CURRENT and RESISTANCE

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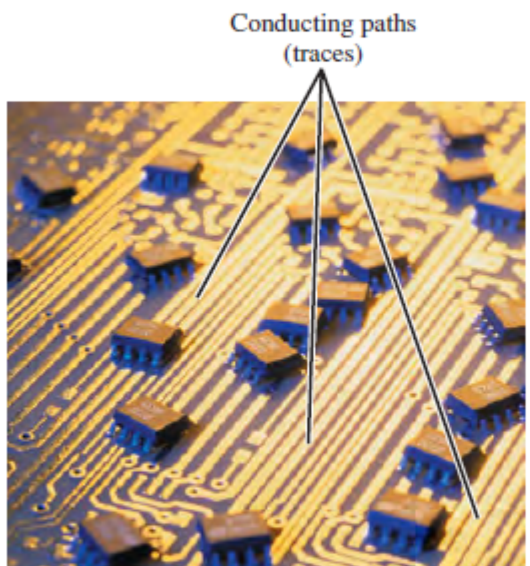
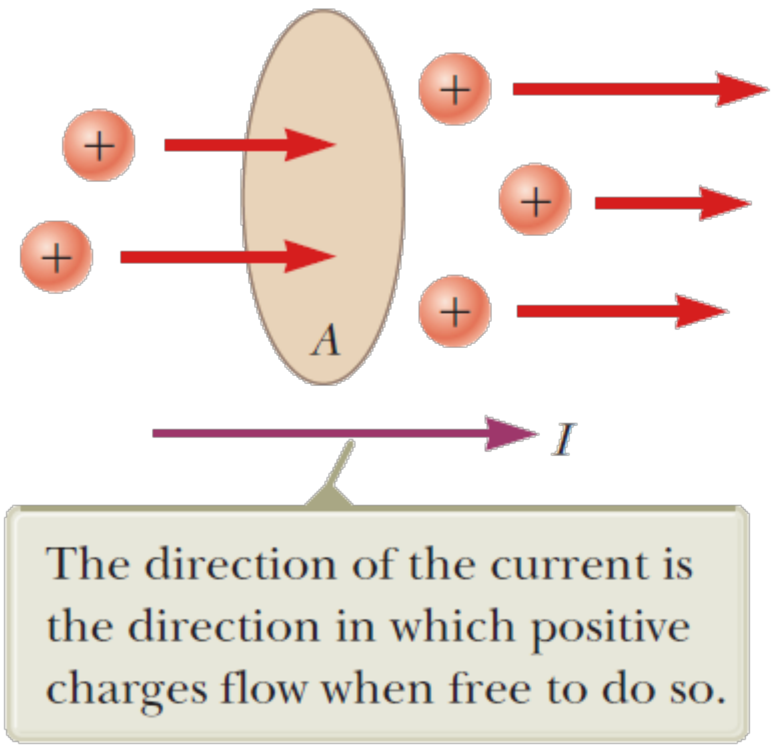
- 6.3 Resistance and Resistivity
- 6.4 Ohm Law
- 6.5 Microscopic view of Ohm Law
- 6.6 Power in Electric Circuits



6.1 Electric Current



The current is the rate at which charge flows through this surface. If Δq is the amount of charge that passes through this area in a time interval Δt, the average current I_{av} is equal to the charge that passes through A per unit time:

$$i_{av} = \frac{\Delta q}{\Delta t}$$

If the rate at which charge flows varies in time, then the current varies in time; we define the instantaneous current i as the differential limit of average current:

$$i = \frac{dq}{dt}$$

6.1 Electric Current

$$i_{av} = \frac{\Delta q}{\Delta t} \qquad i = \frac{dq}{dt}$$

The SI unit of current is the ampere (A):

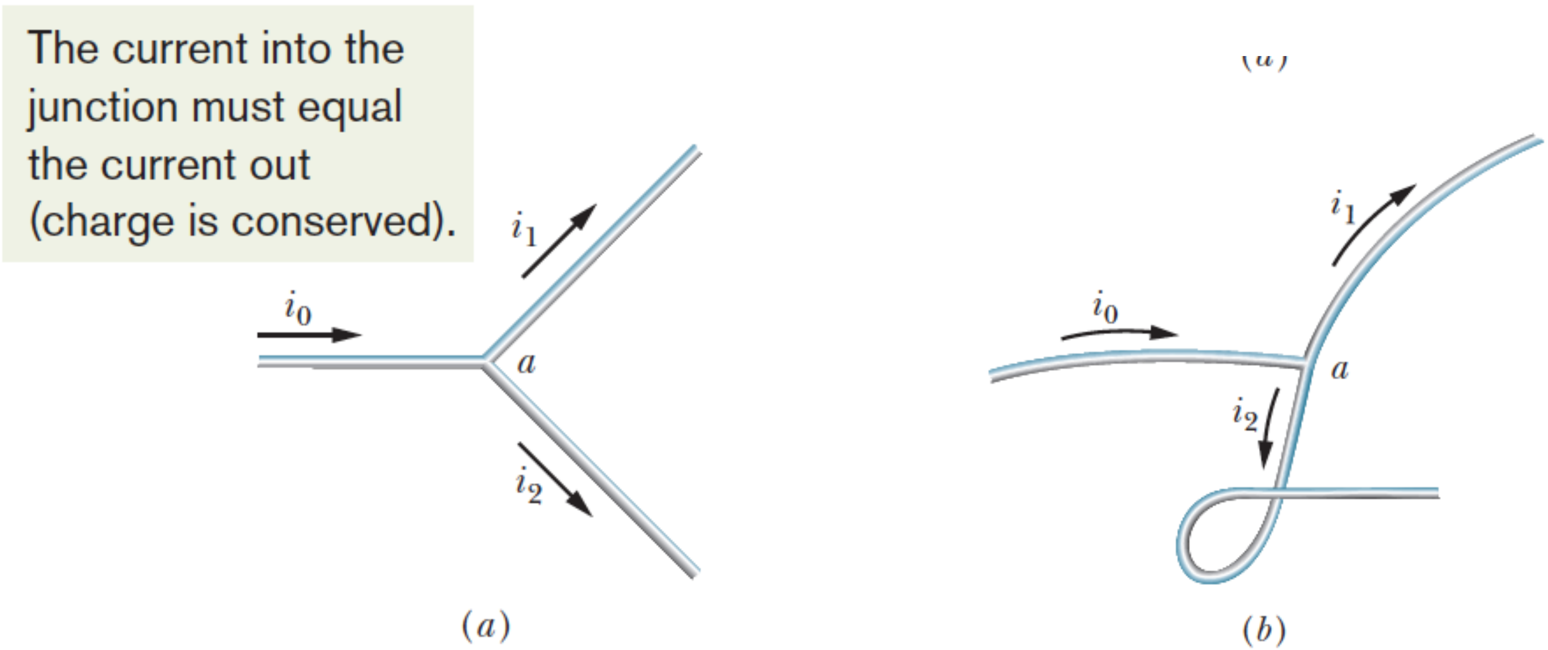
$$1A = 1C / 1s$$

1 A of current is equivalent to 1 C of charge passing through the surface area in 1 s.

6.1 Electric Current

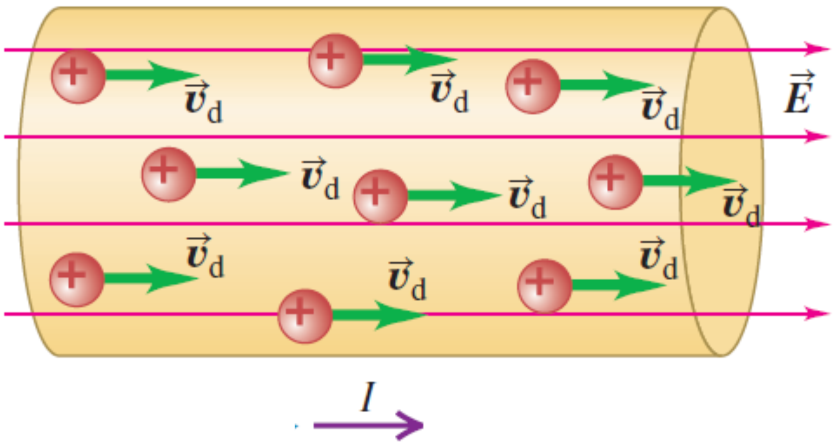
Current is not a Vector !

$$i = \frac{dq}{dt}$$

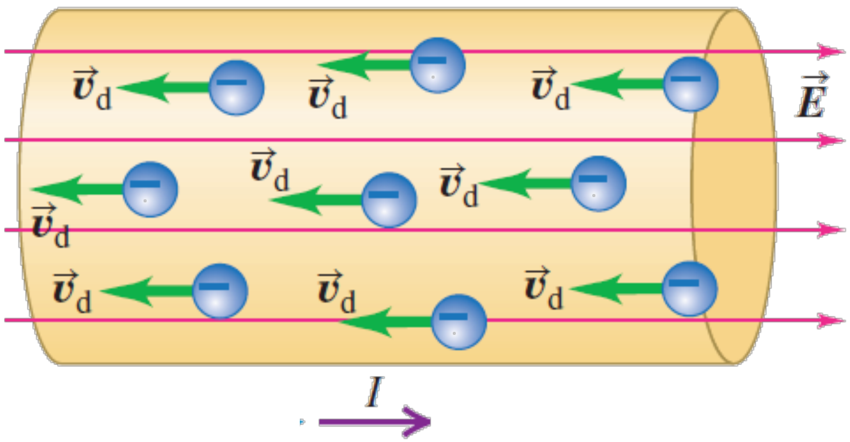


$$i_o = i_1 + i_2$$

The Direction of Current Flow



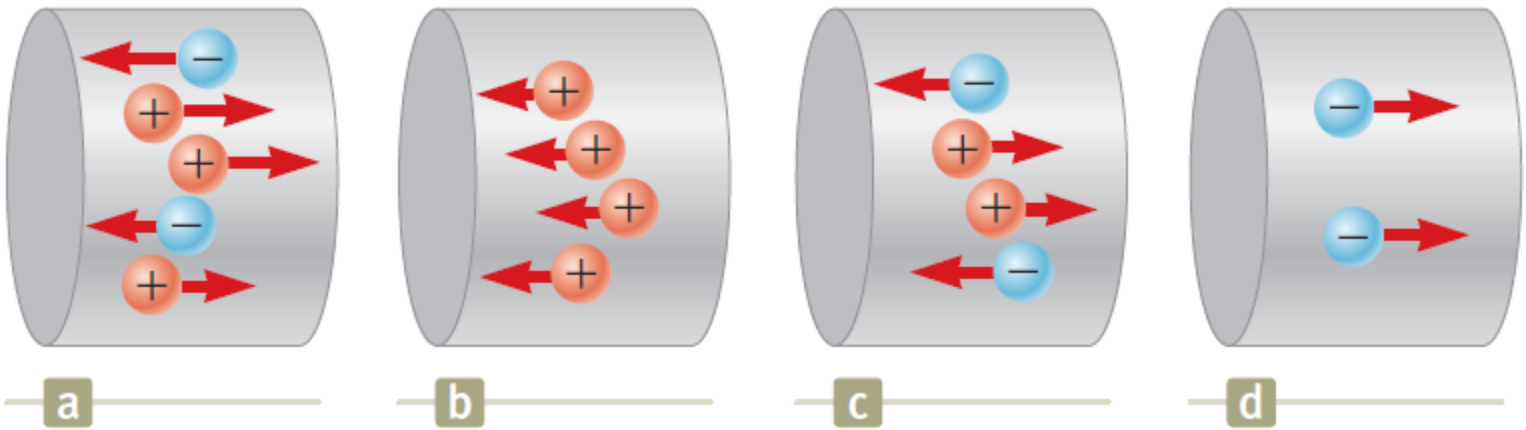
A **conventional current** is treated as a flow of positive charges, regardless of whether the free charges in the conductor are positive, negative, or both.



In a metallic conductor, the moving charges are electrons — but the *current* still points in the direction positive charges would flow.

Example: The Direction of Current Flow

Rank the current in these four regions, from lowest to highest.



Solution: a>b=c>d

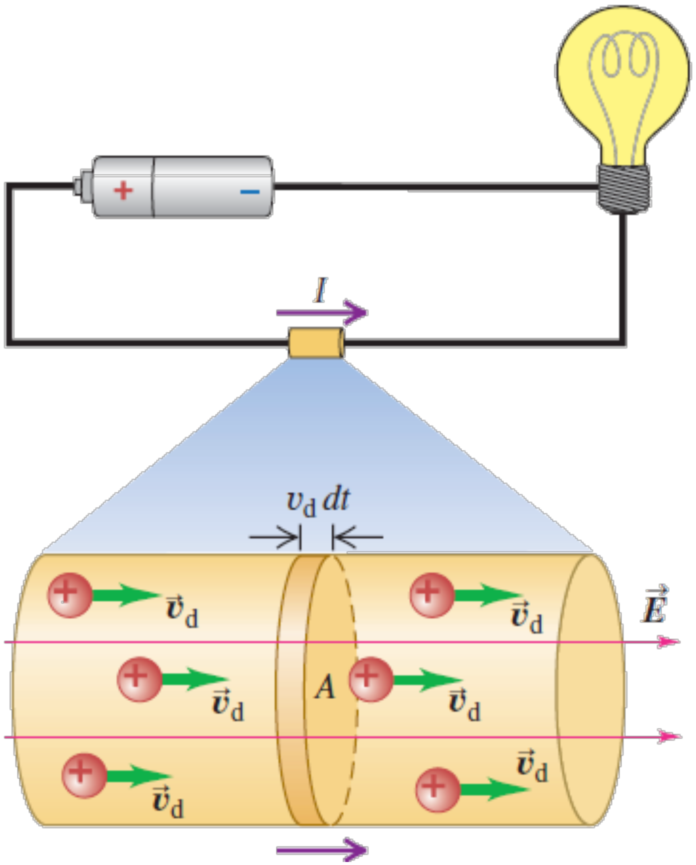
6.2 Current Density

The current per unit cross-sectional area is called the current density

$$J = \frac{i}{A}$$

The SI unit for current density is the ampere per square meter : A/m^2’

Microscopic Model of Current: Drift Speed



- Suppose there are n moving charged particles per unit volume.

n: concentration of charge carriers, its SI unit is m^{-3}

- Assume that all the particles move with the same velocity with magnitude: V_d.
- In a time interval Δt, each particle moves a distance

$L = V_d . \Delta t$

- The volume of the cylinder is $AV_d\Delta t$

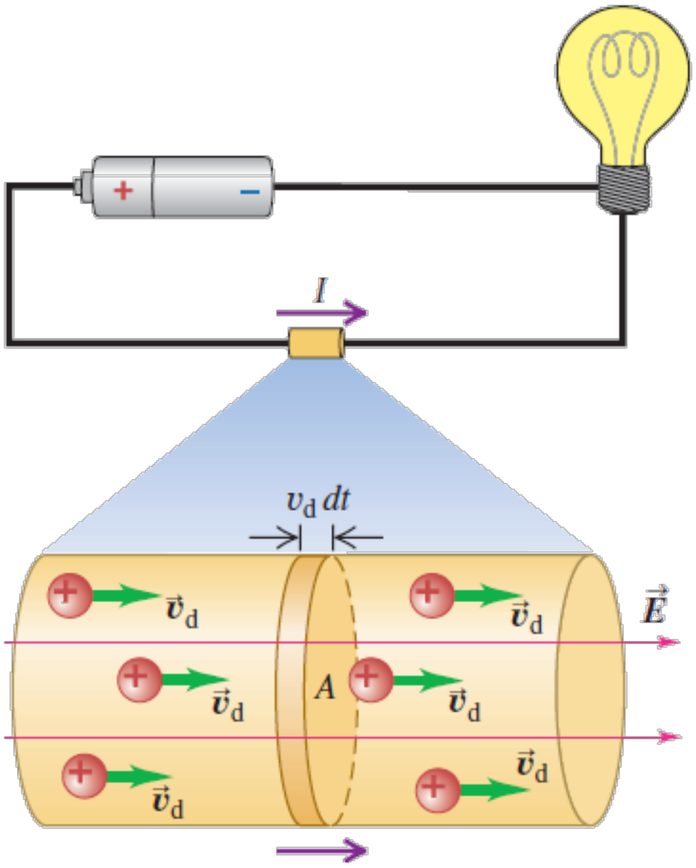
By using the definition of n:

$$\Delta q = nALe = (nAv_d\Delta t)e$$

From that, the current is:

$$i = \frac{\Delta q}{\Delta t} = nAv_d e$$

Microscopic Model of Current: Drift Speed



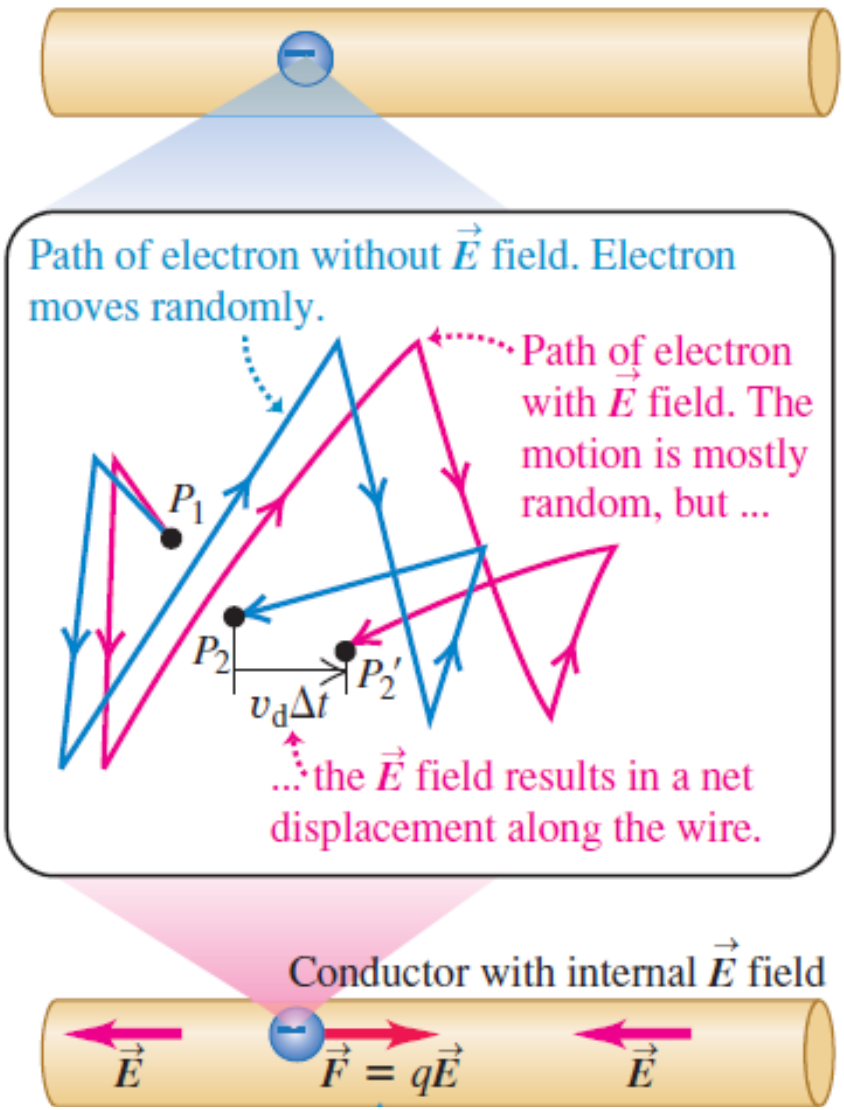
Drift speed:

$$v_d = \frac{i}{nAe} = \frac{J}{ne}$$

In vectoral form:

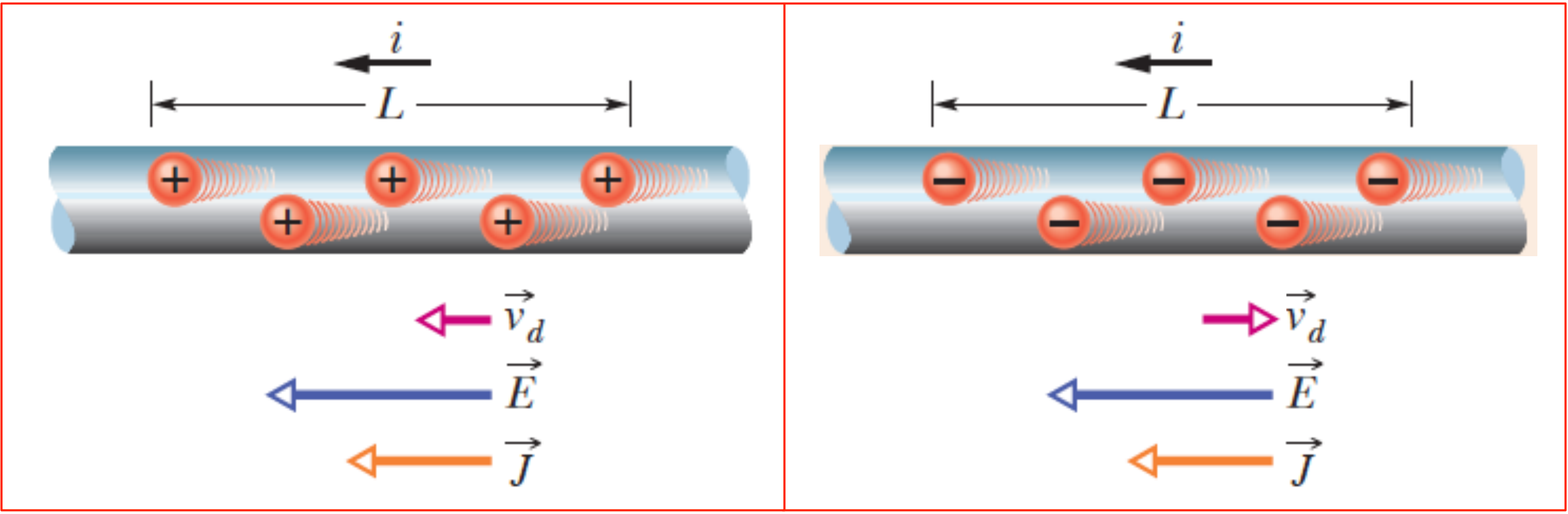
$$\vec{J} = (ne)\vec{v}_d$$

6.2 Current Density



Drift Speed:

$$\vec{J} = (ne)\vec{v}_d$$



The current density is in the direction of charge motion for positive charge carriers and opposite the direction of motion for negative charge carriers.

Example: Drift Speed in a Copper Wire

A copper wire in a typical residential building has a cross-sectional area of 3.31×10^{-6} m^2 . If it carries a current of 10.0 A, what is the drift speed of the electrons? Assume that each copper atom contributes one free electron to the current. The density of copper is 8.95 g/cm3 and molar mass of it is 63.5 g/mol

Solution: Drift Speed in a Copper Wire

Knowing the density of copper, we can calculate the volume occupied by 63.5 g (1 mol) of copper:

$$V = \frac{M}{\rho}$$

Because each copper atom contributes one free electron to the current, we have

$$n = \frac{N_A}{V} = \frac{N_A \rho}{M}$$

From that

$$v_d = \frac{i}{nAe} = \frac{iM}{qAN_A\rho}$$

$$v_d = 2.2x10^{-4} m/s$$

6.3 Resistance and Resistivity

The current density in a conductor depends on the electric field and on the properties of the material. In general, this dependence can be quite complex. However In some materials, the current density is proportional to the electric field:

$$J = \sigma E$$

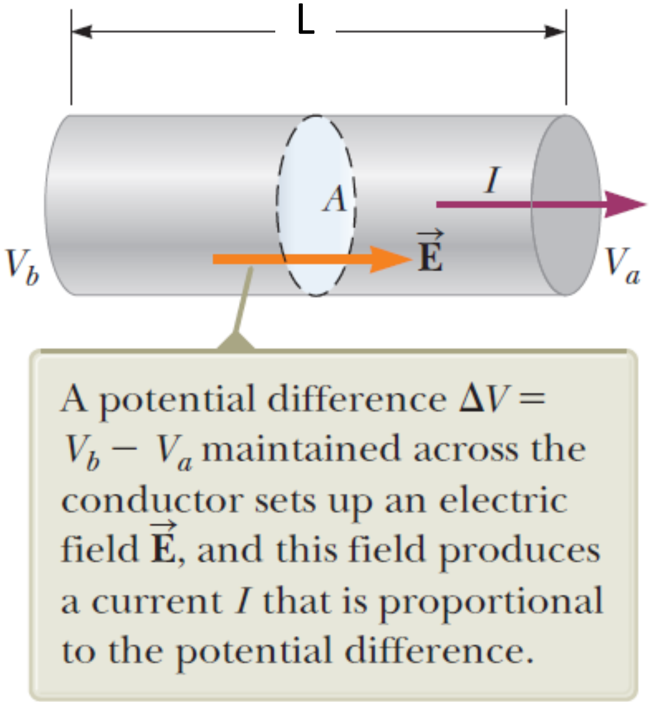
Where σ is the conductivity of a material.

We often speak of the resistivity of a material. This is simply the reciprocal of its conductivity , so

$$\rho = \frac{1}{\sigma} = \frac{E}{J}$$

The SI unit of resistivity is the Ω.m'dir.

Calculating Resistance from Resistivity



Let A be the cross-sectional area of the wire, let L be its length, and let a potential difference $V = V_B - V_A$ exist between its ends.

$$E = \frac{V}{L} \qquad J = \frac{i}{A}$$

By using Ohm law:

$$\rho = \frac{E}{J} = \frac{V/L}{i/A}$$

$$V = \frac{\rho L}{A} i$$

6.3 Resistance and Resistivity

So we obtain th relationship between the potential differences and current:

$$V = \frac{\rho L}{A} i$$

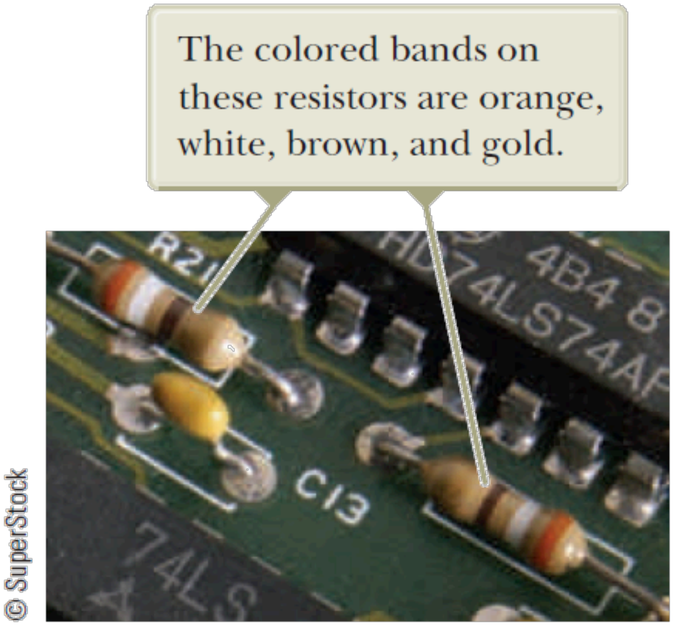
The resistance of the conductor :

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

Resistance has SI units of volts per ampere which is called as ohm (Ω).

Resistance is a property of an object. Resistivity is a property of a material.

6.3 Resistance and Resistivity



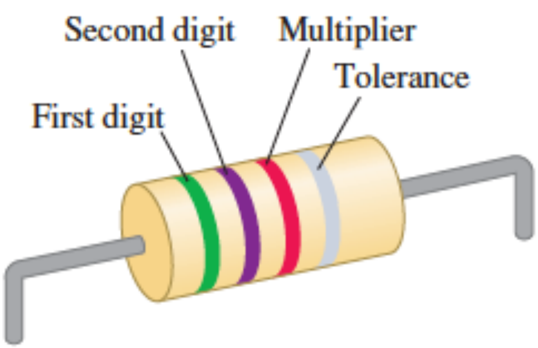
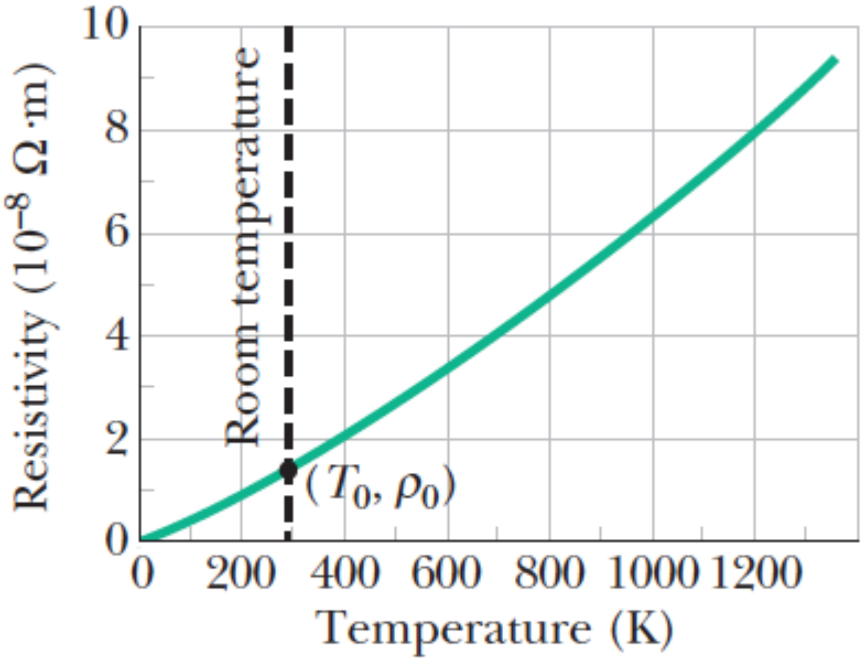


TABLE 27.1 *Color Coding for Resistors*

Color	Number	Multiplier	Tolerance
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5%
Silver		10^{-2}	10%
Colorless			20%



Resistivity can depend on temperature.

$$\rho = \rho_0 \left[1 + \rho_0 \alpha (T - T_0)\right]$$

ρ :is the resistivity at some temperature T (in degrees Celsius),
ρ_0: is the resistivity at some reference temperature T_0 (usually taken to be 20°C),
α: is the temperature coefficient of resistivity.

$$\alpha = \frac{1}{\rho_0} \frac{\Delta \rho}{\Delta T}$$

6.3 Resistance and Resistivity

TABLE 27.2 *Resistivities and Temperature Coefficients of Resistivity for Various Materials*

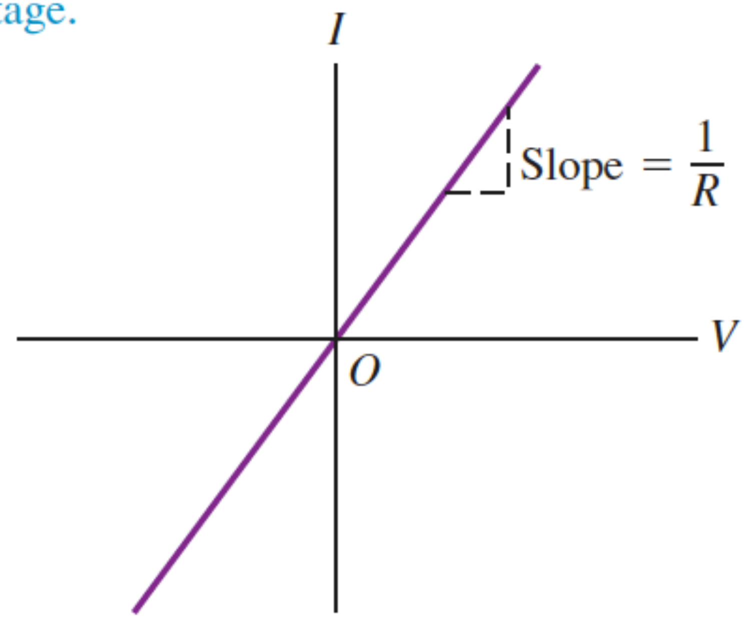
Material	Resistivity[a] ($\Omega \cdot m$)	Temperature Coefficient[b] $\alpha[(°C)^{-1}]$
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.7×10^{-8}	3.9×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10×10^{-8}	5.0×10^{-3}
Platinum	11×10^{-8}	3.92×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Nichrome[c]	1.00×10^{-6}	0.4×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}
Silicon[d]	2.3×10^{3}	-75×10^{-3}
Glass	10^{10} to 10^{14}	
Hard rubber	$\sim 10^{13}$	
Sulfur	10^{15}	
Quartz (fused)	75×10^{16}	

[a] All values at 20°C. All elements in this table are assumed to be free of impurities.

6.4 Ohm Law

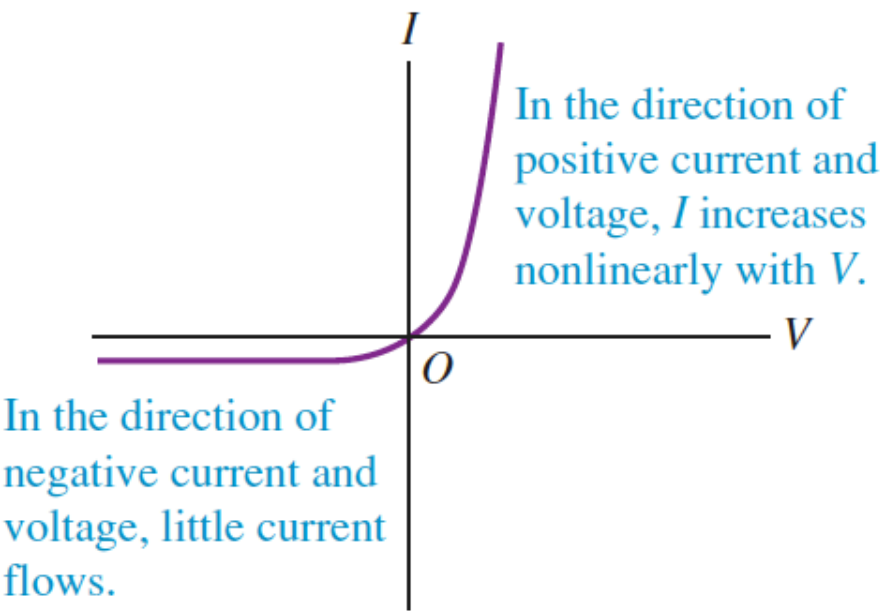
(a)

Ohmic resistor (e.g., typical metal wire): At a given temperature, current is proportional to voltage.



(b)

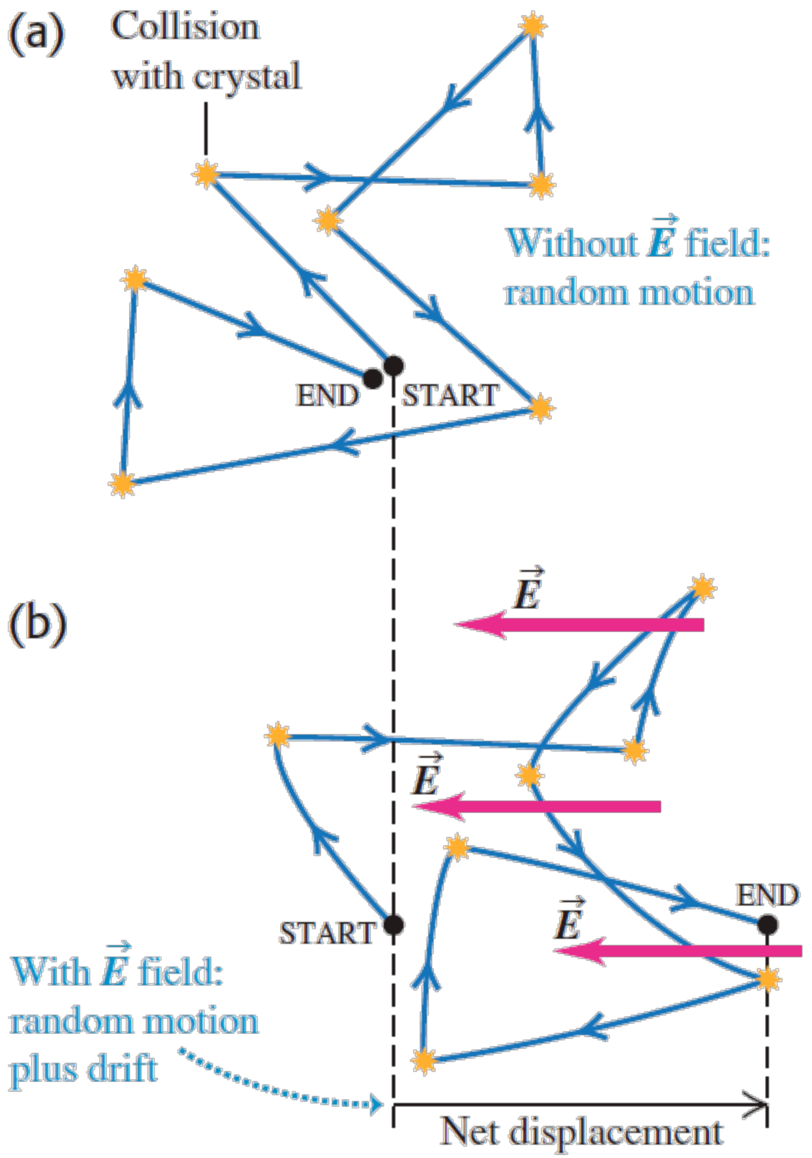
Semiconductor diode: a nonohmic resistor



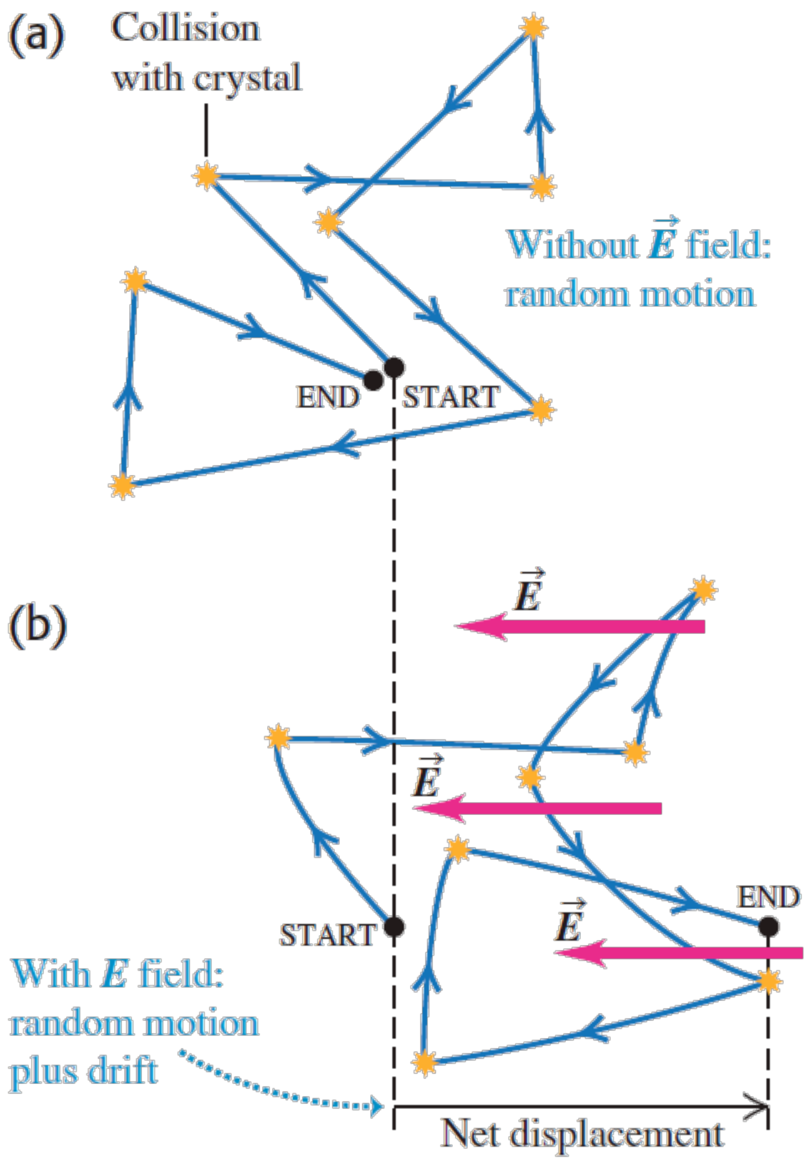
$$V = \frac{\rho L}{A} i \Rightarrow \boxed{V = iR}$$

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

6.5 Microscopic View of Ohm Law



6.5 Microscopic View of Ohm Law



- The motion of an electron after a collision is independent of its motion before the collision.
- The excess energy acquired by the electrons in the electric field is lost to the atoms of the conductor when the electrons and atoms collide..

6.5 Microscopic View of Ohm Law

When a free electron of mass m, is subjected to an electric field E, the electron will experience an acceleration given by Newton's second law:

$$a = \frac{F}{m} = \frac{eE}{m}$$

If v_i is the electron's initial velocity, the instant after a collision (which occurs at a time that we define as t = 0), then the velocity of the electron at time t (at which the next collision occurs) is

$$v_f = v_i + at = v_i + \frac{eE}{m}t$$

$$v_d = \frac{eE}{m}\tau$$

6.5 Microscopic View of Ohm Law

Because the average value of v_f is equal to the drift velocity, we have

$$v_d = \frac{eE}{m}\tau$$

where τ is the average time interval between successive collisions.

6.5 Microscopic View of Ohm Law

The magnitude of the current density is

$$J = nev_d = \frac{ne^2 E}{m}\tau$$

where n is the number of charge carriers per unit volume. Comparing this expression with Ohm's law, w obtain:

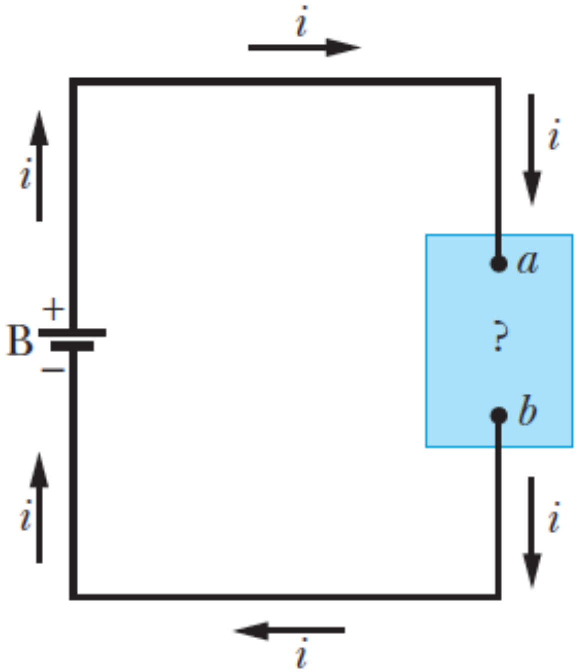
$$J = \sigma E \Rightarrow J = nev_d = \frac{ne^2 E}{m}\tau$$

for conductivity and resistivity of a conductor:

$$\sigma = \frac{ne^2\tau}{m}$$

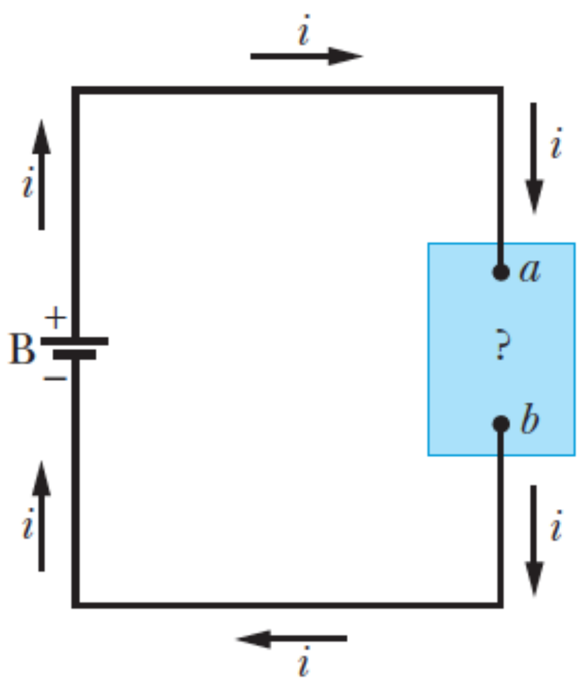
$$\rho = \frac{1}{\sigma} = \frac{m}{ne^2\tau}$$

The battery at the left supplies energy to the conduction electrons that form the current.



6.6 Power in Electric Circuits

The battery at the left supplies energy to the conduction electrons that form the current.



When dq movs from a to b, thus its electric potential energy decreases in magnitude by the amount

$$dU = dqV = idtV$$

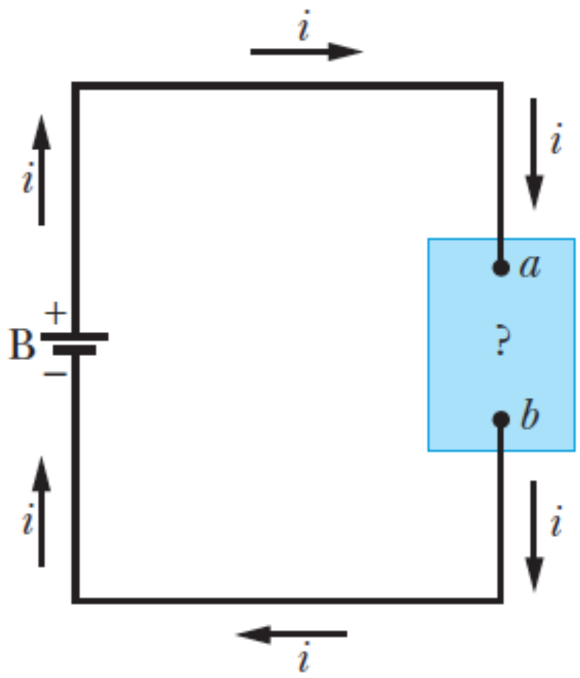
The power P associated with that transfer is the rate of transfer dU /dt:

$$\frac{dU}{dt} = P = iV$$

SI birim sisteminde gücün birimi Watt'tır ve W ile gösterilir.

6.6 Power in Electric Circuits

The battery at the left supplies energy to the conduction electrons that form the current.



When dq movs from a to b, thus its electric potential energy decreases in magnitude by the amount

$$dU = qV = idtV$$

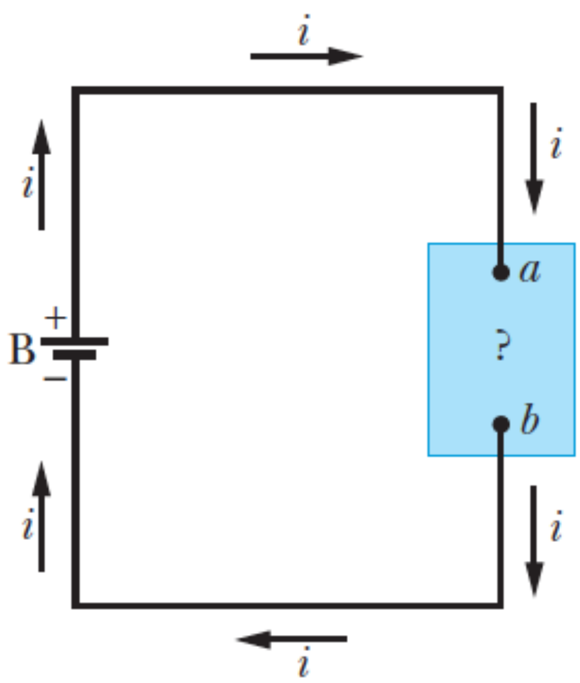
The power P associated with that transfer is the rate of transfer dU /dt:

$$\frac{dU}{dt} = P = iV$$

The unit of power the volt-ampere (V.A) which is equal to 1 Watt (W)

6.6 Power in Electric Circuits

The battery at the left supplies energy to the conduction electrons that form the current.



$$\frac{dU}{dt} = P = iV$$

For a resistor or some other device with resistance R, for the rate of electrical energy dissipation due to a resistance

$$P = i^2 R = \frac{V^2}{R}$$