ANSWER KEY. Values match the simulation readouts for the circuits and settings given in each step.

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Circuit Builder Virtual Lab

Physics | ANSWER KEY

Open **activities.zornscience.org/circuit-builder/** and follow each step. Use V = IR and P = VI. Show your work with units.

Objective

Measure voltage and current in **series** and **parallel** circuits, explain why bulbs glow brighter or dimmer, and test **Ohm's law** (V = IR).

NGSS alignment: HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the changes in energy of the other components and energy flows in and out of the system are known.

Practices and concepts: Analyzing and interpreting data; Using mathematics; Energy and matter (conservation); Systems and system models.

Meet the simulation

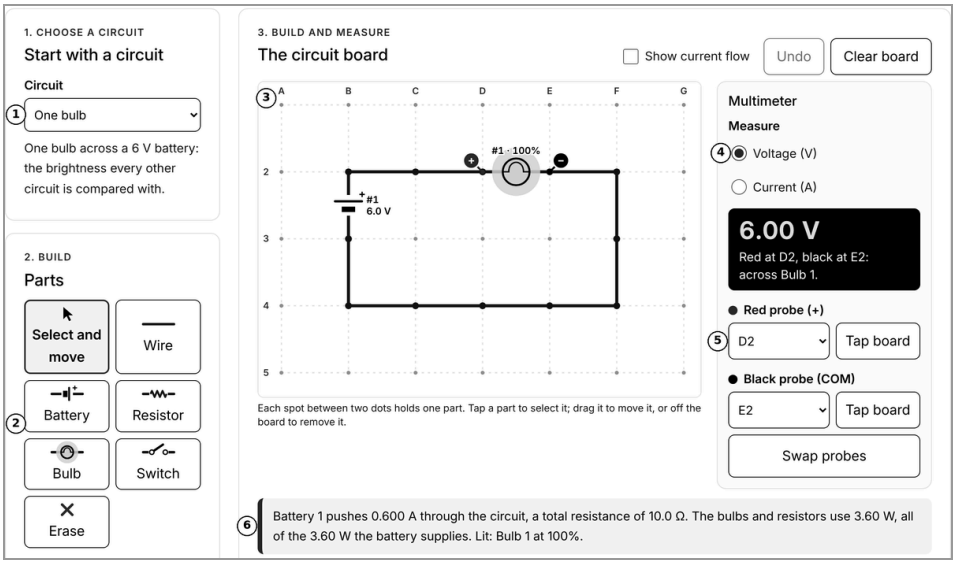


Figure 1. The Circuit Builder with the One bulb circuit loaded.

(1) Circuit menu: loads a ready-made circuit.

(2) Parts: pick a part, then tap a spot on the board.

(3) The board. Tap a part to select it and change its settings.

(4) Multimeter: voltage (V) or current (A) mode.

(5) Probes: red (+) and black (COM) points.

(6) Insight line: battery current and total resistance.

Every bulb is 10 Ω. 100% brightness = 3.60 W, one bulb alone on 6 V.

Pre-lab

1. Name the quantity and its unit for each symbol: V, I and R.

V: voltage, volts (V). I: current, amperes (A). R: resistance, ohms (Ω).

2. One 10 Ω bulb is connected to a 6.0 V battery. Calculate the current through the bulb and the power it uses.

I = V/R = 6.0 V / 10 Ω = <u>0.60 A</u>; P = VI = (6.0 V)(0.60 A) = <u>3.6 W</u>

3. Predict: if you add a second identical bulb in series, will each bulb be brighter, dimmer, or the same as one bulb alone? Explain.

Dimmer (any reasoned prediction is fine). The bulbs share the 6 V, and the current is cut in half.

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Part A. Series and parallel circuits

1. Leave every battery at 6.0 V. Select each circuit below from the **Circuit** menu.
2. Read the **Readings for every part** table (Figure 2). Record the battery's current, and the voltage, current and brightness of one bulb. The bulbs in each circuit are identical.
3. Read the total resistance from the insight line under the board.

PART	WHERE	SETTING	VOLTAGE	CURRENT	POWER	BRIGHTNESS
Battery 1	B3 (–) to B2 (+)	6.0 V	6.00 V	0.300 A	1.80 W	
Bulb 1	C2 to D2	10 Ω bulb	3.00 V	0.300 A	0.90 W	25%
Bulb 2	E2 to F2	10 Ω bulb	3.00 V	0.300 A	0.90 W	25%

Figure 2. The readings table for Two bulbs in series.

Circuit	Battery current (A)	Voltage across one bulb (V)	Current through one bulb (A)	Brightness of one bulb (%)	Total resistance (Ω)
One bulb	**0.600**	**6.00**	**0.600**	**100**	**10.0**
Two bulbs in series	**0.300**	**3.00**	**0.300**	**25**	**20.0**
Three bulbs in series	**0.200**	**2.00**	**0.200**	**11**	**30.0**
Two bulbs in parallel	**1.200**	**6.00**	**0.600**	**100**	**5.0**
Three bulbs in parallel	**1.800**	**6.00**	**0.600**	**100**	**3.3**

4. Series circuits: add the voltages across the three bulbs in series. Compare the sum with the battery voltage. How does the current through each bulb compare with the battery current?

2.00 V + 2.00 V + 2.00 V = 6.00 V, equal to the battery voltage. The bulbs share the battery voltage. The current is the same everywhere (0.200 A) because there is only one path.

5. Parallel circuits: add the currents through the three bulbs in parallel. Compare the sum with the battery current. How does the voltage across each bulb compare with the battery voltage?

0.600 A + 0.600 A + 0.600 A = 1.800 A, equal to the battery current. The current splits among the branches. Each bulb gets the full 6.00 V of the battery.

6. Calculate the total resistance of two 10 Ω bulbs in series and of two 10 Ω bulbs in parallel. Do your answers match the insight line?

Series: $R = R_1 + R_2 = 10\ \Omega + 10\ \Omega =$ <u>20 Ω</u>. Parallel: $1/R = 1/10\ \Omega + 1/10\ \Omega = 0.20\ \Omega^{-1}$, so $R =$ <u>5.0 Ω</u>. Both match.

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7. Use P = VI to calculate the power of one bulb in Two bulbs in series. Use it to explain why that bulb's brightness is 25%.

P = VI = (3.00 V)(0.300 A) = 0.900 W. 0.900 W / 3.60 W = 0.25 = 25%. Half the voltage and half the current give one fourth of the power.

Part B. A switch in a parallel circuit

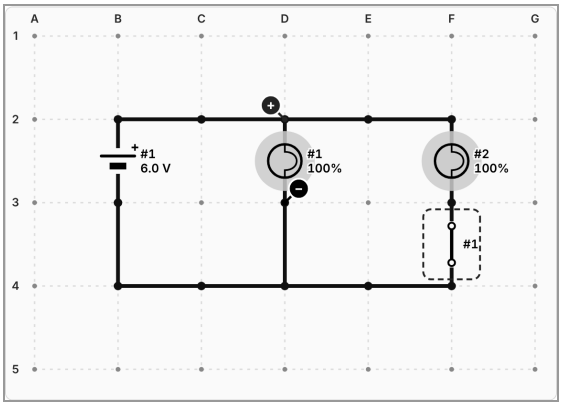


Figure 3. Parallel with a switch, switch closed. Switch 1 is from F3 to F4.

1. Select **Parallel with a switch** from the Circuit menu. The switch starts open.
2. Record the readings in the first row.
3. Tap the switch (F3 to F4) on the board, then select **Close switch**. Record the second row.

Switch	Bulb 1 current (A)	Bulb 1 brightness (%)	Bulb 2 brightness (%)	Battery current (A)
Open	**0.600**	**100**	**0**	**0.600**
Closed	**0.600**	**100**	**100**	**1.200**

8. Did opening the switch change Bulb 1? What did change? Use this to explain why the lights and outlets in a house are wired in parallel.

No. Bulb 1 stayed at 0.600 A and 100% because its branch still connects it across the full 6 V. Only the battery current changed (1.200 A to 0.600 A). In parallel, each device can be switched on or off without affecting the others, and each gets the full voltage.

Part C. Ohm's law

1. Select **One bulb**. Pick **Resistor** in Parts, then tap the bulb (D2 to E2) to replace it with a resistor.
2. In the selected part panel, set **Resistance** to **20 Ω**. The meter should read across Resistor 1 (red at D2, black at E2).
3. Pick **Select and move**, then tap the battery (B2 to B3). Set **Battery voltage** (Figure 4) to each value below. Record the meter reading and the resistor's current from the readings table.

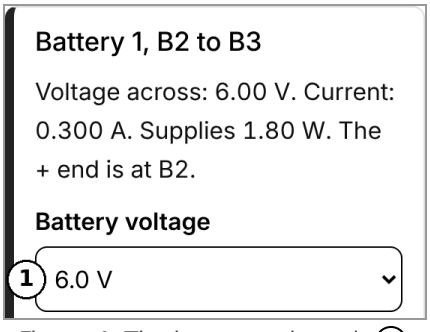
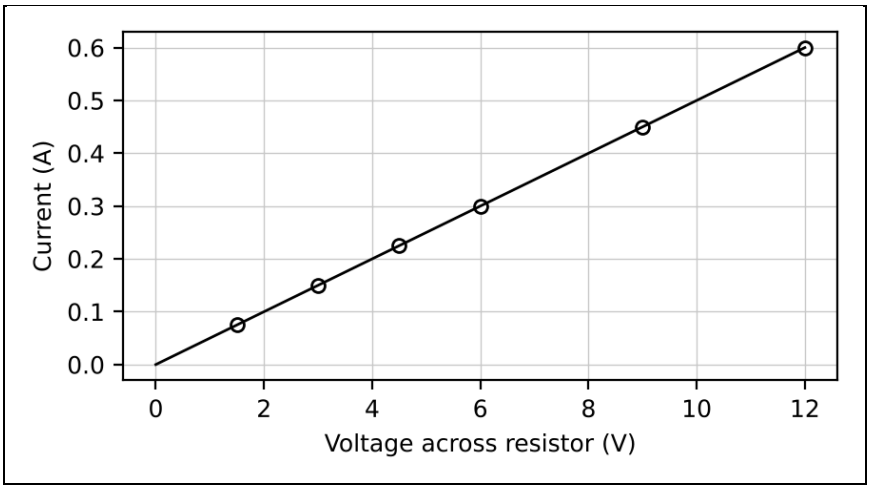


Figure 4. The battery selected: (1) Battery voltage.

Battery setting (V)	1.5	3.0	4.5	6.0	9.0	12.0
Voltage across resistor (V)	**1.50**	**3.00**	**4.50**	**6.00**	**9.00**	**12.00**
Current (A)	**0.075**	**0.150**	**0.225**	**0.300**	**0.450**	**0.600**

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9. Graph current (y-axis) against voltage (x-axis). Label both axes with units and draw a line of best fit. Find the slope.



Straight line through the origin. Slope = ΔI / ΔV = (0.600 A − 0) / (12.00 V − 0) = <u>0.0500 A/V</u>

10. The slope equals 1/R. Use it to find the resistance, and compare with the 20 Ω setting. Then predict the current if you change the resistor to 50 Ω at 12.0 V. Test your prediction.

R = 1/slope = 1 / (0.0500 A/V) = <u>20.0 Ω</u>, the same as the setting. Prediction: I = V/R = 12.0 V / 50 Ω = <u>0.240 A</u>. The simulation reads 0.240 A.

11. The simulation uses ideal batteries and bulbs whose resistance never changes. In a real lab, a bulb's resistance rises as it gets hot, and a battery has some internal resistance. Would real bulbs in series get more or less current than the simulation shows? Explain.

Less. Hot filaments have more resistance, and the battery's internal resistance adds to the total, so I = V/R_{total} is smaller. The battery also gives a bit less than its rated voltage when current flows.

Conclusion

12. Write a claim that explains why identical bulbs glow dimmer in series but stay at full brightness in parallel. Support it with evidence from Part A (specific numbers), then explain your reasoning with V = IR and P = VI.

Claim: In series the bulbs share the battery voltage and carry a smaller current, so each uses less power. In parallel each bulb gets the full voltage and its own full current.
Evidence: Two in series: 3.00 V and 0.300 A per bulb, 25%. Two in parallel: 6.00 V and 0.600 A per bulb, 100%, while the battery current doubled to 1.200 A.
Reasoning: Series resistance adds (20 Ω), so I = V/R is halved and each bulb gets half the voltage. P = VI = (3.00 V)(0.300 A) = 0.900 W, one fourth of 3.60 W. In parallel each branch is across 6 V, so P = (6.00 V)(0.600 A) = 3.60 W. Energy is conserved: the power the battery supplies equals the power the bulbs use.

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