[ i_d = \]

l. (1 pt) Find \( i_b \).

\[ i_b = \]

m. (2 pts) Find \( v_c \).

\[ v_c = \]

n. (1 pt) Find \( i_e \).

\[ i_e = \]

o. (1 pt) Find \( i_a \).

\[ i_a = \]

p. (2 pts) Find \( v_a \).

\[ v_a = \]