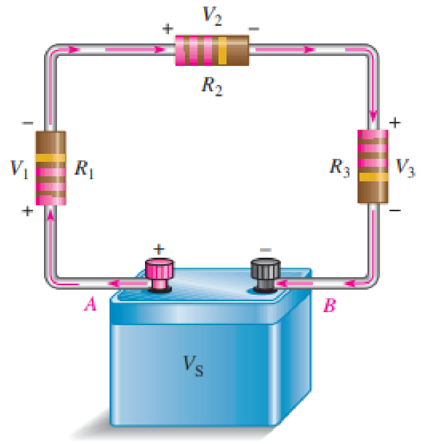
Basic Electronics

- Kirchhoff's Law

Kirchhoff's Voltage Law

- Kirchhoff's voltage law is a fundamental circuit law that states that the algebraic sum of all the voltages around a single closed path is zero or, in other words, the sum of the voltage drops equals the total source voltage
- The voltage from point A to point B in the circuit of Figure is the source voltage, Also, the voltage from A to B is the sum of the series resistor voltage drops. Therefore, the source voltage is equal to the sum of the three voltage drops, as stated by Kirchhoff's voltage law.
- The sum of all the voltage drops around a single closed path in a circuit is equal to the total source voltage in that loop



Kirchhoff's Voltage Law

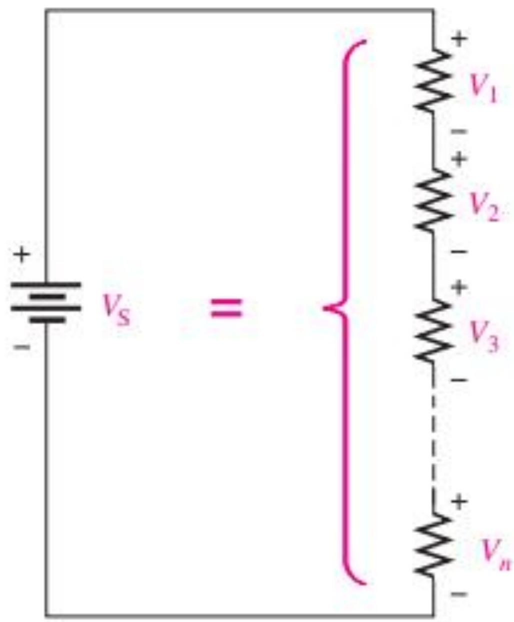


FIGURE 31

Sum of *n* voltage drops equals the source voltage.

The algebraic sum of all the voltages (both source and drops) around a single closed path is zero.

Therefore, another way of expressing Kirchhoff's voltage law in equation form is

$$V_S - V_1 - V_2 - V_3 - \cdots - V_n = 0$$

Verification of Kirchhoff's Law

You can verify Kirchhoff's voltage law by connecting a circuit and measuring each resistor voltage and the source voltage as illustrated in Figure 32. When the resistor voltages are added together, their sum will equal the source voltage. Any number of resistors can be added.

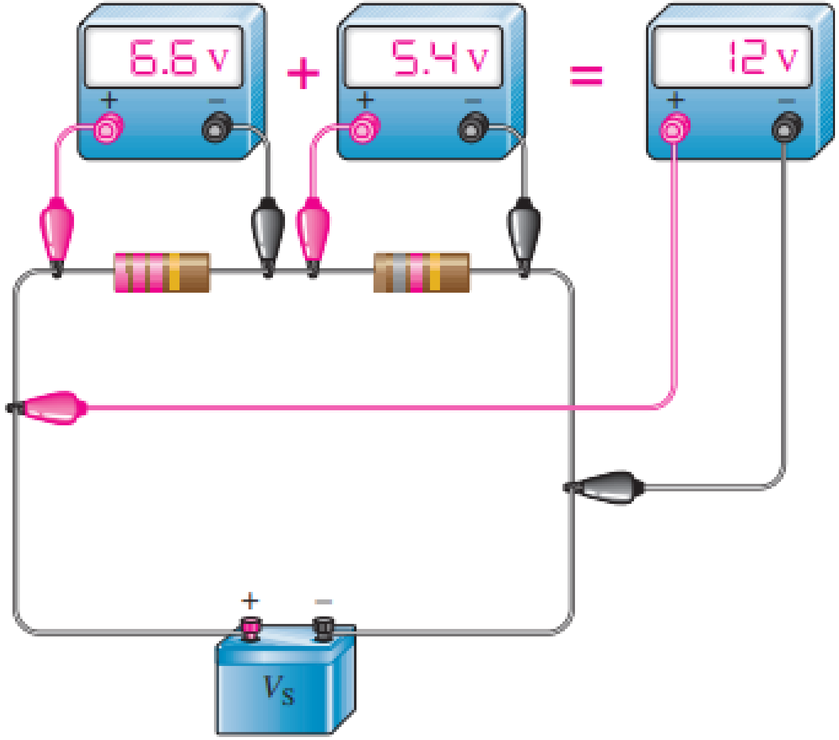


FIGURE 32

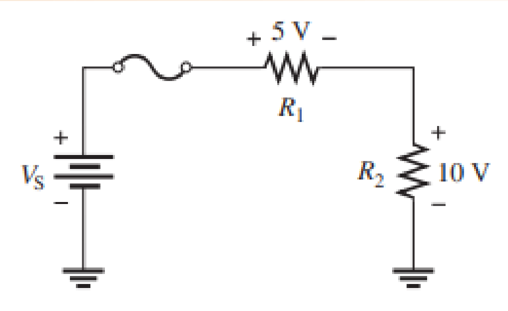
Illustration of an experimental verification of Kirchhoff's voltage law.

Verification of Kirchhoff’s Law

EXAMPLE 13

Determine the source voltage V_S in Figure 33 where the two voltage drops are given. There is no voltage drop across the fuse.

▶ FIGURE 33

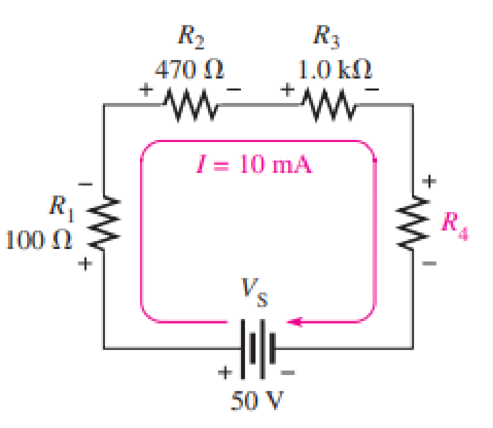


Verification of Kirchhoff's Law

EXAMPLE 14

Find the value of R_4 in Figure 34.

▶ **FIGURE 34**



Verification of Kirchhoff's Law

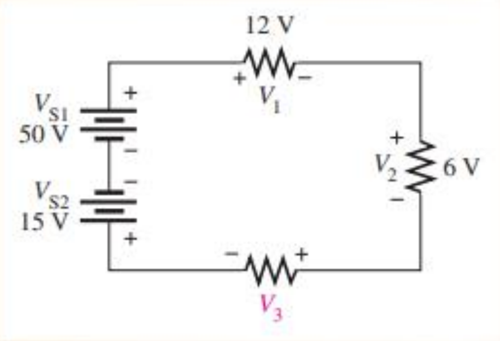
So far, you have seen how Kirchhoff's voltage law can be applied to a series circuit with a voltage source, but it can also be applied to other types of circuits. For example, there are cases where there is no source voltage in a given closed loop. Even so, Kirchhoff's voltage law still applies. This leads to a more-general form of Equation 3.

$$V_1 + V_2 + V_3 + \cdots + V_n = 0$$

Verification of Kirchhoff's Law

EXAMPLE 15 Determine the unknown voltage drop, V_3, in Figure 35.

▶ **FIGURE 35**



Solution By Kirchhoff's voltage law (Eq. 4), the algebraic sum of all the voltages around the circuit is zero. The value of each voltage drop except V_3 is known. Substitute these values into the equation.

$$V_{S1} + V_{S2} + V_3 + V_2 + V_1 = 0$$
$$50\text{ V} - 15\text{ V} - V_3 - 6\text{ V} - 12\text{ V} = 0$$

Basic Electronics

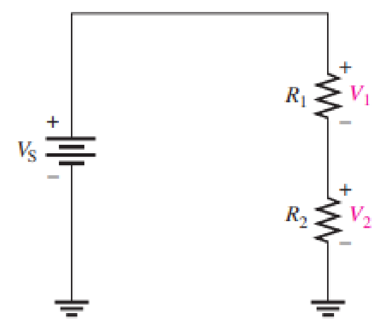
- Voltage Dividers
- Power in series circuit

Voltage Dividers

- A series circuit acts as a voltage divider. The voltage divider is an important application of series circuit
- A circuit consisting of a series string of resistors connected to a voltage source acts as a voltage divider.
- These voltage drops are v1 and v2 respectively, as indicated in the schematic.
- Since each resistor has the same current, the voltage drops are proportional to the resistance values.

▶ FIGURE 36

Two-resistor voltage divider.



Voltage Divider Formula

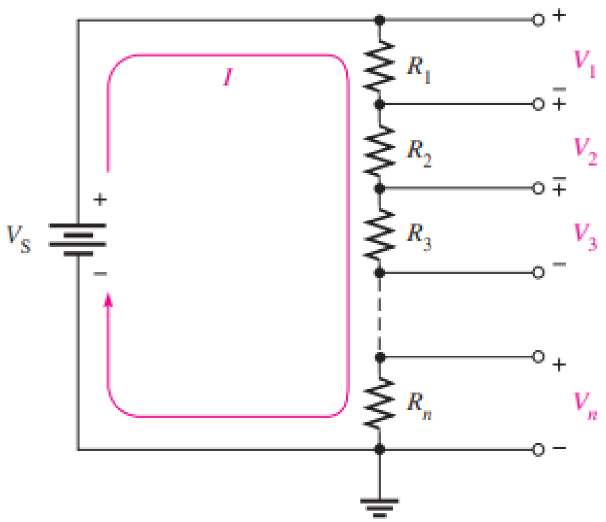


FIGURE 37

Generalized voltage divider with *n* resistors.

Voltage Divider Formula

Let V_x represent the voltage drop across any one of the resistors and R_x represent the number of a particular resistor or combination of resistors. By Ohm's law, you can express the voltage drop across R_x as follows:

$$V_x = IR_x$$

The current through the circuit is equal to the source voltage divided by the total resistance ($I = V_S/R_T$). In the circuit of Figure 37, the total resistance is $R_1 + R_2 + R_3 + \cdots + R_n$. By substitution of V_S/R_T for I in the expression for V_x,

$$V_x = \left(\frac{V_S}{R_T}\right)R_x$$

Rearranging the terms you get

$$V_x = \left(\frac{R_x}{R_T}\right)V_S$$

Voltage Divider Formula

- The voltage drop across any resistor or combination of resistors in a series circuit is equal to the ratio of that resistance value to the total resistance, multiplied by the source voltage.

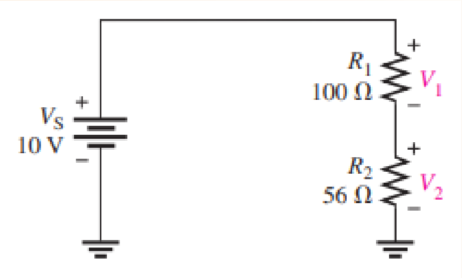
$$V_x = \left(\frac{R_x}{R_T}\right)V_S$$

Voltage Divider Formula

EXAMPLE 16

Determine V_1 (the voltage across R_1) and V_2 (the voltage across R_2) in the voltage divider in Figure 38.

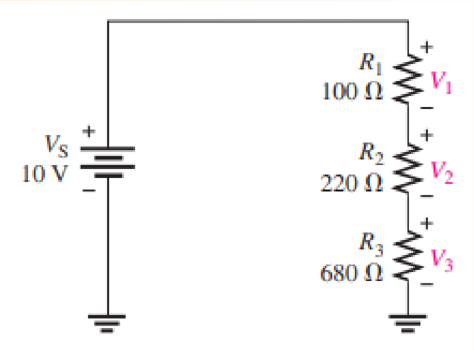
▶ FIGURE 38



Voltage Divider Formula

EXAMPLE 17 Calculate the voltage drop across each resistor in the voltage divider of Figure 39.

▶ FIGURE 39



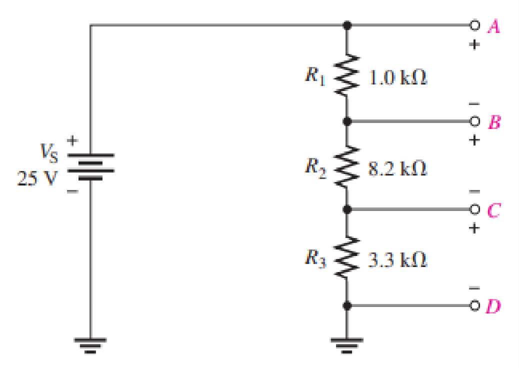
Voltage Divider Formula

EXAMPLE 18

Determine the voltages between the following points in the voltage divider of Figure 40:

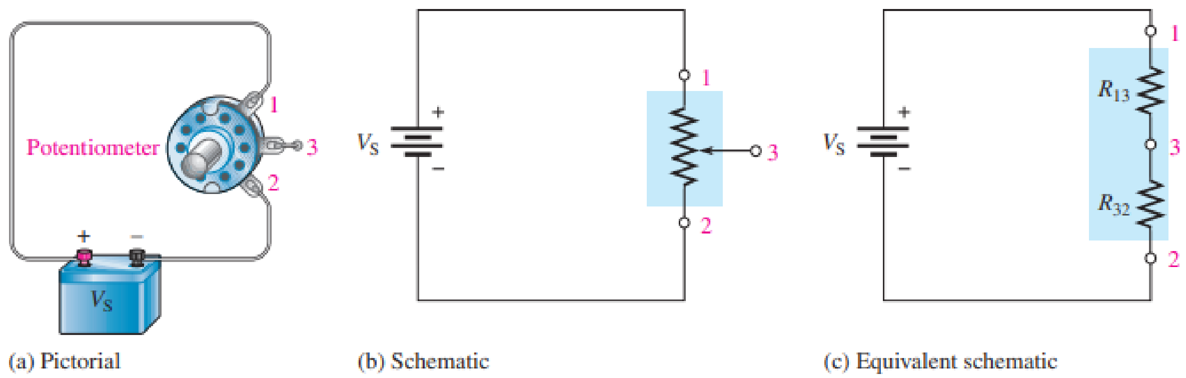
(a) *A* to *B* **(b)** *A* to *C* **(c)** *B* to *C* **(d)** *B* to *D* **(e)** *C* to *D*

▶ FIGURE 40



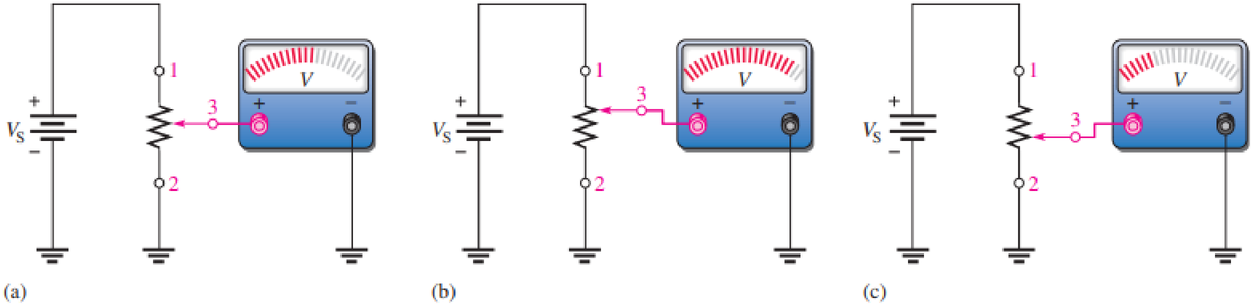
A Potentiometer is an adjustable Voltage Divider

- A potentiometer is a variable resistor with three terminals. A linear potentiometer connected to a voltage source is shown in Figure 41(a) with the schematic shown in part (b).
- Notice that the two end terminals are labeled 1 and 2. The adjustable terminal or wiper is labeled 3. The potentiometer functions as a voltage divider



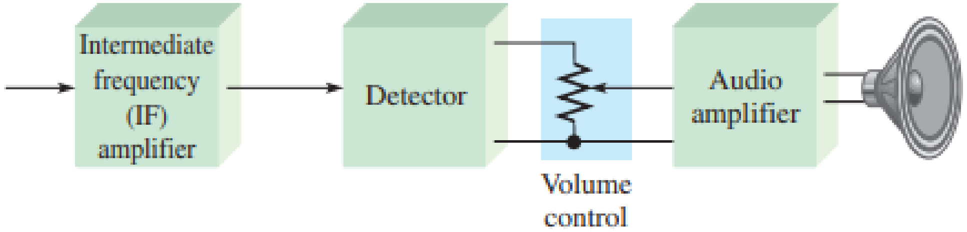
A Potentiometer is an adjustable Voltage Divider

- The resistance between terminal 1 and terminal 3 is one part, and the resistance between terminal 3 and terminal 2 is the other part.
- So this potentiometer is equivalent to a two-resistor voltage divider that can be manually adjusted.



Applications

- The volume control of some radio receivers is a common application of a potentiometer used as a voltage divider.
- Since the loudness of the sound is dependent on the amount of voltage associated with the audio signal, you can increase or decrease the volume by adjusting the potentiometer, that is, by turning the knob of the volume control on the set.
- The block diagram in Figure 43 shows how a potentiometer can be used for volume control in a typical receiver.



Applications

EXAMPLE 19 Assume you have a CdS cell configured as shown in Figure 46 that uses three AA batteries for a voltage source (4.5 V). At dusk, the resistance of the cell rises from a low resistance to above 90 kΩ. The cell is used to trigger a logic circuit that will turn on lights if V_{OUT} is greater than approximately 1.5 V. What value of R will produce an output voltage of 1.5 V when the cell resistance is 90 kΩ?

Power in Series Circuit

The total amount of power in a series resistive circuit is equal to the sum of the powers in each resistor in series.

$$P_T = P_1 + P_2 + P_3 + \cdots + P_n$$

where P_T is the total power and P_n is the power in the last resistor in series.

Power formulas are applicable to series circuits. Since there is the same current through each resistor in series, the following formulas are used to calculate the total power:

$$P_T = V_S I$$

$$P_T = I^2 R_T$$

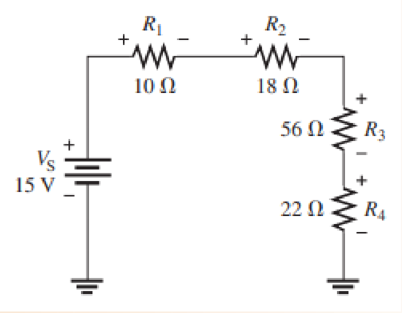
$$P_T = \frac{V_S^2}{R_T}$$

where I is the current through the circuit, V_S is the total source voltage across the series connection, and R_T is the total resistance.

Power in Series Circuit

EXAMPLE 20 Determine the total amount of power in the series circuit in Figure 48.

▶ FIGURE 48



Power in Series Circuit

EXAMPLE 21

Determine if the indicated power rating (½ W) of each resistor in Figure 49 is sufficient to handle the actual power when the switch is closed. If a rating is not adequate, specify the required minimum rating.

▶ **FIGURE 49**