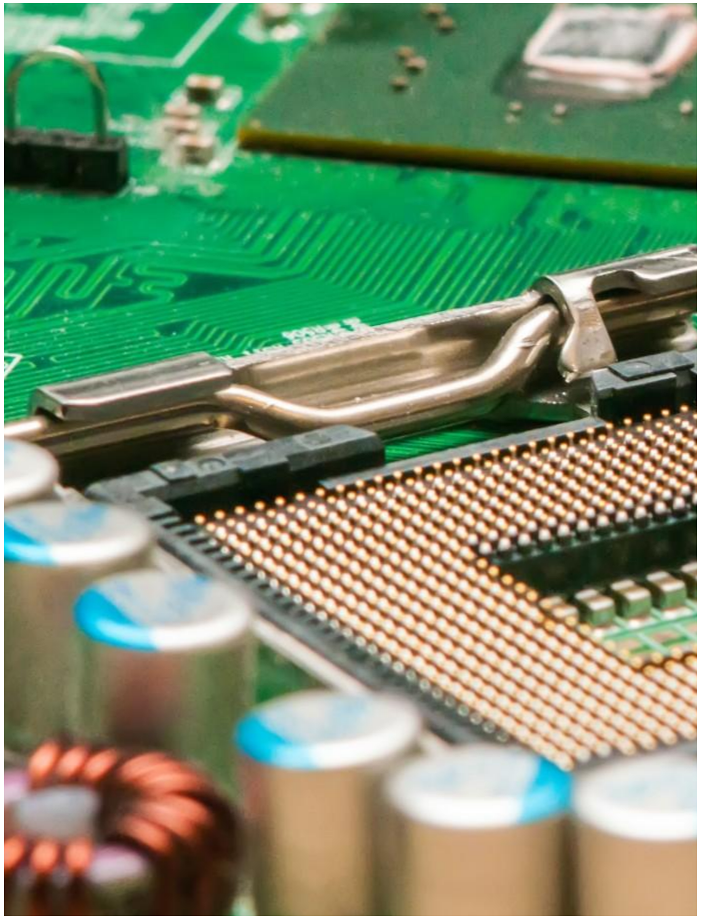
Fundamentals of Electrical & Electronic Engineering

Prof. John G. Breslin, Electrical & Electronic Engineering



Lecture 4

Series Circuits

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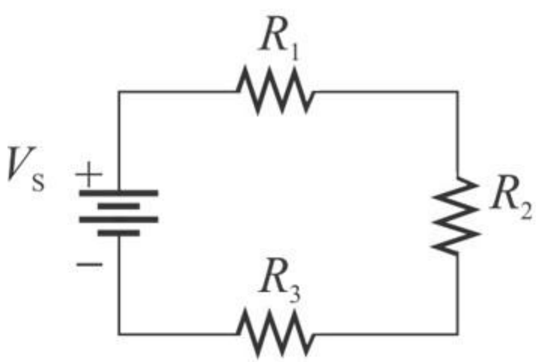
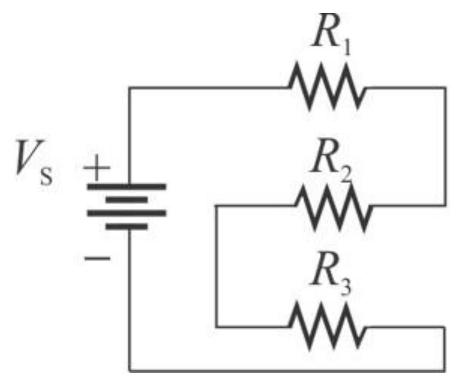
Summary (1 of 28)

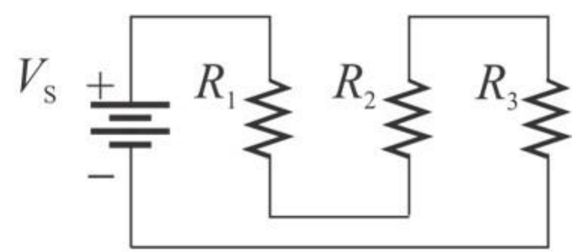
Series Circuits

A ***series circuit*** is one that has only one current path.

Examples:



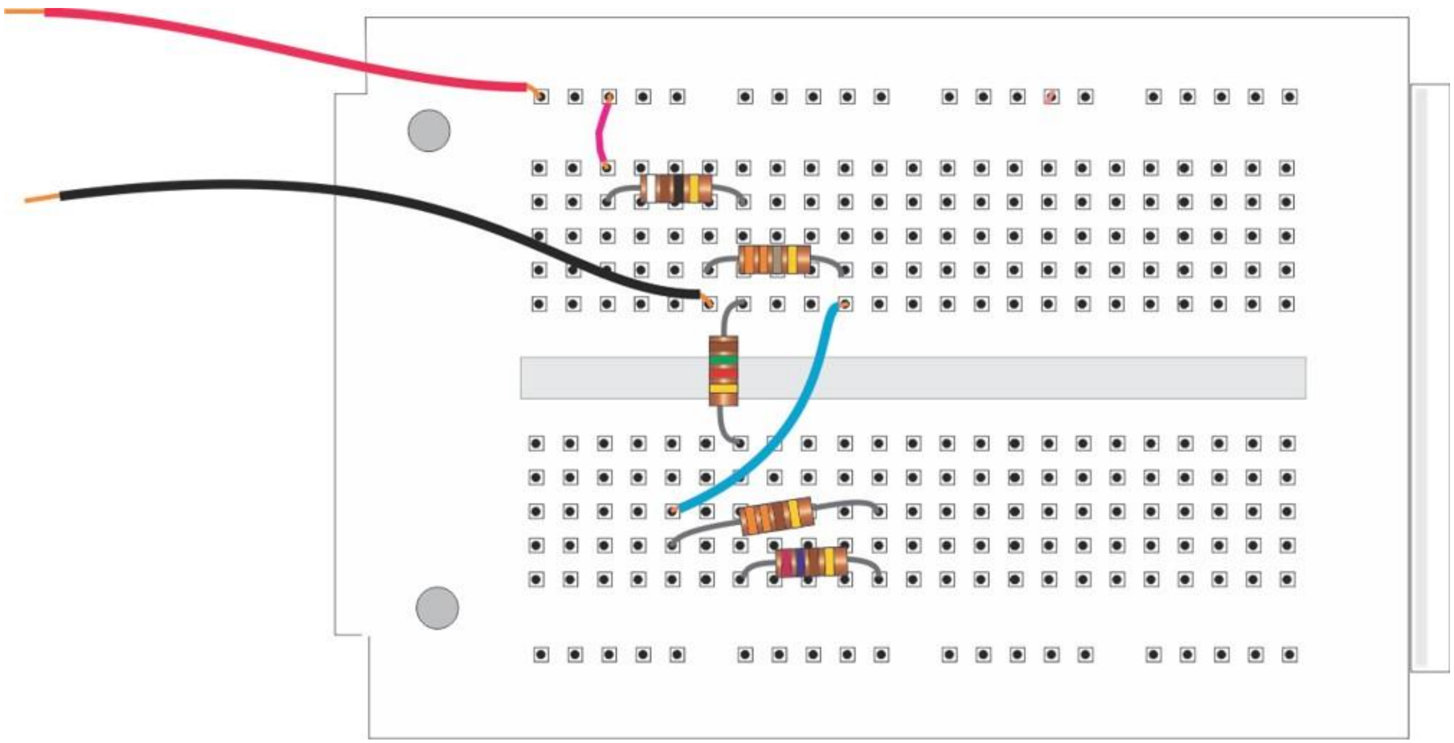




Summary (2 of 28)

Series Circuits

Trace the single path to confirm the resistors are in series.



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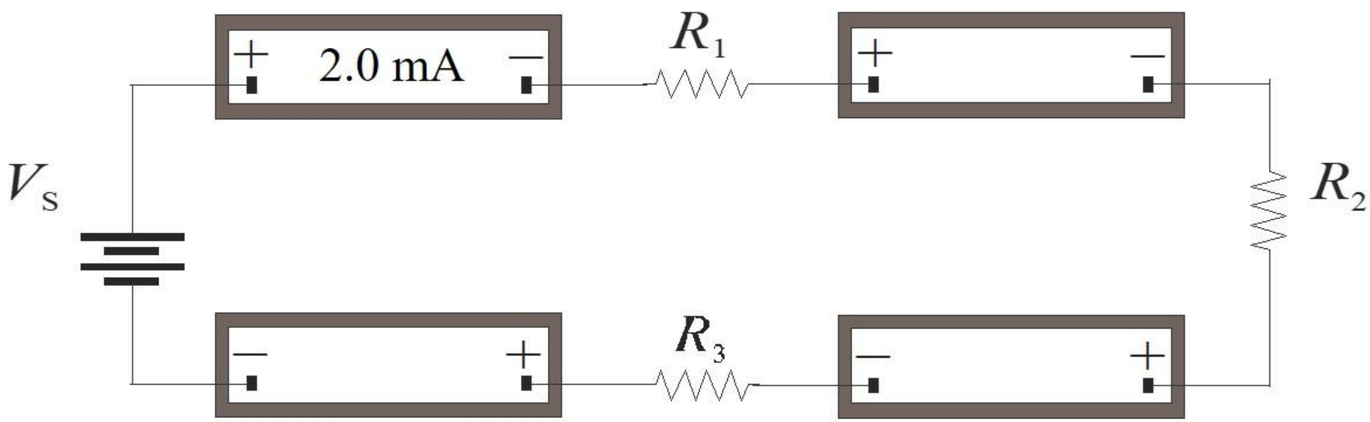
Summary (3 of 28)

Series Circuits

Because there is only one path, the current everywhere is the same.

Example:

The reading on the first ammeter is 2.0 mA, What should the other meters read?



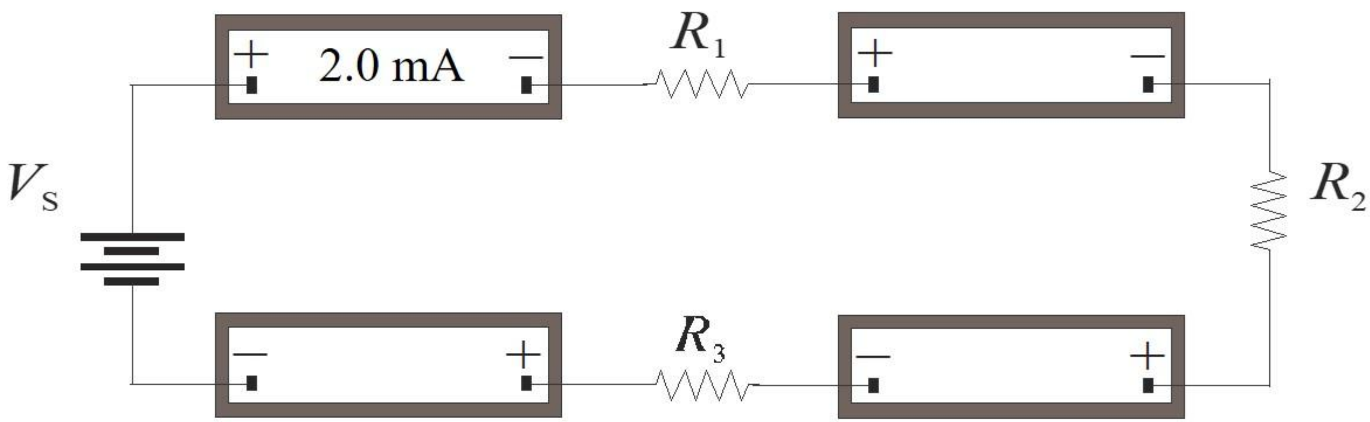
Summary (4 of 28)

Series Circuits

Because there is only one path, the current everywhere is the same.

Example:

The reading on the first ammeter is 2.0 m A, What should the other meters read? Each meter reads 2.0 m A.



Summary (5 of 28)

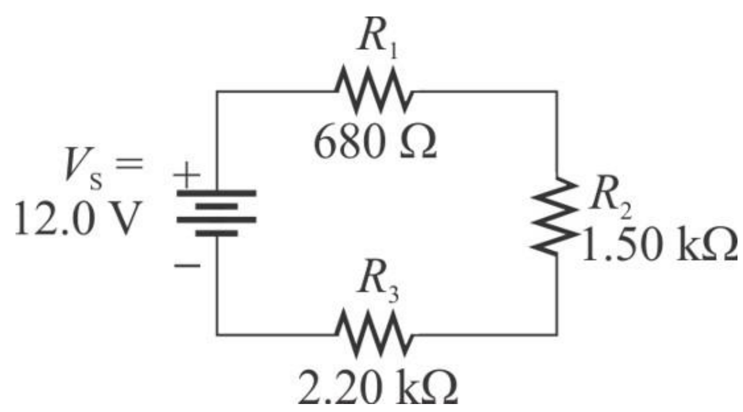
Series Circuits

The total resistance of resistors in series is the sum of the individual resistors.

Example:

The resistors in a series circuit are as shown below.

What is the total resistance. R_T?



Series Circuits

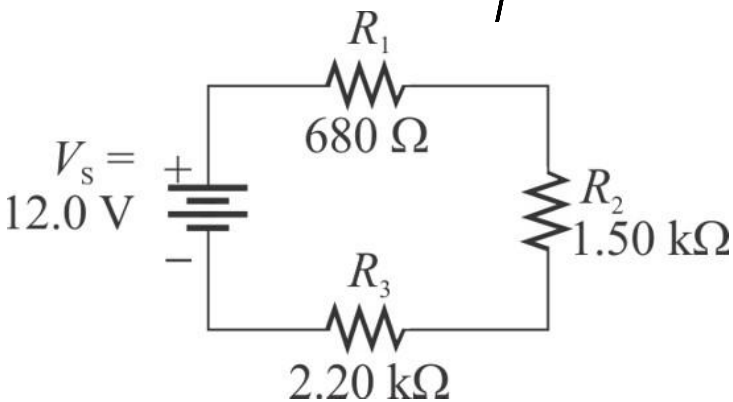
The total resistance of resistors in series is the sum of the individual resistors.

Example:

The resistors in a series circuit are as shown below.

What is the total resistance.

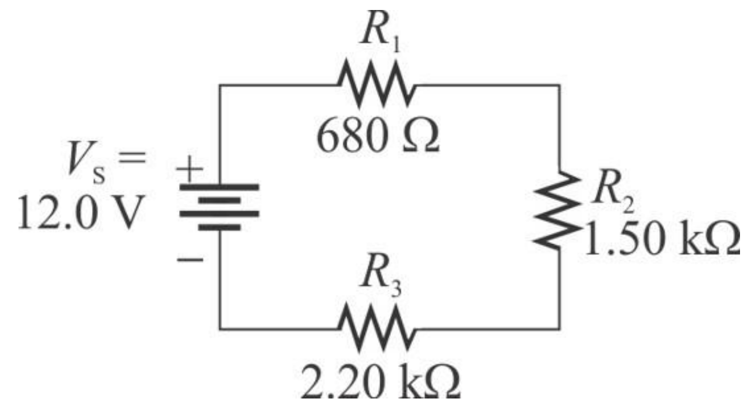
$R_T = 4.38\ \text{k}\Omega$



Summary (7 of 28)

Series Circuits

Tabulating current, resistance, voltage, and power is a useful way to summarize parameters in a series circuit.



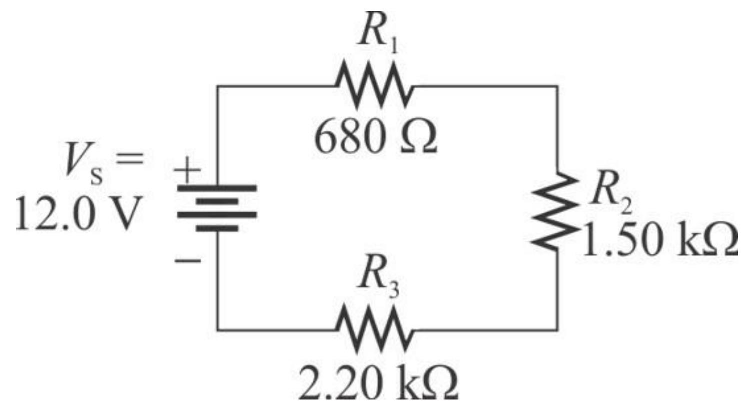
Continuing with the previous example, complete the parameters listed in the Table.

$I_1 =$	$R_1 =$	$V_1 =$	$P_1 =$
$I_2 =$	$R_2 =$	$V_2 =$	$P_2 =$
$I_3 =$	$R_3 =$	$V_3 =$	$P_3 =$
$I_T =$	$R_T =$	$V_s =$	$P_T =$

Summary (8 of 28)

Series Circuits

Tabulating current, resistance, voltage, and power is a useful way to summarize parameters in a series circuit.



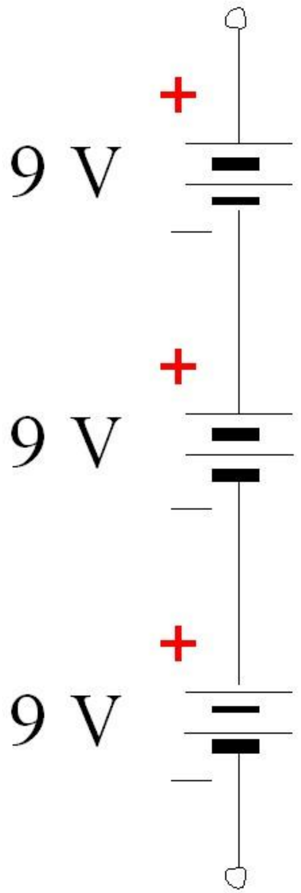
Continuing with the previous example, complete the parameters listed in the Table.

I_1 = **2.74 mA**	R_1 = 0.68 kΩ	V_1 = 1.86 V	P_1 = 5.10 mW
I_2 = **2.74 mA**	R_2 = 1.50 kΩ	V_2 = 4.11 V	P_2 = 11.3 mW
I_3 = **2.74 mA**	R_3 = 2.20 kΩ	V_3 = 6.03 V	P_3 = 16.5 mW
I_T = **2.74 mA**	R_T = 4.38 kΩ	V_s = 12.0 V	P_T = 32.9 mW

Summary (9 of 28)

Voltage Sources in Series

Voltage sources in series add algebraically. For example, the total voltage of the sources shown is 27 V



Question:

What is the total voltage if one battery is accidentally reversed?

Summary (10 of 28)

Voltage Sources in Series

Voltage sources in series add algebraically. For example, the total voltage of the sources shown is 27 V

Question:

What is the total voltage if one battery is accidentally reversed? 9 V

Summary (11 of 28)

Kirchhoff’s Voltage Law

Kirchhoff’s voltage law (K V L) is generally stated as:

The algebraic sum of the voltages around any closed path is zero.

KVL applies to all circuits, but you must apply it to only one closed path. In a series circuit, this is (of course) the entire circuit.

A mathematical shorthand way of writing K V L is

$$\sum_{i=1}^{n} V_i = 0$$

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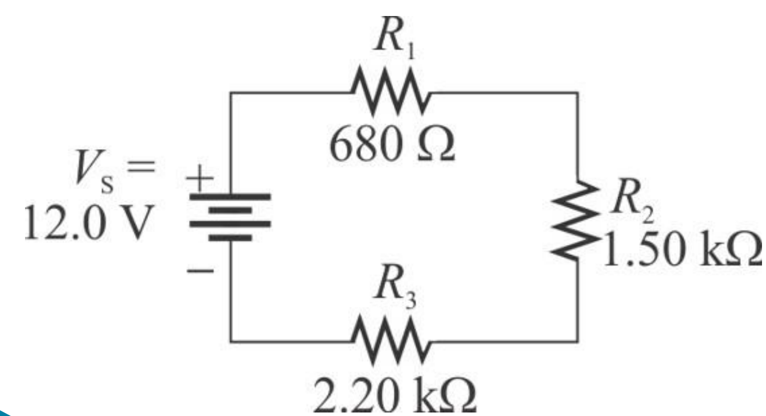
Kirchhoff's Voltage Law

Notice in the series example given earlier that the sum of the resistor voltages is equal to the source voltage.



I_1 = 2.74 mA	R_1 = 0.68 kΩ	V_1 = 1.86 V	P_1 = 5.10 mW
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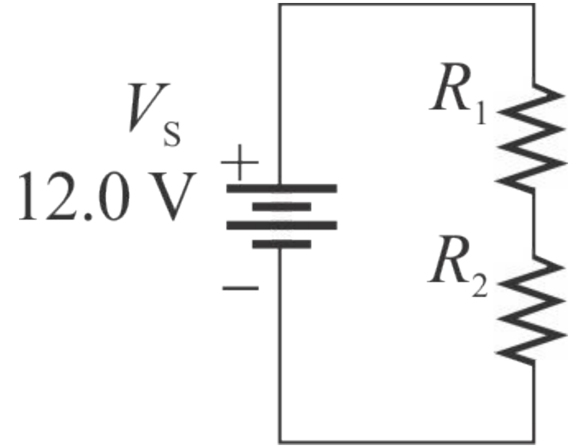
I_T = 2.74 mA	R_T = 4.38 kΩ	V_s = 12.0 V	P_T = 32.9 mW

Summary (13 of 28)

Voltage Divider Rule

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



Question:

Assume R_1 is twice the size of R_2. What is the voltage across R_1?

Follow up:

What is the voltage across R_2?

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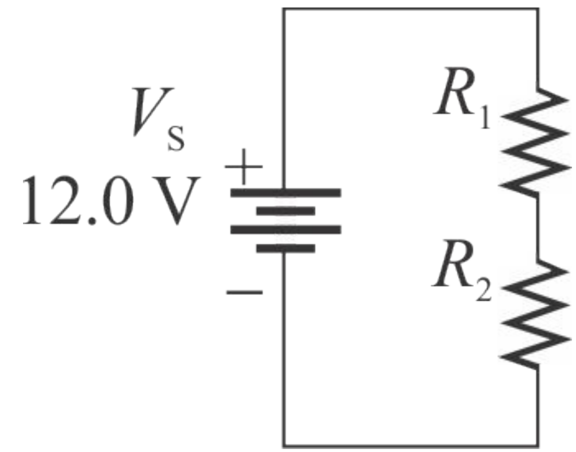
Voltage Divider Rule

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



Question:

Assume R_1 is twice the size of R_2. What is the voltage across R_1? 8.0 V

Follow up:

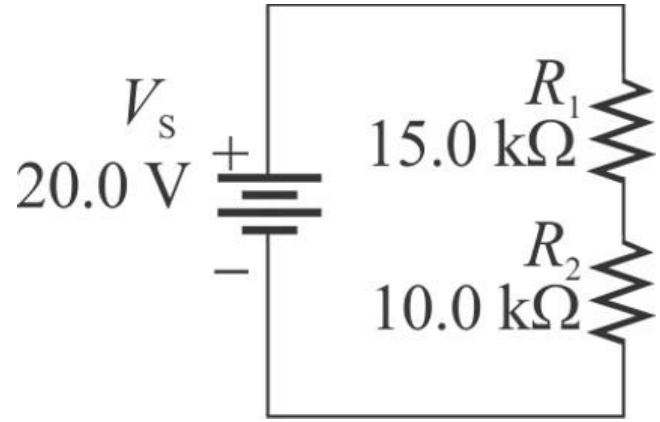
What is the voltage across R_2? 4.0 V

Summary

Voltage Dividers

Example:

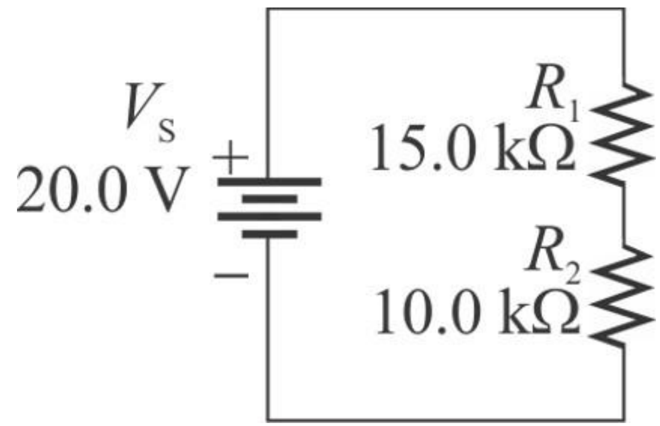
What is the voltage across R_2?



Voltage Dividers

Example:

What is the voltage across R_2?



Solution:

The total resistance is 25 kΩ

Applying the voltage divider formula:

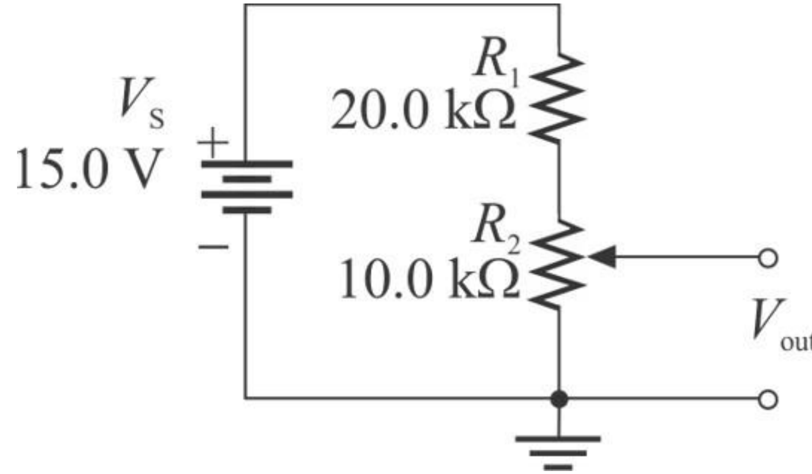
$$V_2 = \left(\frac{R_2}{R_T}\right)V_S = \left(\frac{10\text{ k}\Omega}{25\text{ k}\Omega}\right)20\text{ V} = 8.0\text{ V}$$

Notice that 40% of the source voltage is across R_2, which represents 40% of the total resistance.

Summary

Voltage Dividers

Voltage dividers can be set up for a variable output with a potentiometer. In the circuit shown, the output voltage is variable.



Question:

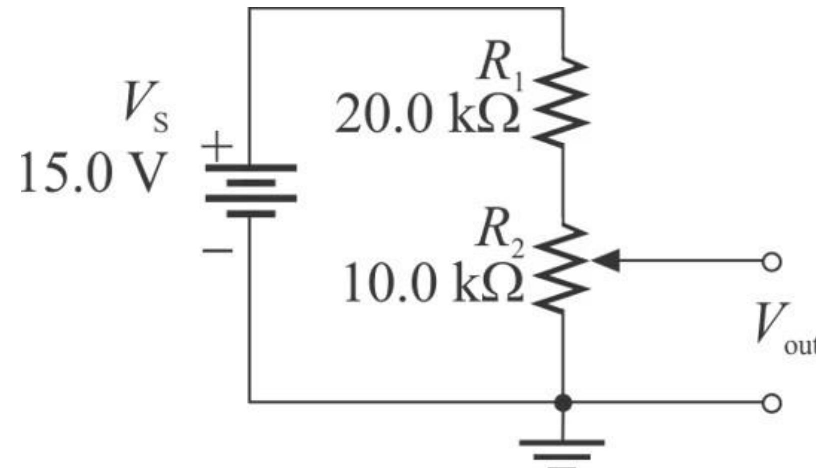
What is the largest output voltage available?

Follow up:

What is the output voltage if the potentiometer is centered? (equal resistance on each side?)

Voltage Dividers

Voltage dividers can be set up for a variable output with a potentiometer. In the circuit shown, the output voltage is variable.



Question:

What is the largest output voltage available? 5.0 V

Follow up:

What is the output voltage if the potentiometer is centered? (equal resistance on each side?) 2.5 V

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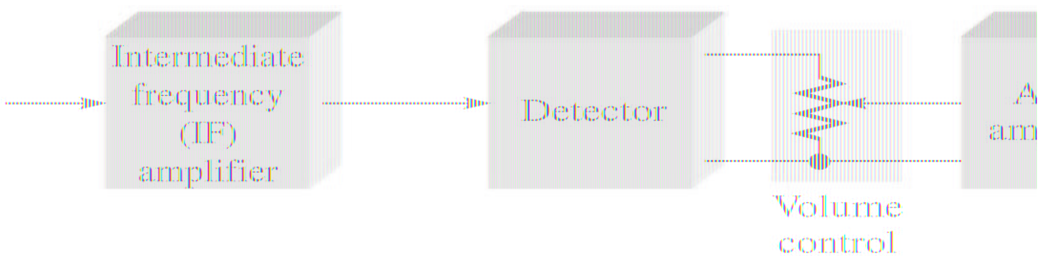
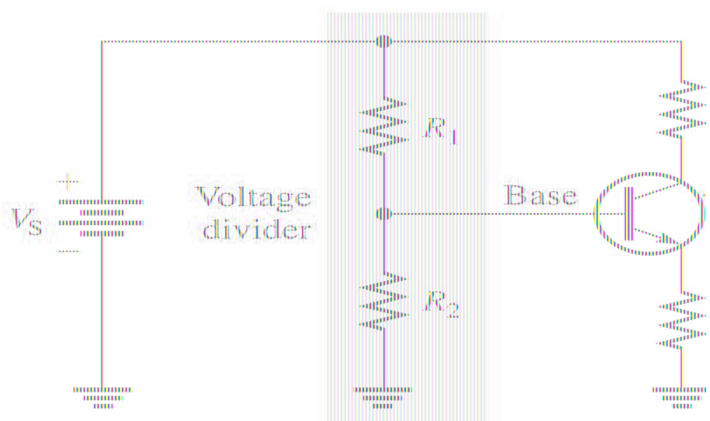
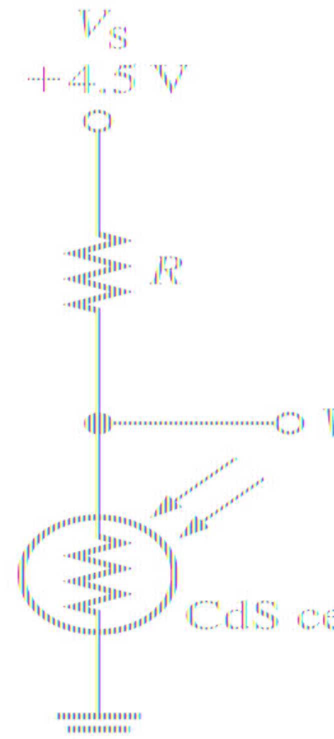
Voltage Dividers

Voltage dividers are widely used in applications. Some examples are:







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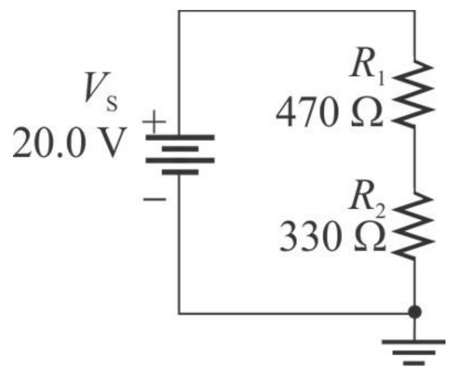
Power in Series Circuits

Example:

Use the voltage divider rule to find V_1 and V_2

Then find the power in R_1 and R_2 and P_T



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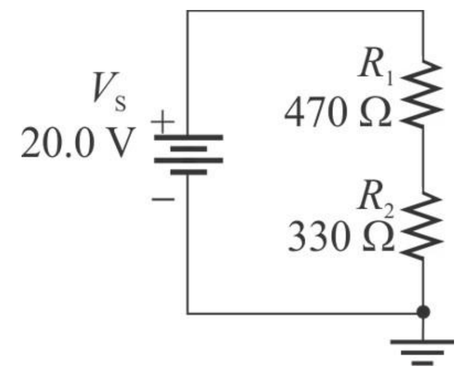
Power in Series Circuits

Example:

Use the voltage divider rule to find V_1 and V_2

Then find the power in R_1 and R_2 and P_T



Solution:

Applying the voltage divider rule:

$$V_1 = \left(\frac{470\ \Omega}{800\ \Omega}\right) 20\text{ V} = 11.75\text{ V}$$

$$V_2 = \left(\frac{330\ \Omega}{800\ \Omega}\right) 20\text{ V} = 8.25\text{ V}$$

The power dissipated by each resistor is:

$$P_1 = \frac{(11.75\text{ V})^2}{470\ \Omega} = 294\text{ mW}$$

$$P_2 = \frac{(8.25\text{ V})^2}{330\ \Omega} = 206\text{ mW}$$

$$P_T = 500\text{ mW}$$

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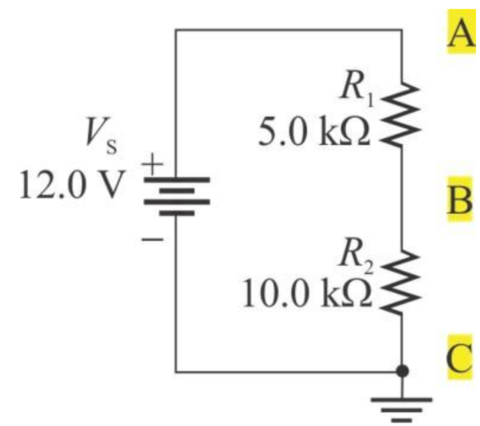
Voltage Measurements

Voltage is relative and is measured with respect to another point in the circuit.

Voltages that are given with respect to ground are shown with a single subscript. For example, V_A means the voltage at point A with respect to ground (called *reference ground*). V_B means the voltage at point B with respect to ground. V_{AB} means the voltage at point A relative to point B.



Question: What are V_A, V_B, and V_{AB} for the circuit shown?

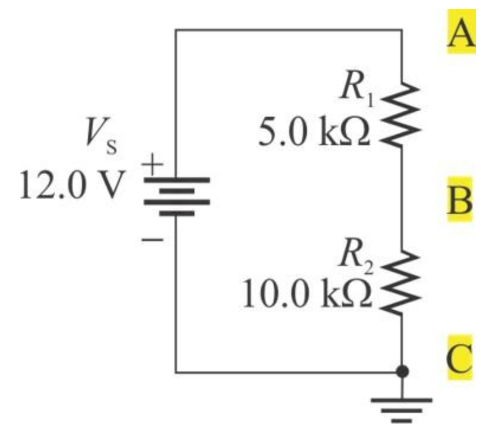
Follow-up: What is V_{BA} for the circuit shown?

Summary (23 of 28)

Voltage Measurements

Voltage is relative and is measured with respect to another point in the circuit.

Voltages that are given with respect to ground are shown with a single subscript. For example, V_A means the voltage at point A with respect to ground (called *reference ground*). V_B means the voltage at point B with respect to ground. V_{AB} means the voltage at point A relative to point B.



Question: What are V_A, V_B, and V_{AB} for the circuit shown?

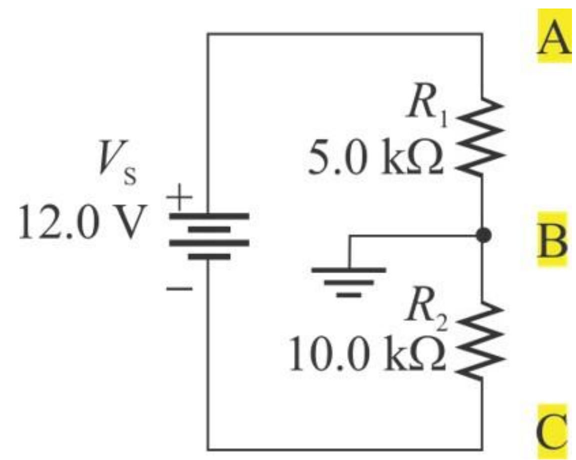
$V_A = 12\text{ V}$ $\quad V_B = 8.0\text{ V}$ $\quad V_{AB} = +4.0\text{ V}$

Follow-up: What is V_{BA} for the circuit shown? $V_{BA} = -4.0\text{ V}$

Summary (24 of 28)

Voltage Measurements

Ground reference is not always at the most negative point in a circuit. Assume the ground is moved to B as shown.



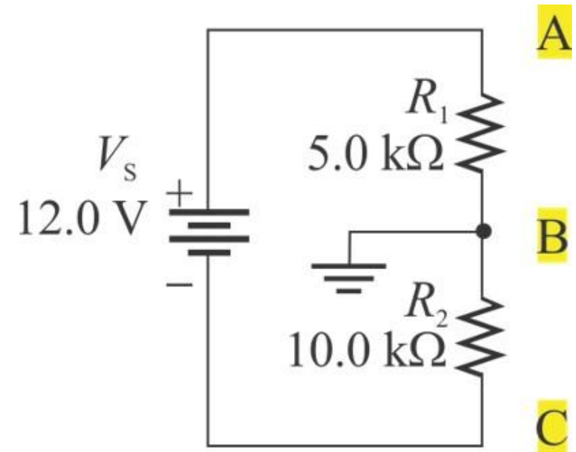
Question: What are V_A, V_B, and V_C for the circuit?

Has V_{AB} changed from the previous circuit?

Summary (25 of 28)

Voltage Measurements

Ground reference is not always at the most negative point in a circuit. Assume the ground is moved to B as shown.



Question: What are $V_A, V_B,$ and V_C for the circuit?

$$V_A = 4.0\text{ V} \quad V_B = 0\text{ V} \quad V_C = -8.0\text{ V}$$

Has V_{AB} changed from the previous circuit?

No, it is still $+4.0$ V

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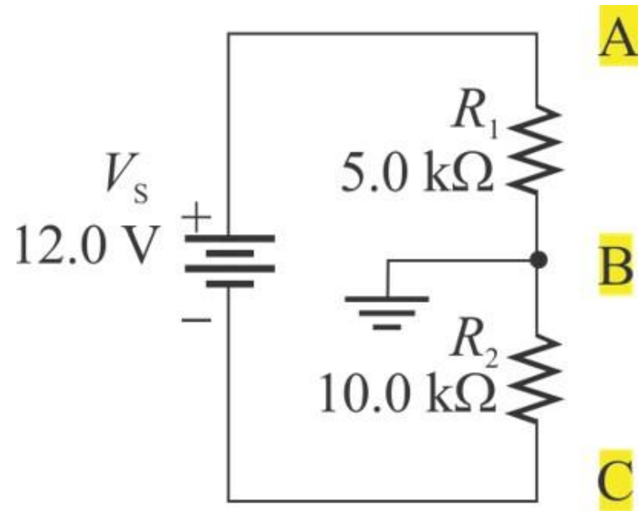
Voltage Measurements

Question:

Assume that R_2 is open. For this case, what are V_A, V_B, and V_C for the circuit?



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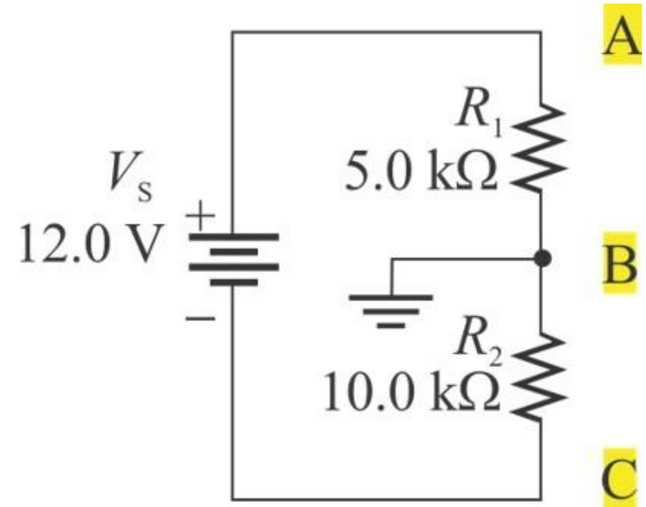
Voltage Measurements

Question:

Assume that R_2 is open. For this case, what are V_A, V_B, and V_C for the circuit?



Answer:

If R_2 is open, there is no current. $V_B = 0$ V because it is ground and $V_A = 0$ V because it has the same potential as V_B.

$V_C = -12.0$ V because the source voltage is across the open.

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Summary (28 of 28)

Voltage Measurements

Another common convention in designating voltages is to use double subscripts for a voltage source. Positive sources are often referred to as V_{CC} (for the positive collector supply of an *npn* transistor). A negative collector supply is used for *pnp* transistors, so you may see it designated as $-V_{CC}$. Other common power supply voltages are V_{DD} (positive), V_{EE} (negative), and V_{SS} (negative).

Selected Key Terms (1 of 2)

Series In an electric circuit, a relationship of components in which the components are connected such that they provide a single path between two points.

Kirchhoff's voltage law A law stating that the algebraic sum of the voltages around any closed path is zero.

Voltage divider A circuit consisting of series resistors across which one or more output voltages are taken.

Selected Key Terms (2 of 2)

Reference ground The metal chassis that houses the assembly or a large conductive area on a printed circuit board is used as a common or reference point; also called common.

Open A circuit condition in which the current path is broken.

Short A circuit condition in which there is zero or an abnormally low resistance between two points; usually an inadvertent condition.

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Quiz (1 of 11)

1. In a series circuit with more than one resistor, the current is

   a. larger in larger resistors.

   b. smaller in larger resistors.

   c. always the same in all resistors.

   d. there is not enough information to say.

Quiz (2 of 11)

2. In a series circuit with more than one resistor, the voltage is

   a. larger across larger resistors.

   b. smaller across larger resistors.

   c. always the same across all resistors.

   d. there is not enough information to say.

Quiz (3 of 11)

3. If three equal resistors are in series, the total resistance is

   a. one third the value of one resistor.

   b. the same as one resistor.

   c. three times the value of one resistor.

   d. there is not enough information to say.

Quiz (4 of 11)

4. A series circuit cannot have

   a. more than two resistors.

   b. more than one voltage source.

   c. more than one path.

   d. all of the above.

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Quiz (5 of 11)

5. In a closed loop, the algebraic sum of all voltages (both sources and drops)

   a. is zero.

   b. is equal to the smallest voltage in the loop.

   c. is equal to the largest voltage in the loop.

   d. depends on the source voltage.

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Quiz (6 of 11)

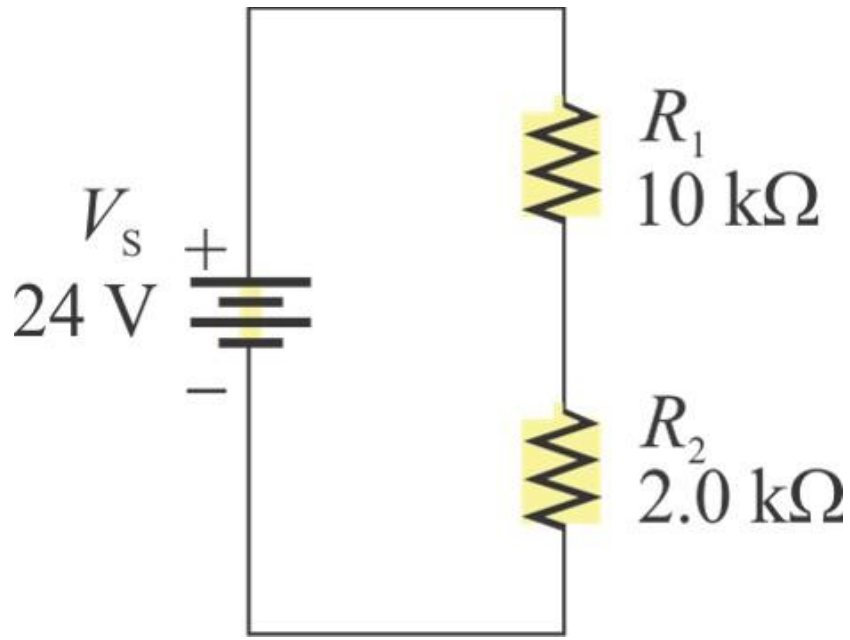
6. The current in the 10 kΩ resistor is

   a. 0.5 mA

   b. 2.0 mA

   c. 2.4 mA

   d. 4.0 mA



Quiz (7 of 11)

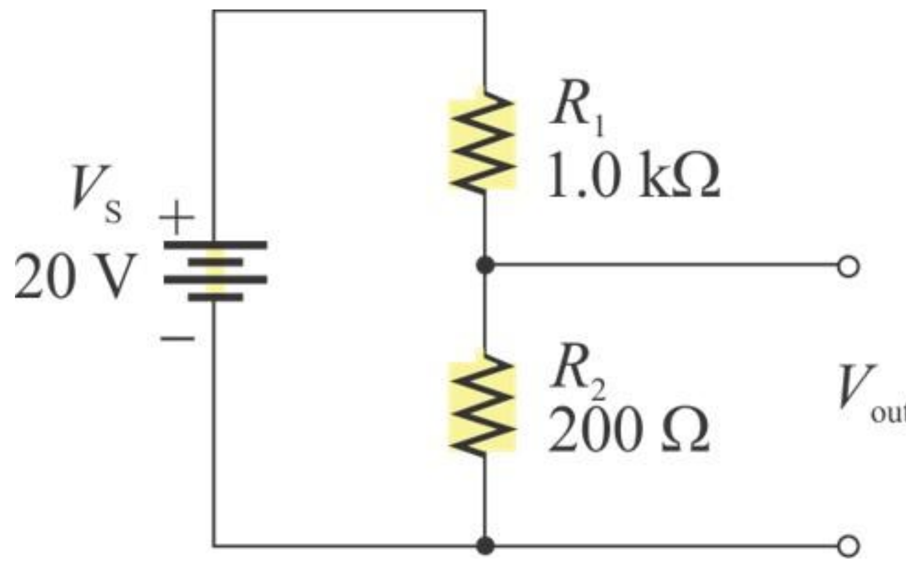
7. The output voltage from the voltage divider is

   a. 3.3 V

   b. 4.0 V

   c. 6.7 V

   d. 16 V



Quiz (8 of 11)

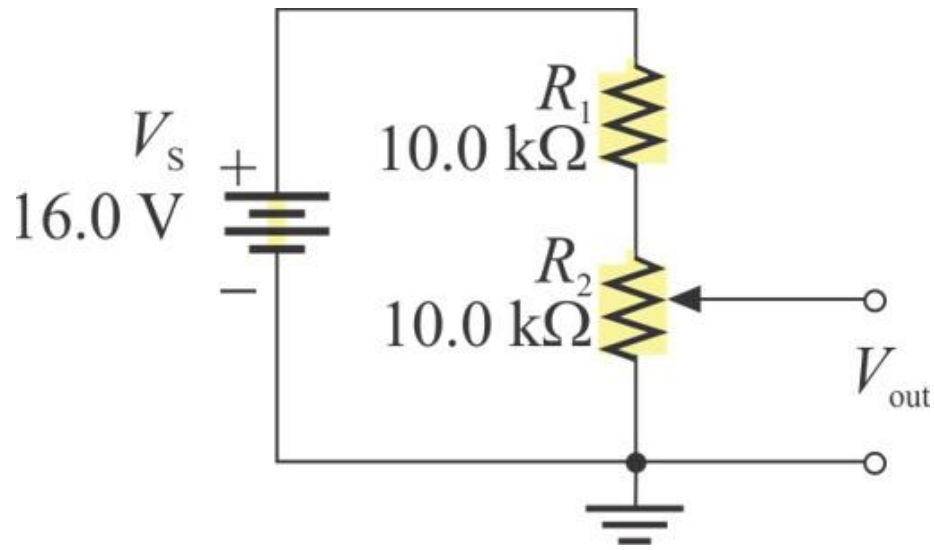
8. Assume the potentiometer is centered such that the resistance on each side is equal. The output voltage is

a. 2.0 V

b. 4.0 V

c. 8.0 V

d. 12.0 V



Quiz (9 of 11)

9. The total power dissipated in a series circuit is equal to the

   a. power in the largest resistor.

   b. power in the smallest resistor.

   c. average of the power in all resistors.

   d. sum of the power in all resistors.

Quiz (10 of 11)

10. The meaning of the voltage V_{AB} is the

a. voltage at point A with respect to ground

b. voltage at point B with respect to ground

c. average voltage between points A and B

d. voltage at point A with respect to the voltage at point B

Quiz (11 of 11)

Answers:

1.	c	6.	b
2.	a	7.	a
3.	c	8.	b
4.	c	9.	d
5.	a	10.	d

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