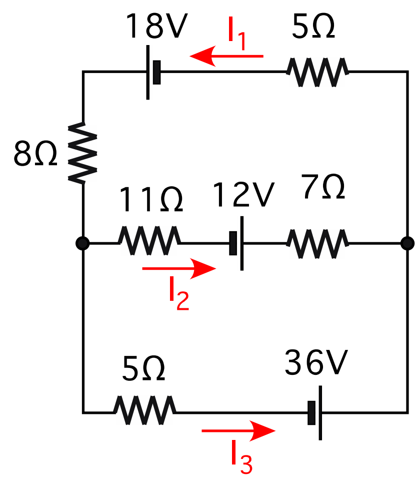
PHY 336L HW1 Due: 9/28/2020 at the beginning of class

Problem 1

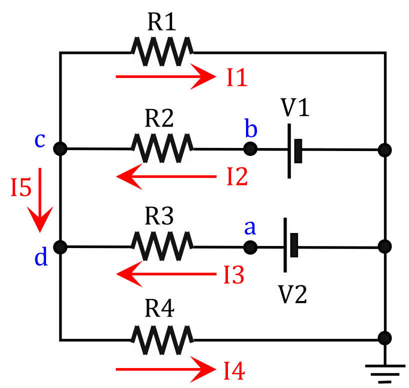


a) For the circuit shown, use Kirchhoff's rules to write down equations for the upper loop, the lower loop, and the node on the left side (where the 8Ω and 11Ω resistor are connected)

b) Solve the equations found in part a) simultaneously for the three unknowns I_1, I_2, and I_3.

c) What is the significance of the negative answer for I_2 ?

Problem 2



The resistors and batteries in this circuit have the following values:

$R_1 = R_4 = 6\text{k}\Omega$
$R_2 = 10\text{k}\Omega$
$R_3 = 5\text{k}\Omega$

$V_1 = 6\text{V}$
$V_2 = 4.5\text{V}$

a) Write the two junction or current equations for the two junctions *c* and *d*, then combine them to eliminate I_5 and express I_4 by the currents I_1, I_2, and I_3.

b) Write down loop equations for the top loop, the bottom loop, and the big loop (outside loop). Use the expression for I_4 from a) so that each equation only contains I_1 and/or I_2 and/or I_3, i.e. when you are done there should not be an I_4 and I_5 in your equations.

c) Solve the system of 3 equations by any means at your disposal. State or show how you do this.

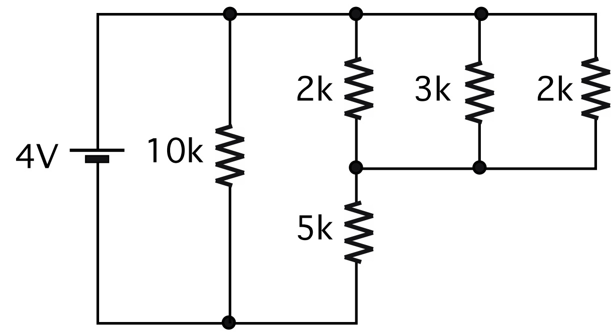
d) Determine the potential difference between points *a* and *b*, i.e. what would a voltmeter show if you'd connect it to *a* and *b*. Explain with a few brief words.

e) How much power does the entire circuit dissipate?

f) Pretend someone assembling the circuit is making a mistake and puts in battery V_2 backwards, i.e. the – terminal connected to point *a* and + terminal on the opposite side. How is the power dissipation affected by this mistake? [State if the dissipation increases or decreases and justify your answer numerically]

Problem 3

Find the currents in all the resistors in the circuit shown. This time don't use the loop and junction equations as in Problem 1, but try to simplify the circuit by combining resistors in parallel and series until you have one battery and one resistor. For details see sections 1.3.1 and 1.5.1 in your text.



For this circuit, you would take the 2k, 3k, and 2k resistors in parallel and collapse them into one equivalent resistor, which then is in series with the 5k resistor. Once you have the series combination of the 5k and the 2k/3k/2k in parallel, that in turn is in parallel with the 10k resistor. So now you have one resistor and a 4-V battery. The current that flows out of the battery and into the one resistor is the same current that flows out of the battery in the actual circuit into all the resistors. Then you retrace your steps, i.e. now you have the battery with the 10-k resistor in parallel with the equivalent value of 5k in series with the parallel combination of 2k/3k/2k. You find the current through the 10k resistor by realizing the voltage drop across it is 4 V (due to the battery), and so on. In this way you unfold the circuit back to the original one, each time finding the currents for the next step.

Problem 4

#13 from section 1.9 (p. 38) in textbook

All currents can be expressed in terms of a rational factor and V_o and R, e.g. $\frac{6}{17}\frac{V_o}{R}$.

Similarly, all voltages can be expressed in terms of a rational factor and V_o, e.g. $\frac{5}{21}V_o$.

Problem 5

#14 from section 1.9 (p. 38) in textbook

Problem 6
#16 from section 1.9 (p. 38) in textbook

Problem 7
#19 from section 1.9 (p. 39) in textbook
For this find the results for the Thevenin equivalent circuit (Fig. 1.40) only.

Problem 8
#27 from section 1.9 (p. 40) in textbook
Think of the circuit as a voltage divider cascade, i.e. a voltage divider that is connected to another voltage divider.

Problem 9
#7 from section 1.9 (p.38)

Problem 10
#8 from section 1.9 (p. 38)

7. ⊗ (1e:1.4) Explicitly demonstrate that equation 1.16 is true for two capacitors in parallel.

8. (1e:1.5) Explicitly demonstrate that equation 1.17 is true for two capacitors in series.

9. A parallel-plate capacitor is built using two metal plates each of surface area $A = 100\,cm^2$. The plates are separated by $1\,mm$ and the gap is filled with air. (a) What is the capacitance of the capacitor? (b) If each plate has $1\mu C$ of charge on it, what is the potential difference across the capacitor?

10. Show that two inductors connected in series will add like resistors.

11. Show that two inductors connected in parallel will add like resistors.

12. ⊗ (1e:1.6) For the circuit in Figure 1.37 above, what is the ratio of $R_2 : R_1$ such that the voltage across A and B is $\frac{1}{2}V_0$? What is the ratio of $R_2 : R_1$ such that the voltage across A and B is $\frac{1}{3}V_0$? $\frac{1}{10}V_0$?

13. (1e:1.7) Consider the circuit shown in Figure 1.38 which is built using six identical resistors. Use Kirchoff's rules to solve for the current flowing through each resistor in the circuit. What is the voltage drop across each resistor in the circuit? (To facilitate labeling, use a notation such as I_{pq} and V_{pq} where these represent the current flowing from point p to point q, and the voltage drop in going from point p to point q.)

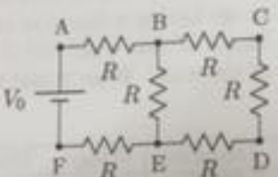


Figure 1.38: The circuit for problem 13.

14. ⊗ (1e:1.8) We now attach two output terminals to the circuit from problem 13. The resulting circuit is shown in in Figure 1.39. **(a)** What is the voltage between the terminals G and H? **(b)** What current flows from G to H? **(c)** If we connect a wire from G to H, what current flows through the wire and what is the voltage between G and H?

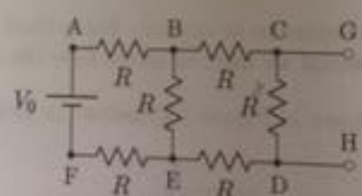


Figure 1.39: The circuit for problem 14.

15. You measure the potential difference across a $10\,k\Omega$ resistor to be $10\,V$. What is the current flowing through the resistor?

16. (1e:1.9) Replace the circuit from problem 14 with the simpler one shown in Figure 1.40. V_{th} is a voltage source and R_{th} is a new resistance. What are the values of V_{th} and R_{th} such that you get the same answer to the current and voltage questions as in problem 14?

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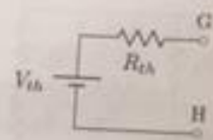

Figure 1.40: The circuit for problem 16.

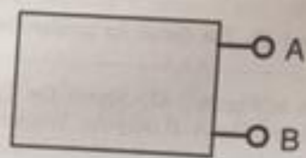

Figure 1.41: The electrical device for problem 17.

17. You are given an electrical device with two output terminals as shown in Figure 1.41. Draw the Thévenin equivalent circuit for device as seen between the two terminals, A and B.

18. (1e:1.10) Replace the circuit in Figure 1.39 with the one shown in Figure 1.42 where I_N is a current source that always delivers I_N amps of current and R_N is a new resistance. What are the values of I_N and R_N such that you get the same answer to the current and voltage between G and H as in problem 14?

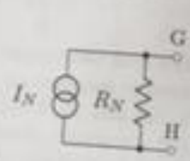

Figure 1.42: The circuit for problem 18.

19. (1e:1.11) We can generate I-V curves for the circuits shown in Figures 1.40 and 1.42 by placing a variable resistor, R_V, between the G and H terminals. As we vary the value for R_V from 0 to ∞, we map a set of (V, I) points. As stated previously, this curve should be linear. Pick four to five values of R_V and evaluate I and V between the G and H terminals for either the Thévenin (Figure 1.40), or the Norton (Figure 1.42) equivalent circuit. Does it matter which one you choose? Plot these values as a graph of I versus V and show that it is indeed linear. What is the slope of the line?

20. ⊛ (1e:1.12) Consider the two circuits shown in Figure 1.16 for measuring the voltage across R and the current through R. Assume that the internal resistance of the voltmeter is $R_v = 100\,R$ and that the internal resistance of the ammeter is $R_a = 0.01\,R$. In terms of V_0 and R, what are the measured voltages and currents in each of the two circuits?

21. (1e:1.13) Show that the open-circuit voltage of a circuit is the Thévenin voltage of the circuit.

22. (1e:1.14) Show that the short-circuit current is the Norton current of the circuit.

23. (1e:1.15) Show that equation 1.34 is correct.

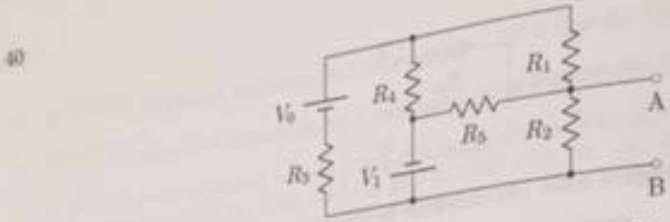

Figure 1.43: The circuit for problem 24.

24. You are given the circuit shown in Figure 1.43. Sketch the Thévenin equivalent circuit for the circuit as seen looking to the left into the A-B outputs. You do not need to determine any values, just sketch the circuit.

25. ⊛ (Ie:1.16) Determine the parameters of the Thévenin equivalent for the circuit shown in Figure 1.44.

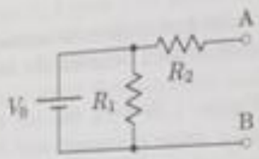

Figure 1.44: The circuit for problem 25.

26. (Ie:1.17) You are given a *black-box* device with two output terminals. You are asked to characterize the behavior of this device, so you proceed to measure an $I-V$ curve for the circuit. You measure the following two (I,V) points: $(2.0I_b, V_b)$ and $(I_b, 5.0V_b)$. **(a)** Sketch the Thévenin and Norton equivalent circuits for the black box. **(b)** Accurately sketch the $I-V$ curve for the black box. Be sure to carefully label your plot. **(c)** From your graph, determine the Thévenin voltage, V_{th}, the Thévenin resistance, R_{th}, the Norton current, I_N and the Norton resistance, R_N for your black box. Express your answer in terms of V_b and I_b. **(d)** A load resistance of value $R_L = R_{th}$ (equal to the Thévenin resistance) is connected across the output terminals of your black box. In terms of V_{th} and I_N, what is the voltage across R_L and the current through R_L?

27. ⊛ (Ie:1.18) You have a so-called *R2R ladder*, with two output terminals as shown in Figure 1.45. **(a)** Sketch the Thévenin equivalent of the R2R ladder as seen when looking into the output terminals to the right of the circuit. **(b)** Sketch the I-V curve for your R2R ladder as seen from the output terminals. Label your axes in terms of V_{th} and R_{th}. **(c)** What is the Thévenin equivalent voltage, V_{th}, and the Thévenin resistance, R_{th}, for the R2R ladder? (Hint: You may find it useful to calculate the voltage at the node between the $5\,k\Omega$ resistors first.)

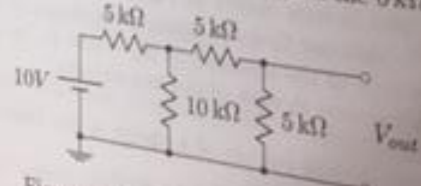

Figure 1.45: The circuit for problem 27.