18

Direct-Current Circuits

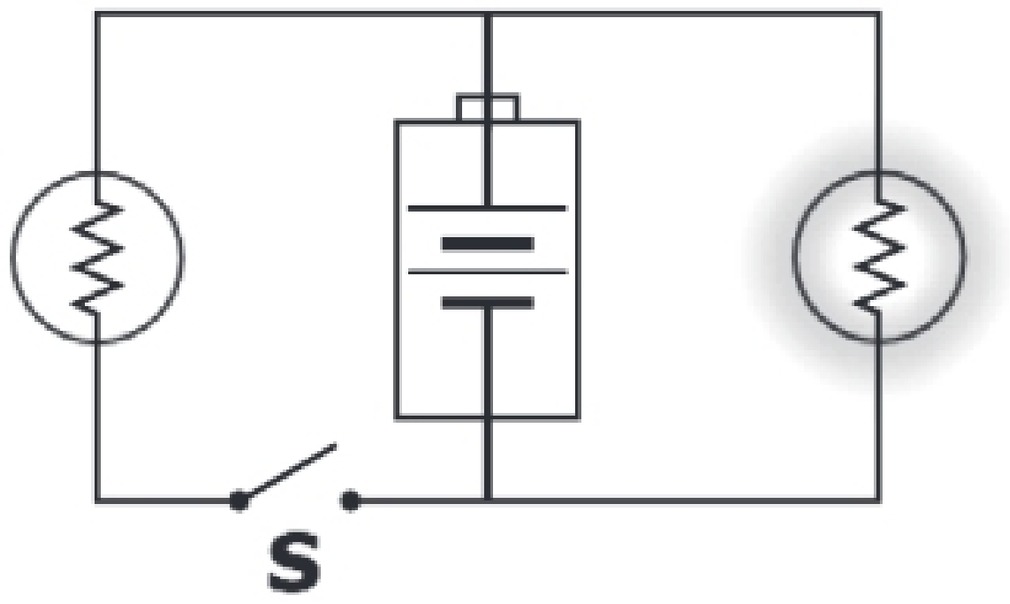
Clicker Questions

Question N2.01

Description: Understanding circuits with parallel resistances.

Question

A battery is used to light a bulb as shown. A second bulb is connected by closing switch S. What happens to the bulbs?



1. The right bulb goes out; the left bulb lights up.
2. The right bulb gets noticeably dimmer; both bulbs have the same brightness.
3. The right bulb gets very slightly dimmer; both bulbs have the same brightness.
4. The right bulb's brightness stays the same; both bulbs have the same brightness.
5. The right bulb gets slightly brighter; both bulbs have the same brightness.
6. The right bulb gets noticeably brighter; both bulbs have the same brightness.
7. The right bulb stays the same; the left bulb does not light.
8. Impossible to determine

Commentary

Purpose: To develop understanding of Kirchhoff's loop law and parallel resistors.

Discussion: Many people think that when the second light bulb is connected to the battery, the first bulb will become dimmer, since the battery must "work harder" to make two bulbs glow or the second light bulb will divert some of the current from the first bulb.

However, Kirchhoff's loop law must always be satisfied, and this can help sort out the ideas here. The sum of the voltage drops around any closed loop must be equal to the sum of the voltage rises. Therefore, the voltage drop across each bulb is the voltage of the battery, whether there is one bulb or two connected. This means that each bulb glows just as brightly after the switch is closed as the one bulb glowed beforehand.

This does not mean that nothing changes in the circuit. With two bulbs glowing, twice as much current is flowing through the battery as before, so it is also delivering twice as much power as before, and will run out of energy twice as quickly.

Note that ideal batteries are *not* sources of constant current. In other words, the same current does not flow through the battery at all times. Instead, an ideal battery maintains a certain voltage across its terminals, adjusting the current to make sure the voltage is constant.

If we include the effects of internal resistance in the battery, we expect the terminal voltage to be slightly smaller, which means the bulbs would glow a little less brightly after the switch is closed. However, unless the resistance of each bulb is very small, this effect is not observable.

Key Points:

- For any closed loop in a circuit, the sum of the voltage rises must equal the sum of the voltage drops.
- The current a battery must provide does not affect its voltage significantly; if the battery's internal resistance is ignored, the voltage is not affected at all.
- Batteries are not sources of constant current. They maintain a certain "terminal voltage" and the current changes to make sure this happens.

For Instructors Only

Many students will think that the glowing bulb will dim noticeably when the second bulb is connected.

Some students will use experience to answer the question. They might have noticed that sometimes the lights in their houses dim when something turns on, such as the compressor of an air conditioner. This experience is not particularly relevant, since internal resistance is a factor. In other words, when the compressor turns on, it draws a very large current, which causes the voltage to dip slightly, which in turn causes the lights in the house to dim. An appropriate experience is simply turning on a light when another light is already on. Houses are wired "in parallel" just as this circuit is wired. We do not generally experience noticeable changes in brightness when various appliances turn on and off in the home, so we should not expect any changes here either.

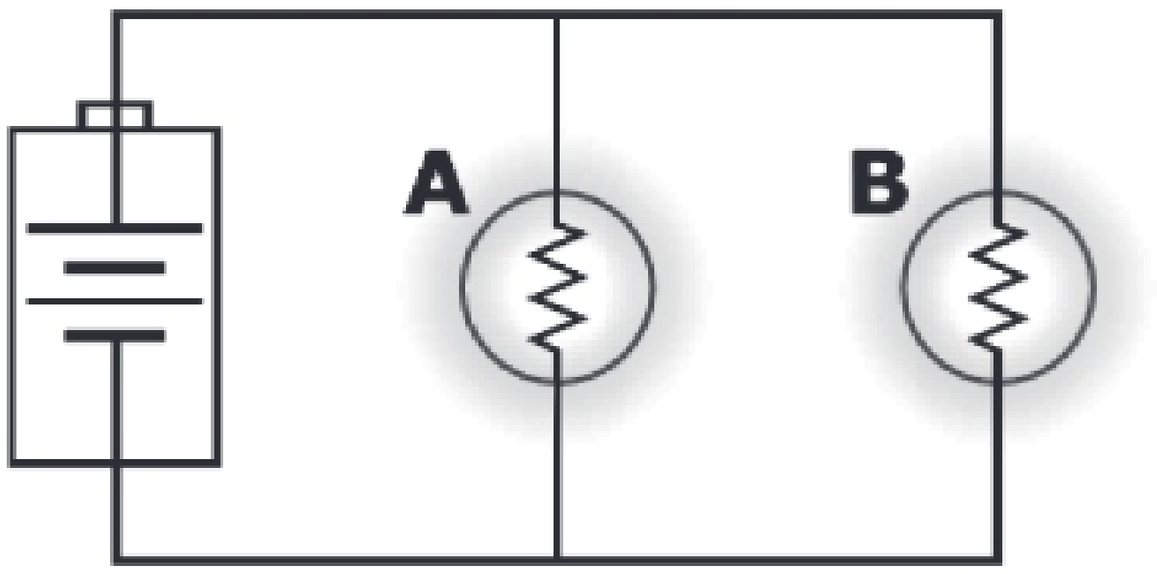
This question can be followed up with a live demonstration.

Question N2.02

Description: Understanding circuits with parallel resistances.

Question

A battery is used to light two bulbs as shown. What happens to bulb B when bulb A is unscrewed from its socket?



1. Bulb B goes out.
2. Bulb B gets noticeably dimmer, without going out.
3. Bulb B gets slightly dimmer.
4. Bulb B's brightness stays the same.
5. Bulb B gets slightly brighter.
6. Bulb B gets noticeably brighter.
7. Impossible to determine

Commentary

Purpose: To develop understanding of Kirchhoff's loop law and parallel resistors.

Discussion: When two circuit elements are arranged in parallel, they necessarily have the same voltage across them. When arranged in series, they have the same current through them. In this situation, the voltages must be the same. The currents will only be the same if the bulbs have the same resistance.

Also, when elements are arranged in parallel, disconnecting one does not disconnect the rest. When bulb A is removed, there is still a closed circuit with the battery and bulb B. No current flows through A, but this does not affect the flow of current through B. Further, the voltage across bulb B does not change when bulb A is removed; it is the voltage across the battery, according to Kirchhoff's loop law. Therefore, the brightness of bulb B does not change.

Your house is wired "in parallel." When you replace a bulb, the rest of the lights in the house do not go out, and they do not change in brightness. The voltage across each light and each appliance remains the same, no matter how many are on and how many are off.

Key Points:

- Circuit elements in parallel have the same voltage across them.
- Removing one path from a circuit does not break paths in parallel with it.

For Instructors Only

Some students will think that bulb B goes out when bulb A is removed, perhaps because they do not recognize that the flow of current is not broken.

They also might recognize that the current through the bulbs beforehand is the same, which suggests to them that they are in series, overgeneralizing a critical feature of the series arrangement. In other words, instructors often emphasize that the current through elements in series is the same. Students might misapply that "rule" here.

Other students might think that bulb B is brighter after A is removed, because then only one bulb is connected to the battery. They might even be surprised when there is no change. It is useful, therefore, to focus some attention on the battery, explaining that the current through it is half as much as before, so the power it delivers is also cut in half.

Internal resistance should not be a factor here. Including its effects would make bulb B glow slightly brighter after A is removed, since the terminal voltage across the battery would be slightly higher than before. If this is issue is raised, you must discuss it carefully, since they may take the message that "bulb B is brighter afterwards" and interpret it as a consequence of the circuit arrangement rather than the battery's internal resistance.

This question can be followed up with a live demonstration.