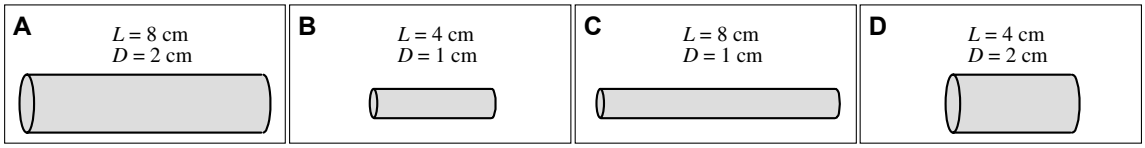
D2-RT01: Carbon Resistors—Resistance

Four different resistors are created from the same piece of carbon. The length and the diameter of each resistor are shown.



Rank the resistance of the four resistors.

☐ 1 Greatest ☐ 2 ☐ 3 ☐ 4 Least OR ☐ All the same ☐ All zero ☐ Cannot determine

Explain your reasoning.

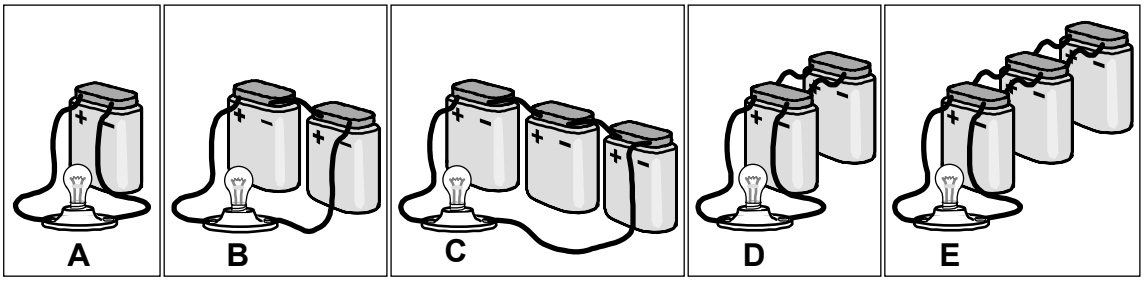
Answer: C > B > A > D.

The resistance is directly proportional to the length and inversely proportional to the cross-sectional area. Since the cross-sectional area is proportional to the square of the diameter, if two resistors have the same length but one has a diameter that is twice as large as the other, the resistance of the wider one will be one-fourth the resistance of the narrower one. In this case, the resistance of A is twice the resistance of D; the resistance of B is twice the resistance of A; and the resistance of C is twice the resistance of B.

D2-WWT02: Batteries and Light Bulbs—Bulb Brightness

All of the batteries in the circuits shown are identical, as are the light bulbs. A student comparing the brightness of the bulbs in these circuits states:

"Bulbs E and C are the brightest since they have three batteries, then bulbs B and D since they have two batteries, and the least bright one is A, since there is only one battery. The more batteries, the brighter the bulb, and it does not matter how they are connected."



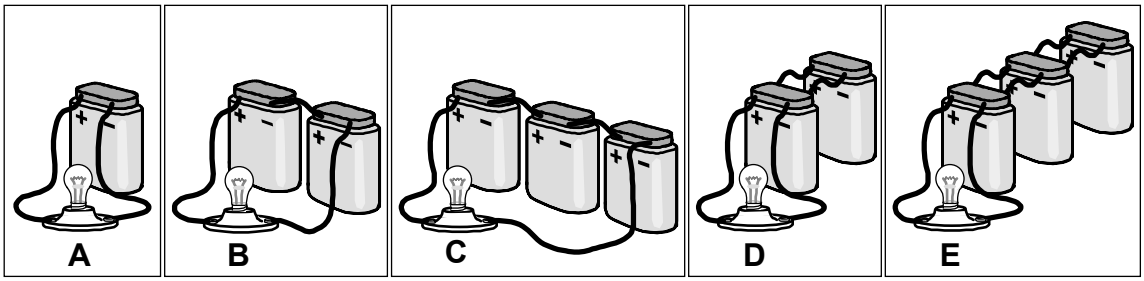
What, if anything, is wrong with this statement? If something is wrong, explain the error and how to correct it. If the statement is correct, explain why.

Answer: The statement is incorrect, because the arrangement of the batteries determines the brightness of the bulbs and not the number of bulbs.

The circuits in cases A, D, and E have the batteries connected in parallel with each other so the potential difference across the bulb in these cases is the voltage of a single battery. Thus the current in the bulb, and consequently the brightness, will be the same for all three. In case C the batteries are connected in series, and the voltage across the bulb is three times the voltage of a single battery, and similarly in case B, the voltage across the bulb is twice the voltage of a single battery. The ranking of the bulb brightnesses is therefore $C > B > A = D = E$.

D2-RT03: Batteries and Light Bulbs—Bulb Brightness

Identical ideal batteries are connected in different arrangements to identical light bulbs as shown.



Rank the brightness of the light bulbs.

					OR			
1 Greatest	2	3	4	5 Least		All the same	All zero	Cannot determine

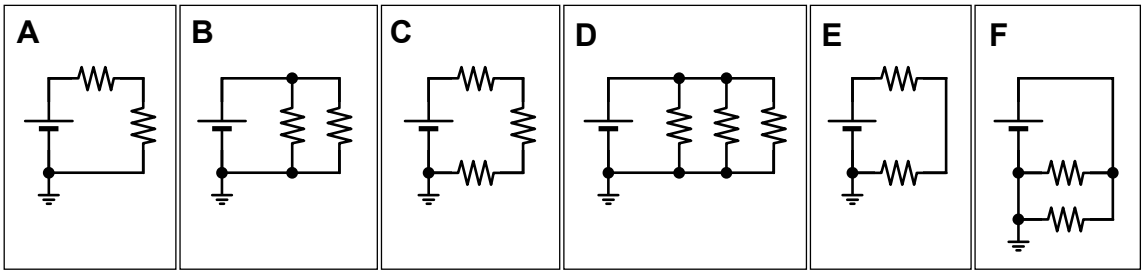
Explain your reasoning.

Answer: C > B > A = D = E.

The circuits in cases A, D, and E have the batteries connected in parallel with each other so the potential difference across the bulb in these cases is the voltage of a single battery. In case C the batteries are connected in series, and the voltage across the bulb is three times the voltage of a single battery, and similarly in case B, the voltage across the bulb is twice the voltage of a single battery. The ranking of the brightness of the bulbs is the same as the ranking of the voltage differences across the bulbs, since the bulbs are identical.

D2-RT04: Simple Resistor Circuits I—Resistance

All of the resistors and batteries are identical in the circuits shown.



Rank the resistance that the circuits present to the battery.

						OR			
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answer: C > A = E > B= F > D.

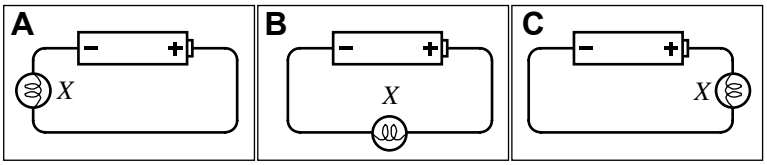
Since resistances add for resistors in series C will have the largest resistance. A and E are the same because they both have two resistors in series. B and F have two resistors in parallel so the resistance of those arrangements is R/2. And D has a resistance of R/3 since it has three resistors in parallel.

D2-RT05: Simple Light Bulb Circuits I—Bulb Brightness

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the three items below, rank the brightness of the bulb labeled *X*.

(a)



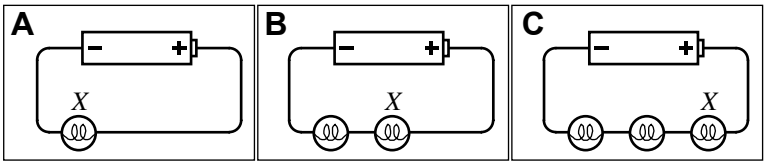
1 Greatest | 2 | 3 Least | OR | All the same | All zero | Cannot determine

Explain your reasoning.

Answer: All the same.

The voltage drop across the bulb must be the same as the voltage of the battery, and the position of the bulb is irrelevant.

(b)



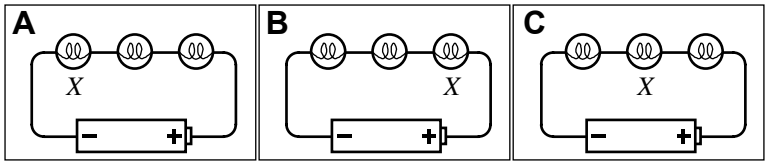
1 Greatest | 2 | 3 Least | OR | All the same | All zero | Cannot determine

Explain your reasoning.

Answer: A > B > C.

The bulbs are in series for each circuit, and the resistance of the circuit increases for each bulb added in series. A large circuit resistance corresponds to a small current. Since all of the bulbs in each circuit will have the same current, the brightness will be determined by the potential differences across the bulbs.

(c)



1 Greatest | 2 | 3 Least | OR | All the same | All zero | Cannot determine

Explain your reasoning.

Answer: All the same.

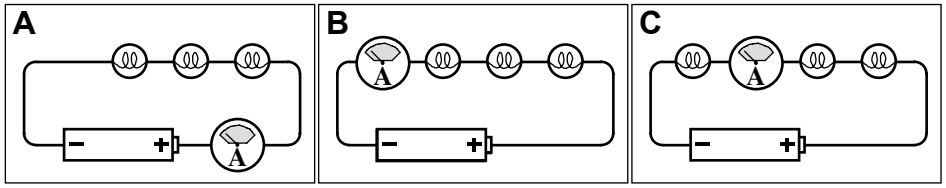
All of the bulbs have the same current and potential difference, so they have the same brightness.

D2-RT07: Simple Light Bulb Circuits I—Ammeter Reading

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below rank the current measured by the ammeter.

(a)



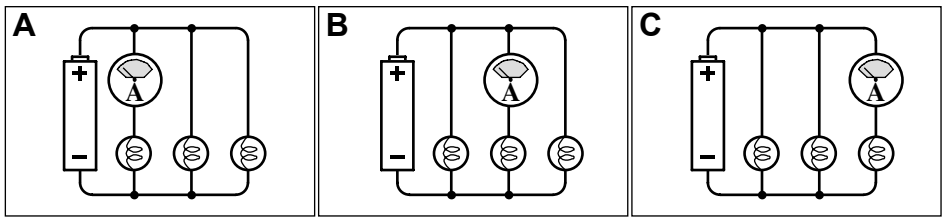
			OR			
1 Greatest	2	3 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answer: All the same.

There is only one path for the current and the resistance is the same in all cases. The current must be the same at all points in each circuit.

(b)



			OR			
1 Greatest	2	3 Least		All the same	All zero	Cannot determine

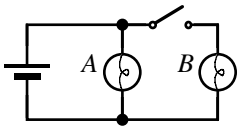
Explain your reasoning.

Answer: All the same.

Since the three bulbs are identical the current from the battery will split into three equal parts in the three parallel branches.

D2-CT08: Circuit with Two Light Bulbs—Current in Bulb

A battery is connected to a circuit with two bulbs and a switch as shown.



When the switch is closed, does the current in bulb *A* (i) *increase,* (ii) *decrease,* or (iii) *remain the same*? _____

Explain your reasoning.

Answer: (iii) The current in bulb A remains the same.

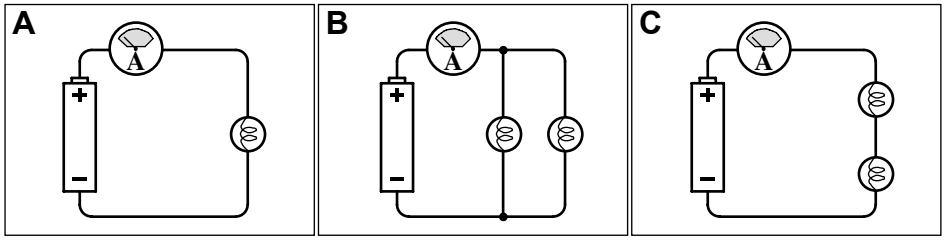
The voltage across bulb A does not change when the switch closes, because the voltage across the bulb must be the same as the battery voltage, and this voltage doesn't change. Since the voltage across the bulb doesn't change, the current in the bulb doesn't change.

D2-RT09: Simple Light Bulb Circuits II—Ammeter Reading

All of the bulbs in the circuits below are identical, as are all of the batteries.

For the two items below rank the current measured by the ammeter.

(a)



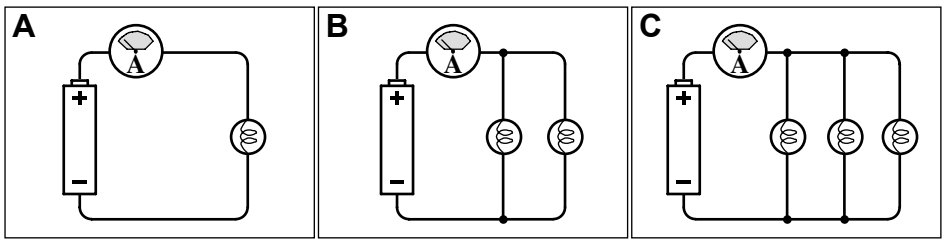
			OR			
1 Greatest	2	3 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answer: B > A > C.

The ammeter reads the current from the battery in each case, which depends on the total resistance of the circuit. Adding resistances in series increases the total resistance while adding them in parallel reduces the total resistance.

(b)



			OR			
1 Greatest	2	3 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answer: C > B > A.

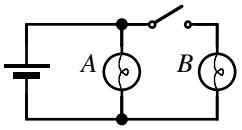
The ammeter is positioned to measure the current in the battery, which depends on the overall resistance of thecircuit. Adding resistances in parallel reduces the total resistance, so the larger the total resistance the smaller the current.

D2-CT10: Circuit with Two Light Bulbs—Current in Battery

A battery is connected to a circuit with two bulbs and a switch as shown.

When the switch is closed, does the current in the battery (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.



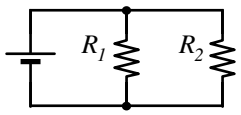
Answer: (i) The current in the battery increases.

When the switch closes, the resistance of the circuit decreases because a path is added for charge to travel in. Since the resistance of the circuit decreases, the current in the battery increases. The current in bulb A remains the same when the switch closes (the voltage across bulb A doesn't change), and when the switch closes additional current from the battery is supplied for bulb B.

D2-QRT19: Two Resistor Circuits—Current, Resistance, and Voltage Drop Chart

For items (a) and (b) below complete the table, showing the value of the currents in and voltages across all elements.

(a) The resistance values for this circuit are given in the table, as is the battery voltage.



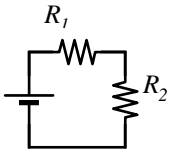
	ΔV	I	
Battery	15.0 V		R
R_1			5.0 Ω
R_2			3.0 Ω

Explain your reasoning.

Answer: The resistors have the same voltage drop as the battery voltage, because the tops of the resistors are connected by a wire to the positive terminal of the battery, and the bottoms of the resistors are connected to the negative terminal of the battery. The currents in the resistors can be found using Ohm's law •V=IR, and these currents add together to give the current in the battery.

	ΔV	I	
Battery	15.0 V	8.0 A	R
R_1	15.0 V	3.0 A	5.0 Ω
R_2	15.0 V	5.0 A	3.0 Ω

(b) The resistance values for this circuit are given in the table, as is the current in the battery.



	ΔV	I	
Battery		4.0 A	R
R_1			2.0 Ω
R_2			1.0 Ω

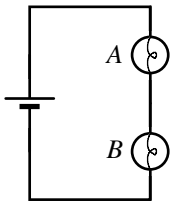
Explain your reasoning.

Answer: The resistors have the same current as the battery since the battery and resistors are in series with each other. The voltage across the resistors can be found using Ohm's law, •V=IR. The potential drops across the resistors add together to equal the voltage drop across the battery.

	ΔV	I	
Battery	12.0 V	4.0 A	R
R_1	8.0 V	4.0 A	2.0 Ω
R_2	4.0 V	4.0 A	1.0 Ω

D2-CT20: Two Light Bulbs in a Circuit—Bulb Brightness

Two identical light bulbs are connected to a battery as shown.



Is bulb *A* (i) *brighter than,* (ii) *dimmer than,* or (iii) *the same brightness as* bulb *B?* _____

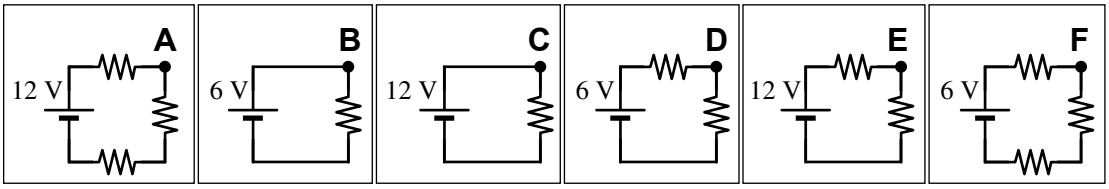
Explain your reasoning.

Answr: (iii) The two bulbs will have the same brightness.

Since there are no branches in the circuit, all of the current in the battery will go through bulb A and through bulb B. Identical bulbs with equal current in them will have equal brightness.

D2-RT25: Simple Resistor Circuits II—Current

All of the resistors in the circuits below are identical. Three of the circuits contain 6-volt batteries and three contain 12-volt batteries.



Rank the current at the upper right-hand corner of each circuit.

						OR			
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

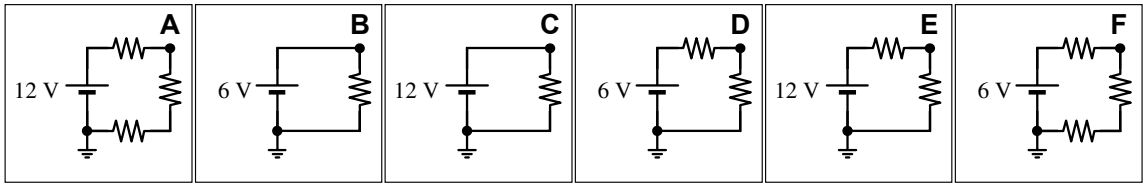
Explain your reasoning.

Answer: C > B = E > A > D > F.

The resistors in each circuit are connected in series, and the current in each resistor is the same as the current in the battery. Because the resistors in each circuit are in series and the resistors are identical the voltage drop across each resistor is equal to the battery voltage divided by the number of resistors in the circuit. The voltage drop across each resistor is 12 volts in case C, 6 volts in cases B and E, 4 volts in case A, 3 volts in case D, and 2 volts in case F. The current in the upper right hand corner is the current in a single resistor of the circuit, which is proportional to the voltage drop across that resistor (since all of the resistors are identical).

D2-RT26: Simple Resistor Circuits with a Ground—Voltage Drop

The following circuits contain either a 6-volt or a 12-volt battery and one or more identical resistors.



Rank the reading on a voltmeter connected between the upper right-hand corner and ground.

						OR			
							☐	☐	☐
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

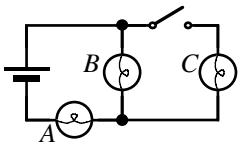
Explain your reasoning.

Answer: C > A > B = E > F > D.

In cases B and C the voltmeter is connected across the battery, i.e., the upper right corner is connected by a wire to the positive terminal of the battery, which is higher in voltage than the negative terminal which is connected to ground. The voltmeter reads the battery voltage in these cases. In cases A, D, E, and F, the resistors are connected in series, and the current in each one is the same, so the voltage drop across each resistor in the circuit is the same. In cases D and E each resistor must have a voltage across it of one-half the battery voltage, and in cases A and F each resistor has one-third of the battery voltage across it. In cases A and F, the voltage at the upper right hand corner must therefore be two-thirds of the battery voltage, and in cases D and E it must be one-half of the battery voltage. The voltmeter reading is 8 volts in case A, 6 volts in case B, 12 volts in case C, 3 volts in case D, 6 volts in case E, and 4 volts in case F.

D2-SCT36: Light Bulb Circuit with Switch—Bulb Brightness

Three light bulbs and a switch are connected to a battery as shown. Four students are discussing what would happen to the brightness of bulb *A* when the switch closes:



Althea: *"The current in bulb A has to be the same as the current in the battery, since they are in the same branch. The battery is going to put out the same current whether the switch is open or closed, so the current in bulb A is going to remain the same, and its brightness won't change when the switch closes."*

Bertha: *"I agree. All that is going to happen when the switch closes is that bulb C is going to turn on, and it's going to get half of the current. Bulb B only gets half the current as well, so it gets dimmer. But bulb A still gets all the current, and its brightness doesn't change."*

Cassidy: *"I think bulb A gets brighter. The current in the circuit goes up, because when the switch closes the resistance of the circuit goes down. Since bulb A gets all the current in the circuit, it gets brighter."*

Dupree: *"When the switch closes, the resistance of the circuit goes up, because you've added one bulb, which has resistance. The current in the circuit goes down, and bulb A gets dimmer."*

With which, if any, of these students do you agree?

Althea _____ Bertha _____ Cassidy _____ Dupree _____ None of them_____

Explain your reasoning.

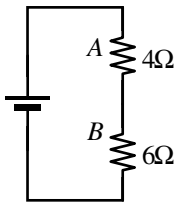
Answer: Cassidy is correct, the brightness of bulb A will increase.

With the switch open, the current in bulb B is the same as the current in the lower bulb. Since the current is the same, the electric potential difference across the two lit bulbs must be the same, and they must add to the battery voltage. So the electric potential difference across bulb A is half the battery voltage. When the switch closes, the overall resistance of the circuit is reduced because a path is added, so the current in the battery increases, and the current in the bulb A must increase because it is the same as the battery current. So the brightness of bulb A must go up when the switch closes.

D2-WWT37: Circuit with Two Resistors—Current

A battery is connected to a circuit containing two resistors as shown. A student states:

"Using Ohm's law, the current is the voltage divided by the resistance, so when you have a bigger resister, you have a smaller current. In this case, resistor B is a larger resistance than A, so it will have a smaller current."



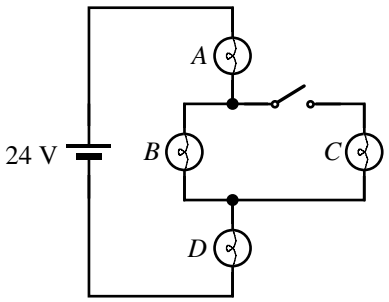
What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

Answer: The student's statement is incorrect.

Since there is only one path for charge, the current will be the same at all points in this circuit. The student is failing to take account of the third quantity in Ohm's Law the voltage, which does vary for the two resistors.

D2-CT40: Four Light Bulbs Circuit with Switch—Effect of Closing Switch

A battery is connected to four identical bulbs and a switch as shown.



(a) When the switch is closed, does the brightness of bulb *C* (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

Answer: (i) The brightness of bulb C increases.
With the switch open, bulb C has no current and is not lit, because there is not a complete circuit that includes bulb C. When the switch is closed, the current in bulb A will split at the junction below bulb A, with half of the current going to bulb B and half to bulb C. Bulb C will light up.

(b) When the switch is closed, does the current in the battery (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

Answer: (i) The current in the battery increases.
The resistance of two bulbs connected in parallel (as B and C are when the switch closes) is smaller than the resistance of a single bulb, so the resistance of the portion of the circuit containing bulbs B and C and the switch decreases when the switch closes. Since this portion of the circuit is connected in series with bulbs A and D, the overall resistance of the circuit goes down, and as a result the current in the battery increases.

(c) When the switch is closed, does the brightness of bulb *A* (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

Answer: (i) The brightness of bulb A increases.
Since the current in the battery increases, the current in bulb A increases as well, since these elements are in the same branch and their currents must be the same.

(d) When the switch is closed, is bulb *D* (i) *brighter* than bulb *A*, (ii) *dimmer* than bulb *A*, or (iii) *the same* brightness as bulb *A*? _____

Explain your reasoning.

Answer: (iii) The brightness of bulb D is the same as the brightness of bulb A whether the switch is open or closed.
Bulb A, bulb D, and the battery are connected in series, and the charge that goes through one of the elements per unit time (the current) must be the same as what goes through the other two as well. With the switch closed, the current in bulb A splits at the junction below A, but then recombines at the junction above D.

(e) When the switch is closed, does the brightness of bulb *D* (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

Answer: (i) The brightness of bulb D increases.
Since the current in the battery increases, the current in bulb D increases as well, since these currents must be equal.

(f) When the switch is closed, does the brightness of bulb *B* (i) *increase*, (ii) *decrease*, or (iii) *remain the same*? _____

Explain your reasoning.

Answer: (ii) The brightness of bulb B decreases.
With the switch open, bulbs A, B, and D are connected in series, with each having the same current. Since these bulbs have the same current and are identical, they also have the same voltage across them, and the sum of these voltages must be equal to the battery voltage, or 24 Volts. Each of these bulbs therefore has 8 volts across it when the switch is open. When the switch closes, the current in the battery goes up (because the resistance of the circuit goes down), and so the current in bulbs A and D goes up as well. Since the current in these bulbs increases, the voltage across these bulbs also increases, and is therefore greater than 8 Volts. Whether the switch is open or closed, however, it remains true that the sum of the voltages across bulbs A, B, and D must add to the battery voltage, 24 Volts. With the switch closed, bulbs A and D have voltages across them greater than 8 Volts each, and so the voltage across bulb B must be smaller than 8 Volts. So the voltage across bulb B goes from 8 Volts when the switch is open to something less than 8 Volts, and bulb B must get dimmer.

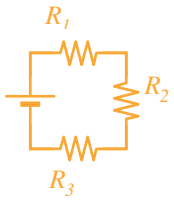
D2-WBT47: Three Resistors Circuit Chart I—Circuit

A circuit contains three resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	
Battery	36.0 V	3.0 A	R
R_1	9.0 V	3.0 A	3.0 Ω
R_2	15.0 V	3.0 A	5.0 Ω
R_3	12.0 V	3.0 A	4.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

The current in all elements is the same, which is consistent with all elements in series and the sum of the potential drops across the three resistors equals the battery potential.



D2-WBT48: Three Resistors Circuit Chart II—Circuit

A circuit contains three resistors and a battery. The chart gives the currents in each element, the potential difference across each element, and the resistance values of the resistors.

	ΔV	I	
Battery	24.0 V	16.0 A	R
R_1	24.0 V	8.0 A	3.0 Ω
R_2	24.0 V	6.0 A	4.0 Ω
R_3	24.0 V	2.0 A	12.0 Ω

Draw an electric circuit that is consistent with the values of this chart. Label the resistors.

The voltage across all of the resistors is that same as the battery voltage, which is consistent with all of the resistors in parallel branches. In addition the sum of the three currents equals the current in the battery.