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# EECS 16A    Designing Information Devices and Systems I

## Spring 2021    Homework 6

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**This homework is due Friday, March 5, 2020, at 23:59.**

**Self-grades are due Monday, March 8, 2020, at 23:59.**

### Submission Format

Your homework submission should consist of **one** file.

- `hw6.pdf`: A single PDF file that contains all of your answers (any handwritten answers should be scanned)

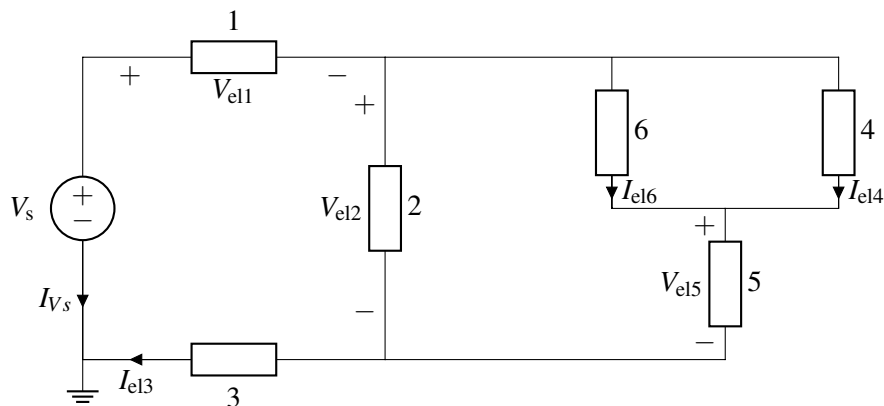
Submit the file to the appropriate assignment on Gradescope.

### 1. Reading Assignment

For this homework, please read Note 11, which introduces the basics of circuit analysis and node voltage analysis. Please also read Note 12, which introduces using circuits for modelling. You are always welcome and encouraged to read beyond this as well. **Question to answer: What is the value of having a systematic procedure for solving circuits?**

### 2. Intro to Circuits

**Learning Goal:** This problem will help you practice labeling circuit elements and setting up KCL and KVL equations.



- (a) How many nodes does the above circuit have? Label them.

*Note:* The ground node has been selected for you, so you don't need to label that, but you need to include it in your node count.

- (b) Notice that elements 1 - 6 and the voltage source  $V_s$  have either the *voltage across* or the *current through* them not labeled. Label the missing *voltages across* or *currents through* for elements 1 - 6, and the voltage source  $V_s$ , so that they all follow **passive sign convention**.

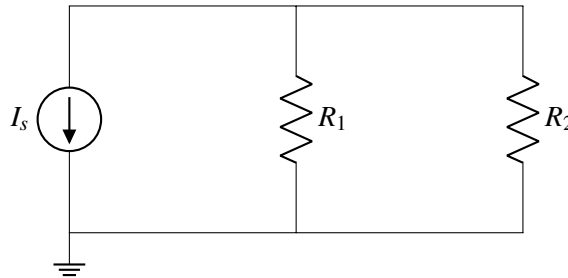
- (c) Express all element voltages (including the element voltage across the source,  $V_s$ ) as a function of node voltages. This will depend on the node labeling you chose in part (a).
- (d) Write one KCL equation that involves the currents through elements 1 and 2.  
*Hint: This will **not** be specific to your node labeling. Your answer may contain currents through other elements too.*
- (e) Write a KVL equation for all the loops that contain the voltage source  $V_s$ . These equations should be a function of element voltages and the voltage source  $V_s$ .

### 3. Circuit Analysis

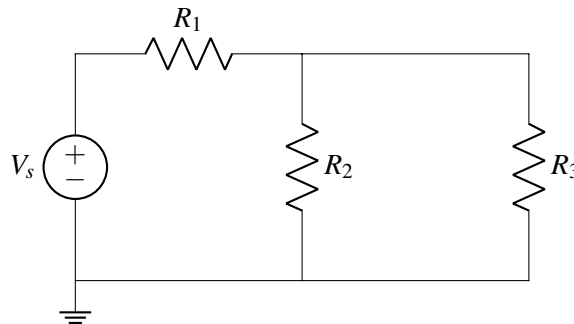
**Learning Goal:** This problem will help you practice circuit analysis using NVA method.

Using the steps outlined in lecture or in Note 11, analyze the following circuits to calculate the currents through each element and the voltages at each node. Use the ground node labelled for you. You may use a numerical tool such as IPython to solve the final system of linear equations.

- (a)  $I_s = 3 \text{ mA}$ ,  $R_1 = 2 \text{ K}\Omega$ ,  $R_2 = 4 \text{ K}\Omega$



- (b)  $V_s = 5 \text{ V}$ ,  $R_1 = R_2 = 2 \text{ K}\Omega$ ,  $R_3 = 4 \text{ K}\Omega$

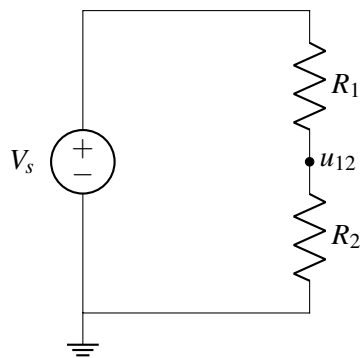


### 4. Voltage divider

**Learning Goal:** This problem will help you practice designing circuits under given conditions using the analysis tools you've learned.

In the following parts,  $V_s = 12 \text{ V}$ . **Choose resistance values such that the current through each element is  $\leq 0.8 \text{ A}$ .**

- (a) Select values for  $R_1$  and  $R_2$  in the circuit below such that  $u_{12} = 6 \text{ V}$ . This is a **design problem**, so there can be more than one set of correct answers to this problem.



## 5. Temperature Sensor

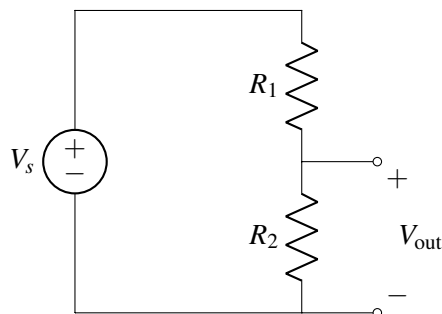
**Learning Goal:** This problem will let you apply the tools we have learned so far to a real world circuits application.

Measuring quantities in the physical world is the job of sensors. This means somehow extracting that information from the world and then converting it into a form that can be observed and processed. Electrical circuits can be very useful for doing this.

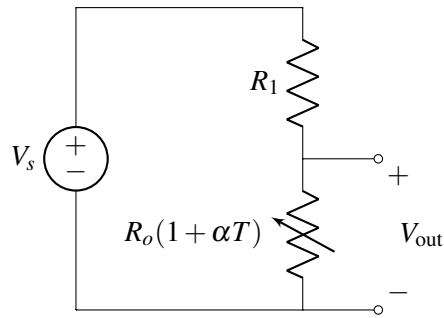
For most materials, resistance increases with increasing temperature; that is, a resistor has higher resistance when it is hot than when it is cold. This is often an annoyance to circuit designers who want their circuits to work the same way at different temperatures, but this fact can also be useful. It allows us to convert temperature, a “physical” quantity, into resistance, an “electrical” quantity, to build an electronic thermometer.

In this problem, we are going to explore how effective a particular circuit made out of various types of resistors is at allowing us to measure temperature.

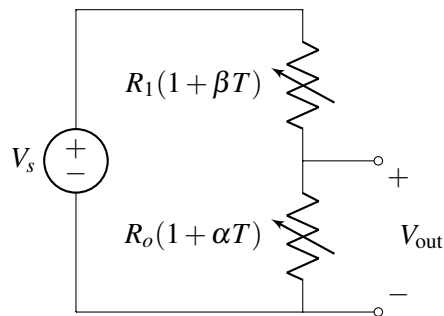
- (a) Let’s begin by analyzing a common topology, the voltage divider shown below. Find an equation for the voltage  $V_{\text{out}}$  in terms of  $R_1$ ,  $R_2$ , and  $V_s$ .



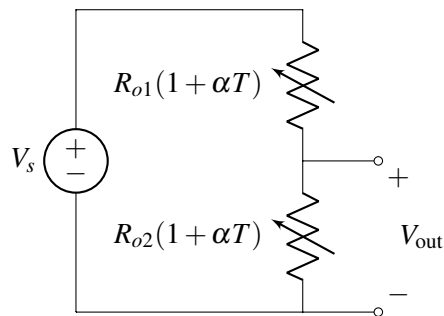
- (b) Now let’s suppose that  $R_1$  is an ideal resistor that does not depend on temperature, but  $R_2$  is a temperature-dependent resistor whose resistance  $R$  is set by  $R = R_o(1 + \alpha T)$ , where  $T$  is the absolute temperature. Find an equation for the temperature  $T$  in terms of the voltage  $V_{\text{out}}$ ,  $V_s$ ,  $R_1$ ,  $R_o$ , and  $\alpha$ .



- (c) It turns out that almost all resistors have some temperature dependence. Consider the same circuit as before, but now,  $R'_1$  has a temperature dependence given by  $R'_1 = R_1(1 + \beta T)$ . Find an equation for the temperature  $T$  in terms of the voltage  $V_{\text{out}}$ ,  $R_1$ ,  $R_o$ ,  $V_s$ ,  $\alpha$ , and  $\beta$ .



- (d) Your colleague who has not taken EECS16A thinks that they can improve this circuit's ability to measure temperature by making both resistors depend on temperature in the same way. He hence came up with the circuit shown below, where both  $R_1$  and  $R_2$  have nominally different values, but both vary with temperature as a function of  $(1 + \alpha T)$ . Can this circuit be used to measure temperature? Why or why not?



## 6. Homework Process and Study Group

Who did you work with on this homework? List names and student ID's. (In case you met people at homework party or in office hours, you can also just describe the group.) How did you work on this homework? If you worked in your study group, explain what role each student played for the meetings this week.