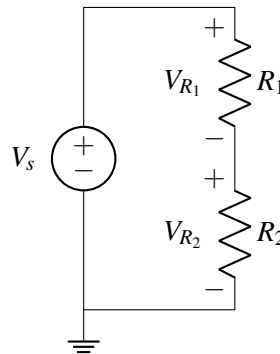


# EECS 16A Designing Information Devices and Systems I Discussion 4D

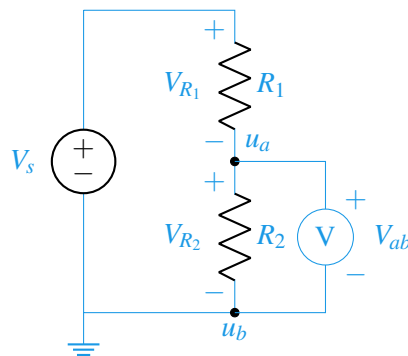
## 1. Volt and Ammeter

- (a) For the voltage divider below, how would we connect a voltmeter to the circuit to measure the voltage  $V_{R_2}$ ?



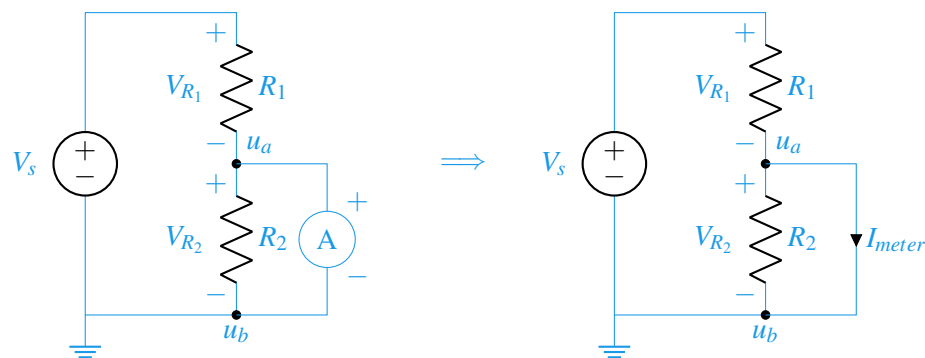
**Answer:** We connect our voltmeter to the voltage divider such that the voltage across the voltmeter nodes is equal to the voltage we want to measure.

i.e.  $V_{ab} = u_a - u_b = V_{R_2}$



- (b) What would happen if we accidentally connected an ammeter in the same configuration instead? Assume our ammeter is ideal.

**Answer:** An ideal ammeter behaves like a wire or a short between two nodes as depicted below:

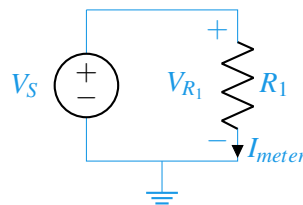


When we have a short, or a new lower resistance path for the current to travel, current will choose to take the path of least resistance. In this case, the ideal wire has no resistance so all of the current leaving  $R_1$  will flow through the wire instead of  $R_2$ .

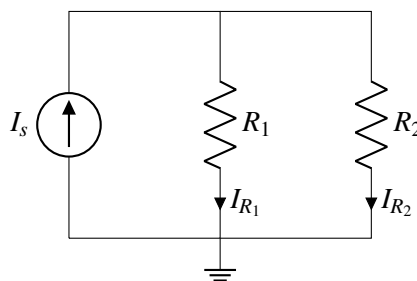
Mathematically, we can see this because this wire has now combined the nodes  $u_a$  and  $u_b$  into one node. In other words,  $u_a = u_b$ . We can use this to show that no current is flowing through  $R_2$ .

$$I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{u_a - u_b}{R_2} = \frac{0}{R_2} = 0$$

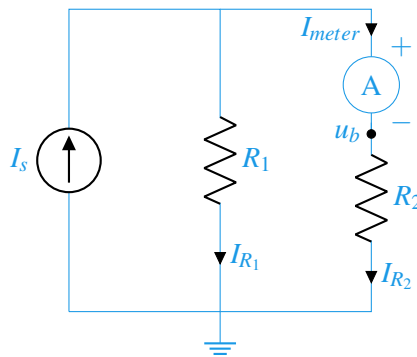
Therefore, an equivalent circuit can be drawn as shown below:



- (c) For the current divider below, how would we connect an ammeter to the circuit to measure the current  $I_{R_2}$ ?

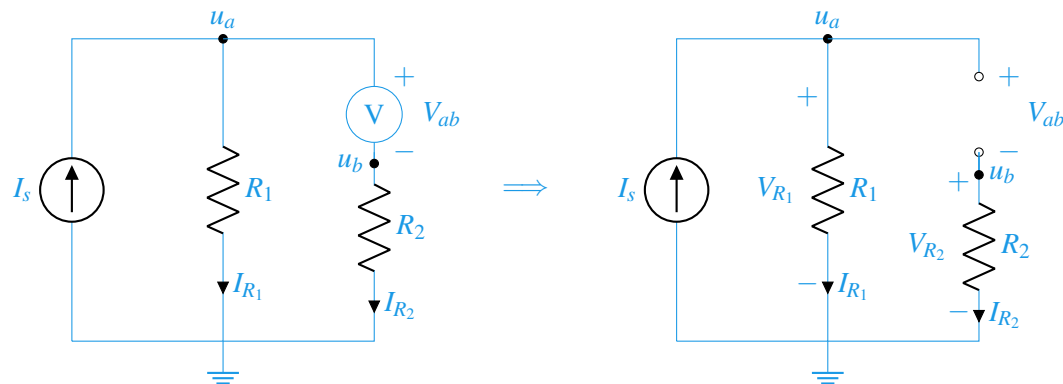


**Answer:** We connect our ammeter to the current divider such that the current going through the ammeter is equal to the current we want to measure. By doing a KCL at node  $u_b$  we can see that  $I_{meter} = I_{R_2}$ .



- (d) What would happen if we accidentally connected a voltmeter in that configuration instead? Assume the voltmeter is ideal.

**Answer:** An ideal voltmeter behaves like an open circuit as depicted below:



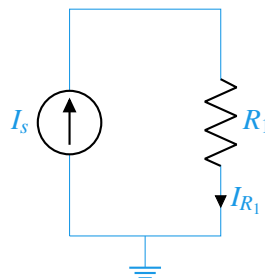
The open circuit creates a dead end and prevents any current from flowing through this circuit branch, therefore  $I_{R_2} = 0$  and there is no voltage drop across resistor  $R_2$ . As a result, the voltage at node  $u_b = V_{R_2}$  is now equal to the reference node voltage.

$$u_b - 0 = V_{R_2} = I_{R_2} R_2 = 0$$

With this knowledge, we can conclude that the voltmeter will actually read the voltage across the resistor  $R_1$ .

$$V_{ab} = u_a - u_b = u_a - 0 = V_{R_1}$$

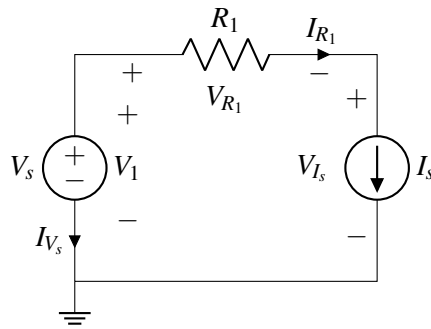
Since  $I_{R_2} = 0$ , the resistor  $R_2$  has no effect on our circuit and an equivalent circuit can be drawn below:



An ideal measurement should be unobtrusive and not change the circuit's behavior.

## 2. Solving For Power

Suppose we have the following circuit and label the currents as shown below. Calculate the power dissipated or supplied by every element in the circuit. Let  $V_s = 5\text{ V}$ ,  $I_s = 0.5\text{ A}$  and  $R_1 = 5\text{ }\Omega$ .



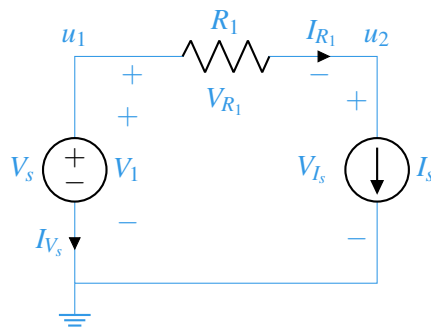
First, we will use NVA to solve this circuit.

**Step 1: Select a reference node.**

The reference node is already given in the question.

**Step 2: Label the rest of the nodes in the circuit.**

The circuit contains three nodes. Since one of them is already labelled as the ground, we will choose the upper left node as  $u_1$  and upper right node as  $u_2$



**Step 3/4: Label elements' voltages and currents following passive sign convention.**

This step is already given in the question.

**Step 5: Identify all unknowns. Then reduce this number by recognizing redundant currents/voltages.**

The unknowns in this circuit are  $u_1$ ,  $u_2$ ,  $V_{I_s}$ ,  $V_{R_1}$ ,  $I_{R_1}$ ,  $I_{V_s}$ ,  $V_1$ . Note the redundancy of  $V_1$  and  $I_{R_1}$  since  $V_1 = V_s$  and  $I_{R_1} = I_s$ .

**Step 6: Apply KCL, KVL, Ohm's Law and express circuit elements in terms of node voltages.**

The KCL equations for nodes  $u_1, u_2$  in this circuit are:

$$I_{V_s} + I_{R_1} = 0$$

$$-I_{R_1} + I_s = 0$$

The IV equations (Ohm's Law for the resistor) for the voltage source and the resistor are:

$$u_1 - 0 = V_1 = V_s$$

$$V_{R_1} = u_1 - u_2 = I_{R_1} R_1$$

Finally, the KVL equation around the one loop formed by the circuit is:

$$V_1 - V_{R_1} - V_{I_s} = 0$$

### Step 7: Simplify Equations and Solve.

First we have

$$\frac{u_1 - u_2}{R_1} = I_s \Rightarrow u_2 = u_1 - I_s R_1 = V_s - I_s R_1$$

Since, we already know that  $u_1 = V_s$ , as it is set by the voltage source. Then we can write that:

$$V_{I_s} = u_2 = 2.5V, \quad V_{R_1} = u_1 - u_2 = 2.5V$$

$$I_{R_1} = I_s = 0.5A, \quad I_{V_s} = -I_{R_1} = -I_s = -0.5A$$

|

Now we can solve for the power dissipated by the resistor:

$$P_{R_1} = IV = I_{R_1} V_{R_1} = 0.5A \cdot 2.5V = 1.25W$$

Next we can solve for the power dissipated by the voltage source:

$$P_{V_s} = IV = I_{V_s} V_1 = -0.5A \cdot 5V = -2.5W$$

Finally, we can solve for the power dissipated by the current source:

$$P_{I_s} = IV = I_s V_{I_s} = 0.5A \cdot 2.5V = 1.25W$$

Notice we calculated a negative value for the power dissipated by the voltage source, implying the voltage source is actually *supplying* power to the circuit.

**Note:** In this case the current source is also dissipating power but it could be also supplying if the numbers were picked differently. For example, if  $I_s = 2A$  the same equations would give  $P_{R_1} = 20W$ ,  $P_{V_s} = -10W$ ,  $P_{I_s} = -10W$ . Also, numbers could have been selected such that the voltage source dissipated and the current source supplied power to the circuit.

Finally, notice that the sum of all the powers calculated equals 0, which is consistent with the Law of Conservation of Power. This is a helpful check to make sure your calculations for power in any circuit is correct.