MASSACHVSETTS INSTITVTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.002x – Circuits and Electronics
Spring 2004

Problem Set 1
Readings and exercises for the week of Feb. 4–10

Issued: 4 February 2004

Textbook: Be sure to do the required readings *before class* as indicated. Your tutor may also be assigning additional readings from the references for case 1.

- From the package for case 1, read the handout on "Typical residential power" before tutorial on Thursday, Feb. 5. **Please bring the entire case package with you to tutorial.**
- From Agarwal and Lang, skim the first two chapters, paying most attention to section 1.5.3 and sections 2.1–2.4. Also read chapter 3 through section 3.3.2. Finish this reading before lecture on February 9.

Cases and tutorials: We will be studying 5 cases over the course of the semester. Readings for each case will consist of reference material that will will be handed out in lecture at when we begin studying the case.

Homework: Homework problems should be done on line, using the 6.002x homework system. You will find a link to the system on the course web site at http://mit.edu/6.002x. You must register with the system before using it for the first time.

The homework system lets you check your work before submitting it. It also keeps track of which problems you've completed and when you've completed them. Some problem sets will contain parts to write up and hand in at lecture, in addition to the problems to be done on line. This first problem set, for example, includes an optional extra credit problem (difficult!) that you can write up and hand in at lecture on Wednesday, February 11.

In general, problem sets will be announced on Monday, with some parts due throughout the week and the remainder due before the following Monday lecture. This first week is different because there was no Monday class.

Part 1: To do and turn in on line before tutorial on Monday, Feb. 9

1.1: Quick question on voltages and currents

1. What's the resistance of a lit 60 Watt light bulb?
2. How much current does the lit blub draw if it's plugged into a 120 Volt circuit?
3. If you connect two 60 Watt light bulbs in series and plug the combination into a 120 Volt circuit, how much power do the two bulbs draw together?

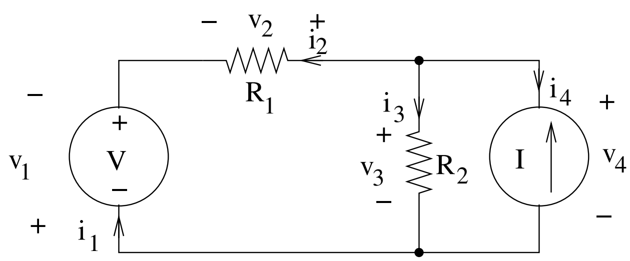

Figure 1: Circuit for problem 1.2

1.2: Practice with KVL and KCL

Figure 1 shows a circuit with four elements: two resistors with resistances R_1 and R_2, a voltage source with strength V, and a current source with strength I. Branch voltage circuit variables (v_k) and branch current circuit variables (i_k) are defined for each element, in associated reference directions.

When you do this problem on line, the system will supply values R_1, R_2, V, and I for you to work with. You can return to the homework system as many times as you like—you'll get the same values for the components each time, although different students will get different values.

Use the following steps to solve for the branch voltages and currents, and use the online system to check and submit your answers:

1. How many nodes are there in the circuit? Write a KCL equation for each node. How many of the KCL equations are independent? Independent means "Cannot be derived from the other equations."
2. How many loops are there in the circuit? Write a KVL equation for each loop. How many of these equations are independent?
3. Write an equation expressing the v–i constraint for each element.
4. You should now have a set of linear equations in the branch voltage and current variables. If you count only the independent equations, you should have one equation for each unknown branch voltage or current. Solve the equations and use the online homework system to submit and check your results.

Part 2: To do and turn in on line before Wednesday, Feb. 11

2.1: Equivalent resistors Problem 5 from chapter 2 of the text (details are on line).

2.2: Christmas Lights Joe found a string of antique Christmas lights in his basement. He draped it over a bush on his lawn. The string consists of 15 lightbulbs in series, each of which consumes 10 Watts when the string is plugged into a 120 Volt branch circuit.

1. How much current is the string intended to draw?
2. One day the middle lightbulb (the eighth one) in the string fails. (It becomes an open circuit.) Joe is pretty clever, so he makes a patch that short-circuits the bulb that has failed. Assuming that the resistance of the bulbs is roughly independent of the current through them (which is not actually true for lightbulbs) do the remaining lightbulbs glow more or less brightly than bulbs in the intact string of 15 bulbs would? Does the string as a whole glow more or less brightly than the original string?
3. Joe insulated his patch with electrical tape. One night there is a rainstorm, producing a connection between the short-circuit of Joe's patch and the bush. The resistance through the bush and the earth beneath it to the service-entrance ground is 100 Ω. How much current goes through the bush? Which lightbulbs become brighter? Which become dimmer?

2.3: Practice with the node method A modified version of exercise 1 from chapter 3 of the text (details are on line).

Part 3: Optional extra credit to turn in at lecture on Feb. 11

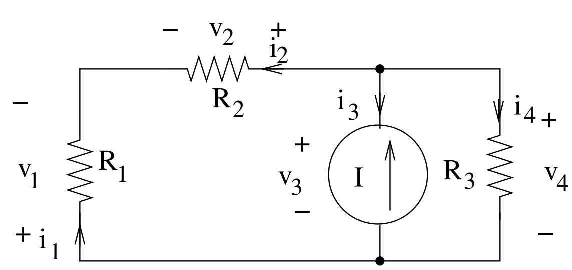

Figure 2: Circuit for Part 3(2)

This is an extra credit problem. If you do it, write up your answer and turn it in on paper at lecture on Feb. 11.

(1): Go back and solve again (for practice) for the branch voltages and currents in the circuit of Problem 1.2 using any values you wish for R_1, R_2, V, and I. Compute the sum of the products $v_1 i_1 + v_2 i_2 + v_3 i_3 + v_4 i_4$ The result should be zero. Explain why.

(2): Now solve for the branch voltages and currents in the circuit of Figure 2, using any values you wish for R_1, R_2, R_3, and I. Verify that the sum of the products $v_1 i_1 + v_2 i_2 + v_3 i_3 + v_4 i_4$ is again zero.

(3) Difficult!: Now do something really weird: Compute once again the sum of products $v_1 i_1 + v_2 i_2 + v_3 i_3 + v_4 i_4$ where the v's are the voltages you computed in (1) and the i's are the corresponding currents you computed in (2). *That's right: the v's and the i's come from different circuits.* This sum should also be zero. You get a *gold star* if you can explain why, and you get *two gold stars* if you can state and prove a general result.