Midterm 1

EE40 - Summer 2014

Gerd Grau

Name:

Section:

Section GSI:

Student ID:

<u>Instructions:</u>

Unless otherwise noted on a particular problem, you must show your work in the space provided or on the back of the exam pages.

Underline your answers to each problem with a double line.

Simplify your answers as far as possible unless otherwise noted.

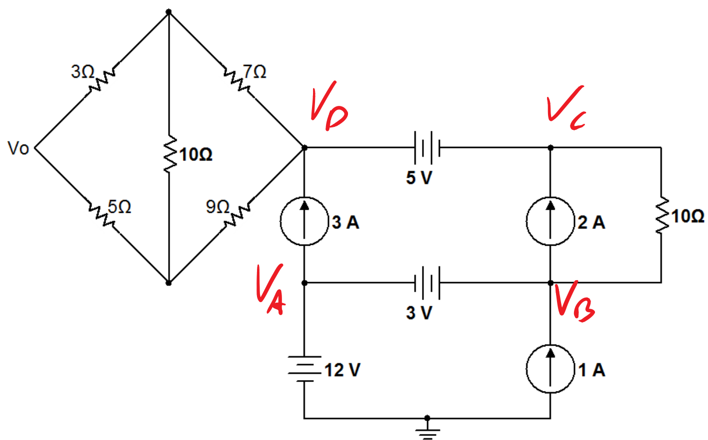
Be sure to provide units where necessary.

GOOD LUCK!

Question	Points	Max
1		6
2		10
3		25
4		18
5		12
Total		71

Question 1 (6 points):

Consider the below circuit. Find the voltage V_o relative to ground. Show all your work.



$V_A = 12V$ 1

$V_B = V_A + 3V = 15V$ 1

KCL at C: $-3 - 2 + \frac{V_C - V_B}{10} = 0$ (no current into diamond at D (no outlet))

$\Rightarrow V_C = 50 + 15 = 65V$ 1

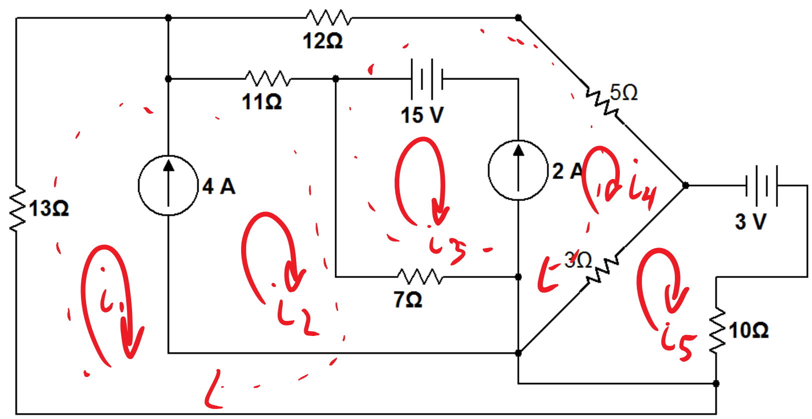
$V_D = V_C + 5 = 70V$ 1

$V_o = V_D = \underline{70V}$ 2 (no current inside diamond)

6

Question 2 (10 points):

Solve the following circuit using **mesh** analysis. Clearly label your loop currents in the circuit diagram. Write down enough KCL/KVL equations to completely solve the circuit. However, you will be penalized for inefficiencies due to unnecessary equations. You do not need to find the final solution. Just write your equations in the form a*i_1 + b*i_2 + … = z where a, b … z are integers. Label each final equation with a Roman number I, II, III, IV… Write down any trivial loop currents directly.



$13i_1 + 11(i_2 - i_4) + 7(i_2 - i_3) = 0$

$13i_1 + 18i_2 - 7i_3 - 11i_4 = 0$ I 2

$i_2 - i_1 = 4A$ II 2

$7(i_3 - i_2) + 11(i_4 - i_2) + 12i_4 + 5i_4 + 3(i_4 - i_5) = 0$

$-18i_2 + 7i_3 + 31i_4 - 3i_5 = 0$ III 2

$i_4 - i_3 = 2A$ IV 2

$3(i_5 - i_4) - 3 + 10i_5 = 0$

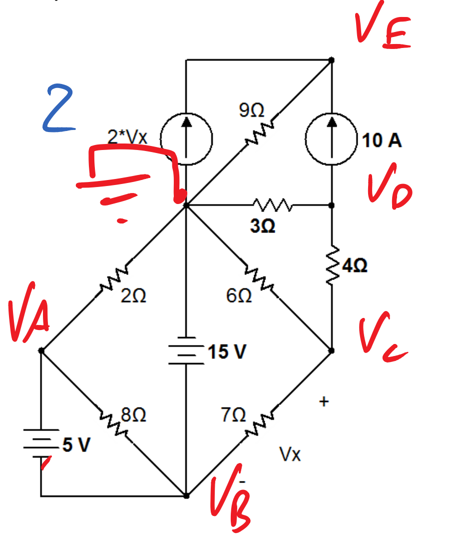
$-3i_4 + 13i_5 = 3$ V 2

10

Question 3 (25 points):

a) Choose an appropriate node in the following circuit as a reference for a nodal analysis. Mark it clearly in the circuit diagram. Give reasons for your choice.

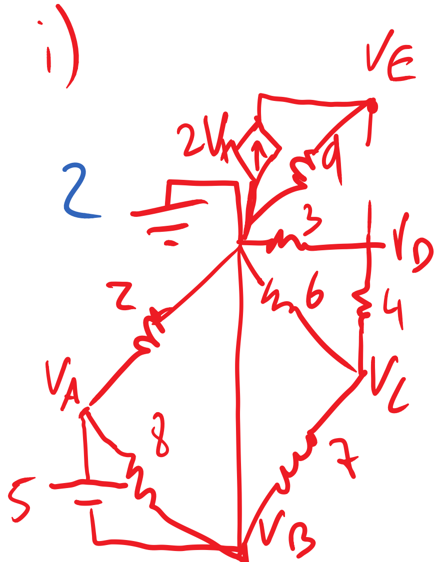
b) Solve the circuit using **a combination of superposition and nodal** analysis. Re-draw the circuit for each superposition calculation. Clearly label your nodal voltages in the circuit diagram. Write down enough KCL/KVL equations to completely solve the circuit for each source. However, you will be penalized for inefficiencies due to unnecessary equations. You do not need to find the final solution. Just write your equations in the form $a*v_1 + b*v_2 + \ldots = z$ where a, b … z are integers. Label each final equation with a Roman number I, II, III, IV… Write down any trivial node voltages directly.



a) Ground is placed at negative terminal of voltage source with the largest number of branches at negative terminal.

b) I-sources: open, V-sources: short (superposition)

i)



$V_B = 0V$

$V_A = V_B + 5 = 5V$

$\frac{V_C}{7} + \frac{V_C}{6} + \frac{V_C - V_D}{4} = 0 \mid \times 12 \times 7$

$(12+14+21)V_C - 21V_D = 0$

$47V_C - 21V_D = 0$ I

$\frac{V_D}{3} + \frac{V_D - V_C}{4} = 0$

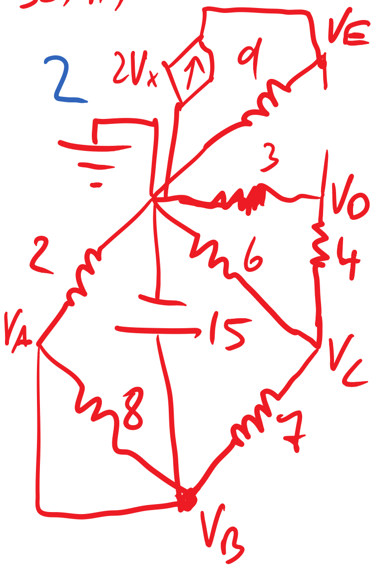
$-3V_C + 7V_D = 0$ II

$V_x = V_C - V_B = V_C$

$\frac{V_E}{9} - 2V_x = 0$

$V_E = 18V_C$ III

3c) ii)



$$V_B = 15V$$

$$V_A = V_B = 15V$$

$$\frac{V_C - 15}{7} + \frac{V_C}{6} + \frac{V_C - V_D}{4} = 0$$

$$47V_C - 21V_D = 15 \times 12 = 180 \quad \text{I}$$

$$\frac{V_D}{3} + \frac{V_D - V_C}{4} = 0$$

$$-3V_C + 7V_D = 0 \quad \text{II}$$

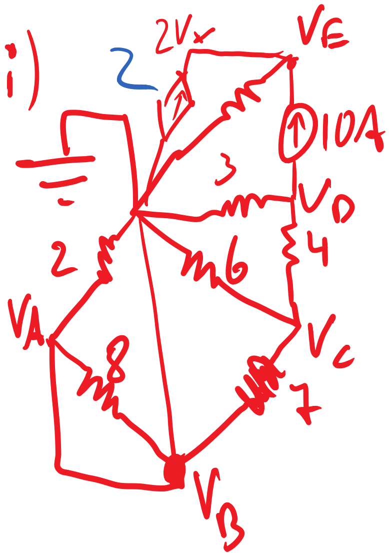
$$V_x = V_C - V_B$$
$$= V_C - 15$$

$$\frac{V_E}{9} - 2V_x = 0$$

$$\frac{V_E}{9} - 2(V_C - 15) = 0$$

$$V_E - 18V_C = -270 \quad \text{III}$$

iii)



$$V_A = V_B = 0V$$

$$\frac{V_C}{7} + \frac{V_C}{6} + \frac{V_C - V_D}{4} = 0$$

$$47V_C - 21V_D = 0 \quad \text{I}$$

$$\frac{V_D - V_C}{4} + \frac{V_D}{3} + 10 = 0$$

$$-3V_C + 7V_D = -120 \quad \text{II}$$

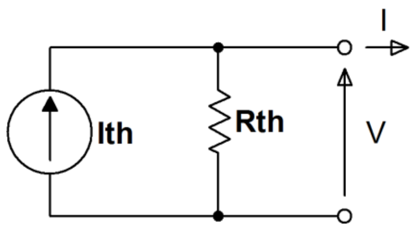
$$\frac{V_E}{9} - 10 - 2V_x = 0 \qquad V_x = V_C - V_B = V_C$$

$$V_E - 18V_C = 90 \quad \text{III}$$

25

Question 4 (18 points):

Consider the below non-ideal current source driving an arbitrary load at voltage V and with current I.



a) Derive an expression for the power efficiency of this source i.e. the ratio of the power delivered to the load and the power provided by the current source. Simplify as far as possible. Your final expression should be in terms of I, I_{th} and/ or R_{th}.

b) Now consider the Thevenin equivalent voltage source of the above current source. Again derive the power efficiency of this source. The result should again be in terms of I, I_{th} and/ or R_{th}.

c) Imagine the load is a resistor R_L. Calculate the power efficiency in terms of the load resistance R_L, I_{th} and/ or R_{th} (simplify as far as possible) for

  i) the non-ideal current source.

  ii) the non-ideal voltage source.

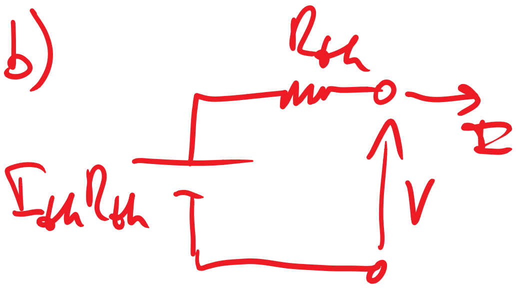
d) In terms of efficiency what kind of load should be driven by the current source? What kind by the voltage source? Give physical arguments that explain the above mathematical results.

a) $P_s = V I_{th}$

$P_L = V I$

$\eta = \frac{P_L}{P_s} = \frac{VI}{VI_{th}} = \frac{I}{I_{th}}$

b)



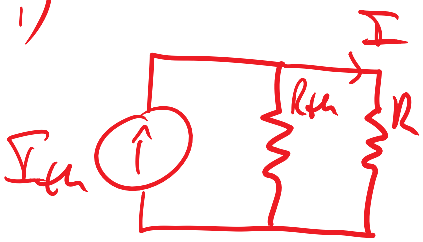
$P_s = I I_{th} R_{th}$

$P_L = V I$

$V = I_{th} R_{th} - I R_{th} = R_{th}(I_{th} - I)$

$\eta = \frac{P_L}{P_s} = \frac{R_{th}(I_{th} - I) I}{I I_{th} R_{th}} = 1 - \frac{I}{I_{th}}$

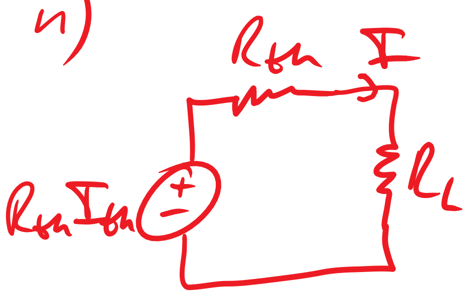
c) i)



$$I = I_{th} \frac{R_{th}}{R_{th}+R}$$ 1 (current divider)

$$\eta = \frac{I}{I_{th}} = \frac{I_{th}}{I_{th}} \frac{R_{th}}{R_{th}+R} = \frac{R_{th}}{R_{th}+R}$$ 2

ii)



$$I = \frac{I_{th} R_{th}}{R_{th}+R_L}$$ 1

$$\eta = 1 - \frac{I}{I_{th}} = 1 - \frac{I_{th} R_{th}}{I_{th}(R_{th}+R_L)}$$

$$= \frac{R_L}{R_{th}+R_L}$$ 2

d) For the current source want a low impedance load to prevent current from flowing through R_{th}, which represents a loss. 2

For the voltage source want a high impedance load to minimize the current flowing out of the voltage source and through R_{th} where power is lost.

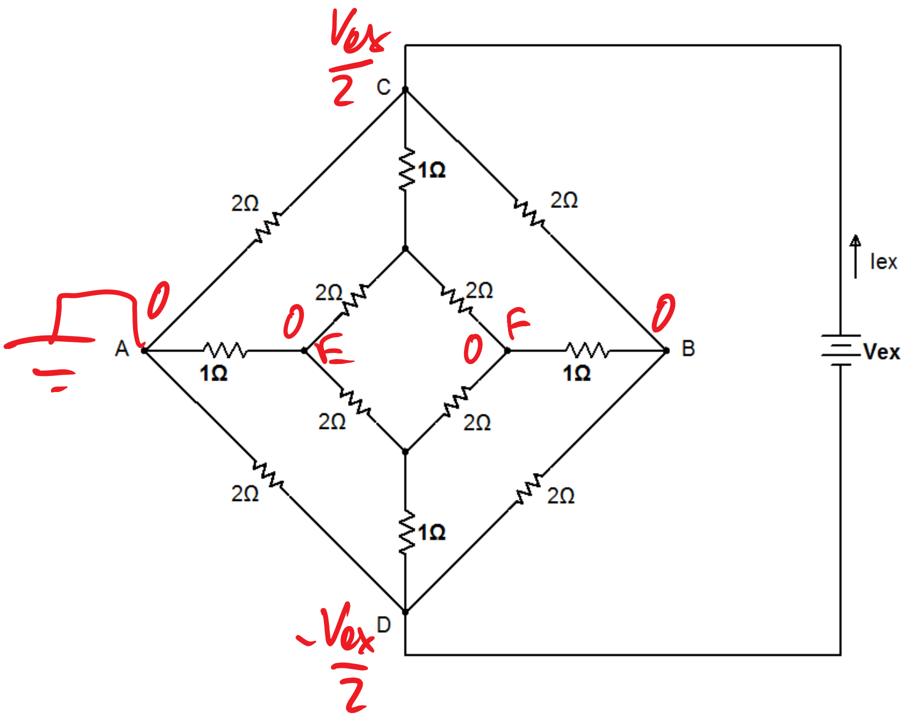
2

18

Question 5:

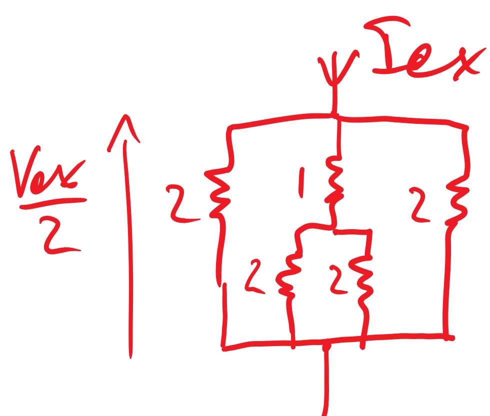
Find the current I_{ex} as a function of the source voltage V_{ex}. You can use whichever method you prefer.

Hint: You might want to simply your calculations by considering symmetry over the axes A-B and/or C-D. However, keep in mind that whilst the resistor network is symmetric over A-B, the applied voltage is anti-symmetric.



Put ground at node A.
Due to symmetry also nodes E, F & B will be 0 V.
3 (use symmetry)

Equivalent circuit:



$$I_{ex} = \frac{V_{ex}}{2} \cdot \left(\frac{1}{2} + \frac{1}{1+2\|2} + \frac{1}{2}\right)$$

$$= \frac{V_{ex}}{2} \cdot \frac{3}{2}$$

$$= \frac{3}{4} V_{ex}$$

3 (final result)

6 (realize equivalent circuit)

(12)

For other methods give full credit for right answer and partial appropriately.