Tufts University
Department of Electrical and Computer Engineering
ES3 Introduction to Electrical Systems

Homework #3

Problem 1 (4 points): Use the voltage-division principle to calculate v in Fig. 1.

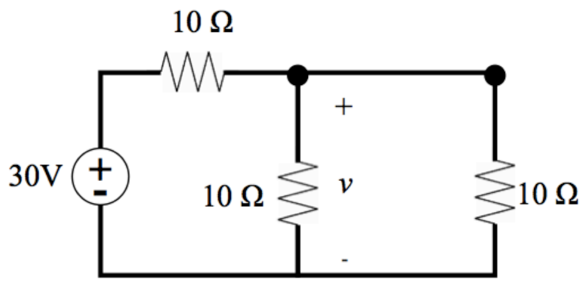

Figure 1. Circuit for Problem 1.

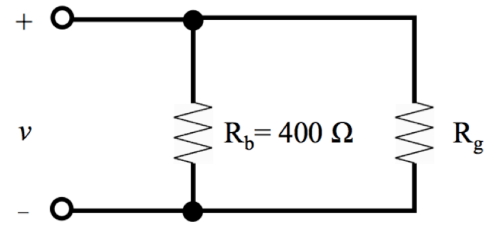

Figure 2. Circuit for Problem 2.

Problem 2 (10 points): You are standing on a wet concrete floor holding an electric drill having a metallic case. The metallic case is connected through a ground wire of a three-terminal power outlet to power-system ground. The resistance of the ground wire Is R_g. The resistance of your body is $R_b = 400\Omega$. Due to faulty insulation in the drill, a current of 1A flows into the metallic case. The electrical equivalent circuit diagram for this scenario is shown in Figure 2. Find the maximum value of the ground wire R_g so that the current through your body does not exceed 0.1mA.

Problem 3 (4 points): A series connected circuit has a 120-V voltage source, a 24 Ω resistor, a 10 Ω resistor, and an unknown resistance R_X. The voltage across the 24 Ω resistor is 60V. Determine the value of the unknown resistance R_X.

Problem 4 (6 points): Suppose that we wish to supply 500mW to a load resistor $R_L = 50\ \Omega$. A 300mA current source and resistors of any value needed are available. Draw a suitable circuit consisting of the current source, the load, and one additional resistor. Specify the value of the resistor.

Problem 5 (6 points): The Wheatstone bridge shown in Figure 2.64 in the textbook on page 105 has $V_S = 10$V, R_1=1 kΩ, R_2 = 10 kΩ, and R_X = 6420 Ω. The detector can be modeled as a 5 kΩ resistance. What value of R_3 is required to balance the bridge?

Problem 6 (10 points): Consider a strain gauge in the form of a long thin wire having a length L and a cross-sectional area A before strain is applied. After the strain is applied, the length increases slightly to $L + \Delta L$ and the area is reduced so that volume occupied by the wire remains constant. Assume $\Delta L/L << 1$ and that the resistivity ρ of the wire material is constant. The expression for ρ can be found in Equation 1.10 of the textbook. Prove that the gauge factor is approximately equal to 2:

$$G = \frac{\Delta R/R_0}{\Delta\, L/L} \backsimeq 2$$

Problem 7 (10 points): Use the node voltage method to solve for the node voltages, v_1 and v_2, shown in Figure 3. Then, find the value of the current i_1.

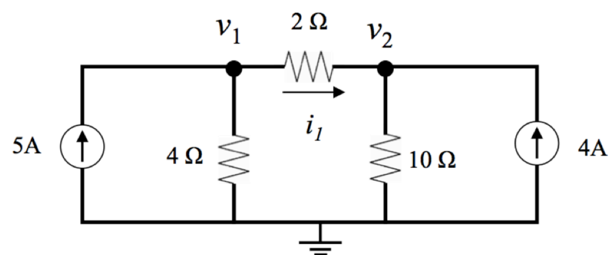

Figure 3. Circuit for Problem 7.

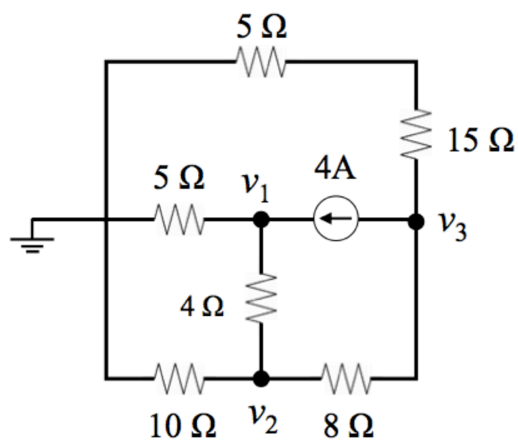

Figure 4. Circuit for Problem 8.

Problem 8 (14 points): Use MATLAB to solve for the node voltages in Figure 4. Write out the equations needed to solve for the node voltages in matrix form.

Problem 9 (12 points): Solve for the node voltages, v_1 and v_2, shown in Figure 5 and find the value of i_S.

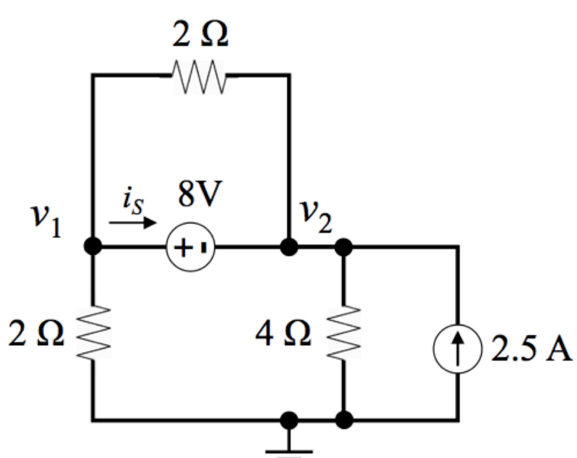

Figure 5. Circuit for Problem 9.

Problem 10 (10 points): Determine the value of i_1 in Figure 6 using the node voltage method to solve the circuit. Select the location of the reference node to minimize the number of unknown node voltages. What effect does the 50 Ω resistance have on the answer? Explain.

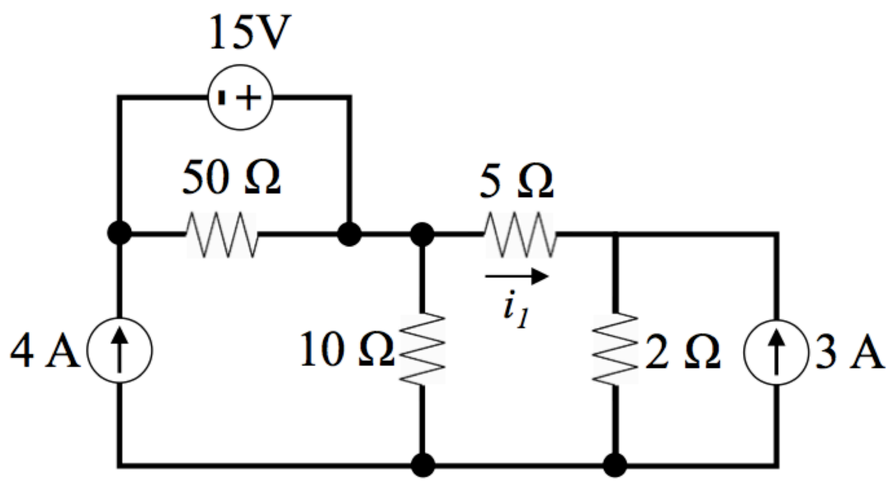

Figure 6. Circuit for Problem 10.

Problem 11 (14 points): Use the symbolic features of MATLAB to find an expression for the equivalent resistance for the network shown in Figure 7. *(Hint: First connect a 1A current source across terminals a and b. Then, use the node voltage method to generate a set of equations. The voltage across the current source divided by the 1A current source is equal in value to the equivalent resistance.)* Finally, use the **subs** command in MATLAB to evaluate the equivalent resistance for $R_1 = 25\ \Omega$, $R_2 = 25\ \Omega$, $R_3 = 25\ \Omega$, $R_4 = 15\ \Omega$, and $R_5 = 15\ \Omega$.

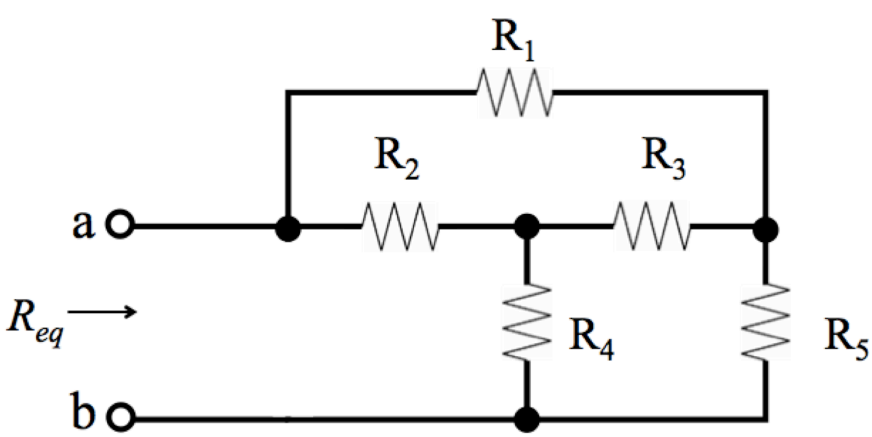

Figure 7. Circuit for Problem 11.