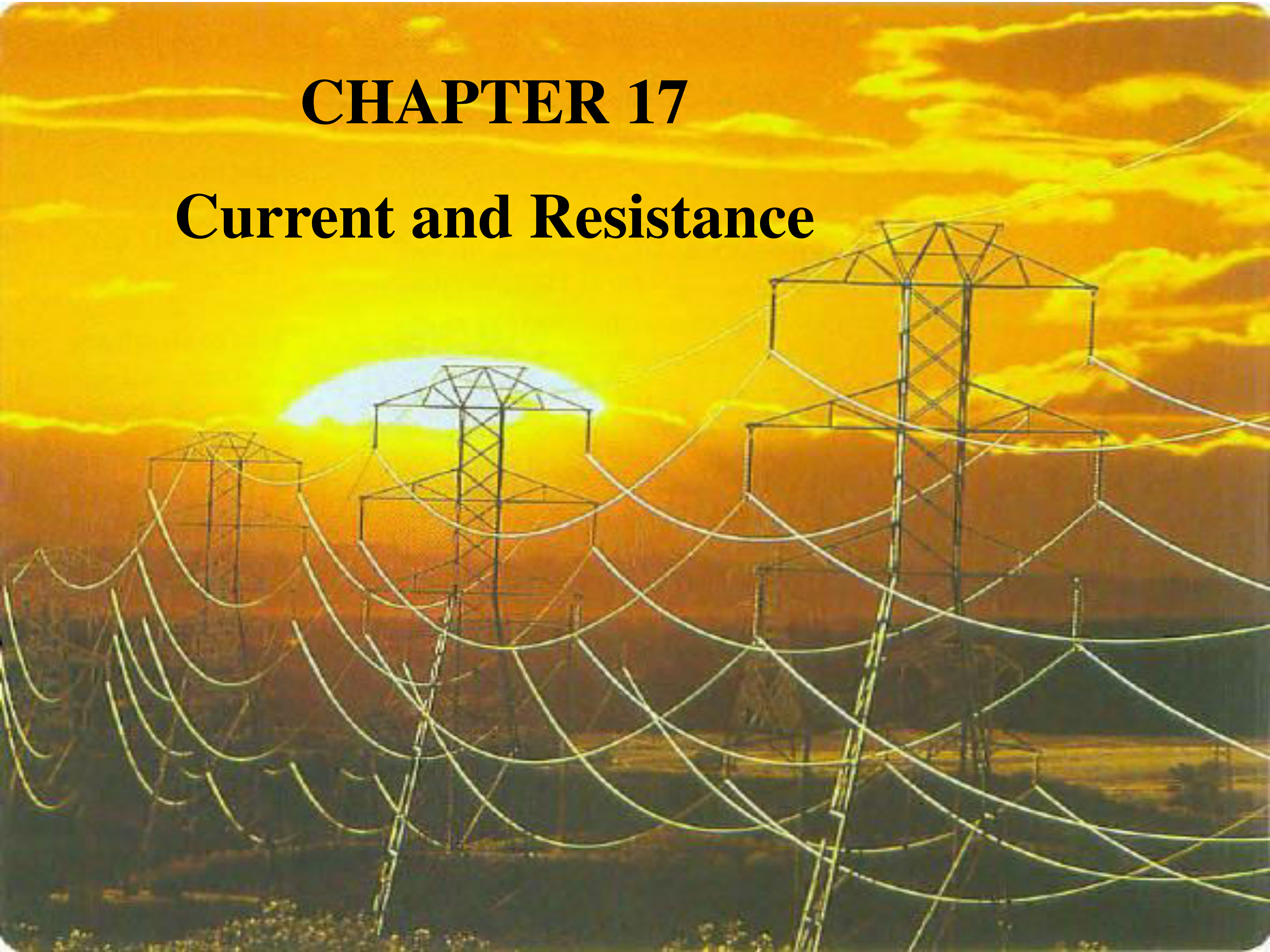
CHAPTER 17

Current and Resistance



Outline

17.1 Electric Current
17.3 Current and voltage measurements in circuits
17.4 Resistance, Resistivity and Ohm’s Law
17.5 Temperature variation of resistance (CO)
17.6 Electrical energy and Power

Electrical Current

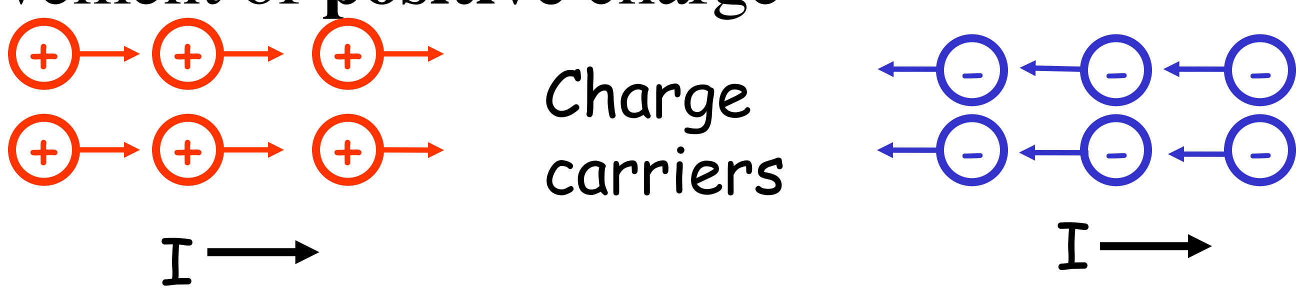
CURRENT I : the rate at which charge flows through cross sectional area in a time interval.

$$I_{av} \equiv \frac{\Delta Q}{\Delta t}$$

Units: 1 ampere (A) = 1 C/s

The instantaneous current:
$$I = \lim_{\Delta t \to 0} I_{av} = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t}$$

Direction: *by convention*, current is the direction of movement of **positive** charge



Ex. 17.1

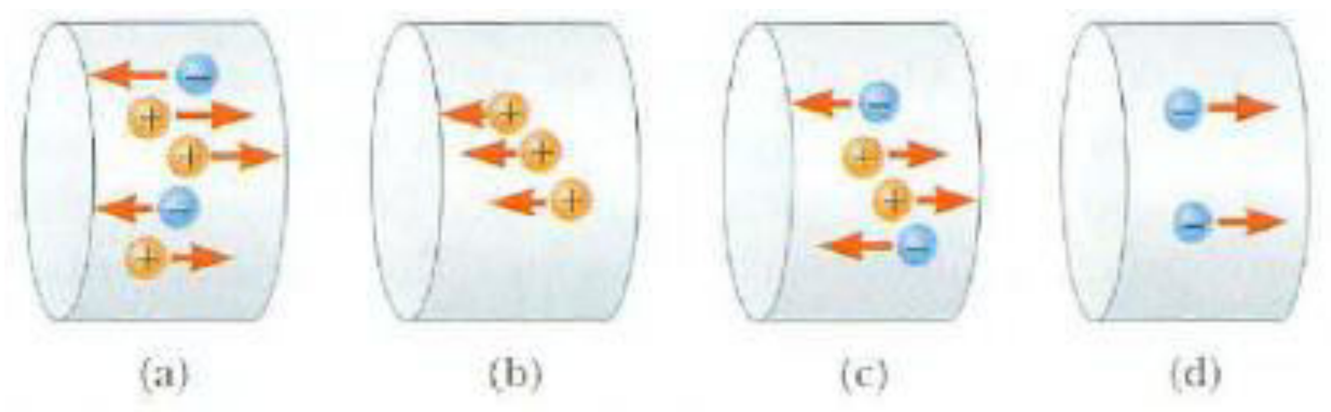
The amount of charge that passes through the filament of a certain lightbulb in 2.00s is 1.67 C. Find

(a) the average current in the lightbulb.

(b) the number of electrons that pass through the filament in 5.00 s.

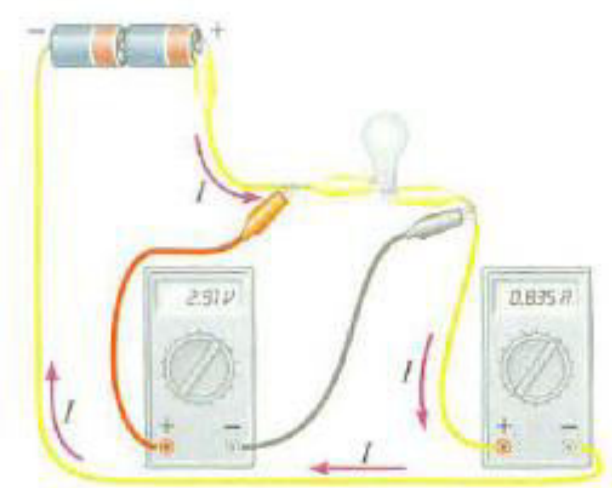
Quiz 17.1

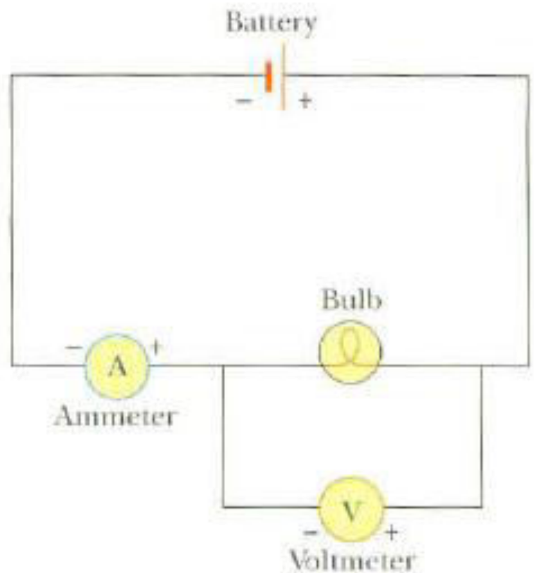
Consider positive and negative charges moving horizontally through the four regions in Figure 17.2. Rank the magnitudes of the currents in these four regions from lowest to highest.



17.3 Current and Voltage Measurements in circuits

Circuit: a closed loop of some sort around which current circulates.





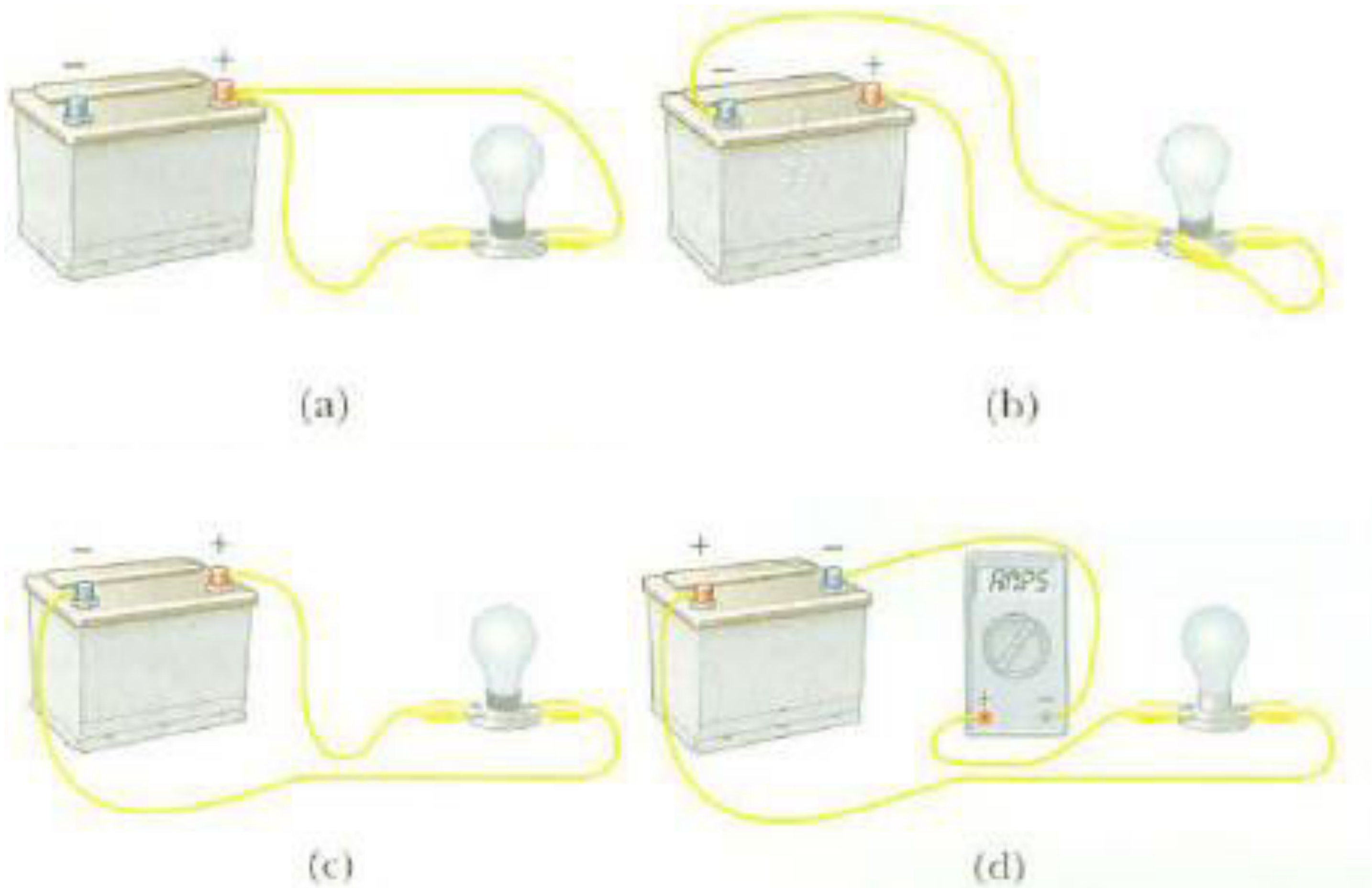
We can measure the current, voltage and resistance by using a device called Multimeter.

Multimeter can be used as Ammeter to measure the current.

Multimeter can be used as Voltmeter to measure the voltage the bulb.

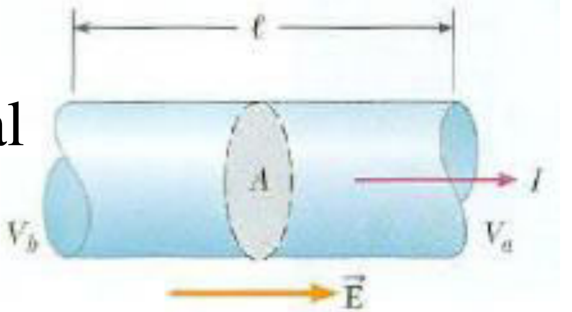
Quiz 17.3

Look at the four circuits shown in Figure 17.6 and select those that will light the bulb.



17.4 Resistance, Resistivity and Ohms Law

Resistance and Ohms Law



The current in the conductor is directly proportional to the applied voltage: $I \propto \Delta V$

The proportionality constant is known as the resistance R:

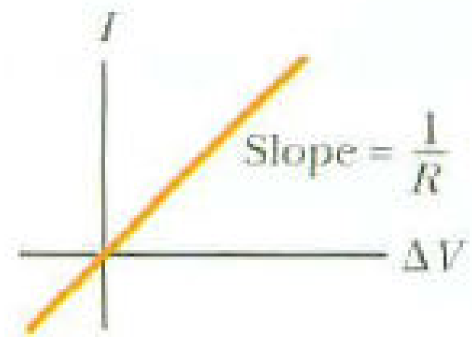
$$\Delta V = IR$$

The resistance remains constant over a wide range of applied voltages or currents. (Ohms Law)

The ratio of the voltage across the conductor to the current it carries is known as the resistance: $R = \Delta V / I$ in SI unit of ohm (Ω)

Ohmic and Non-Ohmic materials

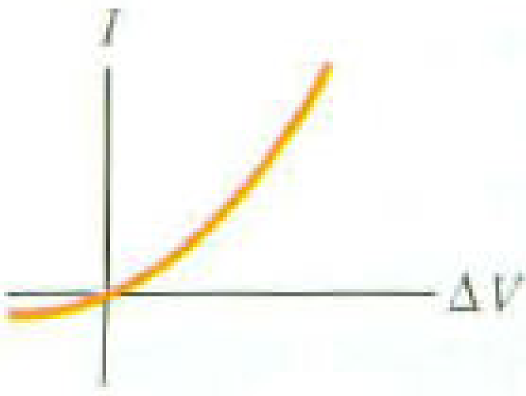
Ohmic materials have a linear currem-voltage relationship over a large range of applied voltages:



Non-ohmic materials have a nonlinear current-voltage relationship such as Diods, Transistors. Violate Ohms Law

The resistance is small for positive ΔV

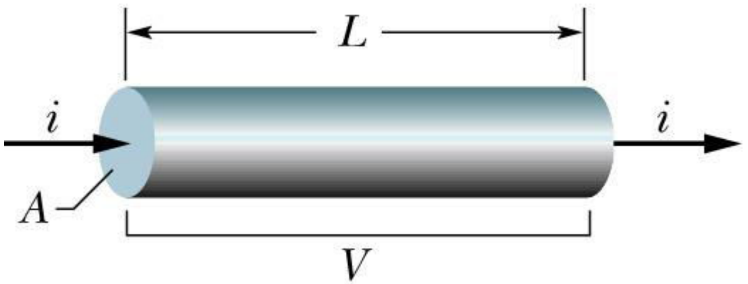
Such as Diods



Resistivity

- Rather than consider the overall resistance of a conductor, we can discuss the property of a material to resist the flow of electric current.
- This is called the *resistivity* ρ $(\Omega.m)$. Note that this IS NOT related to the density.

$$R = \rho \frac{L}{A}$$



L: the length of a conductor

A: Cross-sectional area

The resistivity (ρ) depends on temperature and the physical properties of the material, so it has a different value for each material.

Good electric conductors have very low resistivities, and good insulators have very high resistivities.

Quiz 17.6

Suppose an electrical wire is replaced with one having every linear dimension doubled (i.e., the length and radius have twice their original values). Does the wire now have:

(a) more resistance than before,

(b) less resistance

(c) the same resistance

17.5 Temperature variation of resistance

Temperature dependence of resistance (and resistivity) is generally linear over limited temperature ranges and is characterized by the temperature coefficient of resistivity (**α**):

$$\rho = \rho_0[1 + \alpha(T - T_0)] \qquad R = R_0[1 + \alpha(T - T_0)]$$

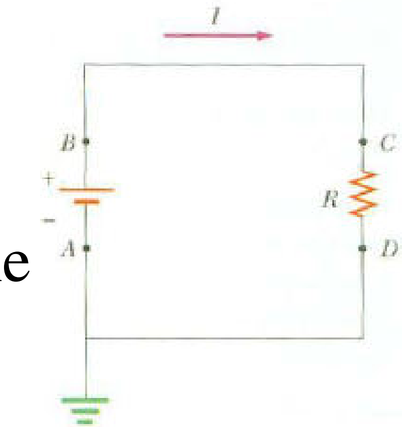
where R_0, ρ_0 and T_0 are the resistance, resistivity and temperature at a standard temperature, usually room temperature or 20 ºC.

TABLE 17.1

Resistivities and Temperature Coefficients of Resistivity for Various Materials (at 20°C)

Material	Resistivity ($\Omega \cdot m$)	Temperature Coefficient of Resistivity $[(°C)^{-1}]$
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.7×10^{-8}	3.9×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10.0×10^{-8}	5.0×10^{-3}
Platinum	11×10^{-8}	3.92×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Nichrome[a]	150×10^{-8}	0.4×10^{-3}
Carbon	3.5×10^{5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}
Silicon	640	-75×10^{-3}
Glass	10^{10}–10^{14}	
Hard rubber	$\approx 10^{13}$	
Sulfur	10^{15}	
Quartz (fused)	75×10^{16}	

17.6 Electrical Energy and Power



- Chemical energy of the battery transformed to kinetic energy of the charge carriers causing an increase in the temperature of the conductor.

• Chemical energy transformed to thermal energy.
• The charge ΔQ loses energy $\Delta Q\ \Delta V$ as it passes through the resistance in a time Δt: the instantaneous rate at which it loses electric potential energy is:

$$\lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} \Delta V = I\, \Delta V$$

• The charge regains this energy when it passes through the battery at the expense of chemical energy in the battery.
• The power representing the rate at which the energy is delivered to the resistor is: $P = I\,\Delta V$ (watt)

$= I^2R = \Delta V^2/R$ **(only for ohmic materials)**

One kilowatt-hour (1kWh) is the energy converted or consumed in 1h.

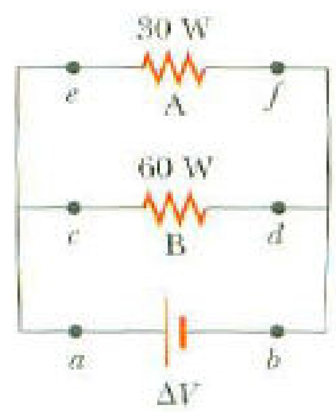
$1kWh = (10^3\ W)(3600\ s) = 3.6\times10^6$ Joul

Quiz 17.7

A voltage ΔV is applied across the ends of a Nichrome heater wire having a cross-sectional area A and length L. The same voltage is applied across the ends of a second Nichrome heater wire having a cross sectional area A and length $2L$. Which wire gets hotter? (a) The shorter wire does. (b) The longer wire does. (c) More in formation is needed.

Quiz 17.8

For the two resistors shown in Figure 17.10, rank the currents at points a through f from the largest to smallest.



(a) $I_a = I_b > I_e = I_f > I_c = I_d$ (b) $I_a = I_b > I_c = I_d > I_e = I_f$
(c) $I_e = I_f > I_c = I_d > I_a = I_b$

Quiz 17.9

Two resistors, A and B, are connected in a series circuit with a battery. The resistance of A is twice that of B. Which resistor dissipates more power? (a) Resistor A does. (b) Resistor B does. (c) More information is needed.

Quiz 17.10

The diameter of wire A is greater than the diameter of wire B, but their lengths and resistivities are identical. For a given voltage difrerence across the ends, what is the relationship between P_A and P_B, the dissipated power of the wires A and B, respectively?

(a) $\mathcal{P}_A = \mathcal{P}_B$ (b) $\mathcal{P}_A < \mathcal{P}_B$ (c) $\mathcal{P}_A > \mathcal{P}_B$

Problems

- Q1. A 60 watt light bulb carries a current of 0.5 A. The total charge passing through it in one hour is:
- مصباح قدرته 60 واط يمر به تيار 0.5 A، مقدار الشحنة التي تمر منه في ساعة واحده هي:
- 30 C
- 120 C
- 1800 C
- 3600 C

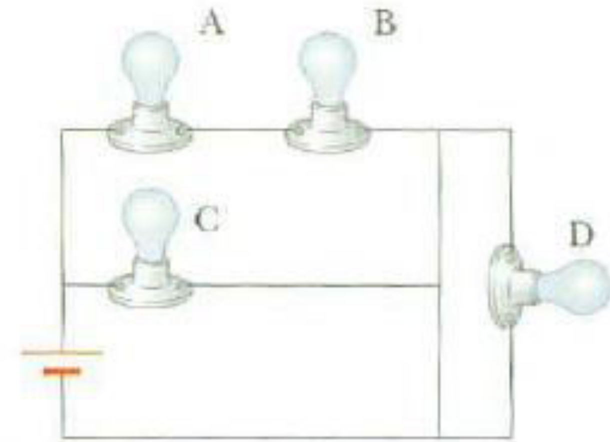
- Q2. Consider two copper wires. A has twice the length and twice the diameter of B. Then:

- سلكان من النحاس، السلك A له ضعفي الطول وضعفي القطر للسلك B هذا يعني:

- $R_A = R_B$
- $R_A = 2\ R_B$
- $R_A = 4\ R_B$.
- $R_A = 0.5\ R_B$.

- Q3. Car batteries are often rated in Ampere-hours. This is a unit:
- عادة يكتب على بطارية السيارة امبير - ساعة هذه الوحدة هي:
- Current
- Power
- Energy
- Charge

- Q4. In the circuit shown, all light bulbs are identical;
- في الشكل المجاور جميع المصابيح متماثلة. علاقة القدرة بين هذه المصابيح هي:



- $P_B > P_A > P_D > P_C$
- $P_A > P_B > P_D > P_C$
- $(P_A = P_B) > P_C$; $P_D = 0$
- $P_C > (P_A = P_B)$; $P_D = 0$

Q5. Is it possible to have an instantaneous current of e/2 per second? Can the average current take this value?