# Chapter 22: Current & Resistance
## Questions & Problems

$$I = \frac{\Delta Q}{\Delta t} \qquad R = \frac{\rho L}{A} \qquad I = \frac{\Delta V}{R} \qquad P_{emf} = I\mathcal{E} \qquad P_R = I_R \Delta V_R = I_R^2 R = \frac{\Delta V_R^2}{R}$$

### Example 22.1
$2.0 \times 10^{13}$ electrons flow through a transistor in 1.0 ms. What is the current through the transistor?

**Prepare:** Equation 22.2 defines current as the ratio of total charge and time during which charge flows.
**Solve:** From Equation 22.2,

$$I = \frac{Q}{\Delta t} = \frac{Ne}{\Delta t} = \frac{(2.0\times10^{13})(1.60\times10^{-19}\,\text{C})}{1.0\times10^{-3}\,\text{s}} = 0.0032\ \text{C/s} = 0.0032\ \text{A} = 3.2\ \text{mA}$$

**Assess:** This is a typical current for a transistor and is reasonable.

### Example 22.2
a. A car battery is rated at 90 A·hr, meaning that it can supply a 90 A current for 1 hr before being completely discharged. If you leave your headlights on until the battery is completely dead, how much charge leave the positive terminal of the battery?
b. The starter motor of a car engine draws a current of 150 A from the battery. The copper wire to the motor is 5.0 mm in diameter and 1.2 m long. The started runs for 0.80 s until the car engine starts. How much charge passes through the starter motor? How much work has been done on the charges that passed through the battery?

**a)**
**Prepare:** We will use Equation 22.2 to find the charge that leaves the battery.
**Solve:** The total charge in the battery is

$$Q = I\Delta t = (90\ \text{A})(3600\ \text{s}) = 3.2 \times 10^5\ \text{C}$$

**Assess:** As expected, this is a large amount of charge.

**b)**
**Prepare:** The starter motor draws a current of 150 A and the motor runs for 0.80 s until the car engine starts. The charge that flows through the starter motor can be obtained from $I = Q/\Delta t$.
**Solve:** The charge delivered in time $\Delta t$ is

$$Q = I\Delta t = (150\ \text{A})(0.80\ \text{s}) = 120\ \text{C}$$

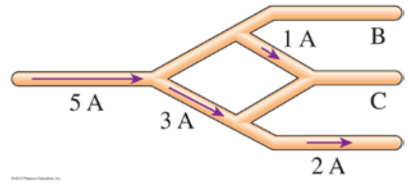
**Assess:** Because the motor draws a lot of current, the charge delivered was expected to be large.

The work done on these charges by the battery is

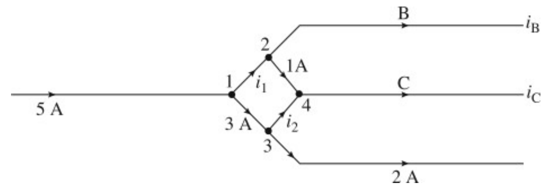
$$W = q_{total}\Delta V = (120\ \text{C})(12.0\ \text{V}) = \boxed{1.44\times10^3\ \text{J} = W}$$

## Example 22.3

The currents through several segments of a wire object are shown in the figure below. What are the magnitudes and directions of the currents $I_B$ and $I_C$ in segments B and C?




**Prepare:** For a junction, the law of conservation of charge requires $\Sigma I_{in} = \Sigma I_{out}$. This says that the total current into a junction must equal the total current out of that junction.
**Solve:** First let's redraw the figure, label the junctions, and give the unknown currents a name.




Now write a junction equation for each junction:
Junction 1: 5 A = 3 A + $i_1$ or $i_1$ = 2 A
Junction 2: $i_1 = i_B$ + 1 A or $i_B = i_1$ – 1 A = 1 A
Junction 3: 3 A = $i_2$ + 2 A or $i_2$ = 1 A
Junction 4: 1 A + $i_2 = i_C$ or $i_C$ = 1 A + $i_2$ = 2A
**Assess:** Notice that the total current going into this arrangement and the total current going out is 5 A.

## Example 22.4

How much work is done to move 1.0 uC of charge from the negative terminal to the positive terminal of a 1.5 V battery?

**Prepare:** The work done in moving a positive charge from the negative terminal to the positive terminal is exactly equal to the increase in the potential energy of the charge. We will use Equation 22.4.
**Solve:**

$$W = \Delta U = q\Delta V = q(V_f - V_i) = (1.0\times10^{-6}\text{ C})(1.5\text{ V}) = 1.5\times10^{-6}\text{ J}$$

**Assess:** The work done by the escalator on the charge is stored as electric potential energy of the charge.

## Example 22.5

Wires 1 and 2 are made of the same metal. Wire 2 has twice the length and twice the diameter of wire 1. What are the ratios (a) $\rho_1/\rho_2$ of the resistivities and (b) $R_1/R_2$ of the resistances of the two wires?

**Prepare:** Resistance and resistivity are related through Equation 22.8. Resistivity depends only on the type of material and not on the geometry of the wire. Equation 22.8 can also be written as $R = \rho L/A = \rho L/(\pi r^2)$, where the wire has length $L$ and radius $r$.
**Solve:** **(a)** Wires 1 and 2 are made of the same material, so $\rho_2$ □ $\rho_1$ and thus $\rho_2/\rho_1$ = 1.00.
**(b)** Because the two wires have the same resistivity,

$$\frac{R_2}{R_1} = \frac{\rho L_2/(\pi r_2^2)}{\rho L_1/(\pi r_1^2)} = \left(\frac{r_1}{r_2}\right)^2 \frac{L_2}{L_1} = \left(\frac{1}{2}\right)^2 \frac{2}{1} = \frac{1}{2} = 0.50$$

**Assess:** A thicker wire has smaller resistance and a larger wire has higher resistance.

## Example 22.6

a. A 1.0-mm-diameter, 20-cm-long copper wire carries a 3.0 A current. What is the potential difference between the ends of the wire? Hint: $\rho_{Cu} = 1.7 \times 10^{-8}\ \Omega\cdot m$

b. A motorcyclist is making an electric vest that, when connected to the motorcycle's 12 V battery, will warm her on cold rides. She is using 0.25-mm-diameter copper wire, and she wants a current of 4.0 A in the wire. What length wire must she use?

a)

**Prepare:** The potential difference between the ends of a copper wire that carries a current can be obtained from Equation 22.6, $I = \Delta V/R,$ and Equation 22.8, $R = \rho L/A.$ The resistivity of copper from Table 22.1 is $1.7\times 10^{-8}\ \Omega\cdot\text{m}.$

**Solve:**

$$\Delta V = IR = I\rho\frac{L}{A} = \frac{(3.0\text{ A})(1.7\times10^{-8}\ \Omega\cdot\text{m})(0.20\text{ m})}{\pi(0.5\times10^{-3}\text{ m})^2} = 13\text{ mV}$$

**Assess:** Because copper's resistivity is small, a potential difference of 13 mV across a 1.0 mm diameter and 20-cm long wire is reasonable.

b)

**Prepare:** Resistance, current, and electric potential difference are related by Ohm's law $R = V/I.$ Resistance, resistivity, length, and cross-sectional area are related by $R = \rho L/A.$

**Solve:** Combining these two expressions and solving for the length of the wire obtain:

$$L = \frac{AV}{I\rho} = \frac{\pi r^2 V}{I\rho} = \frac{\pi(12.5\times10^{-5}\text{m})^2(12\text{ V})}{(4.0\text{A})(1.7\times10^{-8}\ \Omega\cdot\text{m})} = 8.7\text{ m}$$

**Assess:** This is a reasonable length and can be sewn into a vest.

## Example 22.7

A 3.0 V potential difference is applied between the ends of a 0.80-mm-diamter, 50-cm-long nichrome wire. What is the curent in the wire? Hint: $\rho_{nichrome} = 1.5 \times 10^{-6}\ \Omega\cdot m$.

**Prepare:** The current ***I*** in a wire when a potential difference is applied to the ends of the wire can be obtained from Equation 22.6, $I = \Delta V/R,$ and Equation 22.8, $R = \rho L/A.$ The resistivity of nichrome from Table 22.1 is $1.5\times10^{-6}\ \Omega\cdot\text{m}.$

**Solve:**

$$I = \Delta V\left(\frac{A}{\rho L}\right) = \frac{(3.0\text{ V})\pi(0.40\times10^{-3}\text{ m})^2}{(1.5\times10^{-6}\ \Omega\cdot\text{m})(0.50\text{ m})} = 2.0\text{ A}$$

**Assess:** The resistivity of nichrome is small, so a current of 2.0 A is reasonable.

## Example 22.8

A 60-cm-long heating wire is connected to a 120 V outlet. If the wire dissipates 45 W, what are (a) the current in and (b) the resistance of the wire?

**Prepare:** The resistance, potential difference, and current in a wire are related by $\Delta V = IR.$ The power dissipated by the wire may be determined by any of the following: $P = I\Delta V = I^2R = \Delta V^2/R.$ Based on these expressions, we can approach the problem three different ways. Let's do two methods and if the answers agree, we can feel confident that we are correct.

**Solve:** **(a)** The simplest approach is to determine the current by

$I = P/\Delta V = 45\text{ W}/(120\text{ V}) = 0.38\text{ A}$

**(b)** The resistance may be determined by

$R = \Delta V/I = 120\text{ V}/(0.375\text{ A}) = 320\,\Omega$

Also

$R = P/I^2 = 45\text{ W}/(0.375\text{ A})^2 = 320\,\Omega$

**Assess:** Since we have determined the resistance by two methods and obtained the same result, we can be confident that our answer is correct.

## Example 22.9

An electric eel develops a potential difference of 450 V, driving a current of 0.80 A for a 1.0 ms pulse. For this pulse, find (a) the power, (b) the total energy, and (c) the total charge that flows.

**Prepare:** The relationships needed for this problem are $P = IV,$ $P = \Delta U / \Delta t$ and $Q = I\Delta t.$

Solve: (a) The power is $P = IV = 360\text{ W}.$

(b) The total energy is $\Delta U = P\Delta t = 0.36\text{ J}.$

(c) The total charge that flows is $Q = I\Delta t = 8.0\times 10^{-4}\text{ C}.$

**Assess:** Given the electric potential, current, and time pulse, these are reasonable values for the power, total energy, and total charge.