

SI Physics - Full Discipline Demo

Resistors - Series and Parallel

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term to the best description.

Conventional current	An electrical device that limits the flow of electric charge	1
Electron current	A measure of the difficulty required to push charges through a device	2
Potential difference	Depends on material, measures how strongly a material resists the flow of charge	3
Resistance	Moves from the positive terminal of a battery to the negative terminal	4
Resistivity	Moves from the negative terminal of a battery to the positive terminal	5
Resistor	Work per unit charge	6

Correct answers:

- 1 Resistor 2 Resistance 3 Resistivity 4 Conventional current
5 Electron current 6 Potential difference

Identify each statement as referring to a series or parallel circuit.

⚡ Current through each resistor depends on the resistance of the resistor.	
⚡ Total current through the circuit is equal to the sum of the current through each resistor.	
⚡ Total voltage of the battery is equal to the sum of the voltages across each resistor.	
⚡ Voltage across each resistor depends on the resistance of the resistor.	
⚡ Voltage is the same across each resistor.	⚡ Power is the same in each resistor.
Series	Parallel
1	2

Correct answers:

1

Total voltage of the battery is equal to the sum of the voltages across each resistor.

Power is the same in each resistor.

Voltage across each resistor depends on the resistance of the resistor.

2 Voltage is the same across each resistor.

Total current through the circuit is equal to the sum of the current through each resistor.

Current through each resistor depends on the resistance of the resistor.

Identify each statement as true or false.

⚡ Current equals the product of voltage and resistance for an ohmic device.	
⚡ The greater the length of a wire, the higher the resistance of the wire.	
⚡ The potential difference produced by a battery varies depending on the circuit in which it is used.	
⚡ The power produced by a battery varies depending on the circuit in which it is used.	
⚡ The thicker an electrical wire, the higher the resistance of the wire.	
True	False
1	2

Correct answers:

1 The greater the length of a wire, the higher the resistance of the wire.

The power produced by a battery varies depending on the circuit in which it is used.

2 Current equals the product of voltage and resistance for an ohmic device.

The thicker an electrical wire, the higher the resistance of the wire.

The potential difference produced by a battery varies depending on the circuit in which it is used.

Exploration

The larger the resistance of a device, the more difficult it is for charge to move through the device.

- ☒ True
- ☐ False



The resistance of a wire depends on the ____ of the wire.

- ☐ length
- ☐ thickness
- ☐ material
- ☒ All of the above

✓

A ____ consists of graphite mixed with clay and hardened.

- ☐ wirebound resistor
- ☒ carbon composition resistor
- ☐ rheostat
- ☐ All of the above

✓

Current is measured in units of ____.

- ☒ amperes
- ☐ volts
- ☐ ohms
- ☐ All of the above

✓

Voltage and electric potential difference are two terms for the same quantity.

- ☒ True
- ☐ False

✓

Conventional current moves from the negative terminal to the positive terminal of a battery in a circuit.

- ☐ True
- ☒ False

✓

Kirchhoff's junction rule states that the total electric potential entering a junction equals that leaving the junction.

- ☐ True
 - ☒ False
- ✓

Resistors combined in series all have the same ____.

- ☐ resistance
 - ☒ current
 - ☐ potential difference
 - ☐ All of the above
- ✓

The equivalent resistance of resistors combined in parallel is the ____ of the individual resistances.

- ☐ sum
 - ☐ product
 - ☒ inverse of the sum of the inverse
 - ☐ None of the above
- ✓

A circuit that draws a large amount of power will discharge a battery faster than a circuit that draws a small amount of power.

- ☒ True
 - ☐ False
- ✓

Exercise 1

What is the current in mA through a $500\ \Omega$ resistor that is connected to a 1.5 V battery? Show all calculations using Ohm's law ($V = IR$).

$I = V/R = 1.5 \text{ V} / 500 \, \Omega = 0.003 \text{ A}$. Convert Amperes to milliamperes: $0.003 \text{ A} * 1000 \text{ mA/A} = 3.0 \text{ mA}$. The current through the $500 \, \Omega$ resistor is 3.0 mA.

Describe the similarities and differences between circuits with resistors combined in series and circuits with resistors combined in parallel.

Resistors can be combined in series or in parallel to create a new equivalent resistance that is larger or smaller than the resistance of the individual resistors used in the circuit. Resistors combined in series in a circuit will all have the same current through them and the equivalent resistance is the sum of the resistance of each individual resistor. Resistors combined in parallel in a circuit will all have the same voltage across them and the equivalent resistance is the inverse of the sum of the inverses of the individual resistors, so the equivalent resistance is smaller than any individual resistor.

Do the measured resistance values for each of the three resistors agree with the printed color bands on each device? Explain your answer referencing Data Table 1.

The resistance for the $100 \, \Omega$ resistor is measured to be $100 \, \Omega$ with a tolerance of $5 \, \Omega$, which does match the Color Code Resistance. The resistance for the $1000 \, \Omega$ resistor is measured to be $998 \, \Omega$ with a tolerance of $50 \, \Omega$, which does match the Color Code Resistance. The resistance for the $2200 \, \Omega$ resistor is measured to be $2180 \, \Omega$ with a tolerance of $110 \, \Omega$, which does match the Color Code Resistance.

How did your current and voltage measurements differ between the series and parallel circuits you created? Did this conform to the information presented in the background for this lesson? Explain your answer referencing Data Tables 1 and 2.

The current for resistors in series is 0.36 mA for all three resistors, which does agree with the information in the background stating that the current through resistors in series is the same for each resistor. The voltages are 0.03 V, 0.36 V, and 0.80 V for the three resistors, which also agrees with the background information that the sum of the voltages of each resistor in a series circuit is equal to the voltage of the battery. The voltage for resistors in parallel is 1.2 V for all three resistors, which does agree with the background information that states the voltage is the same for each resistor combined in parallel, and equal to that of the battery. The currents are 10.32 mA,

1.12 mA, and 0.52 mA for the three resistors, which also agrees with the background information that states the sum of the currents through each resistor in parallel is equal to the total current through the battery, when accounting for experimental error.

How do the magnitudes of the currents through the full circuits compare for Parts I-III of this exercise, in which resistors are combined in series, in parallel, and in combination? Use the data recorded in Data Tables 1-3 to answer this question.

The current in the series circuit is much lower than the current in each branch of the parallel circuit (current is 0.36 mA in series and 0.52 mA is the smallest current in parallel for the 2200 Ω resistor). This makes sense because the resistance of the parallel circuit must be smaller than the resistance in the series circuit. By Ohm's law, $I = V/R$ for the same total voltage, this requires the current to be smaller in the series circuit.

The total circuit current for resistors in parallel should be equal to the sum of the current through each resistor. Do your measurements of current for resistors in parallel recorded in Data Table 2 support this statement? Why or why not?

Yes, the total current for the resistors in parallel is 11.77 mA and the sum of the current through each resistor in parallel is 11.96 mA, which is the same within uncertainty. This works because there is very little resistance in the wires.

Were the currents through R_2 and R_3 in the combination circuit in Part III identical? Explain your answer referencing Data Table 3.

The currents through R_2 and R_3 in the combination circuit are 1.02 mA and 0.47 mA, which are not the same. This is because R_2 and R_3 are in parallel with one another, so they have the same voltage, but different currents. R_3 has the largest resistance, so it has the smaller current according to Ohm's law $I = V/R$.

Data Table 1: Resistors in Series
(SAMPLE ANSWER BELOW)

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Battery Voltage1.20V	R_1	R_2	R_3	R_{eq}
Calculated Resistance (Ω)	100	1000	2200	3300
Tolerance from Color Code (Ω)	± 5	± 50	± 110	± 165
DMM Resistance (Ω)	100.0	998	2180	3270
DMM Current (mA)	0.36	0.36	0.36	0.36
DMM Voltage (V)	0.03	0.36	0.80	1.20
Calculated Voltage (V)	0.04	0.36	0.78	1.18
Calculated Current (mA)	0.30	0.36	0.36	0.37

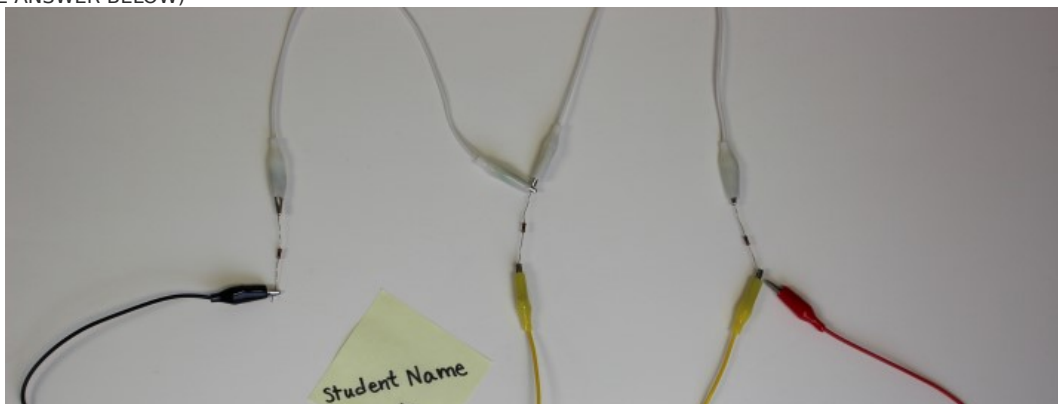
Data Table 2: Resistors in Parallel
(SAMPLE ANSWER BELOW)

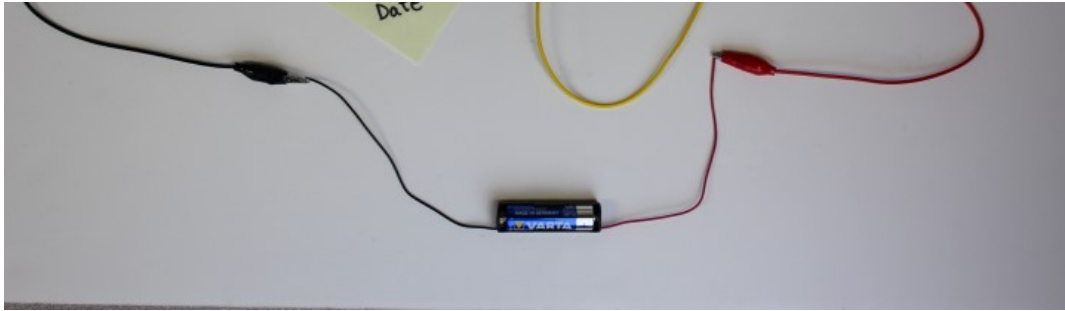
Battery Voltage1.20V	R_1	R_2	R_3	R_{eq}
Calculated Resistance (Ω)	100	1000	2200	87.3
DMM Resistance (Ω)	100.0	998	2180	87.0
DMM Voltage (V)	1.12	1.12	1.12	1.12
DMM Current (mA)	10.32	1.12	0.52	11.77
Calculated Voltage (V)	1.03	1.12	1.13	1.02
Calculated Current (mA)	11.20	1.12	0.51	12.87

Data Table 3: Resistors in Combination
(SAMPLE ANSWER BELOW)

Battery Voltage1.20V	R_1	R_2	R_3	R_{23}	R_{eq}
Calculated Resistance (Ω)	100	1000	2200	687.5	787.5
DMM Resistance (Ω)	100.0	998	2180	684.0	783.0
DMM Voltage (V)	0.15	1.02	1.02	1.02	1.17
DMM Current (mA)	1.48	1.02	0.47	1.48	1.48
Calculated Voltage (V)	0.15	1.02	1.02	1.01	1.16
Calculated Current (mA)	1.50	1.02	0.47	1.49	1.49

Photo 1: Completed Circuit of Resistors in Combination
(SAMPLE ANSWER BELOW)





Exercise 2

What is the relationship between power and bulb brightness (intensity)? Explain your answer referencing Data Tables 4, 5 and 6.

The larger the power, the brighter, or more intense the bulb. The power in the series circuit is lower for each bulb than for the single bulb or the two bulbs in parallel (0.02 W, 0.17 W and 0.15 W, respectively) and the bulbs are brightest in the single bulb circuit and the parallel bulb circuit.

How did the brightness of the bulbs differ between the simple circuit, series circuit, and parallel circuit? Explain your answer referencing Data Tables 4, 5, and 6, using the equation for power ($P = IV$).

The brightness was the same for the single bulb and the bulbs in parallel, but dimmer for the bulbs in series. This is because the voltage across the single and the parallel circuits was the same, while the voltage was less through the series circuit. At the same time, the current in the single and parallel circuits was the same, but smaller in the series circuit. Power is $P = IV$, so the bulb with the smaller current and smaller voltage will have the smallest power, meaning they will be the least bright, which is exactly what was observed.

How does the resistance of the light bulbs differ when the bulbs are cold and when the bulbs are hot? Why do you think this happens?

The cold bulb resistance is much lower (around $4\ \Omega$) than the hot bulb resistance (around 20 to 30 Ω). This is because the resistivity of the light bulbs depends on temperature, meaning as the temperature increases, so does the resistivity, and therefore the resistance. The resistance increases with temperature because an increase in temperature means the atoms and electrons move more quickly. The more the electrons in the bulb are moving, the harder it is for them to move through the bulb as current, so the current is resisted more.

How do the results recorded in Photo 2 and Photo 3 compare to the discussions of current through series and parallel circuits in the background?

In the series circuit, light bulb 2 was extinguished when light bulb 1 was removed. This is because the circuit was incomplete without light bulb 1 in place. In the parallel circuit, light bulb 2 was unaffected by the removal of light bulb 1. This is because each bulb had the same voltage across it and had approximately the same resistance, so the current through each loop of the parallel circuit was the same regardless of whether there were one or two loops. The power produced by the battery in the parallel circuit was reduced when the light bulb was removed, but the power in the single remaining bulb remained the same.

Why is it beneficial to wire circuits in a house in parallel instead of in series? Use your results in Data Tables 4, 5, and 6, as well as Photos 2 and 3 to support your answer.

If a house were wired in series, any time one appliance or light bulb burned out or was unplugged, every appliance in the house would stop working, as shown in the series circuit in Photo 2. Wired in parallel, the power provided to each appliance or light bulb is independent of every other appliance and light bulb. If one appliance is disconnected, the others are unaffected, as shown in the parallel circuit in Photo 3. When many appliances are in use simultaneously for a circuit in parallel, the power drawn from the utilities provider will be larger, but the circuit will not be broken. This increase in power for a parallel circuit is indicated in Table 6, where the total power is 0.33 W, compared to the power drawn on the battery with the bulbs in series in Table 5, which is only 0.13 W. The power drawn in the single circuit is 0.17 W, less than the total power in the parallel circuit, similar to the power drawn by each bulb in the parallel circuit and greater than the power drawn in the series circuit.

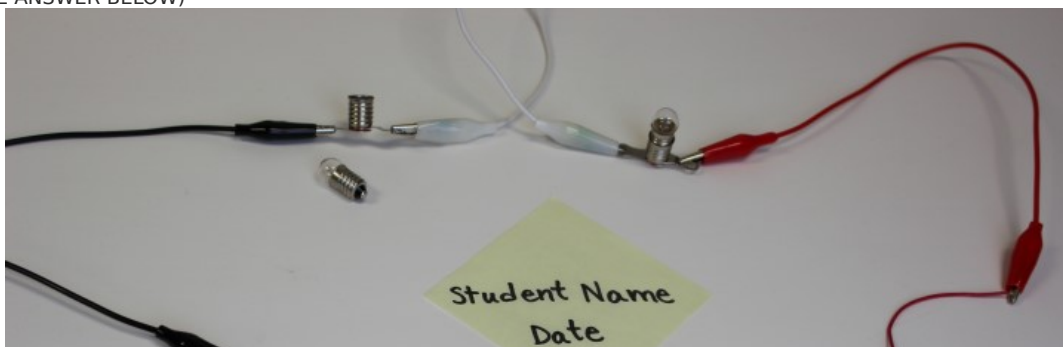
Data Table 4: Single Light Bulb Circuit
(SAMPLE ANSWER BELOW)

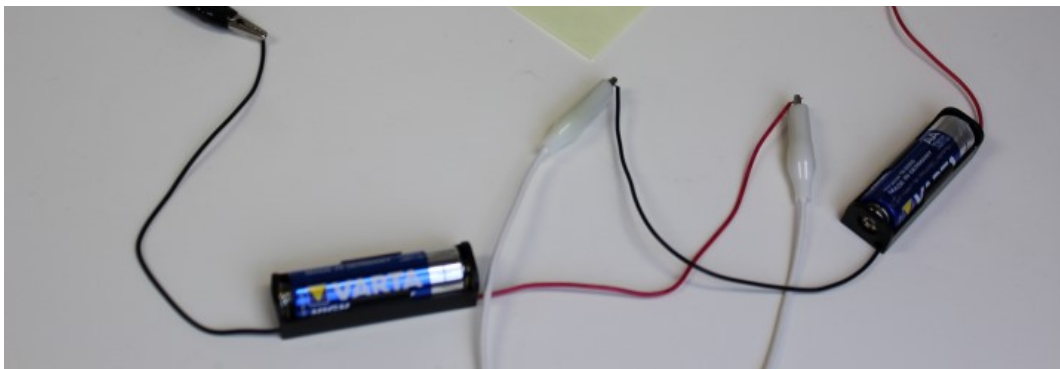
Battery Voltage (V)	Cold Bulb Resistance (Ω)	Current (mA)	Calculated Hot Bulb Resistance (Ω)	Bulb Brightness (intensity)	Calculated Power (W)
2.2	4.0	77.8	28.28	Bright	0.17

Data Table 5: Two Light Bulbs in Series Circuit
(SAMPLE ANSWER BELOW)

Battery Voltage 2.2(V)	Bulb 1	Bulb 2	Bulbs 1 and 2 in Series
Cold Bulb Resistance (Ω)	4.0	4.1	8.1
Current (mA)	57.10	57.10	
Voltage (V)	1.04	1.11	
Calculated Hot Bulb Resistance (Ω)	18.21	19.44	37.65
Bulb Brightness (Intensity)	Dim	Dim	
Calculated Power (W)	0.0594	0.0634	0.123

Photo 2: Series Circuit with One Bulb Removed
(SAMPLE ANSWER BELOW)



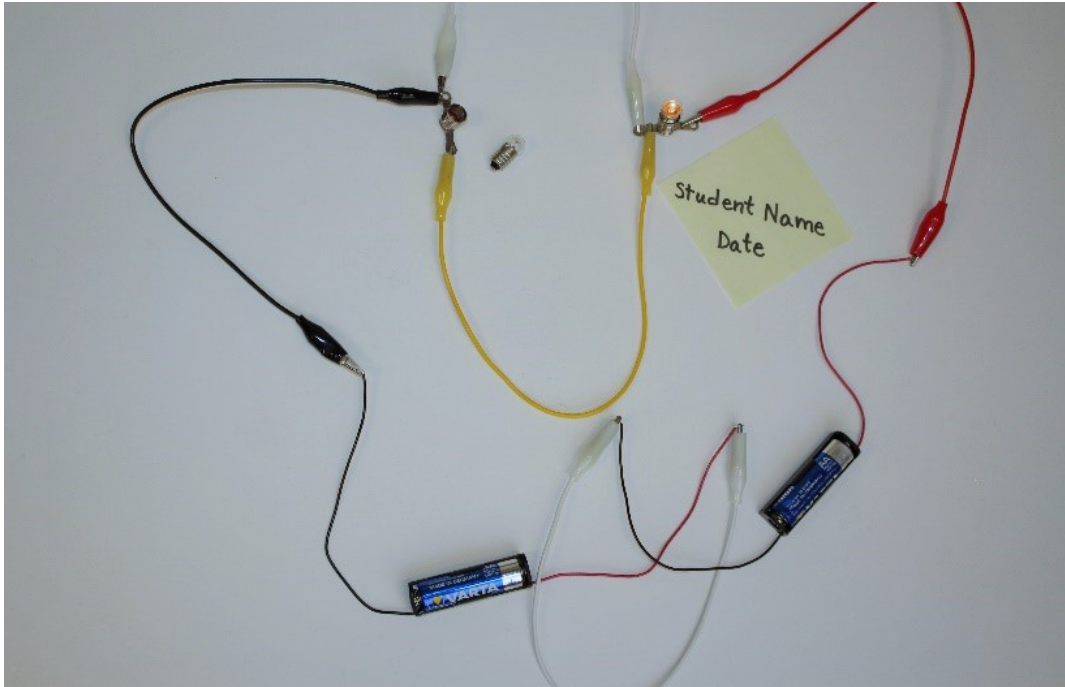


Data Table 6: Two Light Bulbs in Parallel Circuit
(SAMPLE ANSWER BELOW)

Battery Voltage	2.2(V)	Bulb 1	Bulb 2	Bulbs 1 and 2 in Parallel
Cold Bulb Resistance (Ω)		4.0	4.1	2.4
Current (mA)		74.50	73.70	148.2
Voltage (V)		1.99	1.99	
Calculated Hot Bulb Resistance (Ω)		26.71	27.00	13.43
Bulb Brightness (Intensity)		Bright	Bright	
Calculated Power (W)		0.148	0.147	0.295

Panel 3: Parallel Circuit with One Bulb Removed
(SAMPLE ANSWER BELOW)





Competency Review

Resistance is a measure of the difficulty required to push voltage through an electrical device.

- ☐ True
- ☒ False ✓

_____ is dependent upon the material from which a resistor is constructed.

- ☐ Resistance
- ☒ Resistivity ✓
- ☐ Voltage
- ☐ None of the above

The _____ is the rate of flow of charges past a particular point in a circuit.

- ☒ current ✓
- ☐ voltage
- ☐ power
- ☐ None of the above

Ohm's law states that the current is proportional to the _____ and inversely proportional to the _____.

- ☐ resistance; voltage
- ☐ voltage; power
- ☒ voltage; resistance ✓
- ☐ None of the above

Kirchhoff's loop rule states that the total change in ____ around a closed loop is zero.

- ☐ current
- ☒ electric potential ✓
- ☐ resistance
- ☐ All of the above

The equivalent resistance of three resistors connected in series, each with a resistance of 50.0 ohms, is ____ ohms.

- ☒ 150 ✓
- ☐ 50
- ☐ 16.7
- ☐ None of the above

Two resistors connected in parallel, with $R_1 = 150$ ohms and $R_2 = 75$ ohms, are connected to a battery that experiences a current of 0.18 A. The current through R_1 is ____ A.

- ☐ 0.18
- ☐ 0.09
- ☒ 0.06 ✓
- ☐ None of the above

Power is the work per unit charge in a circuit.

- ☐ True
- ☒ False ✓

An efficient LED light bulb dissipates less power for the same illumination as a typical incandescent light bulb.

- ☒ True ✓
- ☐ False

The schematic diagram represents three resistors in ____.



- ☒ series
- ☐ parallel
- ☐ combination series and parallel
- ☐ None of the above

✓

A 1.5 V battery is connected to a 1000 ohm resistor and a 500 ohm resistor in series. The voltage across the 1000 ohm resistor is ____ V.

- ☐ 0.001
- ☐ 0.1
- ☒ 1
- ☐ None of the above

✓

When using a digital multimeter (DMM) to measure voltage across a resistor, the leads should be connected in ____ with the resistor.

- ☐ series
- ☒ parallel
- ☐ combination series and parallel
- ☐ All of the above

✓

When using a digital multimeter (DMM) as an ohmmeter, the circuit should always be complete (connected to a battery or other energy source).

- ☐ True
- ☒ False

✓

The equivalent resistance of $R_1 = 1000$ ohms and $R_2 = 1500$ ohms connected in parallel is ____ ohms.

- ☐ 2500
- ☒ 600 ✓
- ☐ 0.002
- ☐ None of the above

The equivalent resistance of two resistors connected in series is always greater than the equivalent resistance of the same two resistors connected in parallel.

- ☒ True ✓
- ☐ False

The power dissipated by two resistors connected in series is always greater than the power dissipated by the same two resistors connected in parallel.

- ☐ True
- ☒ False ✓

A brighter light bulb dissipates more power than a dimmer light bulb.

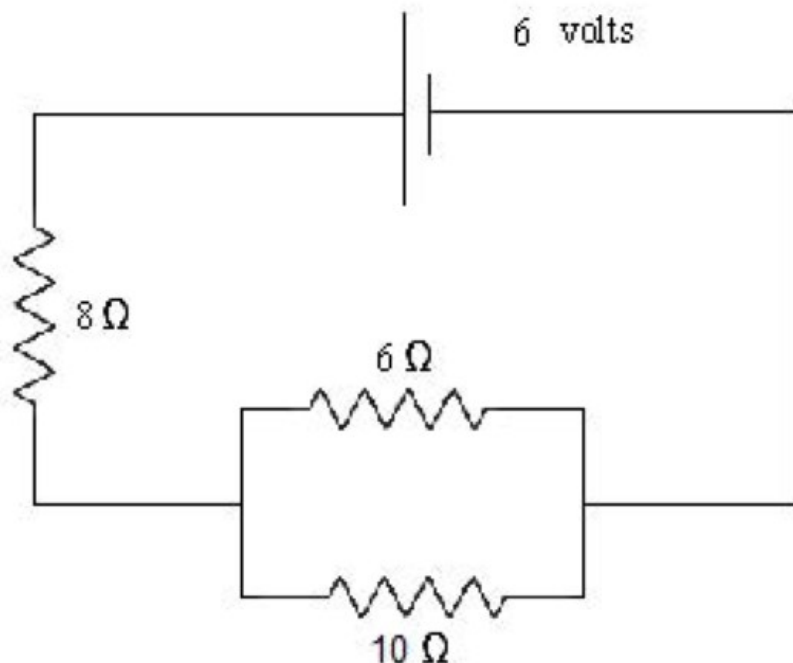
- ☒ True ✓
- ☐ False

Two identical light bulbs connected in series will be ____ the same two identical light bulbs connected in parallel.

- ☐ brighter than
- ☐ the same brightness as
- ☒ dimmer than ✓
- ☐ None of the above

Extension Questions

Use the circuit diagram to calculate the following, showing all work: a. R_{eq} , b. total current, c. voltage through the 6 ohm resistor, d. current across the 6 ohm resistor.



(SAMPLE ANSWER BELOW)

$$\text{a. } R_{6,10} = \left(\frac{1}{R_6} + \frac{1}{R_{10}} \right)^{-1} = \left(\frac{1}{6\ \Omega} + \frac{1}{10\ \Omega} \right)^{-1} = 3.75\ \Omega$$

$$R_{eq} = R_8 + R_{6,10} = 8\ \Omega + 3.75\ \Omega = 11.75\ \Omega$$

$$\text{b. } I_{eq} = \frac{V_{tot}}{R_{eq}} = \frac{6\ \text{V}}{11.75\ \Omega} = 0.51\ \text{A}$$

$$\text{c. } V_{6,10} = I_{eq} R_{6,10} = 0.51\ \text{A} \times 3.75\ \Omega = 1.91\ \text{V} = V_6$$

$$\text{d. } I_6 = \frac{V_6}{R_6} = \frac{1.91\ \text{V}}{6\ \Omega} = 0.32\ \text{A}$$

