Ch. 12. The Solid State

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Ionic Solid

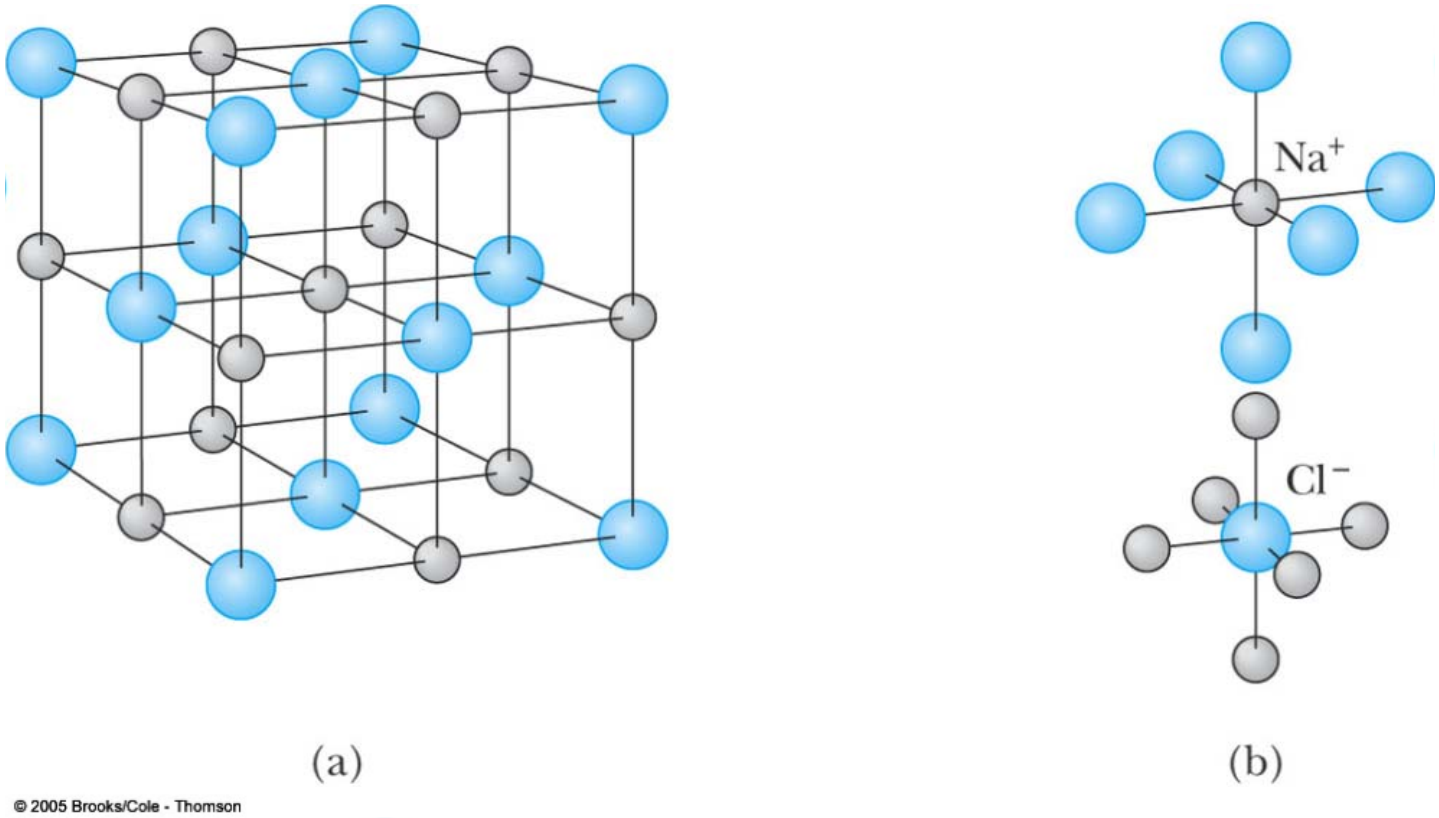


Fig. 12-1, p.405

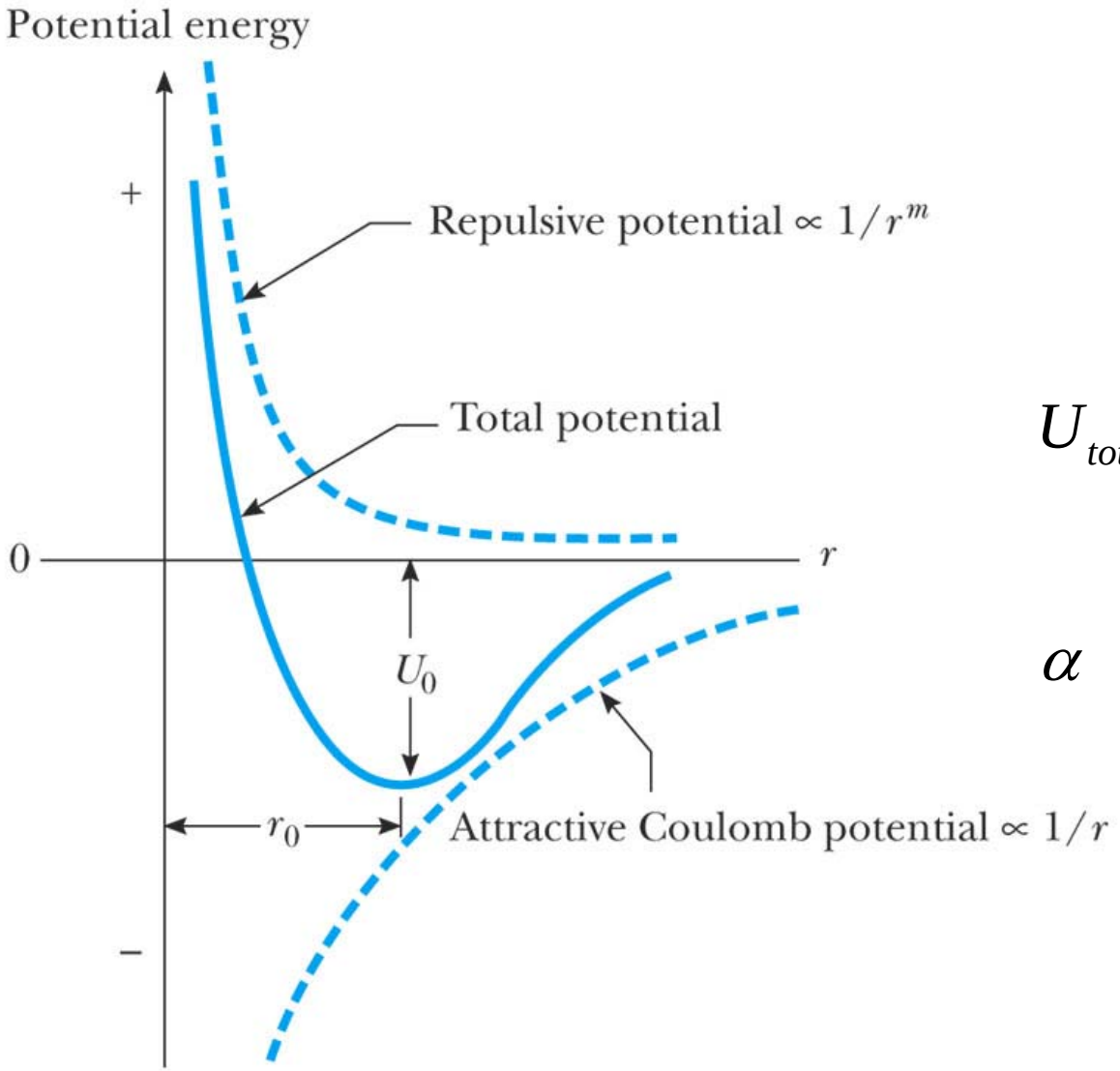


Fig. 12-2, p.406

$$U_{total} = -\alpha k \frac{e^2}{r} + \frac{B}{r^m}$$

α Madelung constant

Covalent Solid

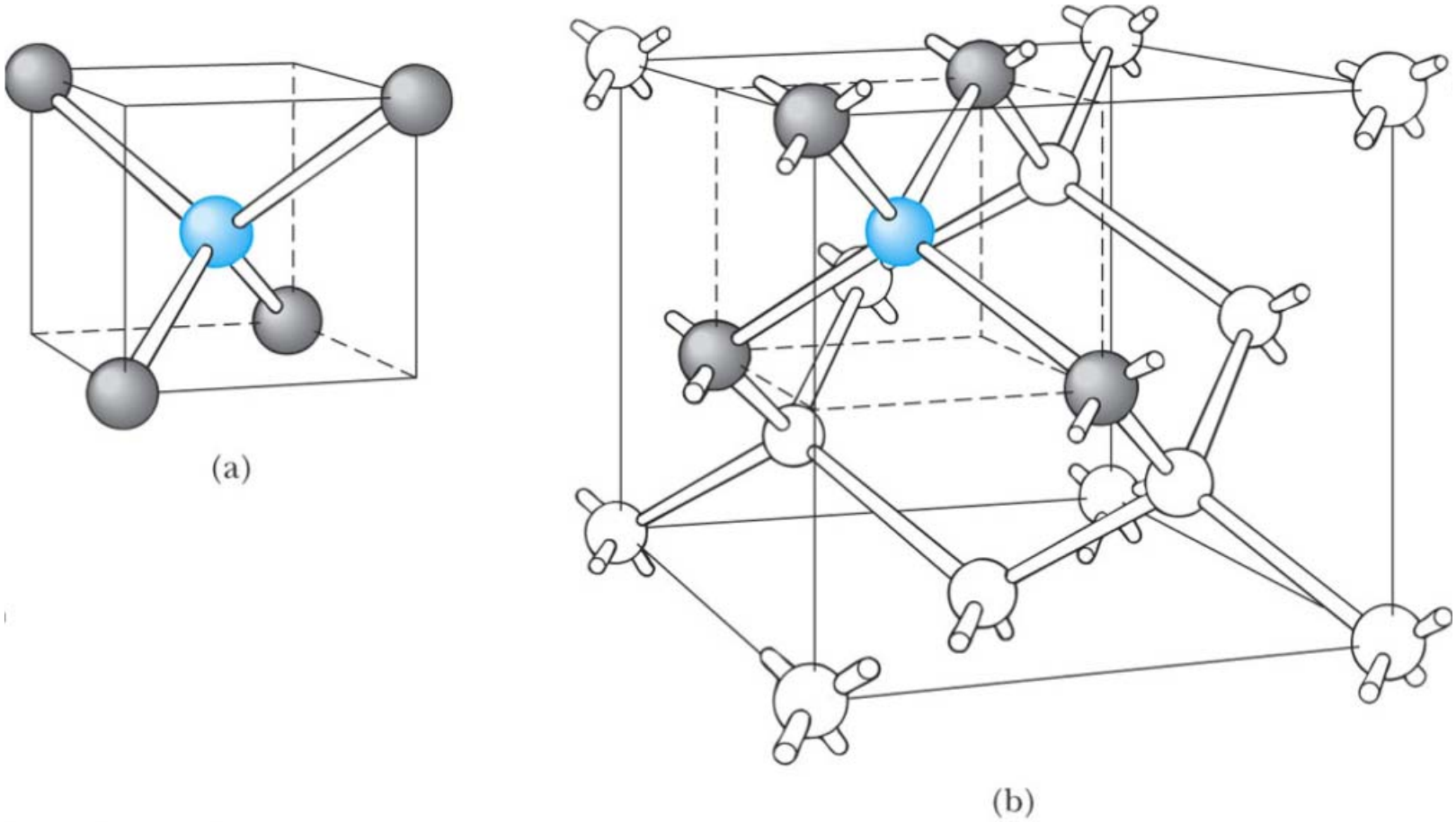


Fig. 12-3, p.408

Metallic Solid

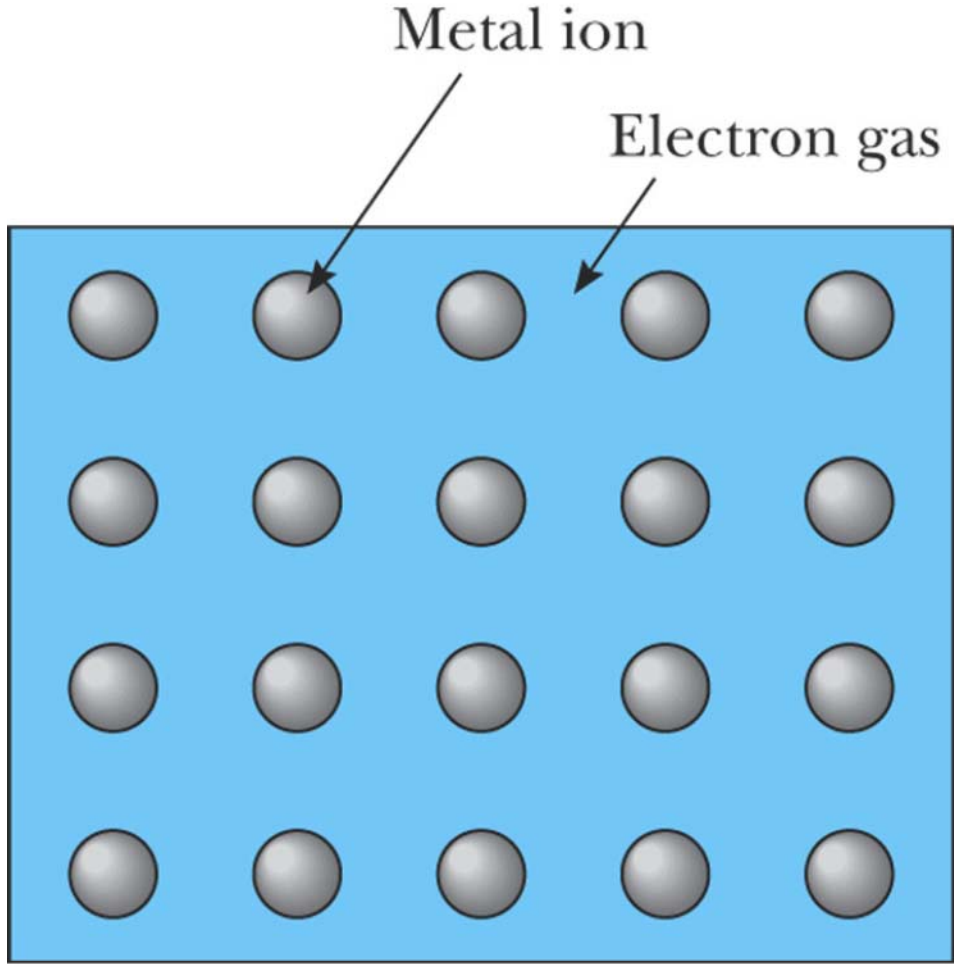


Fig. 12-4, p.409

Amorphous Solid

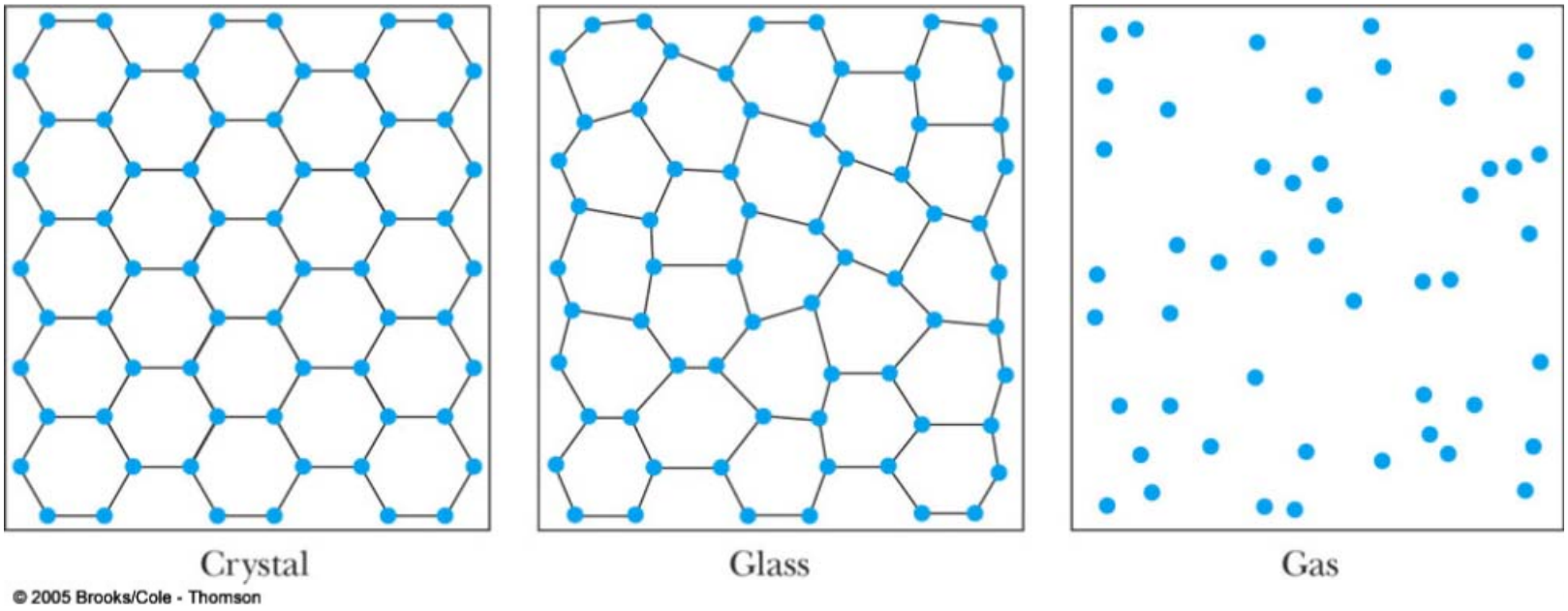


Fig. 12-5, p.410

Ohm's Law

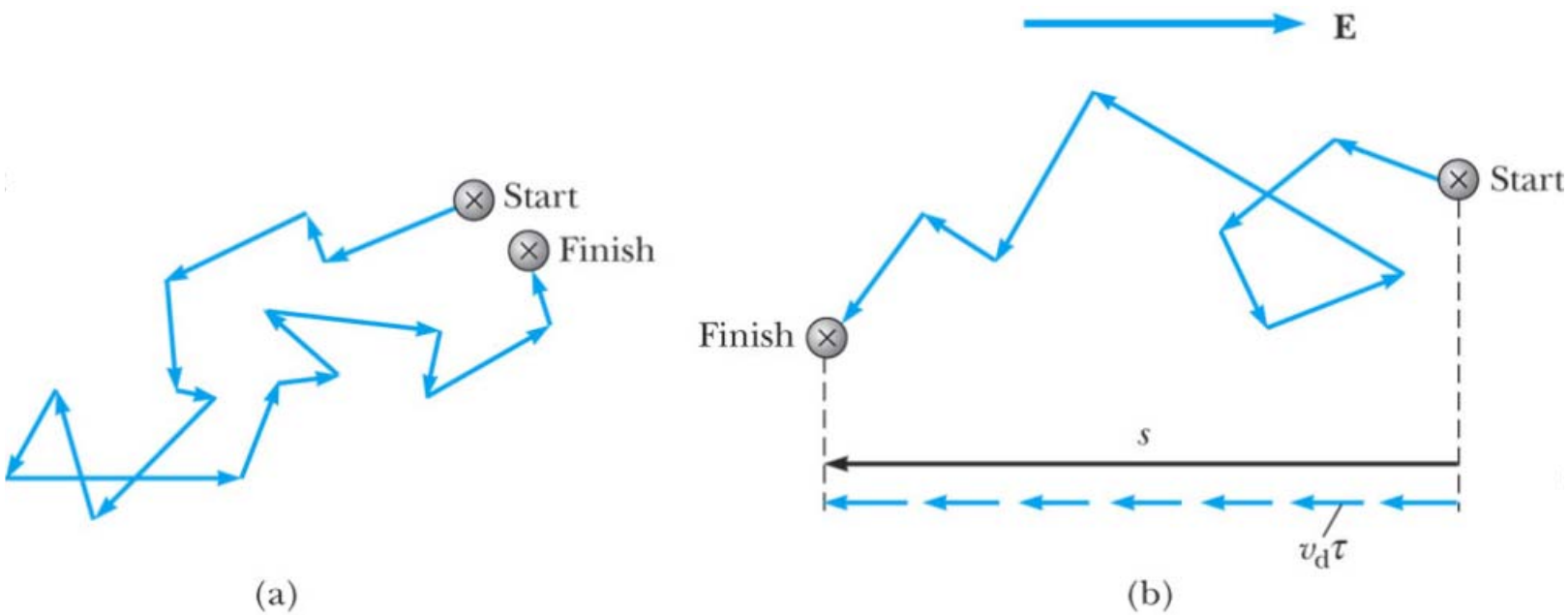


Fig. 12-11, p.415

Ohm's Law

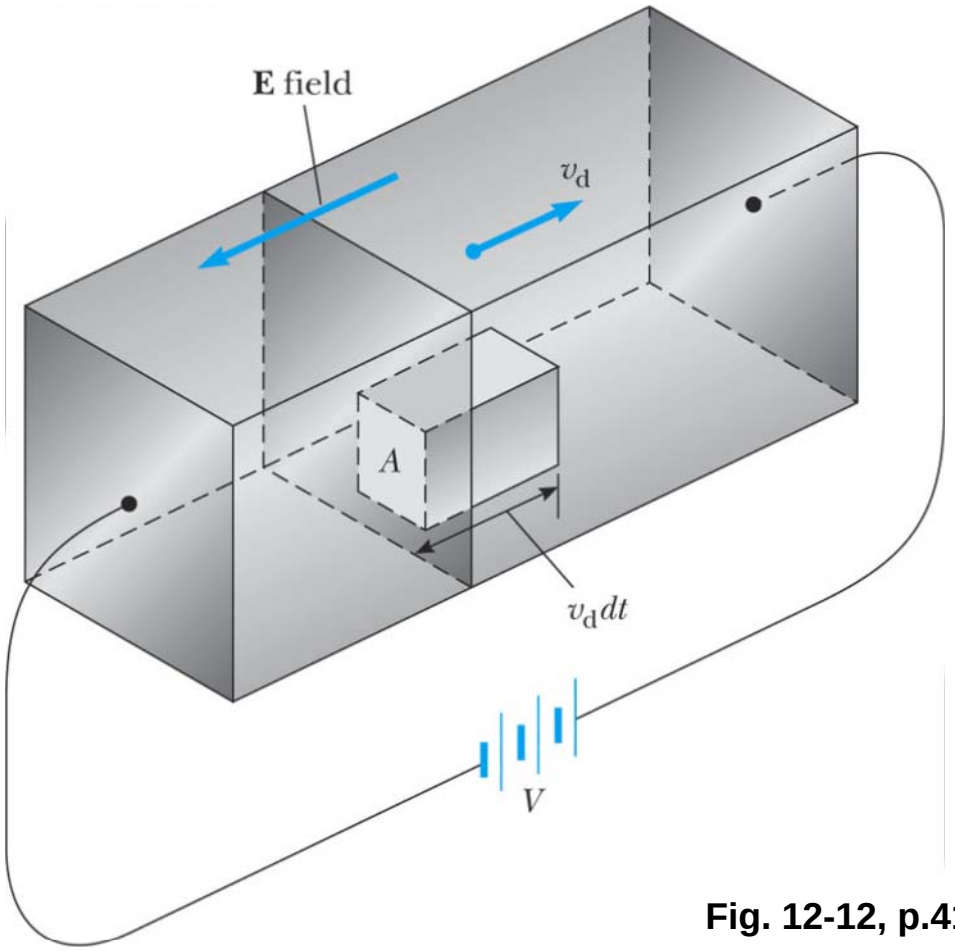


Fig. 12-12, p.416

$$V = IR$$

$$\mathbf{J} = \sigma \mathbf{E}$$

Ohm's Law

$$\frac{1}{2} m_e \left\langle v^2 \right\rangle = \frac{3}{2} k_B T$$

$$v_{rms} = \sqrt{\left\langle v^2 \right\rangle} = \sqrt{\frac{3k_B T}{m_e}}$$

L mean free path

τ mean free time

$$L = v_{rms} \tau$$

Ohm's Law

$$s = \frac{a}{2}\left(t_1^2 + t_2^2 + t_3^2 + \cdots + t_b^2\right)$$

$$a = \frac{eE}{m_e}$$

$$s = \frac{a}{2} b \left\langle t^2 \right\rangle$$

$$\left\langle t^2 \right\rangle = 2\tau^2$$

$$s = ab\tau^2 = \frac{eE}{m_e} b\tau^2$$

$$s = v_d b\tau$$

$$v_d = \frac{eE\tau}{m_e} \quad \text{drift speed}$$

Ohm's Law

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

$$\sigma = \frac{ne^2\tau}{m_e} = \frac{ne^2 L}{m_e v_{rms}} \quad \text{conductivity}$$

Using Maxwell-Boltzmann rms thermal speed,

$$\sigma = \frac{ne^2 L}{\sqrt{3k_B T m_e}}$$

$$\rho = \frac{1}{\sigma} \quad \text{resistivity}$$

Table 12.5 Thermal Conductivity, K, and Electrical Conductivity, σ, of Selected Substances at Room Temperature

Substance	K in $W \cdot m^{-1}K^{-1}$	σ in $(\Omega \cdot m)^{-1}$
Silver	427	62×10^6
Copper	390	59×10^6
Gold	314	41×10^6
Aluminum	210	35×10^6
Iron	63	10×10^6
Steel	50	1.4×10^6
Nichrome	14	0.9×10^6
Quartz	13	
NaCl	7.0	$<10^{-4}$

Table 12-5, p.414

Table 12.7 Experimental Lorentz Numbers $K/\sigma T$ in Units of $10^{-8}\ \mathrm{W}\cdot\Omega/\mathrm{K}^2$*

Metal	273 K	373 K
Ag	2.31	2.37
Au	2.35	2.40
Cd	2.42	2.43
Cu	2.23	2.33
Ir	2.49	2.49
Mo	2.61	2.79
Pb	2.47	2.56
Pt	2.51	2.60
Sn	2.52	2.49
W	3.04	3.20
Zn	2.31	2.33

Table 12-7, p.420

Quantum Theory of Metals

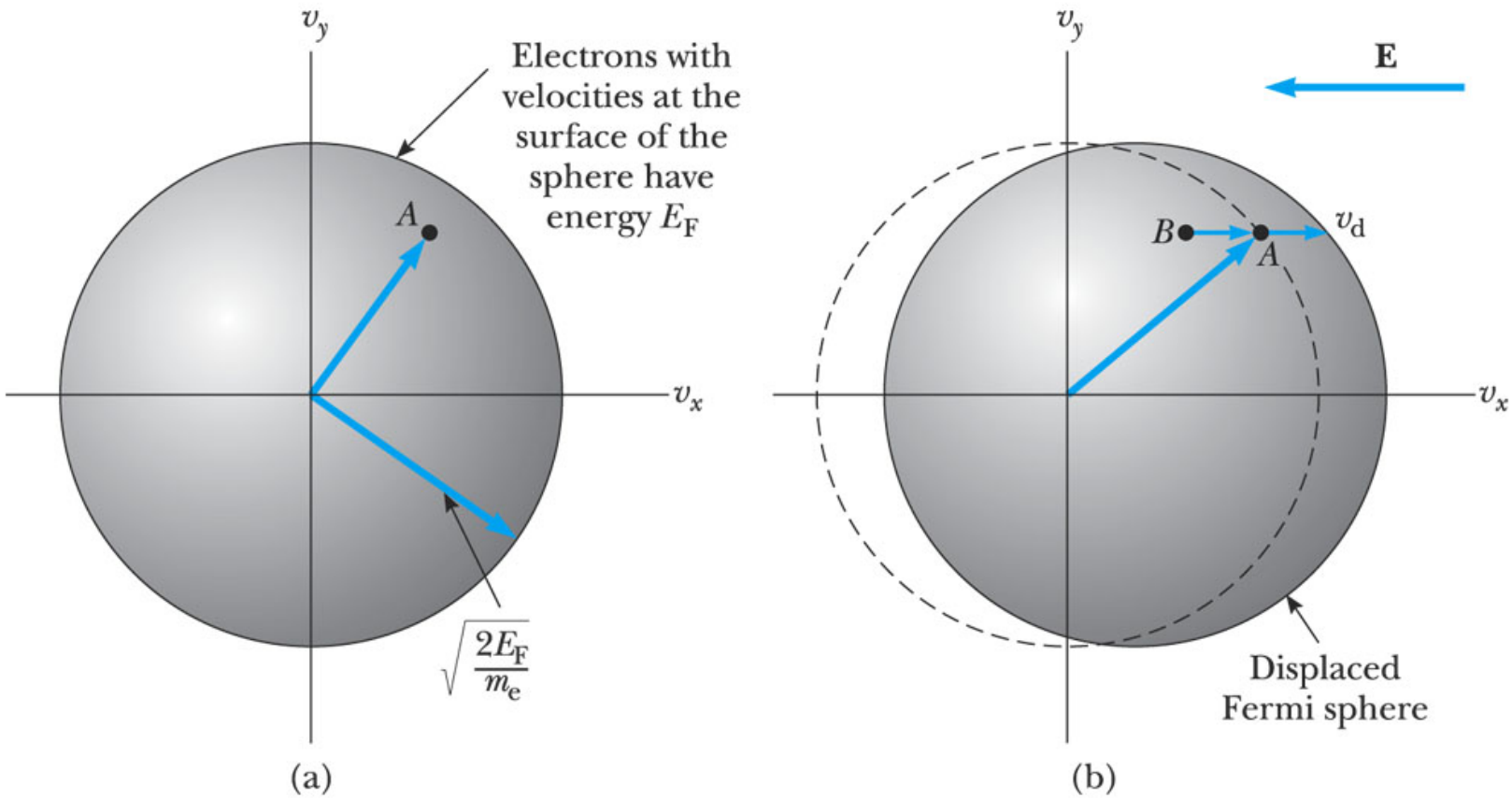


Fig. 12-14, p.421

Quantum Theory of Metals

$$\sigma = \frac{ne^2 L}{m_e v_F}$$

$$E_F = \frac{1}{2} m_e v_F^2$$

$$L = \frac{m_e v_F \sigma}{ne^2}$$

Energy Band

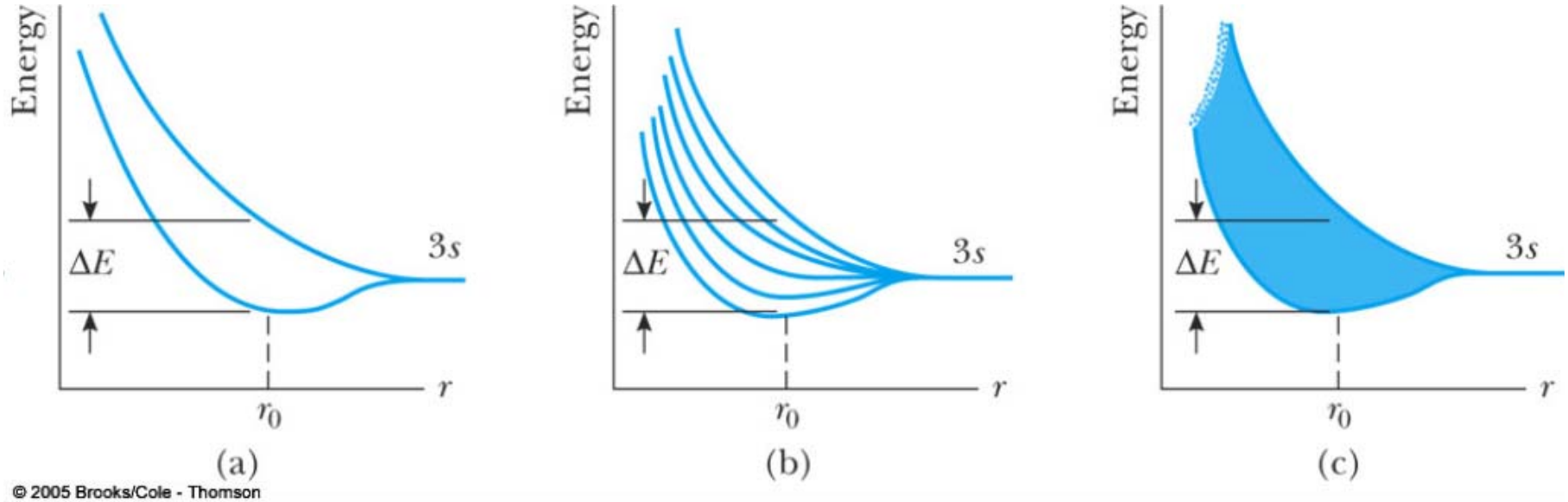


Fig. 12-16, p.426

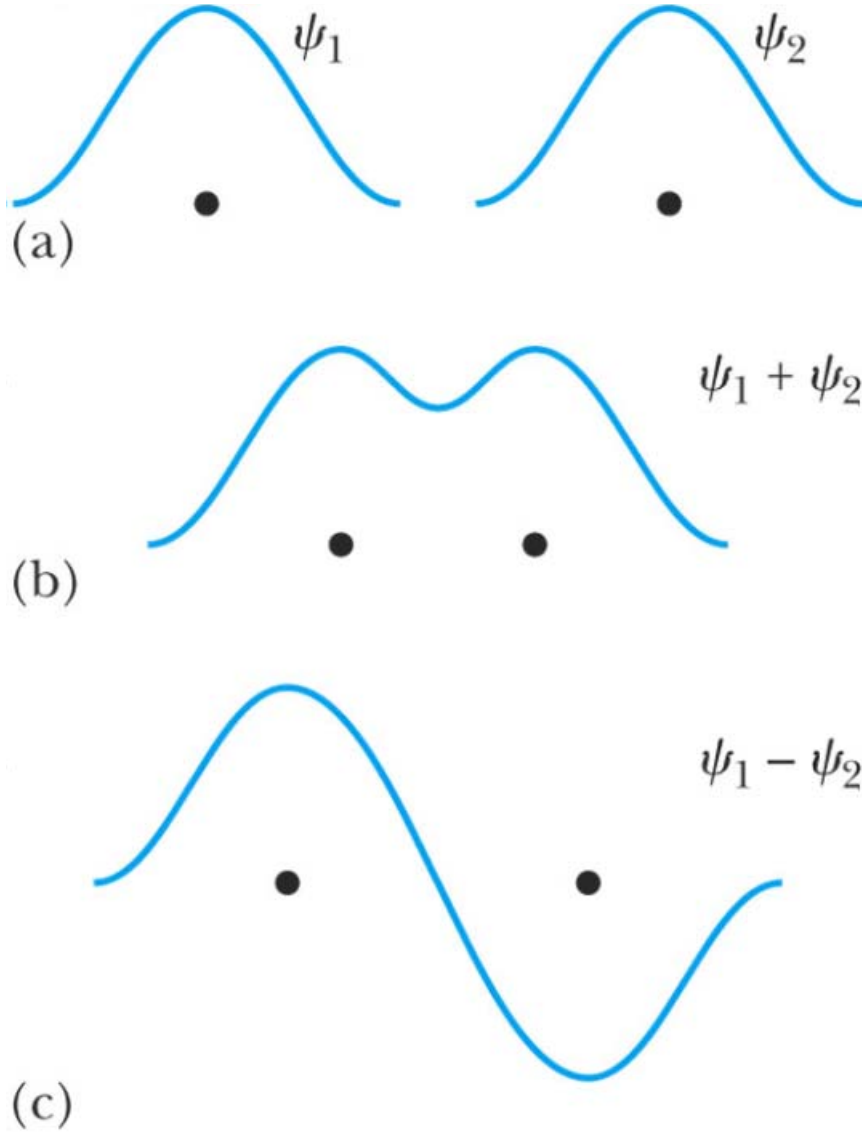


Fig. 12-17, p.426

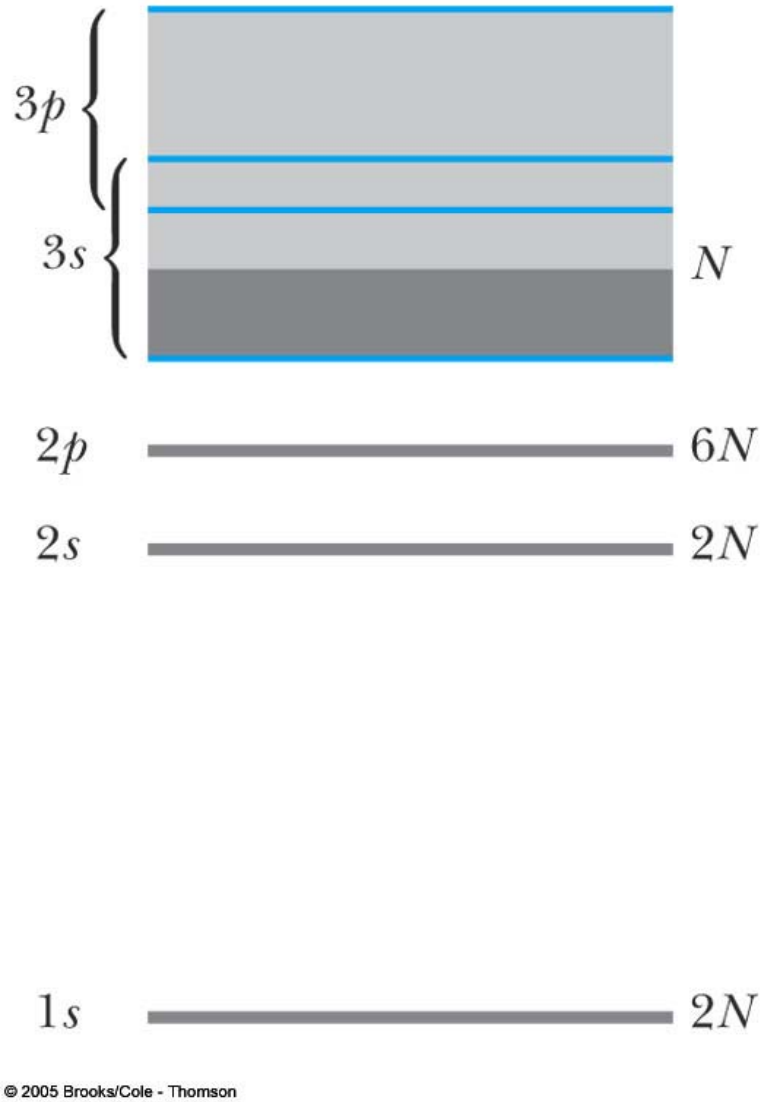


Fig. 12-18, p.426

Metal

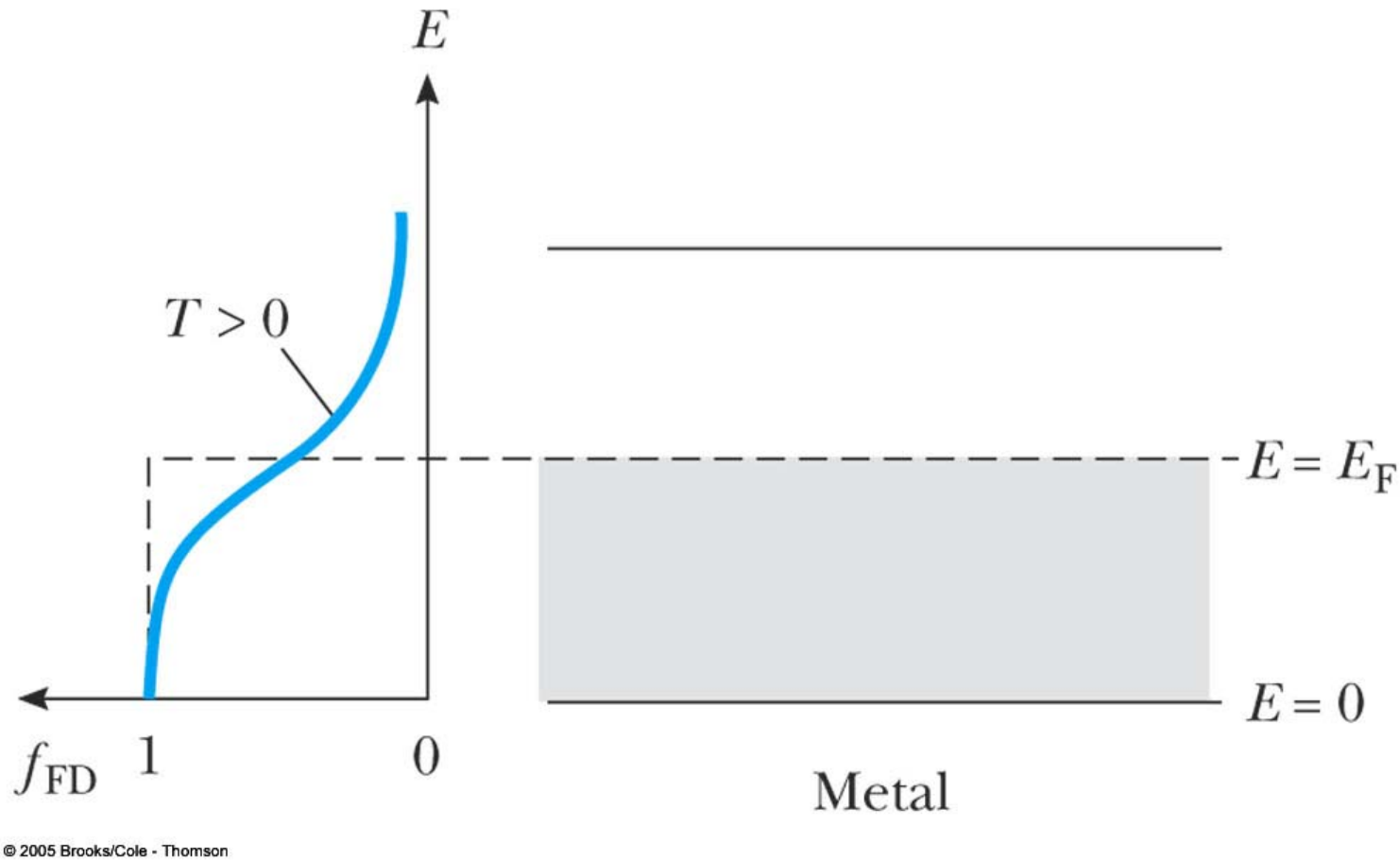


Fig. 12-19, p.427

Insulator

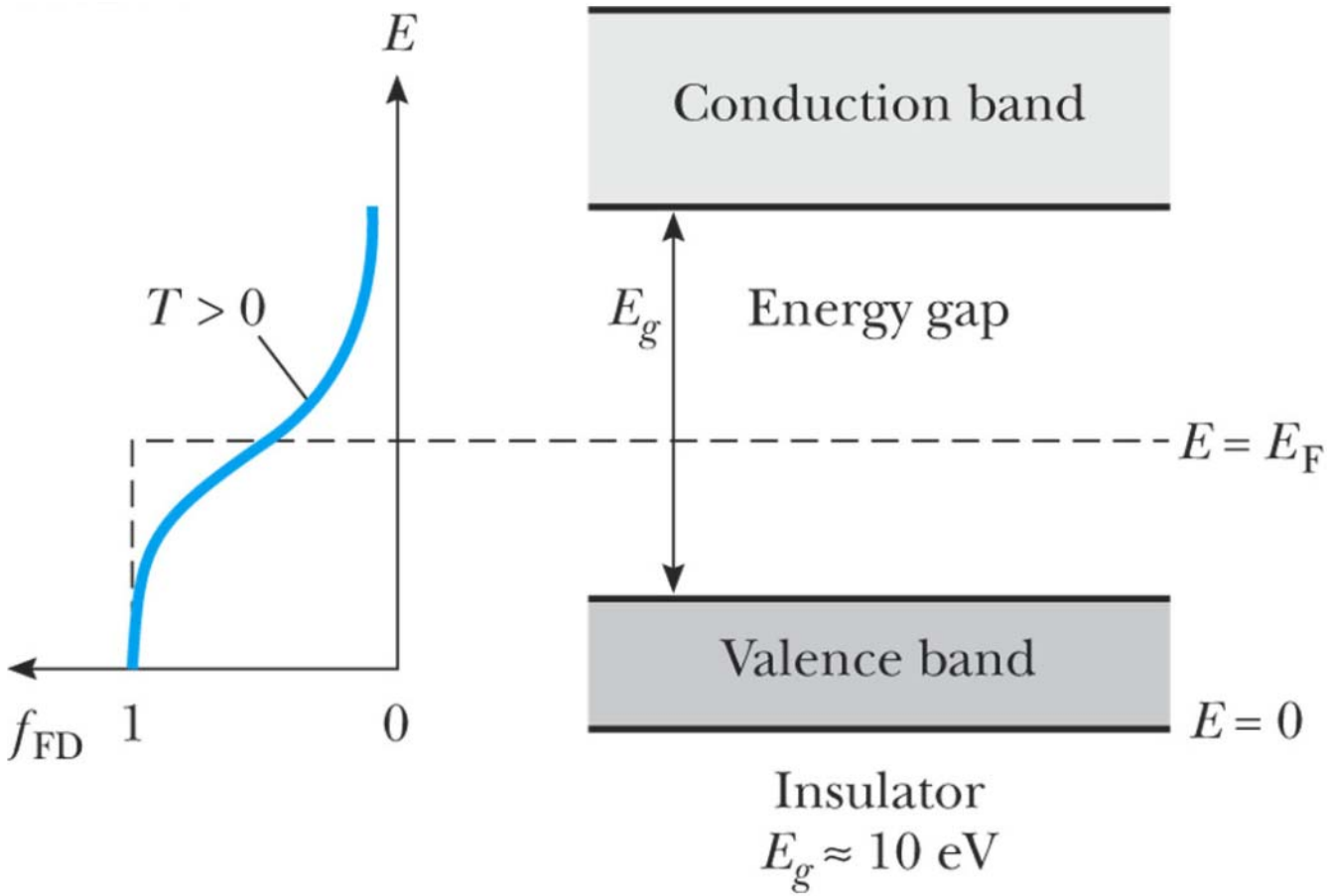


Fig. 12-20, p.428

Table 12.8 Energy-Gap Values for Some Semiconductors*

	E_g(eV)	
Crystal	**0 K**	**300 K**
Si	1.17	1.14
Ge	0.744	0.67
InP	1.42	1.35
GaP	2.32	2.26
GaAs	1.52	1.43
CdS	2.582	2.42
CdTe	1.607	1.45
ZnO	3.436	3.2
ZnS	3.91	3.6

Table 12-8, p.428

Semiconductor

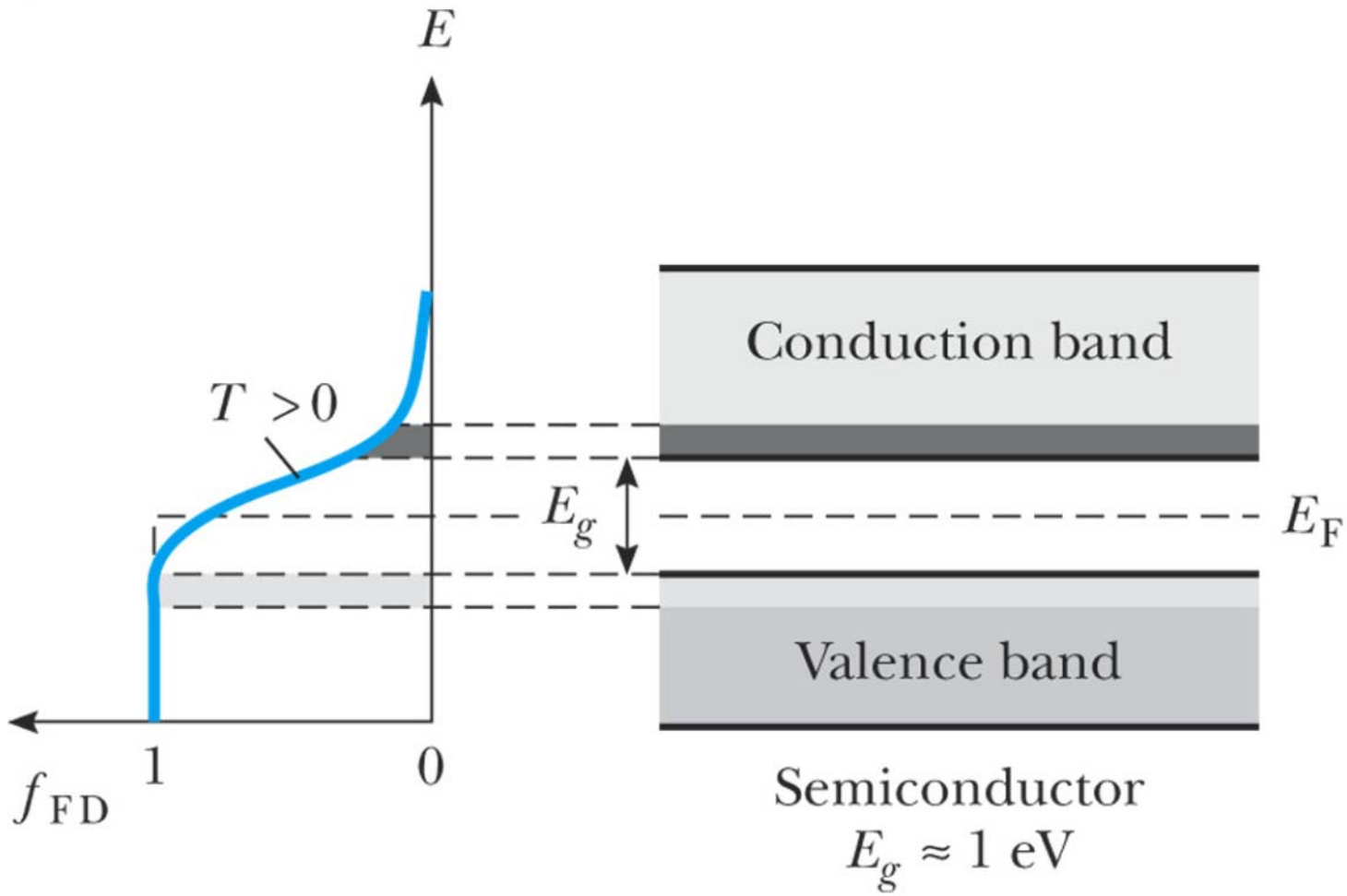


Fig. 12-21, p.428

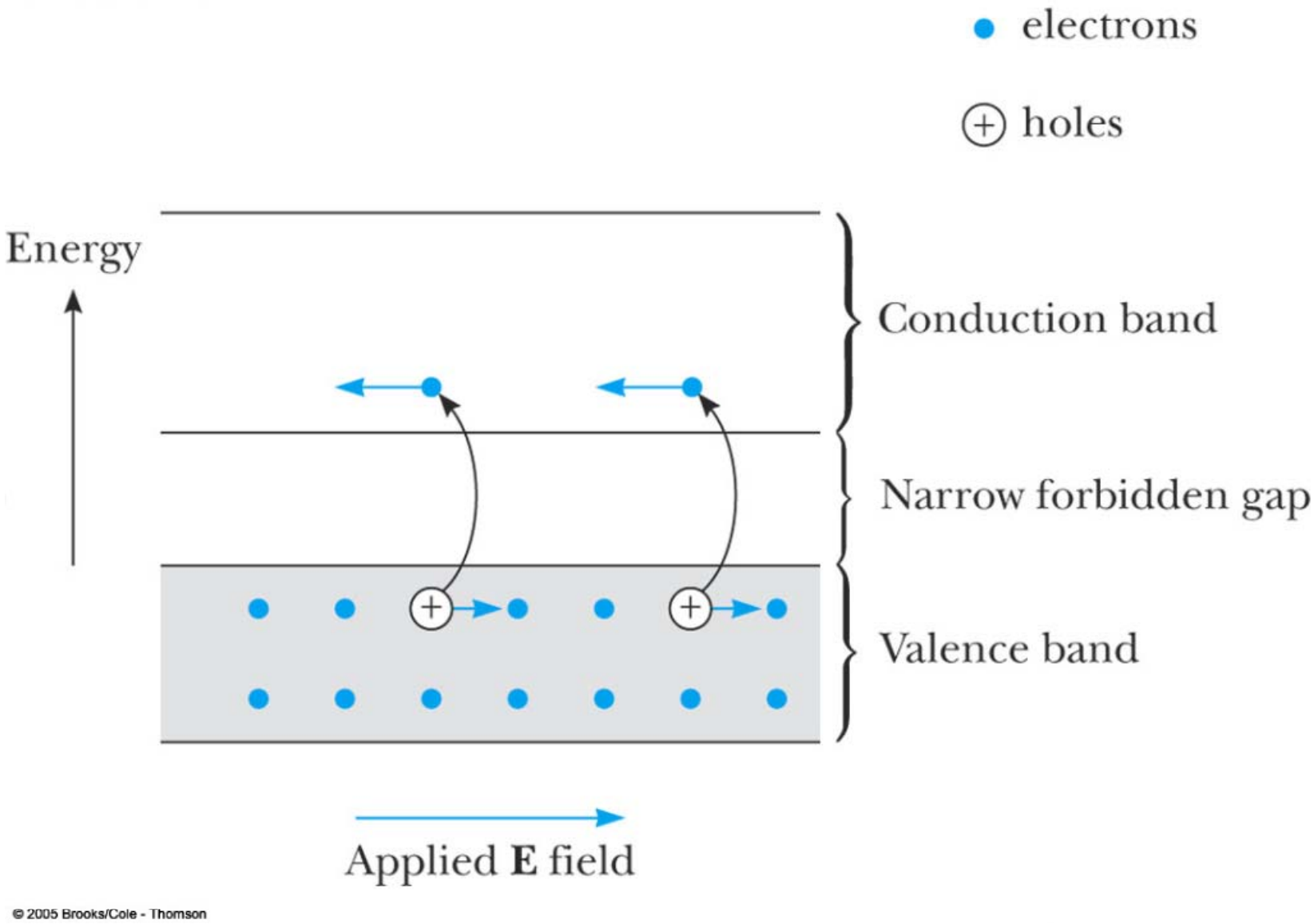


Fig. 12-22, p.429

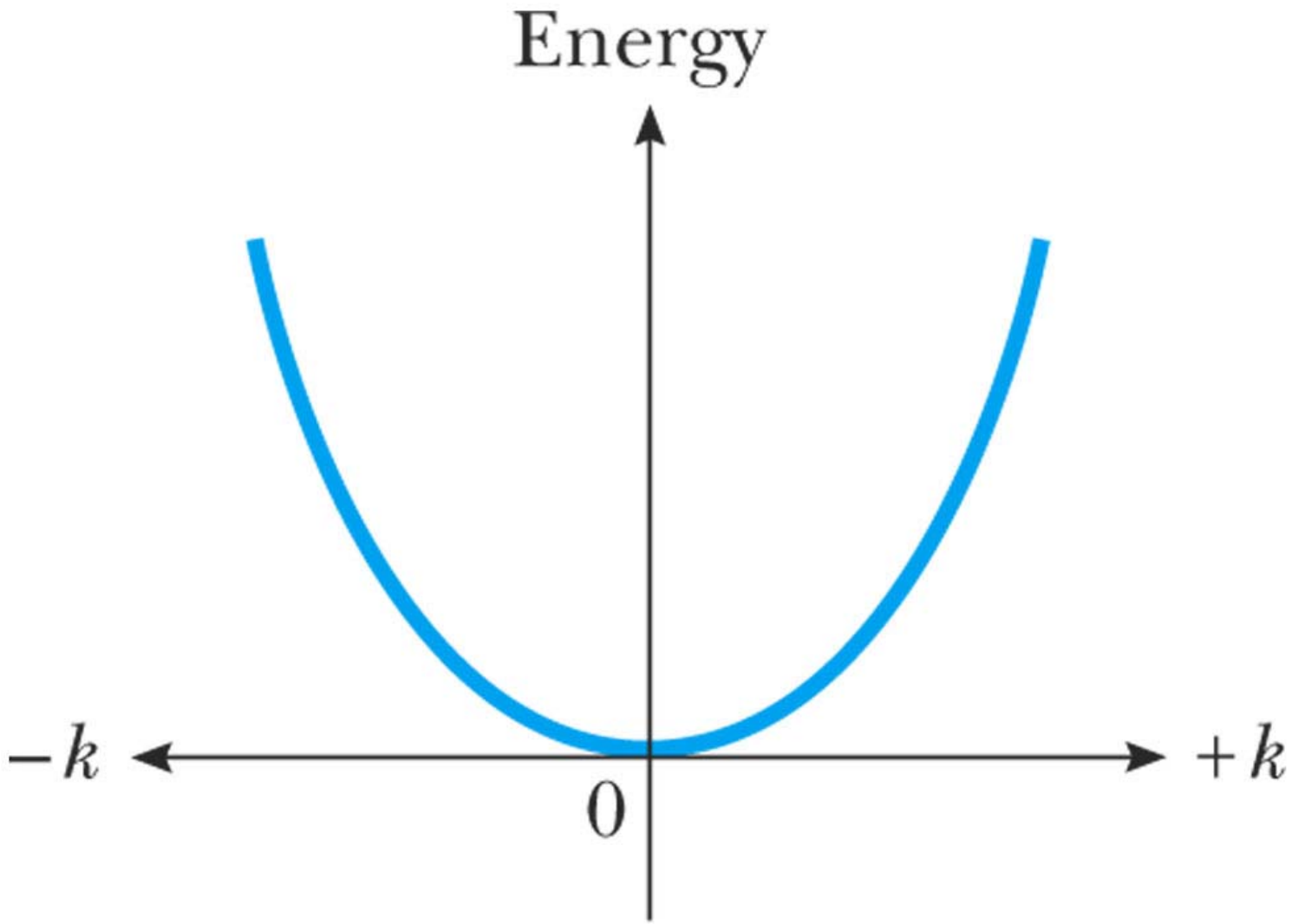
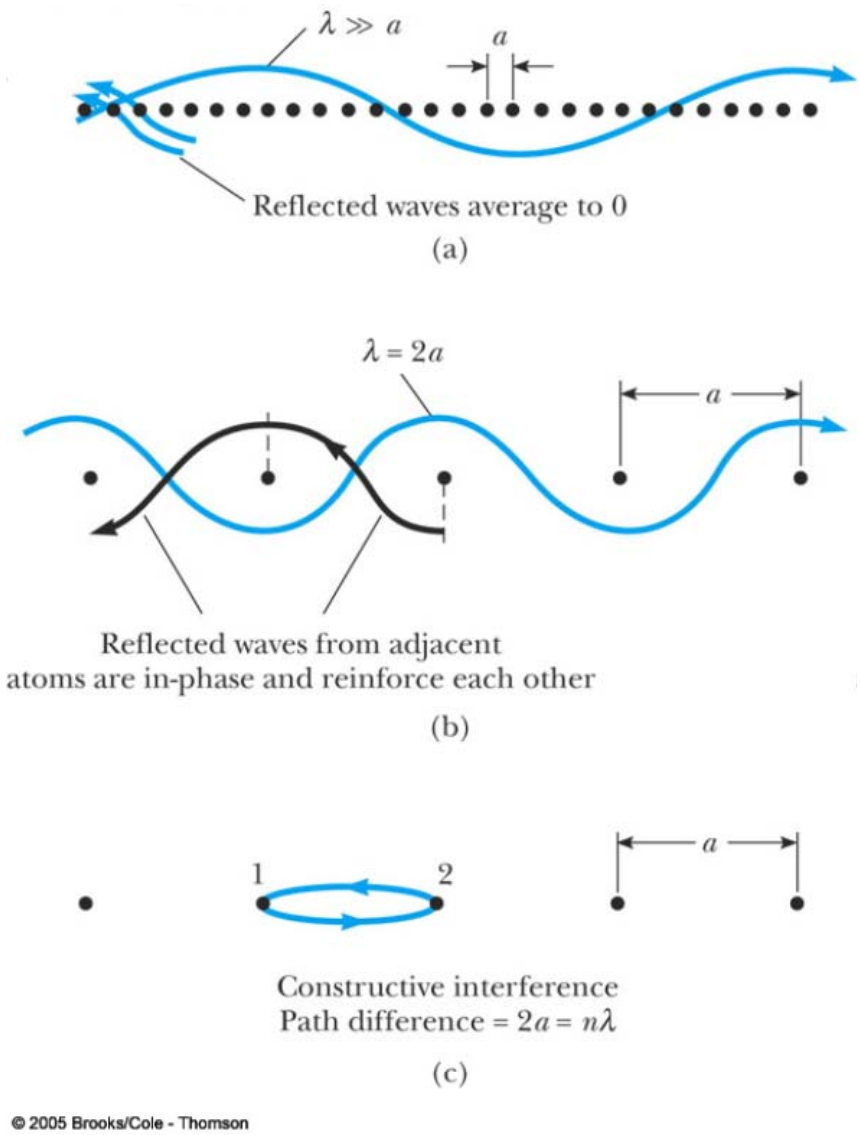


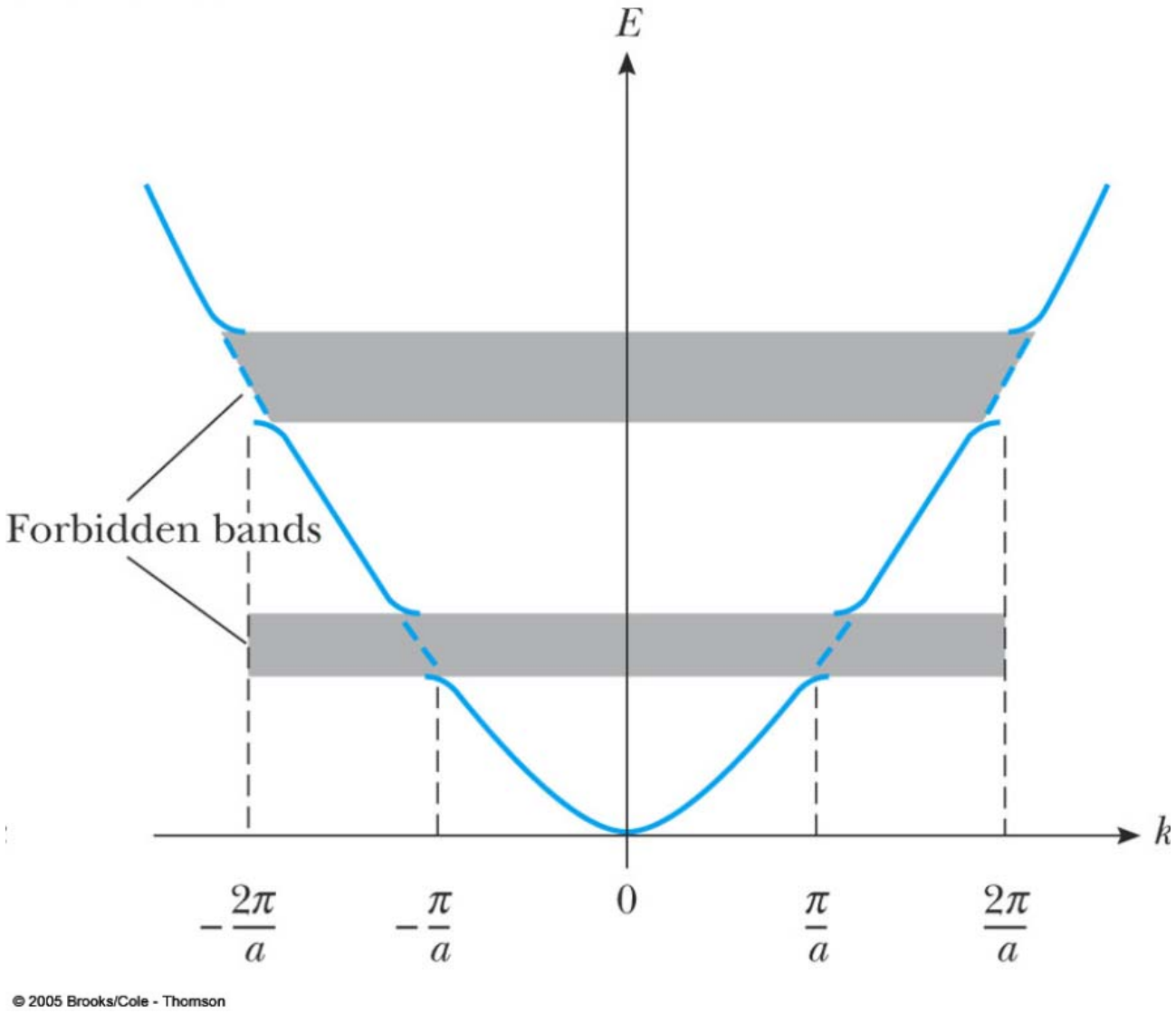
Fig. 12-23, p.430



$$2a = \pm n\lambda \qquad n = 1, 2, 3, \cdots$$

$$k = \frac{2\pi}{\lambda} = \pm\frac{n\pi}{a}$$

Fig. 12-24, p.430



$$\frac{1}{m_e} = \frac{1}{\hbar^2}\frac{\partial^2 E}{\partial k^2}$$

$$v_g = \frac{1}{\hbar}\frac{\partial E}{\partial k}$$

Fig. 12-25, p.432

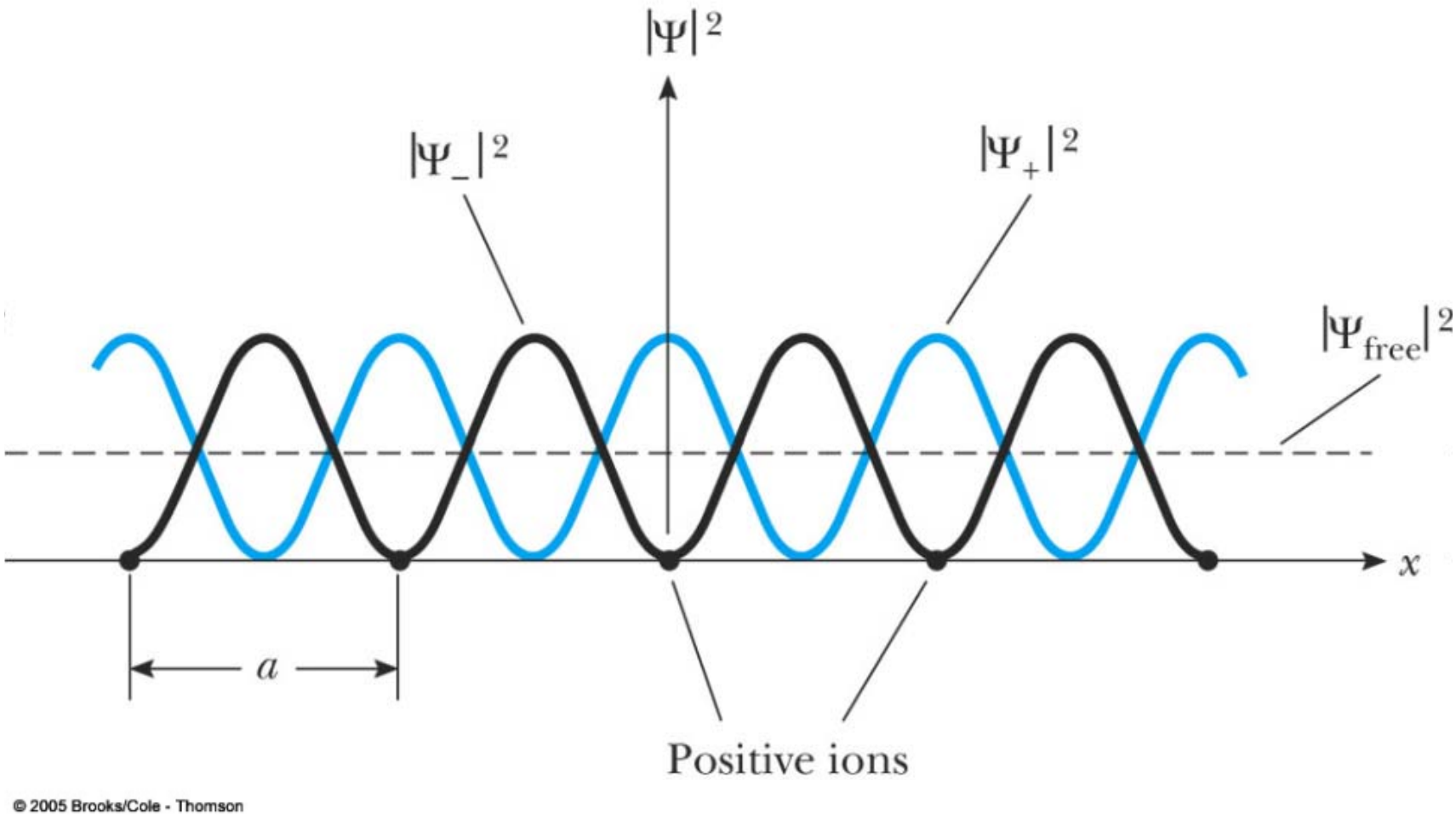
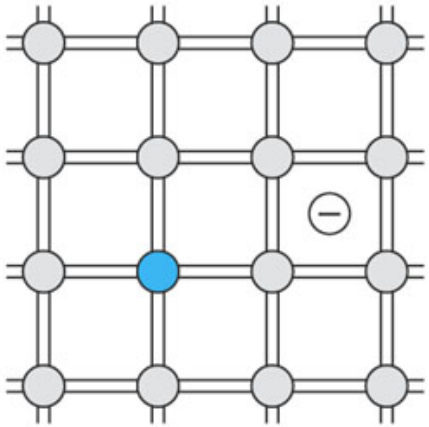


Fig. 12-26, p.432

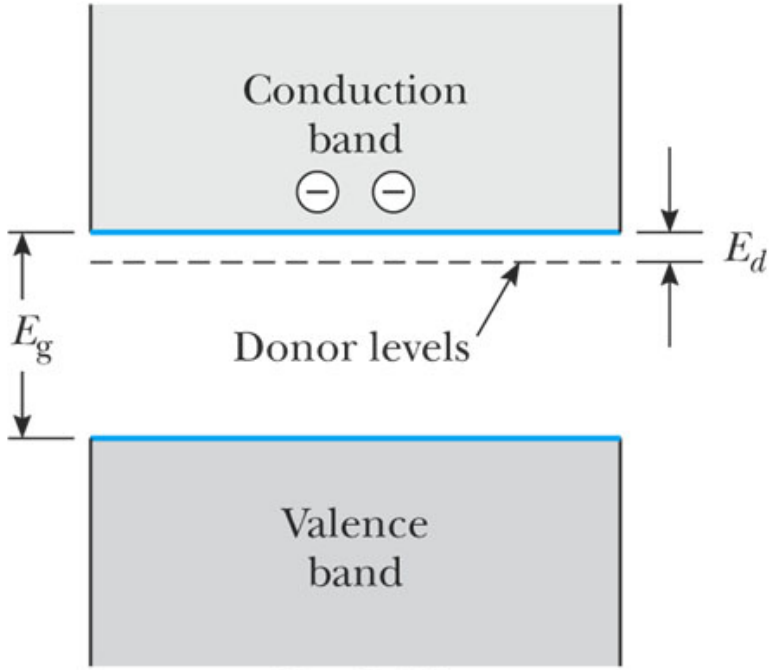


= Semiconductor atoms

= Impurity atom with five valance electrons

= Extra electron from impurity atom

(a)



$E_g \approx 1$ eV

$E_d \approx 0.05$ eV

(b)

Fig. 12-27, p.433

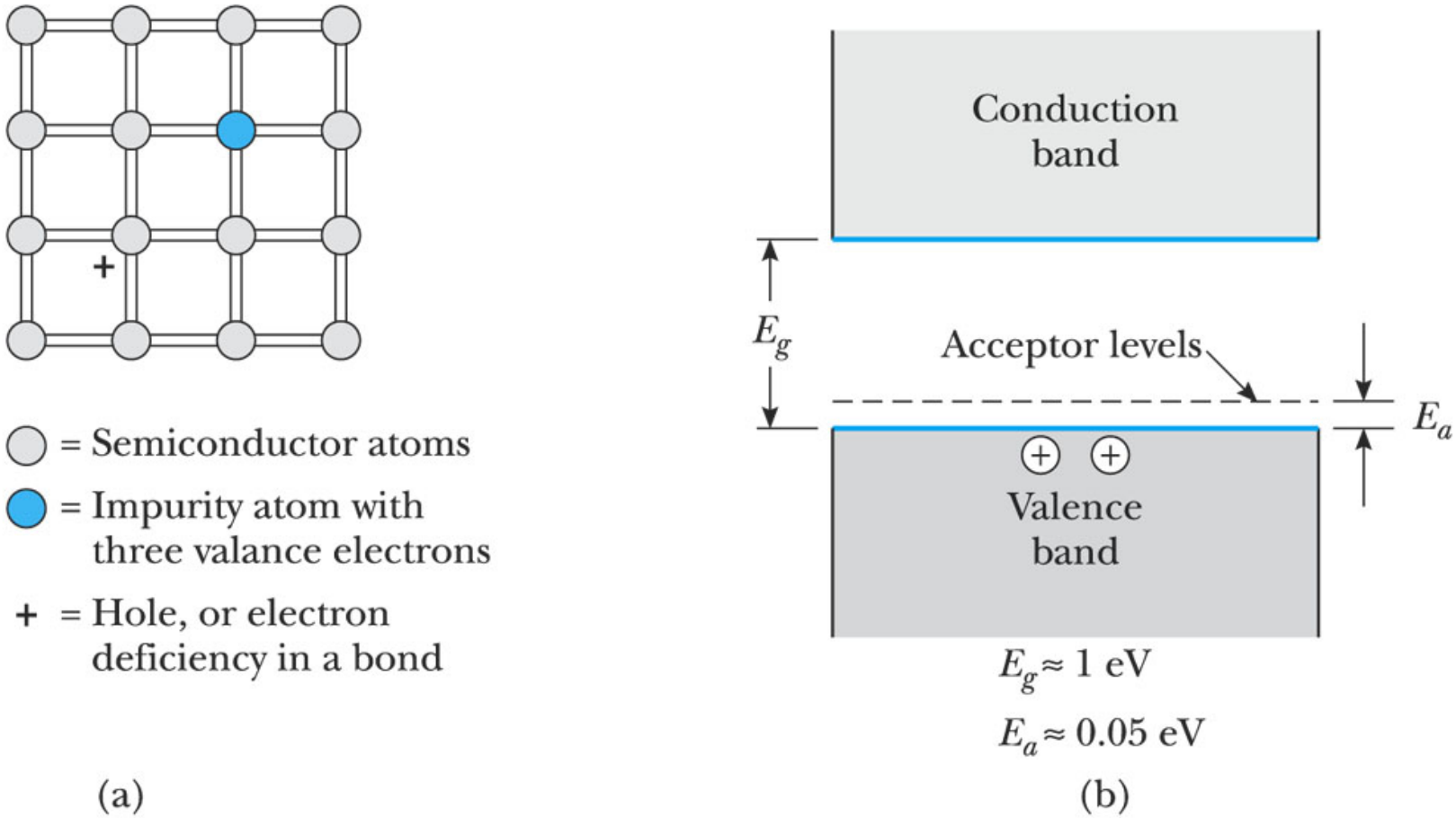


Fig. 12-28, p.434