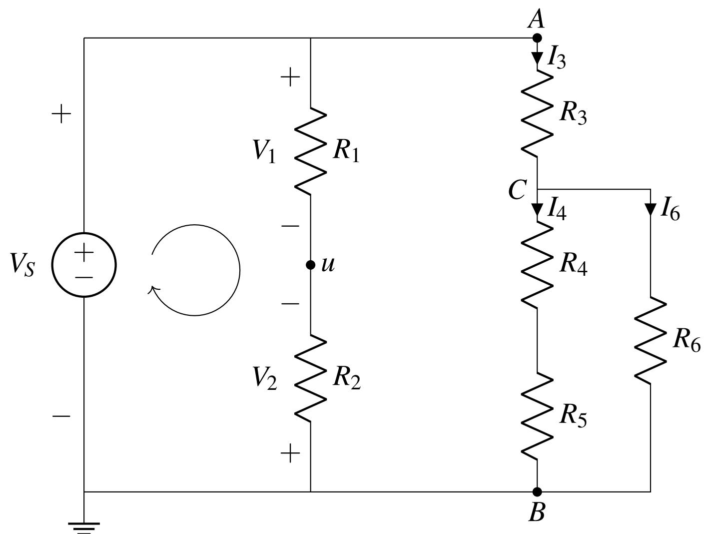
EECS 16A Designing Information Devices and Systems I
Spring 2023 Exam Prep 7B

1. Circuit Analysis (Spring 2021 Midterm 2 Question 3)

For the circuit in the following diagram, answer parts (a) – (e).



(a) Following the passive sign convention, label (i) the current I_S through the voltage source V_S, (ii) the current I_1 through the resistor R_1, and (iii) the voltage V_3 across the resistor R_3.

(b) Write the KVL expression for the loop drawn in the circuit diagram in terms of voltages V_S, V_1, and V_2.

(c) Write the KCL expression at node C in terms of currents I_3, I_4, and I_6 as labeled in the circuit diagram.

(d) Given $V_S = 5$ V, $R_1 = 1$ kΩ, $R_2 = 4$ kΩ, $R_3 = 2.5$ kΩ, $R_4 = 1$ kΩ, $R_5 = 4$ kΩ, $R_6 = 5$ kΩ, solve for the values of the element voltages V_1, V_2, and the node voltage u.

(e) Given $V_S = 5$ V, $R_1 = 1$ kΩ, $R_2 = 4$ kΩ, $R_3 = 2.5$ kΩ, $R_4 = 1$ kΩ, $R_5 = 4$ kΩ, $R_6 = 5$ kΩ.

i. If we combine R_3, R_4, R_5, and R_6 as an equivalent resistor R_{eq} connecting between the nodes A and B, what is the value of R_{eq}?

ii. What are the values of the current I_3 and the power dissipated by R_3?

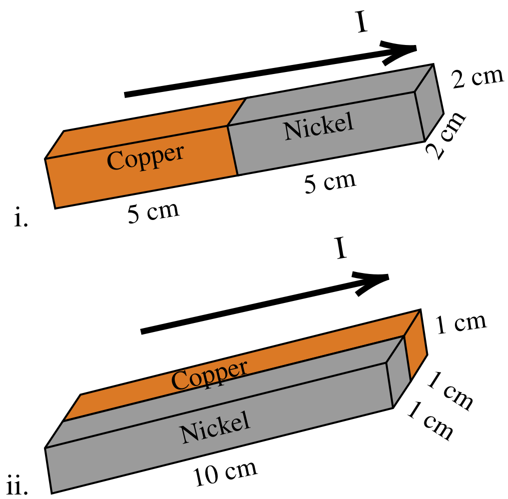
2. Resistive Temperature Sensor (Spring 2021 Midterm 2 Question 5)

Oh no! Predictably, your lab TA gets hurt on the first day of her ski trip and is instructed to ice her injury regularly. However, she's finding that the ice packs are often too cold or too warm and needs a way to track their temperature.

Fortunately, she remembers from 16A that the resistance of many resistors is dependent on temperature! Using this information, you decide to help her build a temperature-sensing device.
Note: in this problem, temperature T is measured in the unit of Celsius.

(a) You have different types of resistive bars available in your lab. For each of the following two resistive bars, express the total resistance in terms of the given quantities and dimensions.

$$\text{resistivity of copper } = \rho_{C_o}(1+\alpha T)\ \Omega\cdot\text{cm}$$
$$\text{resistivity of nickel } = \rho_{N_o}(1+\beta T)\ \Omega\cdot\text{cm}$$



(b) You have the following circuit that has a temperature dependent resistive bar R_T and a resistor with fixed resistance R_f. For this part only, assume $V_s = 5$ V, $R_f = 4$ kΩ, and R_T has resistivity $\rho_T = 100(1 + 0.01T)\ \Omega \cdot \text{cm}$ and cross-sectional area $A = 1\ \text{cm}^2$.

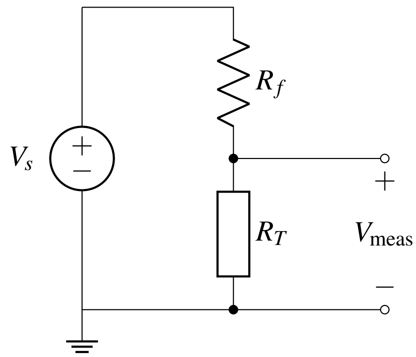


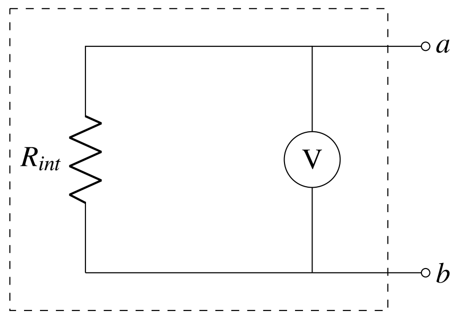
Figure 1: Circuit diagram for parts (b) and (c).

You want to be able to measure temperature T within the range $-10°\text{C} \leq T \leq 30°\text{C}$. You also want to limit the current flow through the resistive bar to be no more than 1 mA. Find the minimum length of the resistive bar R_T such that the current limit is met for *all* temperatures in the specified range.

(c) Next, you are tasked with measuring the voltage across R_T.

i. Draw how you would attach an *ideal* voltmeter to the circuit in Figure 1, in order to measure the voltage across R_T.

ii. Instead of an ideal voltmeter, you only have a practical voltmeter that can be modeled as an ideal voltmeter coming with a parallel internal resistance R_{int}, shown below. You connect the practical voltmeter to the same two nodes where you would attach the ideal voltmeter. Assuming $R_T = 1000$ Ω for this part, determine the minimum value of R_{int} such that the equivalent resistance across the voltmeter is no less than 99% of R_T.



3. Take a Load Off (Fall 2020 Midterm 2 Question 4)

Your 16A TA Amanda is an undergraduate researcher in Berkeley's power electronics lab, where she is working on building power converters to drive motors on electric aircraft.

As a part of her project, Amanda is building a piece of test equipment known as a resistive load bank. You are helping her do the calculations!

(a) Consider the model in Figure (2) for the resistive load bank.
The load resistor $R_L = 100\,\Omega$ and $V_S = 100\,\text{V}$. When the switch is closed, what is value of the power dissipated by R_L? The switch is ideal for this part, i.e. it acts a wire when it is closed.

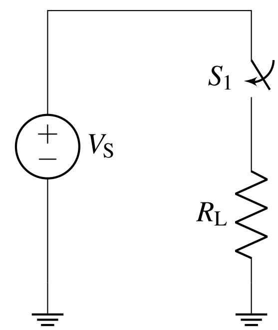


Figure 2: Model of resistive load bank in a circuit.

(b) Consider again the circuit from Figure (2) with the switch closed. Assume that the load resistor $R_L = 100\,\Omega$ can dissipate a max of $P_{max} = 2.5\,\text{kW} = 2.5 \cdot 10^3$ W without exceeding thermal limitations. What is that maximum value of V_S you can use without exceeding the thermal limits? You may assume the switch is ideal, i.e., it acts a wire when it is closed.

(c) For this part, we will no longer assume the switch is ideal; instead, the closed switch has a nonzero on-resistance R_{on}, as shown in Figure (3). You found the R_{on} dissipating 2.5 W at load current $I_L = 5\,\text{A}$, as shown in Figure (3). What is the value of R_{on}?

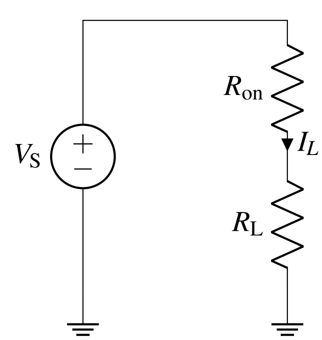


Figure 3: Resistive load bank in a circuit with a non-ideal switch.

