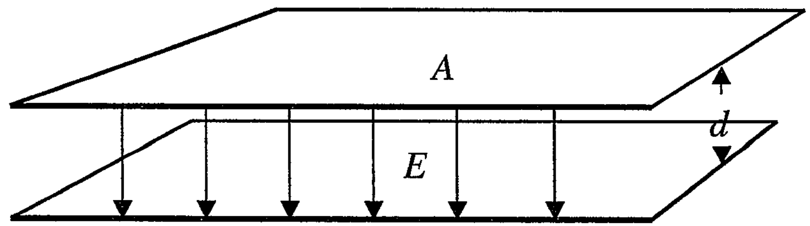
Lecture # 14

a. Capacitors with dielectrics

b. resistivity

Energy of parallel plate capacitor



1. What is the Voltage, V, across the plate?

a. Ed ✓ b. Ad c. EdA

2. What is the magnitude of the charge, Q, on each plate?

a. $Q = \varepsilon_0 E$ b. $Q = \varepsilon_0 EA$ c. $Q = \varepsilon_0 EAd$

3. What is the minimum energy required to take a positive charge Δq from the top plate to the bottom plate?

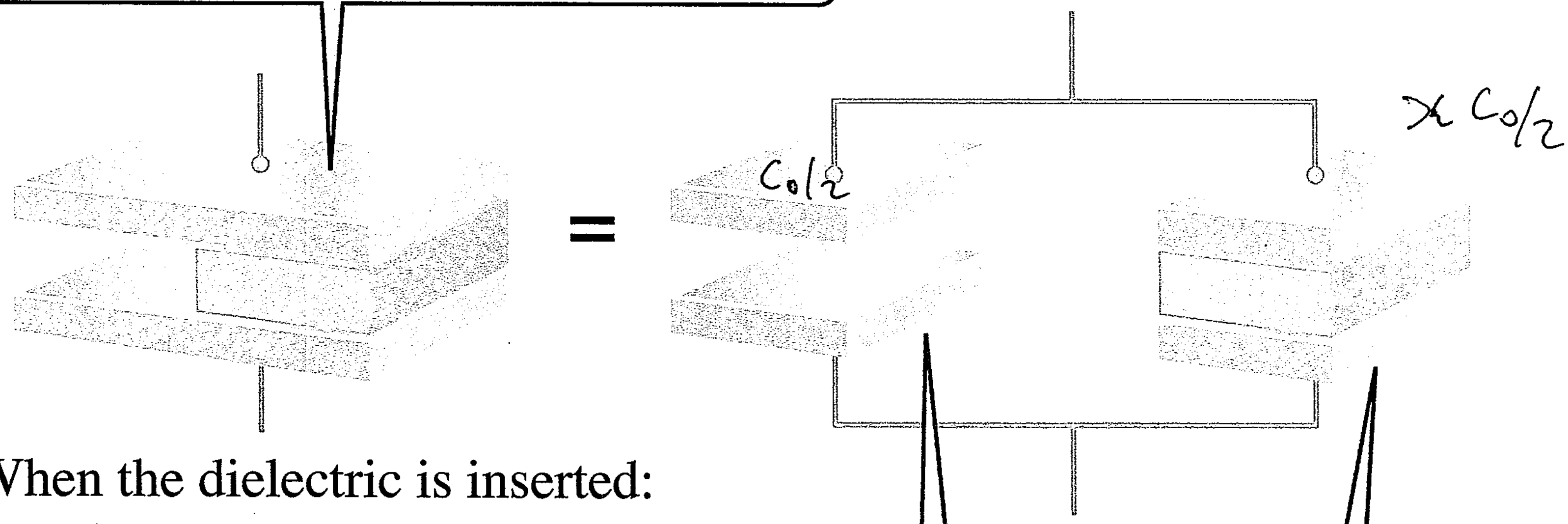
a. $\Delta q\, Ed$ b. $\Delta q\, Ad$ c. $\Delta q\, EdA$

4. Which of these expressions most thoroughly describes the minimum energy required to place charges Q and -Q on each plate?

a. $Q\, Ed/2$ b. $QV/2$ c. $Q^2 d/2A\varepsilon_0$ d. $\varepsilon_0 E^2 Ad/2$ e. all these expressions! ✓

$$V = dE = \frac{Qd}{\varepsilon_0 A}$$

Since plates are equipotentials, this half-filled capacitor…



…is equivalent to one empty and one full capacitor connected in parallel.

When the dielectric is inserted:

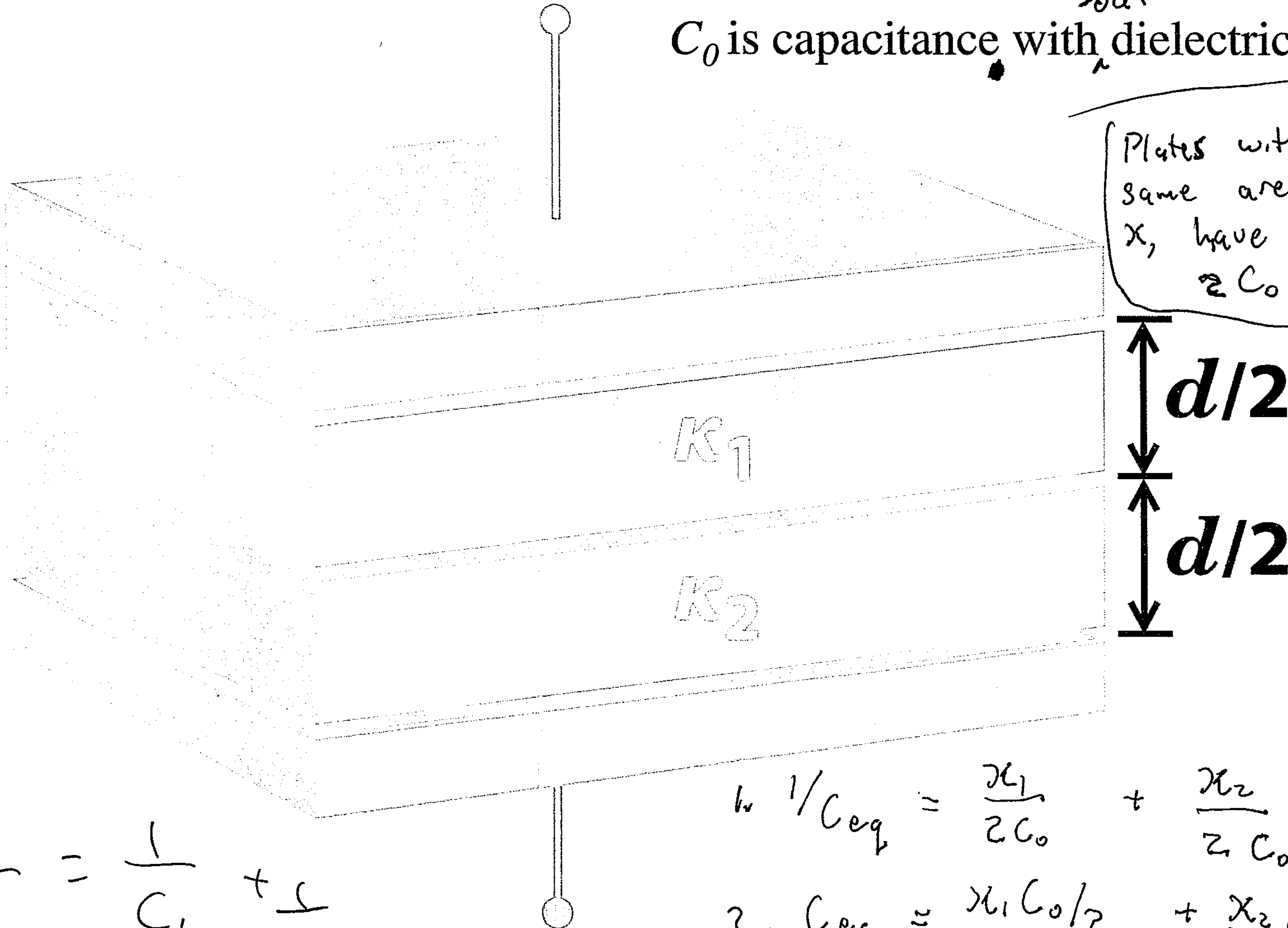
1. The potential will vary on a conducting plate
2. The charge density will vary on a conducting plate.
3. An electric field will be induced tangential to the conducting plate

$$C_{eq} = \frac{C_0}{2} + \frac{\kappa C_0}{2}$$

Find equivalent capacitance

C_0 is capacitance without dielectrics

Plates with the same area, without κ, have capacitance $2C_0$



1. $1/C_{eq} = \frac{\kappa_1}{2C_0} + \frac{\kappa_2}{2C_0}$
2. $C_{eq} = \kappa_1 C_0/2 + \frac{\kappa_2}{2} C_0$
3. $1/C_{eq} = 1/\kappa_1 C_0 2 + 1/\kappa_2 C_0 2$ ✓
4. $C_{eq} = 2\kappa_1 C_0 + 2\kappa_2 C_0$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_{1,2} = C_0 \kappa_{1,2}$$

ELECTRIC CURRENT
(FLOW OF CHARGE PER UNIT OF TIME)

$$I = \frac{\Delta Q}{\Delta t} \quad \text{or} \quad I = \frac{dq}{dt}$$

Equation 27-2 derivatives Physics for Engineers and Scientists 3/e

SI UNIT OF ELECTRIC CURRENT

$$1 \text{ ampere} = 1 \text{ A} = 1 \text{ C/s}$$

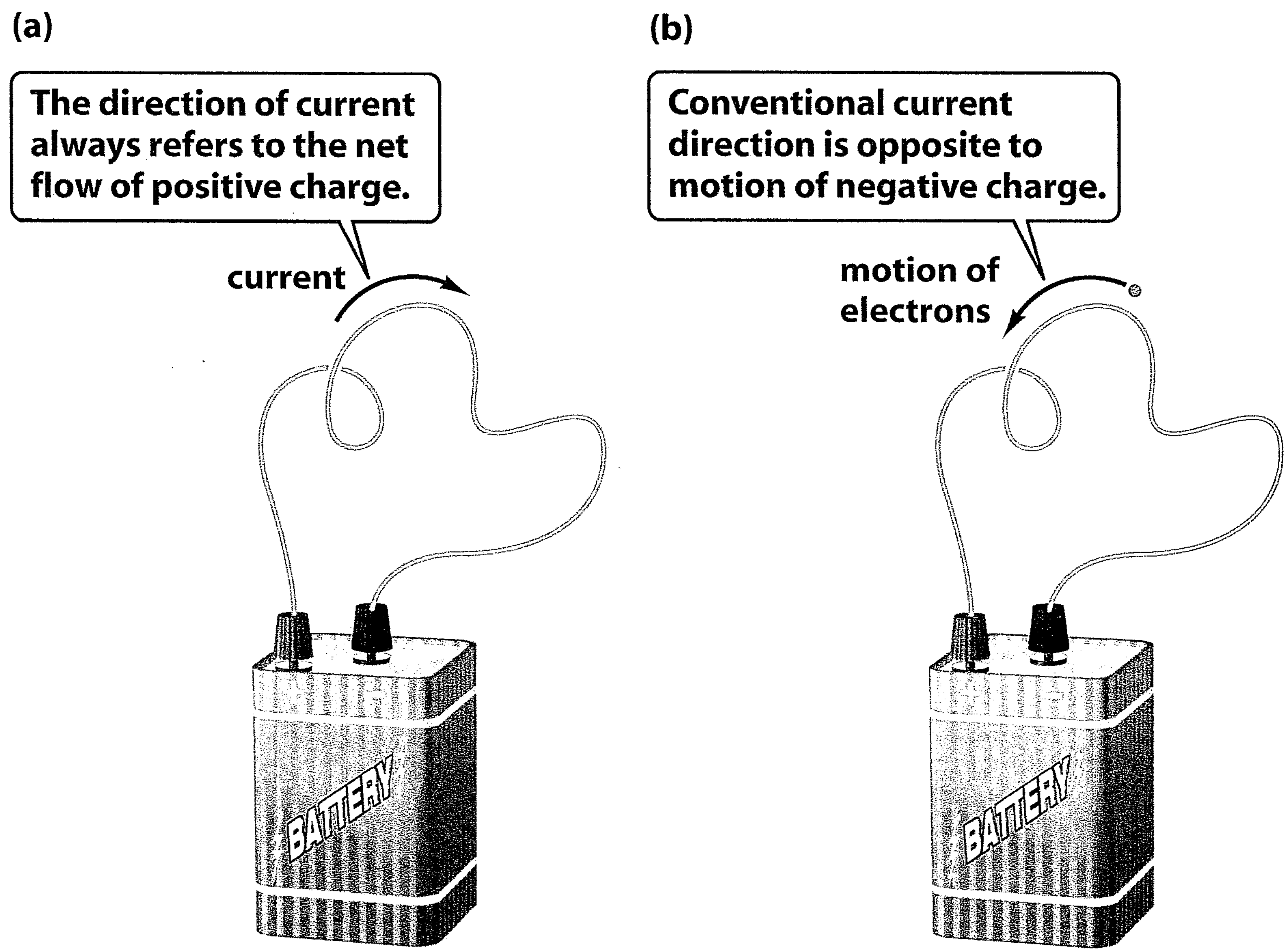


Figure 27-4 Physics for Engineers and Scientists 3/e

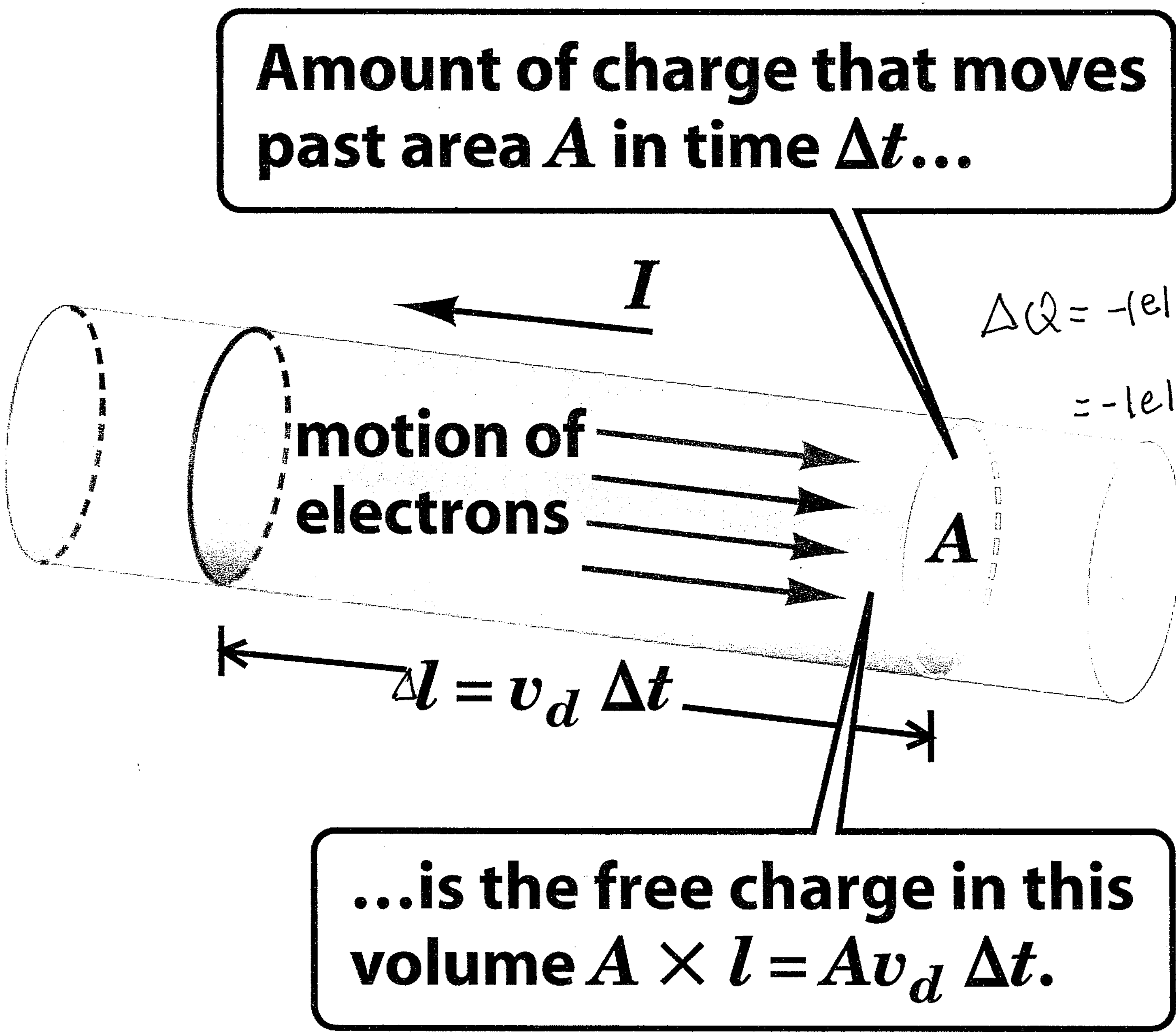


Figure 27-7 Physics for Engineers and Scientists 3/e

$\Delta Q = -|e| n_e A \Delta l$

$= -|e| n_e A v_d \Delta t$

$\frac{\Delta Q}{\Delta t} \to I$

$= |e| n_e v_d A$

$\equiv j A$

$I/A \equiv j \equiv$ current density

$\therefore \frac{dQ}{dt} = j A$

current $\equiv$ curent density × cross sectional area

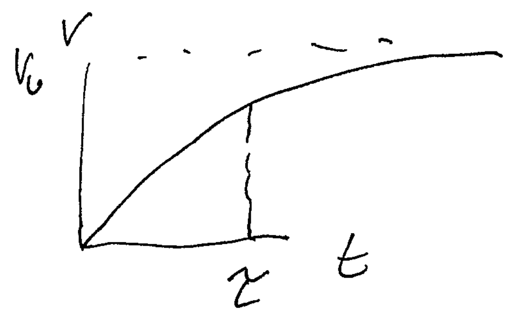
Frictional Force on electrons

$$F_{ric} = -\frac{m_e v_e}{\tau} \; ; \quad \tau \equiv \text{relaxation time.}$$

In conductor electrons reach zero force condition when friction force equals (balances) E-force

$$m_e \frac{dv_e}{dt} = -\frac{m_e v_0}{\tau} - |e| E = 0$$

$$\boxed{v_0 = \frac{-|e| E \tau}{m_e}}$$



$j \equiv$ electron current density $= -n_e v_0 |e|$ (eliminate v_0)

$$= \frac{n_e e^2 \tau}{m_e} E$$

$$j = \frac{n_e e^2 \tau}{m_e} E \equiv \sigma E \qquad \boxed{\sigma = \frac{n_e e^2 \tau}{m_e}}$$

σ electrical conductivity $\equiv$ depends on substance and temperature

Ohm's Law

$q \equiv$ charge of carrier

current density $\equiv j = \sigma E = \frac{q^2 n}{m\tau} E$

$$j = \frac{\sigma}{d} \widehat{Ed} = \frac{\sigma}{d} V$$

$$I = jA = \left(\frac{\sigma}{d} A\right) V$$

$IR = V \equiv$ ohm's Law

$$R = \frac{V}{I} = \frac{d}{\sigma A} = \frac{m\tau}{q^2 n} \frac{d}{A}$$

$$\frac{1}{\sigma} = \rho_c$$

$$R = \frac{\rho_c d}{A}$$

ρ = electrical resistivity = $1/\sigma$ ≡ ohm·meter

TABLE 27.2 RESISTIVITIES AND TEMPERATURE COEFFICIENTS OF RESISTANCE OF METALS[a]

$\rho = \rho_0 (\frac{T}{T_0}) + \alpha (T - T_0)$

MATERIAL	ρ	α
Silver	$1.6 \times 10^{-8}\ \Omega \cdot m$	$3.8 \times 10^{-3}/°C$
Copper	1.7×10^{-8}	3.9×10^{-3}
Aluminum	2.8×10^{-8}	3.9×10^{-3}
Brass	$\approx 7 \times 10^{-8}$	2×10^{-3}
Nickel	7.8×10^{-8}	6×10^{-3}
Iron	10×10^{-8}	5×10^{-3}
Steel	$\approx 11 \times 10^{-8}$	4×10^{-3}
Constantan	49×10^{-8}	1×10^{-5}
Nichrome	100×10^{-8}	4×10^{-4}

[a] At a temperature of 20°C.

Table 27-2 Physics for Engineers and Scientists 3/e

TABLE 27.3 RESISTIVITIES OF INSULATORS

MATERIAL	ρ
Polyethylene	$2 \times 10^{11}\ \Omega\cdot m$
Glass	$\approx 10^{12}$
Porcelain, unglazed	$\approx 10^{12}$
Rubber, hard	$\approx 10^{13}$
Epoxy	$\approx 10^{15}$

Table 27-3 Physics for Engineers and Scientists 3/e

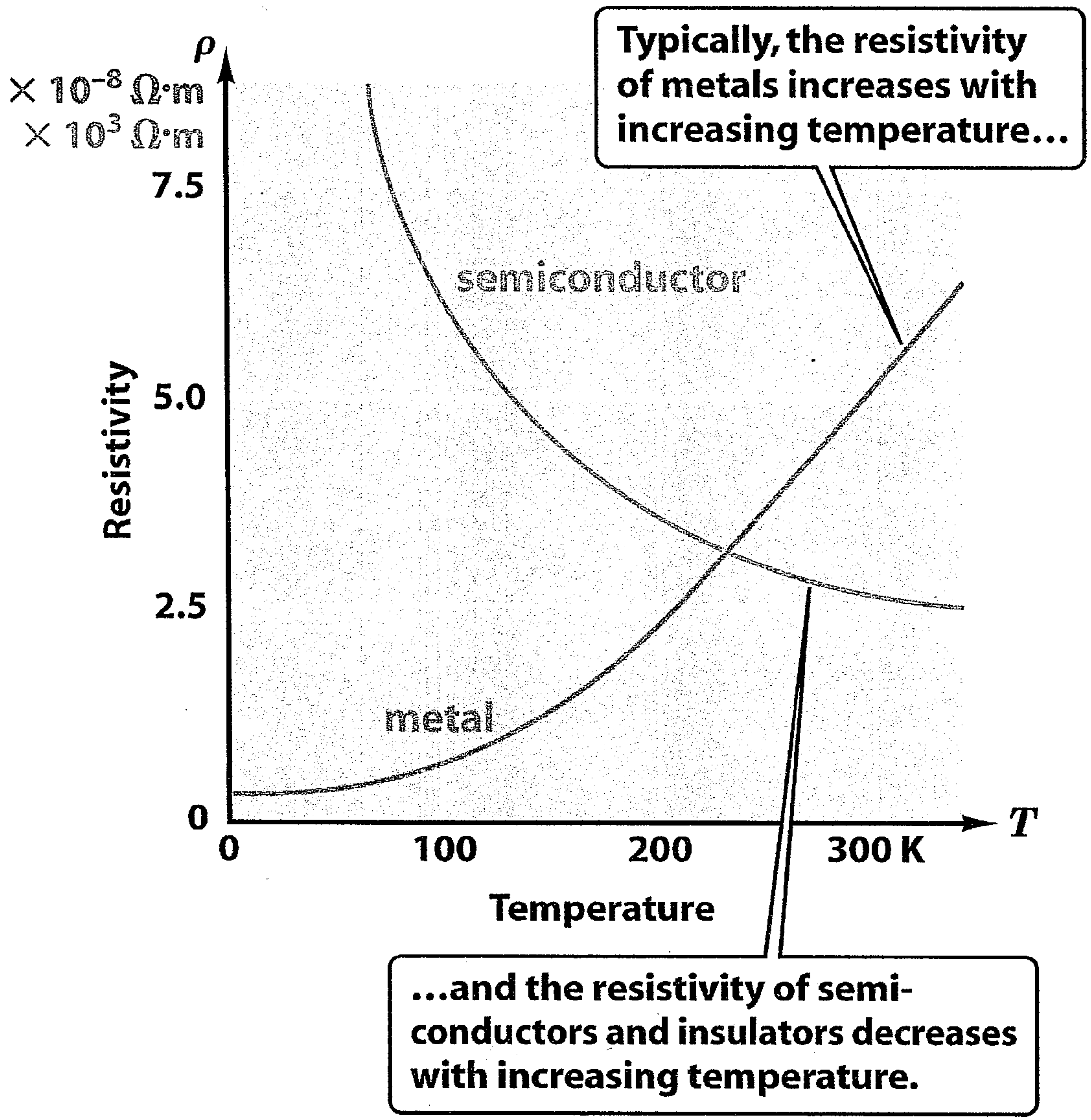


Figure 27-8 Physics for Engineers and Scientists 3/e

TABLE 27.4 RESISTIVITIES AND TEMPERATURE COEFFICIENTS OF RESISTANCE OF SEMICONDUCTORS[a]

MATERIAL	ρ	α
Carbon (graphite)	$3.5 \times 10^{-5}\ \Omega\cdot\text{m}$	$-5 \times 10^{-4}/°\text{C}$
Silicon	2.6×10^{3}	-8×10^{-2}
Germanium	4.2×10^{-1}	-5×10^{-2}

[a] At a temperature of 20°C.

Table 27-4 Physics for Engineers and Scientists 3/e

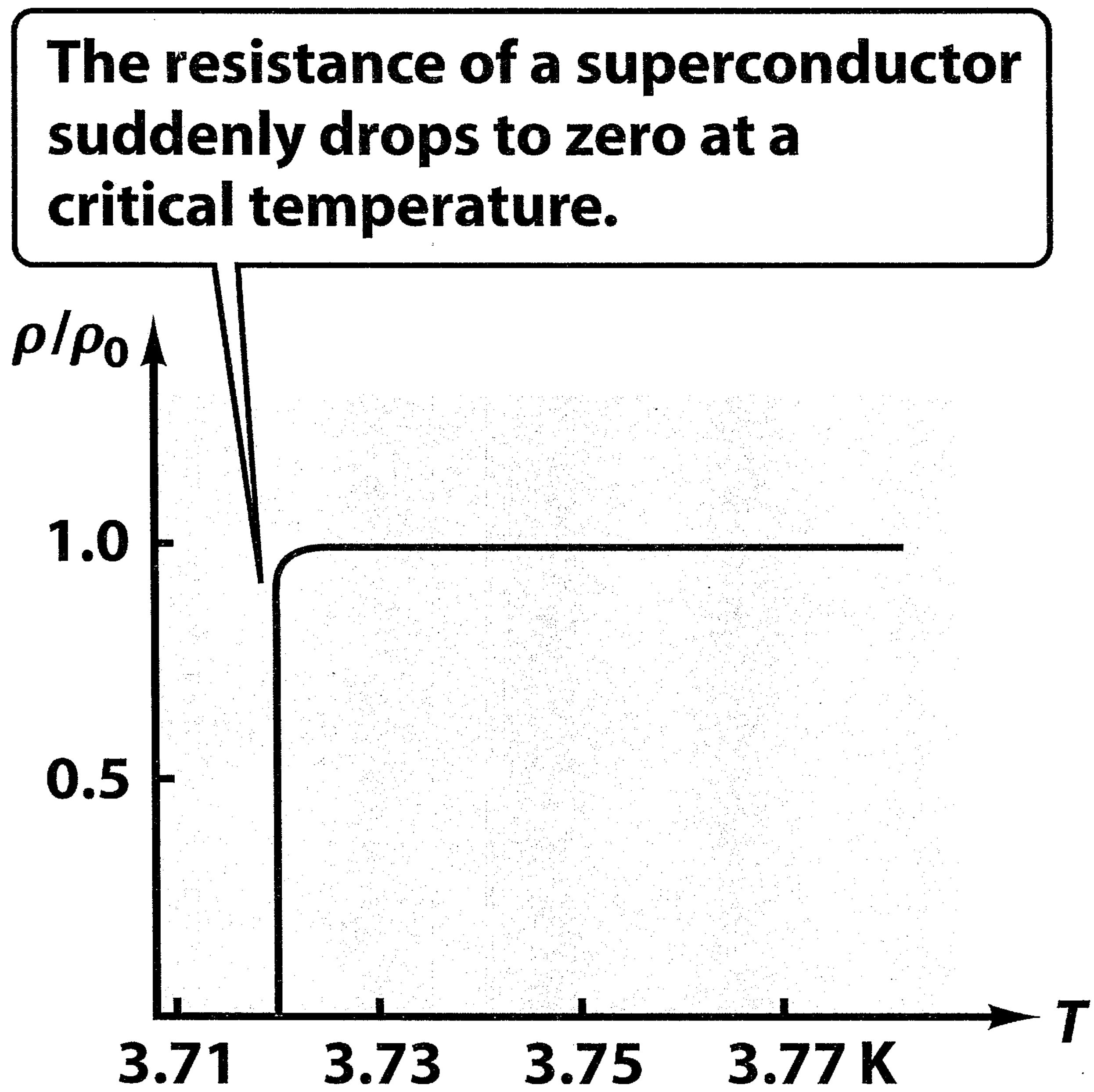


Figure 27-10 Physics for Engineers and Scientists 3/e