Lab 1: DC Voltage Divider

Physics 327

Spring 2025

Goals

Learn about voltage dividers and non-ohmic devices, while gaining experience using basic electronic equipment and circuit simulations.

Pre-Laboratory Exercises

To prepare for this laboratory, read this laboratory manual carefully, then:

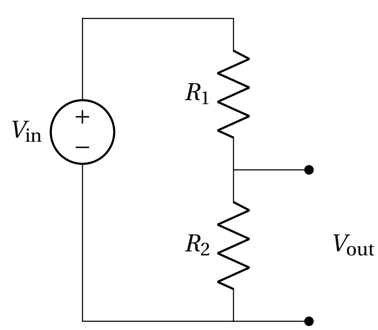
1. Answer **Question 1**, starting from the expression in Eq. 1.
2. Following the video tutorial on Canvas, construct the standard voltage divider in a SPICE simulation program, such as `LTspice`. Perform step (1) of part (A) below and record your results.

Note: Pre-laboratory exercises will appear in most laboratory manuals, and serve to build intuition that will make things much easier for the time-limited lab work. They must be completed prior to the lab meeting, and the results should be included in your report.

A Resistive voltage divider

The purpose of the widely-used *resistive voltage divider* circuit is to convert one DC voltage into a different (smaller) voltage. In this laboratory, you will explore the properties and limitations of this device.

A standard voltage divider, consisting of a voltage source and a pair of resistors in series, is shown below:



This circuit is described by the following equation, as shown in class:

$$V_{\text{out}} = V_{\text{in}} \frac{R_2}{R_1 + R_2}. \tag{1}$$

Consider the behavior of this equation when R_2 is small compared to R_1: the output voltage V_{out} varies almost linearly with R_2. In contrast, when R_2 is large compared to R_1, the value of the latter doesn't matter much, $R_2/R_2 = 1$, and the output voltage is about equal to the input voltage V_{in}.

Question 1: Verify the previous statements mathematically, working out the appropriate expressions with a first-order term plus a second-order correction. (Tip: Consider a Taylor series expansion.)

Now, verify the same holds true experimentally. Build the circuit shown above on the **breadboard**, using the **power supply** as the source of a 12 V DC input voltage V_{in}. Note that lab reports should include a schematic for every circuit you build. Perform the following steps and record your measurements:

1. First, choose $R_1 = 100\ \text{k}\Omega$ and let $R_2 = 1, 10, 100, 1\text{k}, 10\text{k}, 100\text{k}$, and $1\ \text{M}\Omega$. Use discrete components, not the resistor boxes, for R_2. Measure each resistor with the **multimeter**, and compare to the value shown by the color code. For each value of R_2, measure V_{in} and V_{out}.

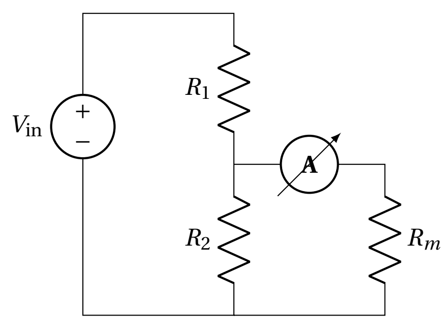
2. Second, reduce R_1 to $100\ \Omega$ and repeat the measurements for all of the values of R_2 equal to and greater than $100\ \Omega$.

For the first set of measurements, use **Origin** to graph V_{out}/R_2 vs. $\log(R_2)$, and for the second, graph V_{out} vs. $\log(R_2)$ On each plot, add a smooth curve calculated from the voltage divider equation above. Your lab report should include these plots, along with tables with all your measurements.

Question 2: For what values of R_2 is the dependence approximately linear, and for what values is $V_{\text{out}} \approx V_{\text{in}}$? Comment on the level of agreement with the calculation.

Question 3: How do your measurements compare to the simulation you performed as a pre-laboratory exercise? Comment on any differences.

Loading of a circuit occurs when additional circuitry with a finite impedance is connected to the output. Consider a voltage divider with $V_{\text{in}} = 12$ V, and $R_1 = R_2 = 1\ \text{k}\Omega$. Rather than directly measuring V_{out}, a $10\ \text{k}\Omega$ resistor R_m can be put in parallel with R_2, the current through R_m measured, and V_{out} calculated. This circuit is arranged according to the diagram below:



Build this circuit, perform the measurement and calculation, and explain your results. Compare this to the case with no resistor R_m (which corresponds to an infinite load impedance). Then, repeat with $R_m = 1\ \text{k}\Omega$. Remember that an ammeter must be connected in series with the circuit being measured.

⚠ *It is easy to blow the fuse in the multimeter when measuring current. Do not exceed 30 mA for the input current to the multimeter.*

Question 4: How does the output voltage of a voltage divider depend on the load resistance? Why might this be a challenge for using this circuit in practice? Can you think of any ways to improve it?

B LEDs: A non-ohmic device

The resistors used in the DC voltage divider are an example of a device where the resistance is independent of the applied voltage. Such devices are called *ohmic devices*; they obey Ohm's law. Some circuit elements, however, have a resistance that depends on the applied voltage; in other words, the current is not proportional to the voltage. These are called *non-ohmic* devices. We will use the **light-emitting diode (LED)** as an example of a non-ohmic device. This *semiconductor* device will be explored in much greater detail later in the course.

Unlike a resistor, a diode like an LED has a specific direction of current flow. The longer pin is the *anode*, which is the *more positive* side, which would point toward the power supply, i.e. connect to R_1. The shorter pin (and usually a flat edge of the bulb) indicates the *cathode*, which is the *more negative* side, which here connects to ground. If oriented correctly, current will flow through the LED when the voltage across it is more than about 1 V. If oriented backwards, the voltage across it will be essentially the input voltage, and the current through it will be about zero.

Construct a voltage divider consisting of a resistor R_1 in series with an LED (in place of R_2). Choose $R_1 = 1\ \mathrm{M}\Omega$, $100\ \mathrm{k}\Omega$, $10\ \mathrm{k}\Omega$, $1\ \mathrm{k}\Omega$, and $100\ \Omega$. Apply a voltage $V_{\mathrm{in}} = 5$ V. For each value of R_1, measure the current through the circuit, and the voltage across the resistor and the LED. Make a plot of current through the diode vs. the voltage across it. Calculate the power dissipated in each of the two elements.

⚠ *Be careful when you set up the LED: if the LED is connected without a resistor in series it will burn out, so take care to always have a 100 Ω resistor in series with it.*

Question 5: For which values of R_1 do you see light from the LED?

Question 6: How does the plot demonstrate that the LED does not obey Ohm's Law?