Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Circuits & Electronics
Spring 2004

Quiz #1

24 February 2004

Name: SOLUTIONS

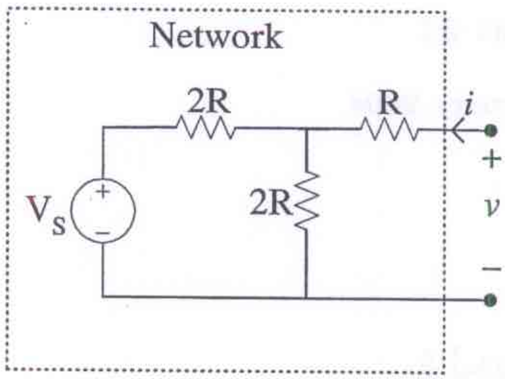
Instructor:	Kassakian	Kassakian	Wilson	Berggren	Berggren
Time:	10	11	12	1	2

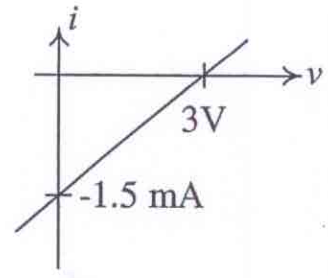
- Please put your name in the space provided above, and circle the name of your recitation instructor together with the time of your recitation.
- Do your work for each question within the boundaries of the question. When finished, write your answer to each question in the corresponding answer box that follows the question.
- This is a closed-book quiz, but calculators are allowed.
- Graded quizzes will be returned in recitation on Friday February 27. If you do not attend recitation on that day, then it is your responsibility to get your quiz from your recitation instructor. You will have until recitation on Friday March 12 to request a quiz grading review, regardless of whether or not you attend recitation on Friday February 27 and take back your quiz. If you wish to have your quiz grade reviewed, you must return your quiz to your recitation instructor, within the two week period, together with a written explanation of why you think a grading mistake was made. This is the only way in which a quiz grade will be reviewed.
- Good luck!

Problem 1	Problem 2	Problem 3	Problem 4	Total Grade

Problem 1 – 40%

This problem involves a network that is implemented with three resistors and a voltage source as shown below. Its terminal characteristics are also given graphically below.





(1A) From the graphical data given above, determine numerical values for the parameters of the Thevenin equivalent of the network.

V_{TH}: 3 Volts	R_{TH}: 2 kΩ

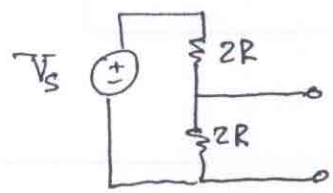
$$v_{TH} = \text{Open-circuit } (i=0) \text{ voltage} = 3V$$

$$R_{TH} = -\frac{\text{Open-circuit voltage}}{\text{Short-circuit } (v=0) \text{ Current}} = \frac{3V}{1.5mA} = 2k\Omega$$

(1B) Determine numerical values for the parameters V_S and R that characterize the implementation of the network shown above.

V_S: 6 Volts	R: 1 k Ω

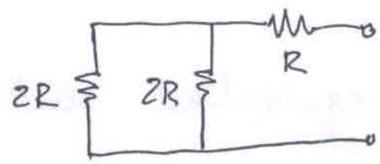
Open circuit voltage $\Rightarrow$



$V_{oc} = \frac{V_S}{2}$

$\Rightarrow V_S = 2 V_{TH} = 6$ V

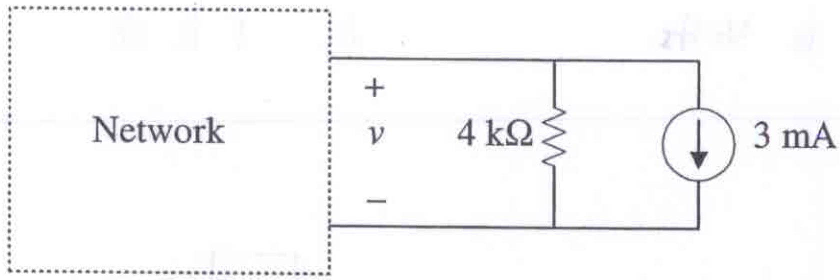
$R_{TH} =$



$= 2R = 2 k\Omega$

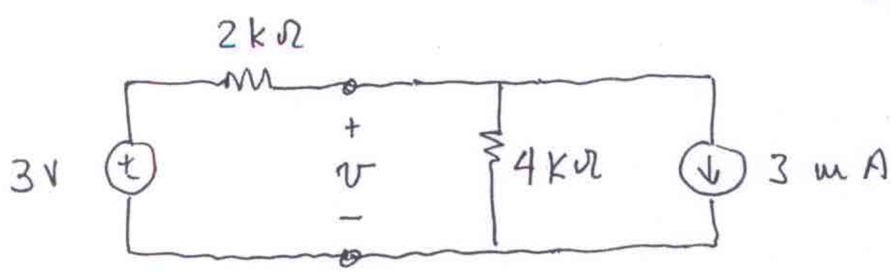
$\Rightarrow R = 1 k\Omega$

(1C) The network is connected to an external current source and resistor as shown below. Determine the value of its terminal voltage v given the external connection.



v: − 2 Volts

Use the Thevenin equivalent and superposition.

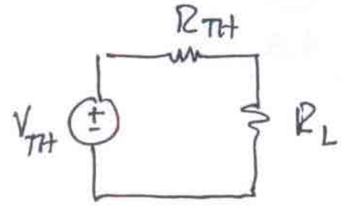


$$v = \frac{2}{3} \cdot 3\,V - \frac{4\,k\Omega \cdot 2\,k\Omega}{6\,k\Omega} \cdot 3\,mA = -2\,V$$

(1D) A load resistor is connected across the terminals of the network. Determine the value of load resistance that will result in the maximum power dissipated in the load resistor. Also determine the maximized load power.

Load Resistance: $2\ k\Omega$	Load Power: $\frac{9}{8}\ mW$

Again, use the Thevenin equivalent.



$$\text{Power In } R_L = R_L \cdot \left(\frac{V_{TH}}{R_{TH} + R_L} \right)^2$$

$$\frac{d}{dR_L}\left(\text{Power In } R_L\right) = \frac{2V_{TH}^2 (R_{TH} + R_L)^2 - 4R_L (R_{TH} + R_L) V_{TH}^2}{(R_{TH} + R_L)^4}$$

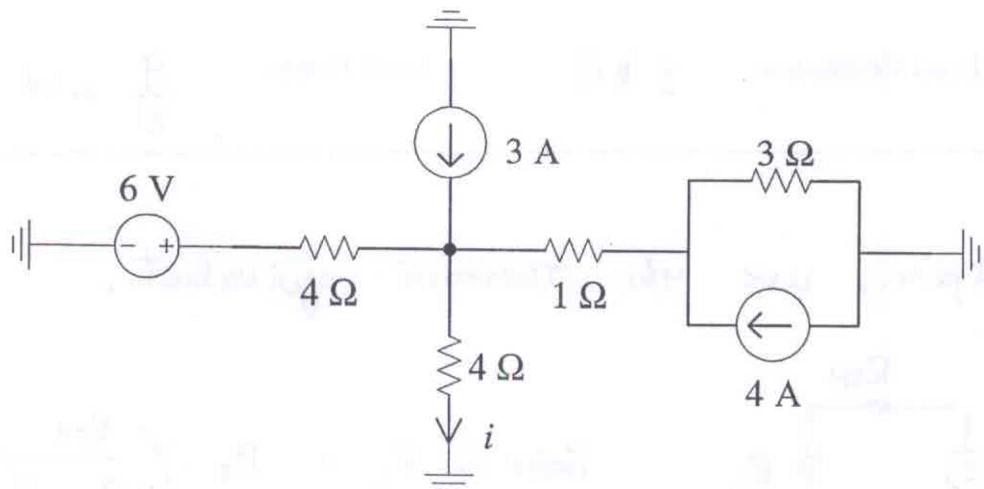
$$= 0$$

$$\Rightarrow \quad R_L = R_{TH} = 2\ k\Omega$$

$$\text{Load Power} = \frac{(3 \text{ Volts})^2}{2k\Omega + 2k\Omega} \cdot \frac{1}{2} = \frac{9}{8}\ mW$$

Problem 2 – 20%

Determine the current i in the network below.



i:	2.5 Amps

Use superposition.

6V Source ⇒ $i = \frac{1}{2} \cdot \frac{6V}{6\Omega} = \frac{1}{2}$ A

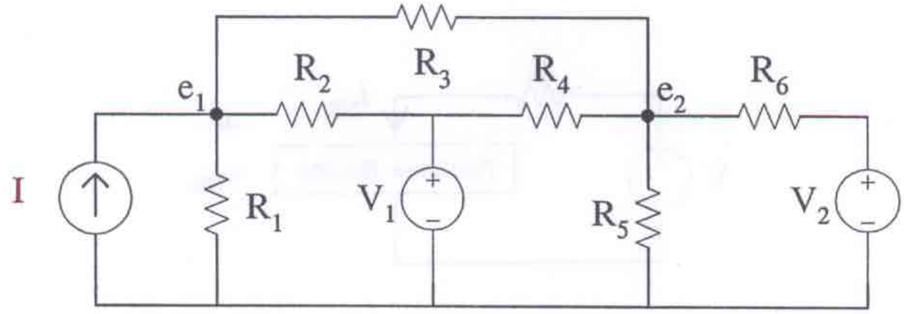
3A Source ⇒ $i = \frac{1}{3} \cdot 3A = 1$ A

4A Source ⇒ $i = \frac{1}{2} \cdot \frac{1}{2} \cdot 4A = 1$ A

Total $i = 2\frac{1}{2}$ A

Problem 3 – 10%

The network shown below has two nodes with unknown node voltages e_1 and e_2. Carry out a node analysis and determine two node equations that can be used to determine e_1 and e_2. You need not solve the equations.

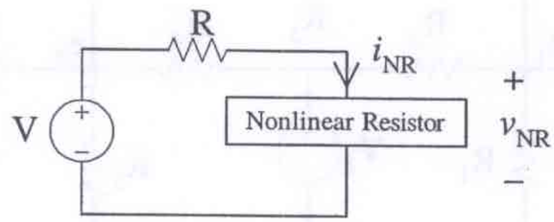


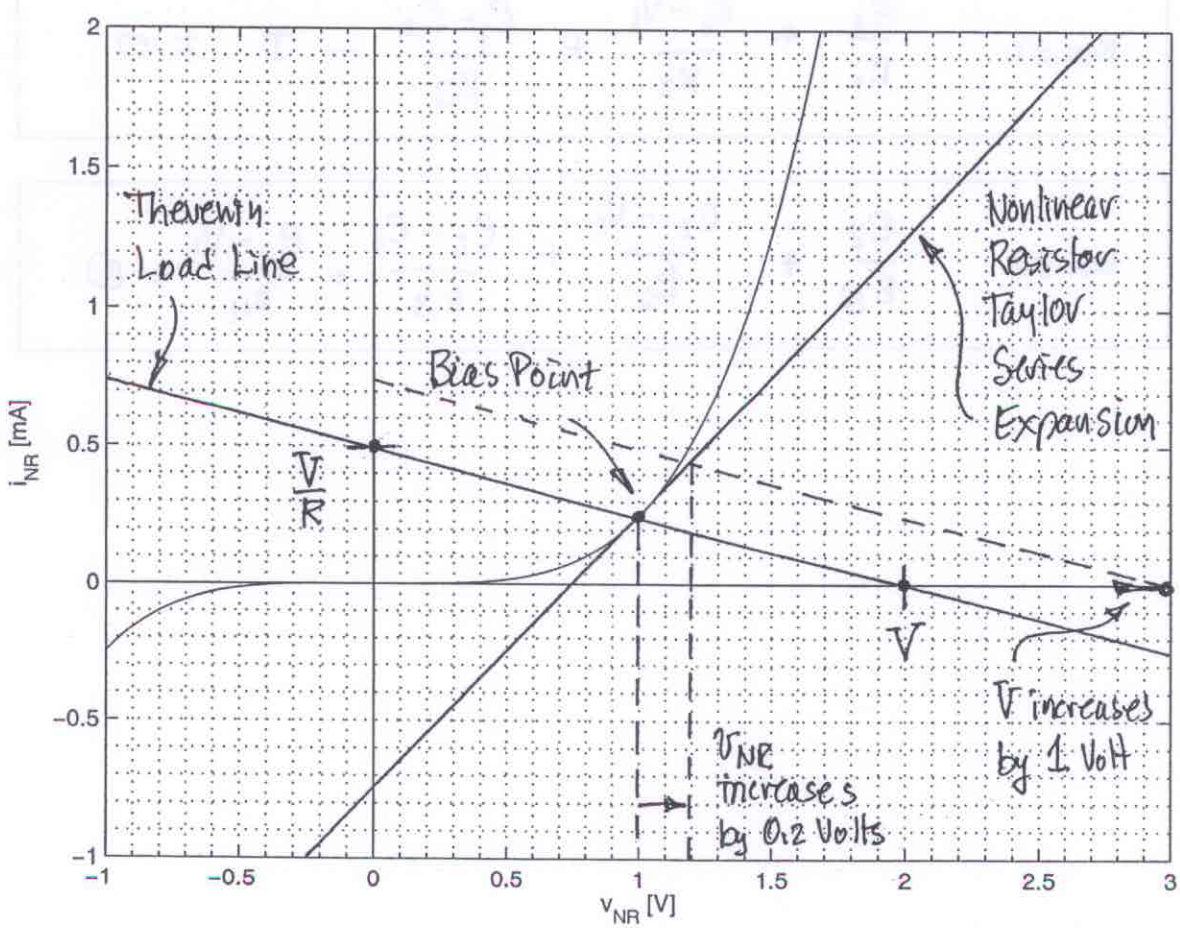
Eqn #1:	$\frac{e_1}{R_1} + \frac{e_1 - V_1}{R_2} + \frac{e_1 - e_2}{R_3} - I = 0$

Eqn #2:	$\frac{e_2}{R_5} + \frac{e_2 - V_2}{R_6} + \frac{e_2 - e_1}{R_3} + \frac{e_2 - V_1}{R_4} = 0$

Problem 4 – 30%

A nonlinear resistor having terminal voltage v_{NR} and terminal current i_{NR} is connected to an external network as shown below. The terminal characteristics of the nonlinear resistor are also given graphically below. *Note carefully the scales of the graph, volts and milliamps, and the location of its origin.*





(4A) Assume that $V = 2$ V and $R = 4$ kΩ in the external network. Using the graphical terminal characteristics of the nonlinear resistor, determine v_{NR} and i_{NR}. *Hint: draw a load line for the external network on the graph given above.*

v_{NR}: 1 Volt	i_{NR}: 0.25 mA

See graph. Use Thevenin load line to find the bias point.

(4B) Assume now that $V = (2 + 0.1\sin(t))$ V and $R = 4$ kΩ in the external network. In this case, v_{NR} will be given approximately by $v_{\text{NR}} \approx A + B\sin(t)$. Using the terminal characteristics of the nonlinear resistor determine A and B.

A: 1 Volt	B: 0.02 Volts

V increases by 1 volt $\Rightarrow$ V_{NR} increases by 0.2 volts.

$\Rightarrow$ V_{NR} increases by 0.02 volts when V increases by 0.1 volts. See graph.