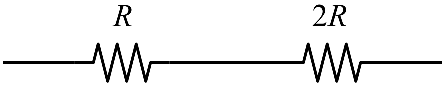
Current and Resistance

Consider two resistors wired in series as in the diagram below. If there is an electric current through the combination, the current in the second resistor (resistance = $2R$) is ____________________ the current through the first resistor (resistance = R).



A. equal to

B. half

C. twice

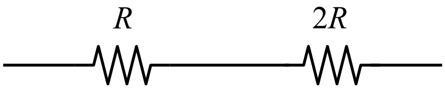
D. smaller than, but not necessarily half

E. more than, but not necessarily twice

ANS: A—The currents in the two resistors are equal.

The same electric current flows through all circuit elements in series. Current is not "used up" or changed as it passes through a resistor. Remenber, current is a measure of the rate of flow of electric charge. If the current were not the same through both resistors, we would expect charge to build up between them. This does not happen.

Consider two resistors wired in series as in the diagram below. If there is an electric current through the combination, the potential difference across the second resistor (resistance $= 2R$) is ____________________ the potential difference across the first resistor (resistance $= R$).



A. equal to

B. half

C. twice

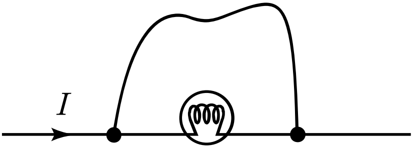
D. smaller than, but not necessarily half

E. more than, but not necessarily twice

ANS: C—The potential difference across $2R$ is *twice* the potential difference across $1R$.

We know from the previous question that both resistors have the same current through them. According to Ohm's law, the potential difference across the first resistor would be $\Delta V_1 = IR$, while the potential difference across the second resistor would be $\Delta V_2 = I(2R) = 2\Delta V_1$.

Charge flows through a light bulb. Suppose a wire is connected across the bulb as shown.



When the wire is connected,

A. all the charge continues to flow through the bulb.

B. half the charge flows through the wire, the other half continues through the bulb.

C. all the charge flows through the wire.

D. none of the above

ANS: C—All of the charge flows through the wire.

The addition of the wire, which we treat as an ideal conductor, changes the circuit so that the potential difference between the two black dots is zero (ideal wires are equipotentials). This means that the potential difference across the light bulb is zero. Because the bulb has a resistance, the current through it is $I = \Delta V/R = 0$, so all of the current coming from the left will pass through the wire before heading off to the right.

Now consider the case where we added a resistance rather than a wire in parallel with the bulb. The resistor and bulb will have the same potential difference across them, so the currents through each element will be inversely proportional to the resistance. More current would flow through the lower resistance and less would flow through the higher resistance. The example given is just this case taken to an extreme: one of the resistances is zero (the wire), so all of the current will flow through it.

Warmup Question

The electrical power dissipated by a resistor is given by $P = I^2 R$. It is also given by $P = (\Delta V)^2 / R$. So is the power really proportional to R or to $1/R$ or is neither really true? Discuss thoroughly.

ANS: The answer depends on what is being held constant. In cases where the potential difference is held constant while R varies, such as when plugging different kinds of light bulbs into your 120 V wall outlet, use $P = (\Delta V)^2/R$. In this case, power delivered to (and dissipated by) the bulb is inversely proportional to the resistance of the bulbs. Brighter incandescent bulbs have less resistant filaments than do dimmer ones.

If current is held fixed while R varies, which is much less often the case, then $P = I^2R$ shows that the power dissipated will be proportional to the resistance. However, because it is very likely that the current will depend on the resistance, it takes a rather contrived setup to realize this case.

Warmup Question

Unlike the new, compact florescent bulbs, an ordinary light bulb is basically a thin wire filament that acts as a simple resistor. Estimate the resistance of such a bulb using some common numbers from ordinary household experience that previously may not have meant much to you. And look at the equations I gave you in the first question.

ANS: Let's consider a bright, 100 W bulb. This is the electrical power drawn (and dissipated) by the bulb when it is plugged into a 110 V outlet (call it 110 V).
The resistance is related to the voltage (ΔV) and power P by

$$R = \frac{(\Delta V)^2}{P} = \frac{(100\,\mathrm{V})^2}{100\,\mathrm{W}} = 100\,\Omega\ .$$

A dimmer bulb (say 60 W) will have an even higher resistance.