

**Figure 1 (b)**

The circuit in Figure 1 (a) has as its reference point **B**. Positive and negative voltages are shown. If the reference point is moved to point **C**, the circuit voltages are all positive, as shown in Figure 1 (b). Voltage is always measured between two points. To define the two points, subscripts are used. The voltage difference (or simply voltage) between points **A** and **B** is written as  $V_{AB}$  where the second letter in the subscript identifies the reference point. If a single subscripted letter is shown, the voltage is defined between the lettered point and the circuit's reference ground.

### Elements Needed:

Resistors:

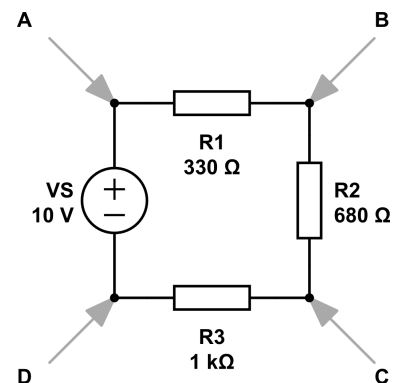
$R_1 = 330\ \Omega$ ,  $R_2 = 680\ \Omega$ , and  $R_3 =$  the first four digits of your student ID (e.g., 2345  $\Omega$ ).

### Procedure:

- For the first two resistors with the listed values given in Table 1, write down the expected resistor colour bands (1st digit, 2nd digit, multiplier, tolerance of 5%) for each one.

Table 1				
Component Listed Value	Colour Bands			
	1	2	M	T
$R_1 = 330\ \Omega$				
$R_2 = 680\ \Omega$				
$R_3$ (from ID)				

	Measured Value
$V_S$	
$V_{AB}$	
$V_{BC}$	
$V_{CD}$	



**Figure 2**

- Build the resistor circuit shown in Figure 2 using CircuitLab. Add a power supply with a DC voltage of +10 V, and include a ground at point **D**. Measure the voltage across each resistor in the circuit using the Simulate function. Enter the measured values in Table 2.
- Keep point **D** as the reference ground in CircuitLab (the downwards arrow symbol). Measure the voltage at points **A**, **B**, and **C** with respect to point **D**. The voltage readings are made with the reference ground at point **D**. Enter the measured values in Table 3. Then use the measured voltages to compute the voltage differences  $V_{AB}$ ,  $V_{BC}$ , and  $V_{CD}$ .

Table 3		
	Measured Voltage	
$V_A$		Voltage Difference Calculation $V_{AB} = V_A - V_B =$ $V_{BC} = V_B - V_C =$ $V_{CD} = V_C - V_D =$
$V_B$		
$V_C$		
$V_D$	0.0 V (reference ground)	

4. Now measure the voltages in the circuit with respect to point **C**. The circuit is *not changed*. Only the reference point changes. Change the reference to point **C**. This point will now represent ground. The voltage at point **D** now has a negative value. Enter the measured voltages in Table 4. Compute the voltage differences as before and enter them in Table 4.

**Table 4**

	Measured Voltage	Voltage Difference Calculation
$V_A$		
$V_B$		$V_{AB} = V_A - V_B =$
$V_C$	0.0 V (reference ground)	$V_{BC} = V_B - V_C =$
$V_D$		$V_{CD} = V_C - V_D =$

5. Change the circuit reference point to point **B**. Again, there is no change to the circuit other than the reference ground. Repeat the measurements of the voltages with respect to circuit ground. Compute the voltage differences and enter the data in Table 5.

**Table 5**

	Measured Voltage	Voltage Difference Calculation
$V_A$		
$V_B$	0.0 V (reference ground)	$V_{AB} = V_A - V_B =$
$V_C$		$V_{BC} = V_B - V_C =$
$V_D$		$V_{CD} = V_C - V_D =$

6. Now make point **A** reference ground and repeat measurements. Enter data in Table 6.

**Table 6**

	Measured Voltage	Voltage Difference Calculation
$V_A$	0.0 V (reference ground)	
$V_B$		$V_{AB} = V_A - V_B =$
$V_C$		$V_{BC} = V_B - V_C =$
$V_D$		$V_{CD} = V_C - V_D =$

**Conclusions:** (What did you learn overall?)

**Evaluation and Review Questions:**

1. Compare the *voltage difference calculation* in Table 3 through Table 6. Does the circuit's reference point have any effect on the voltage differences across any of the resistors? Explain your answer.
2. Define the term *reference ground*.
3. If you measured  $V_{AB}$  as 12.0 V, what is the  $V_{BA}$ ?
4. Assume  $V_M = -220$  V and  $V_N = 150$  V. What is  $V_{MN}$ ?
5. If a test point in a circuit is marked +5.0 V and a second test point is marked -3.3 V, what voltage reading would you expect on a voltmeter connected between the two test points? Assume the reference lead on the meter is at the lowest potential.

**For Further Investigation:**

Replace the +10 V supply used in this experiment with two +5 V supplies in series. Attach the +5 V output of one supply to the negative side of the second supply. Call this point (in between the two power supplies) the reference ground for the circuit. Measure the voltages throughout the circuit. Summarise your results.