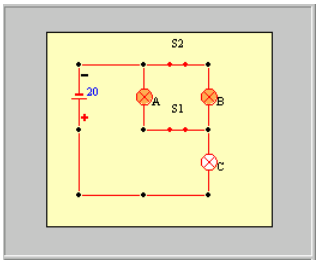
Worksheet for Exploration 30.2: Light Bulbs



In this animation, you can close and open switches to determine the resistance of each light bulb. The current and voltage readings show the current through the battery and the voltage across the battery **(voltage is given in volts and current is given in amperes)**. In order to solve such problems, you can always use Kirchhoff loop equations. If it is possible, a faster way to work problems is in terms of the effective resistance of the network of resistors. You consider the resistors that are in parallel and resistors that are in series. It is, however, worth looking at the circuit in a bit more detail first, before diving into equations, to see if there is a way to understand the problem conceptually and to solve it faster.

Notice that when both switches are closed, bulbs A and B are dimmer than bulb C. This should not be surprising because the current through bulb C is the sum of the currents through A and B. Open one of the switches and leave the other one closed. Now bulb C is in series with one of the bulbs (which one?).

When ____Switch is closed, bulb C is in series with bulb ____.

Notice that the total current from the battery is less, but that either bulb A or bulb B is brighter than it was before.

a. Why?

Go back to the case where both switches are closed and notice that bulbs A and B look to be the same brightness. If the brightness were exactly the same, they would have the same resistance.

b. With switch 1 open and switch 2 closed, what is the current?

c. What about with switch 1 closed and switch 2 open?

d. How does this "prove" that bulbs A and B are identical?

e. Furthermore, when one switch is open and one closed, how does the brightness of bulb C compare with the bulb it is in series with?

f. What does that indicate?

Now for some math.

g. Since $R_A = R_B$, explain why, when both switches are closed, the effective (equivalent) resistance of the circuit is $1/2R_A + R_C$. (Hint: with both switches closed, A and B are in parallel with each other).

i. Show that the effective resistance of R_A and R_B in parallel with each other is $1/2R_A$:

ii. Show that effective resistance of complete circuit is $1/2R_A + R_C$:

h. When **both switches are closed**, use the voltage across the battery and the current through the battery to find the value of the effective resistance.

R_1 = _____ (where $R_1=1/2R_A+R_C$)

i. With **one switch open** and one switch closed, use the voltage across the battery and the current through the battery to find the value of the effective resistance. The effective resistance is equal to $R_A + R_C$ (or $R_B + R_C$).

R_2 = _____ (where $R_2= R_A + R_C$)

j. Solving these equations, you should find that all the bulbs are indeed identical (something you surmised from the brightness of the bulbs).

i. You have two equations (for R_1 and R_2) and two unknown: (R_A and R_C). Solve for the values of R_A and R_C.

Notice that in this problem, trying to understand conceptually what was happening helped to guide the problem-solving process. Although the Kirchhoff loop rules will work, they are not necessarily the easiest way to solve a problem.