

Ch. 12. The Solid State

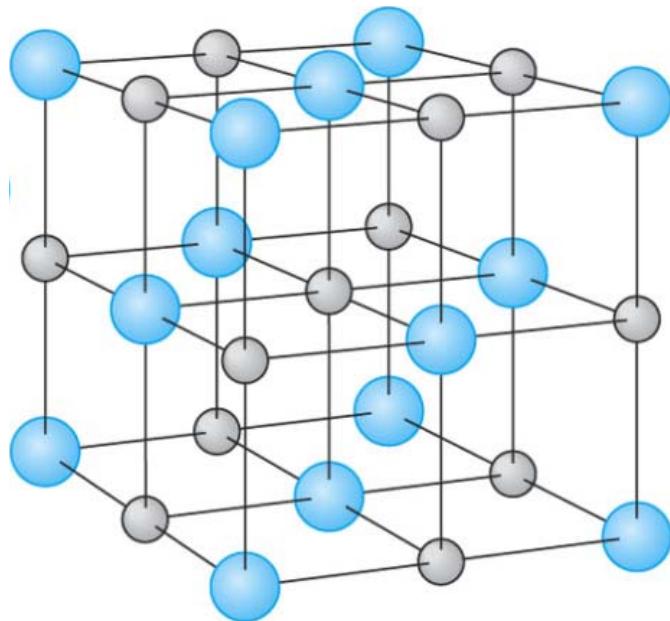
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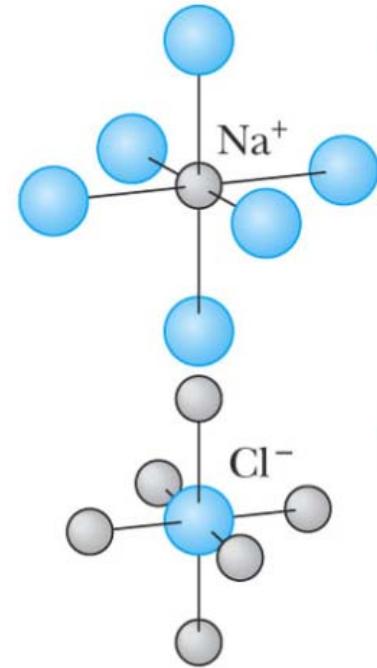
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Ionic Solid



(a)

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(b)

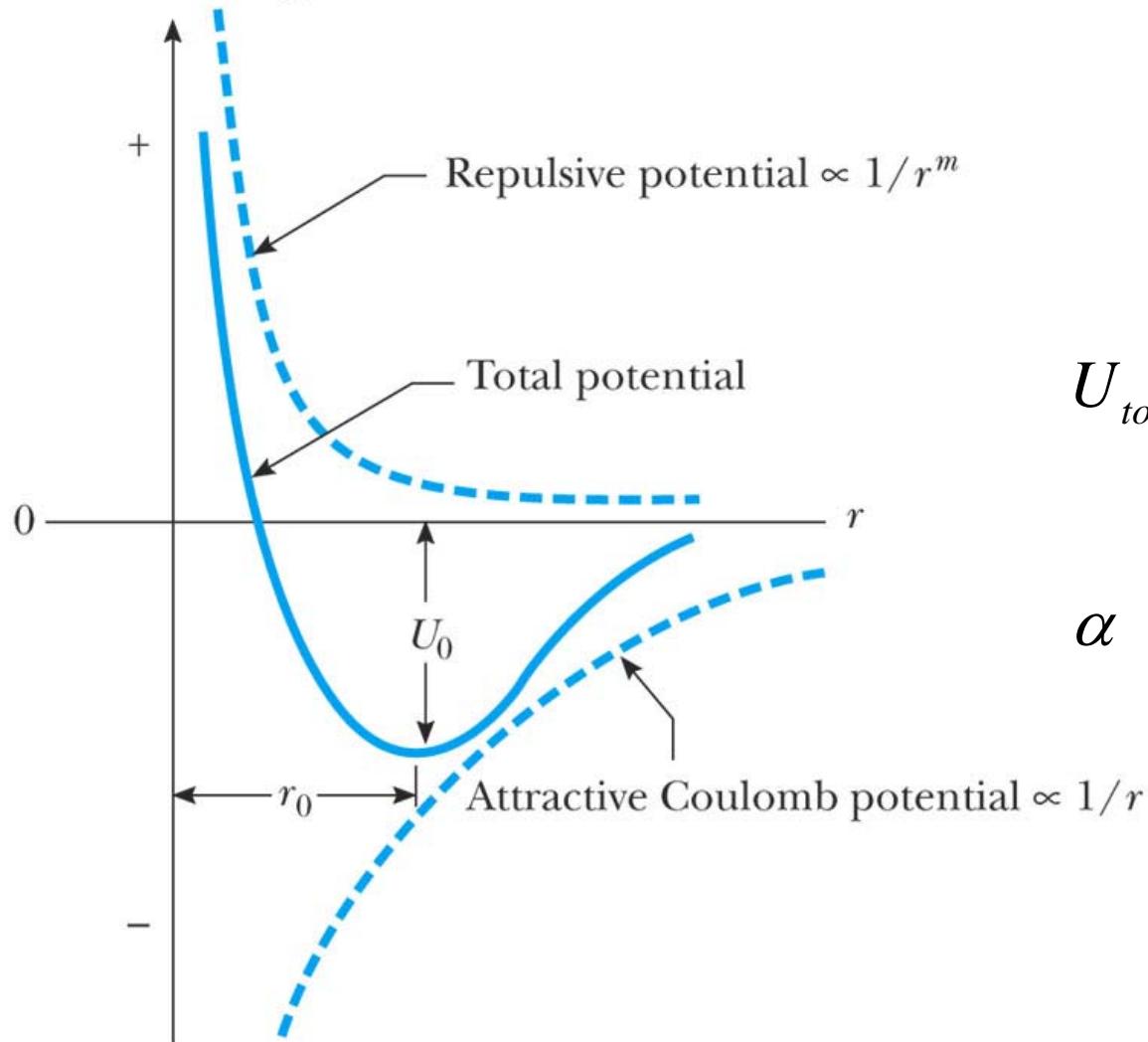
Fig. 12-1, p.405



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Potential energy



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

α Madelung constant

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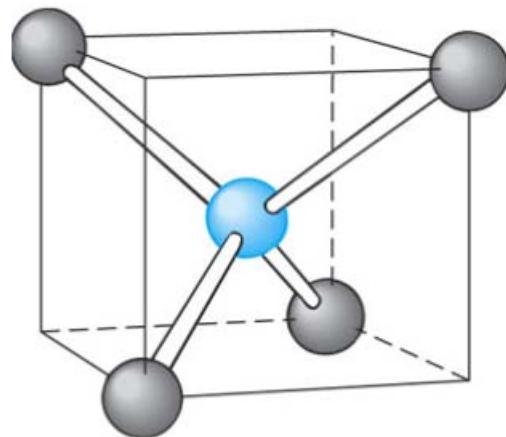
Fig. 12-2, p.406



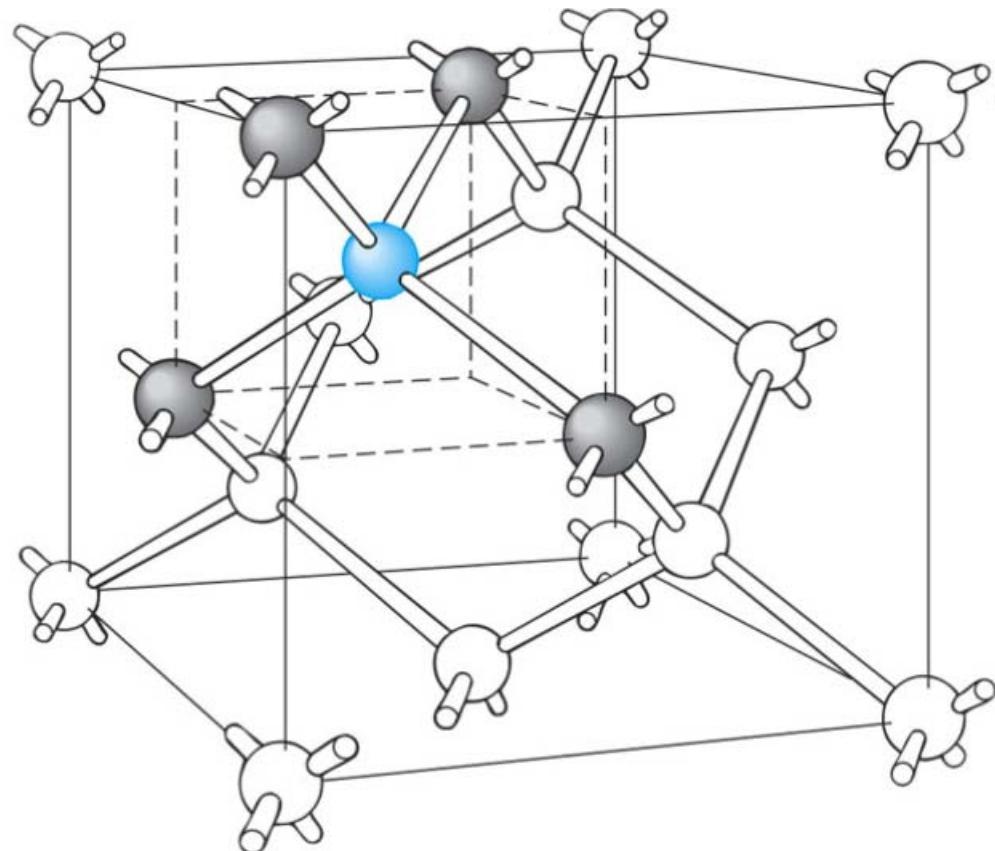
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Covalent Solid



(a)



(b)

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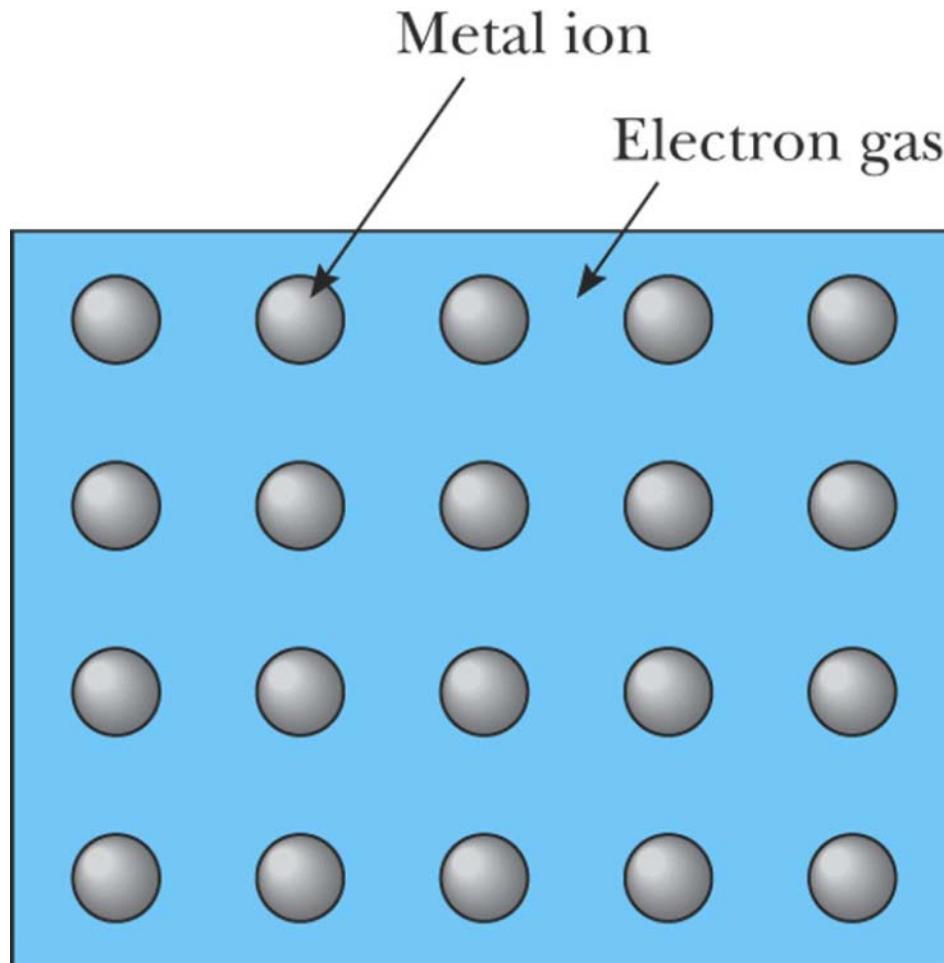
Fig. 12-3, p.408



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Metallic Solid



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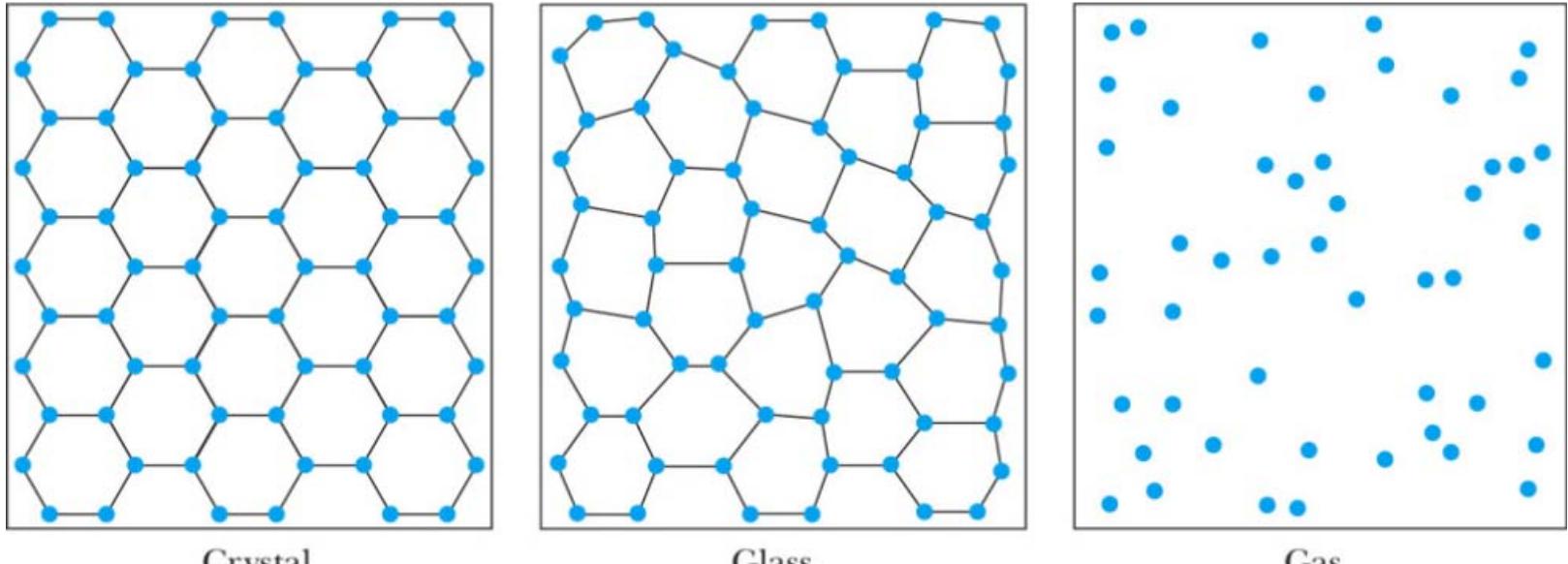
Fig. 12-4, p.409



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Amorphous Solid



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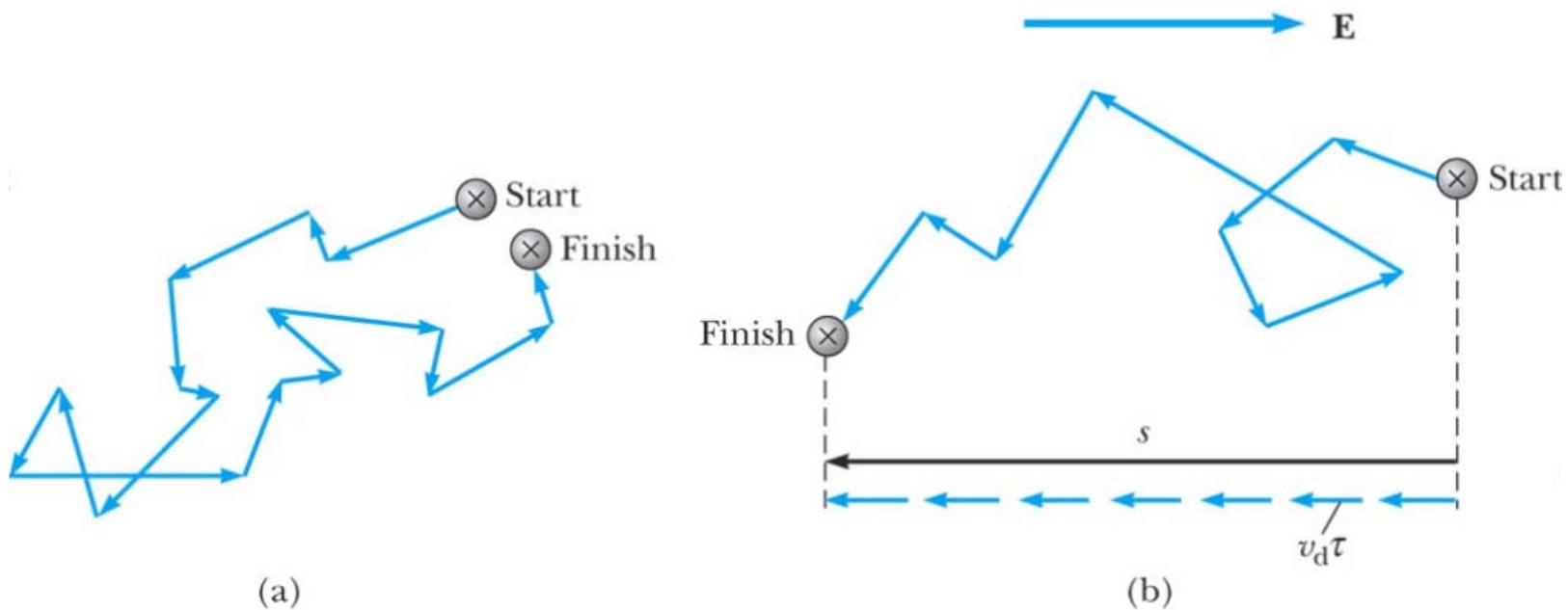
Fig. 12-5, p.410



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Ohm's Law



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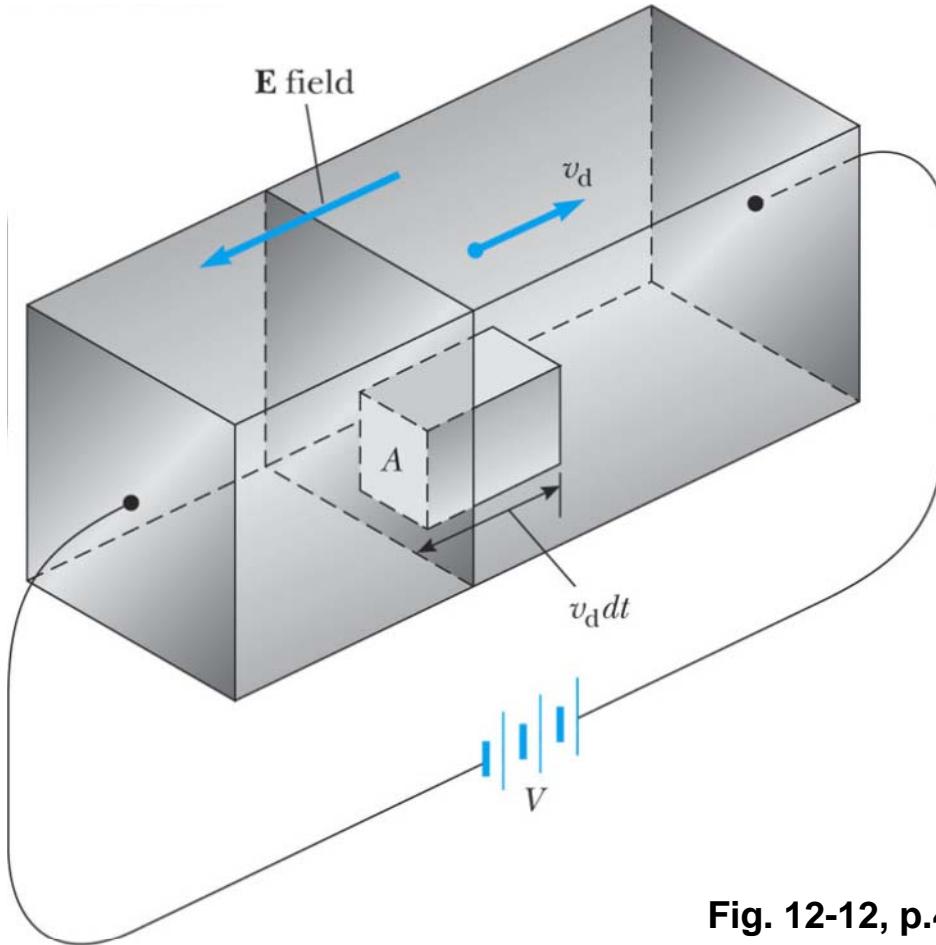
Fig. 12-11, p.415



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Ohm's Law



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

Fig. 12-12, p.416

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Ohm's Law

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

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

L mean free path

τ mean free time

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



Ohm's Law

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

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

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

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

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

$$s = v_d b\tau$$

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



Ohm's Law

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

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

Using Maxwell-Boltzmann rms thermal speed,

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

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



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

Substance	K in $\text{W} \cdot \text{m}^{-1}\text{K}^{-1}$	σ in $(\Omega \cdot \text{m})^{-1}$
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	$<10^{-4}$

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Table 12-5, p.414



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

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

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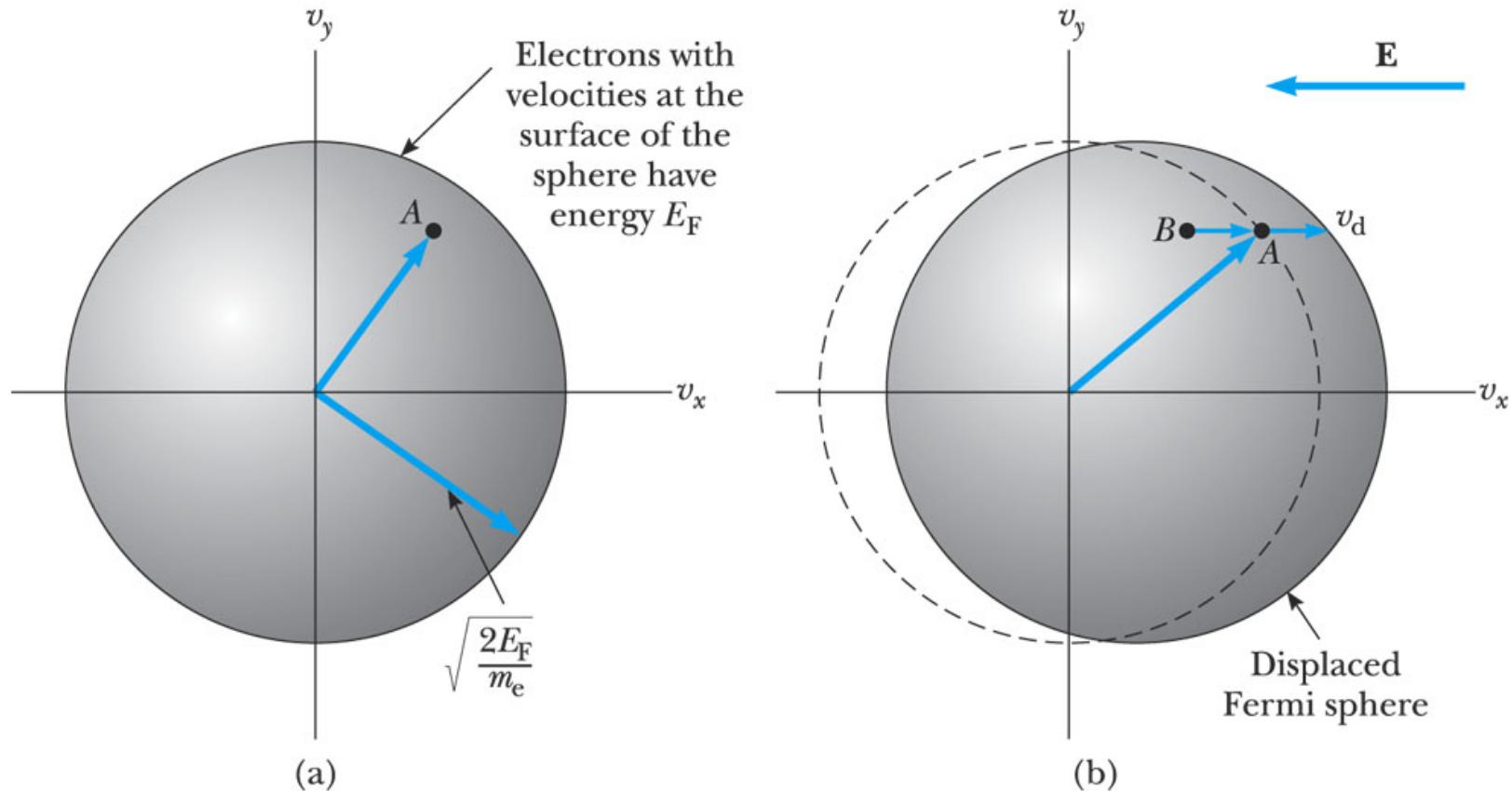
Table 12-7, p.420



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Quantum Theory of Metals



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Fig. 12-14, p.421



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Quantum Theory of Metals

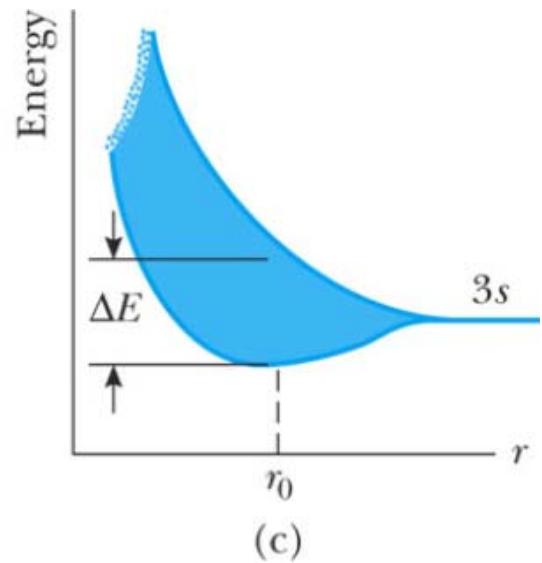
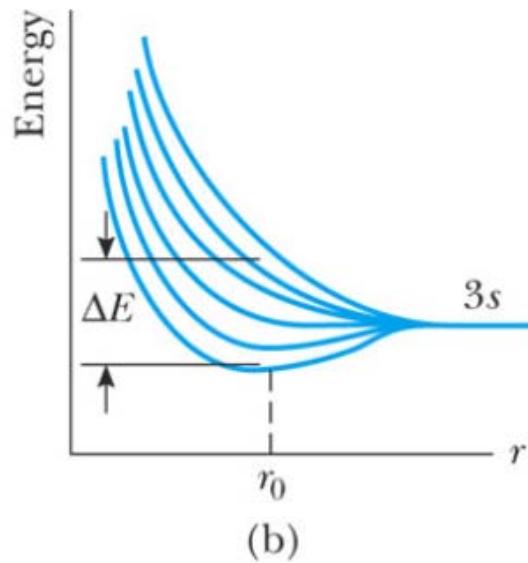
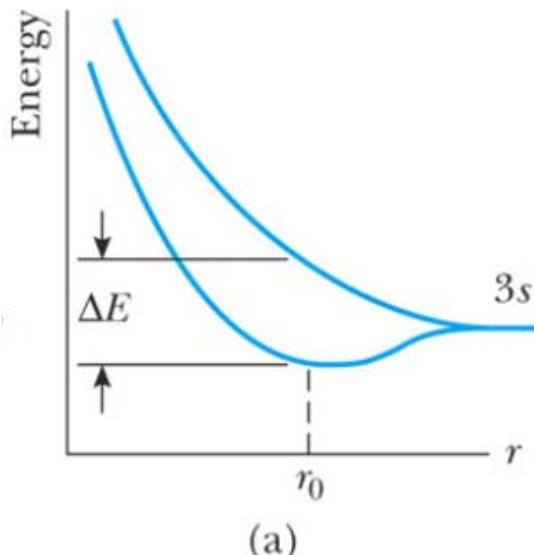
$$\sigma = \frac{ne^2 L}{m_e v_F}$$

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

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



Energy Band



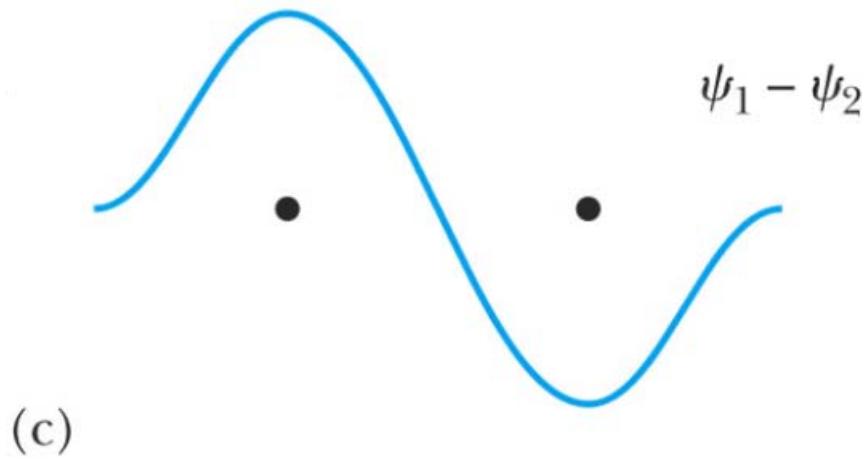
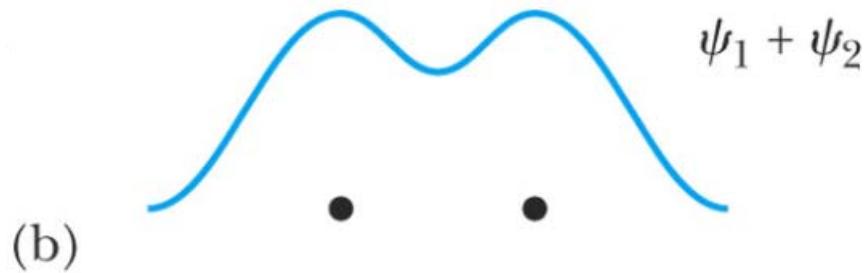
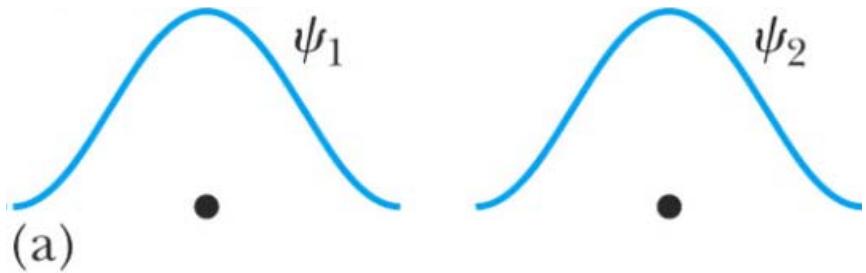
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Fig. 12-16, p.426



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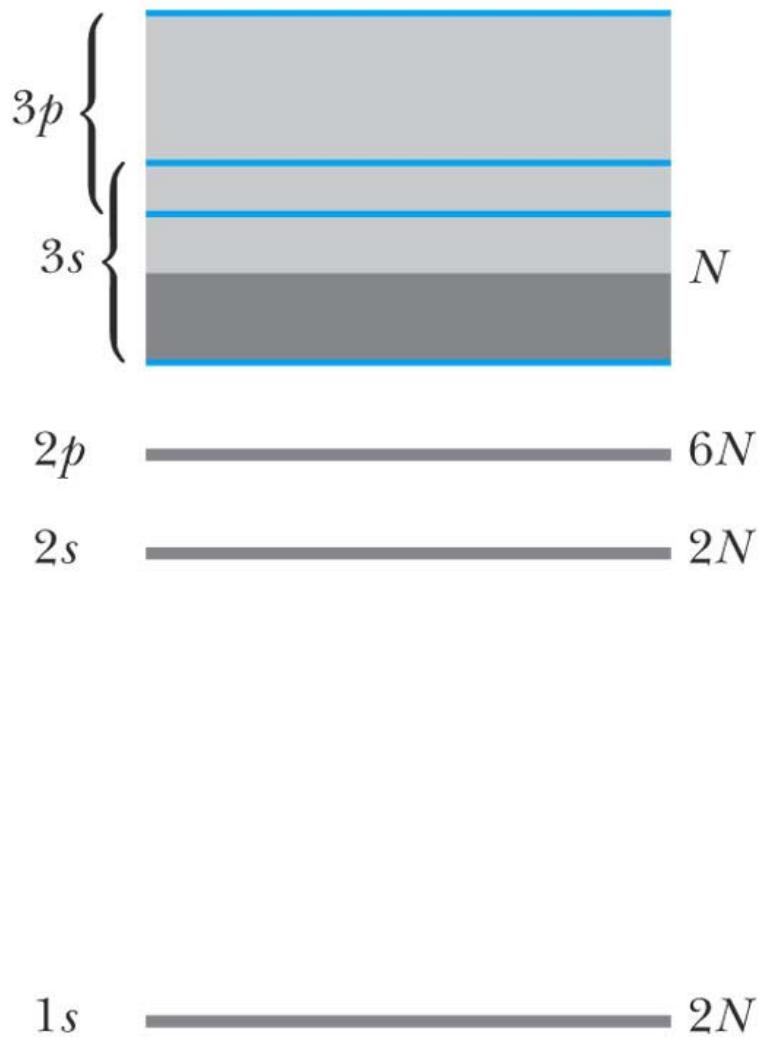
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Fig. 12-17, p.426



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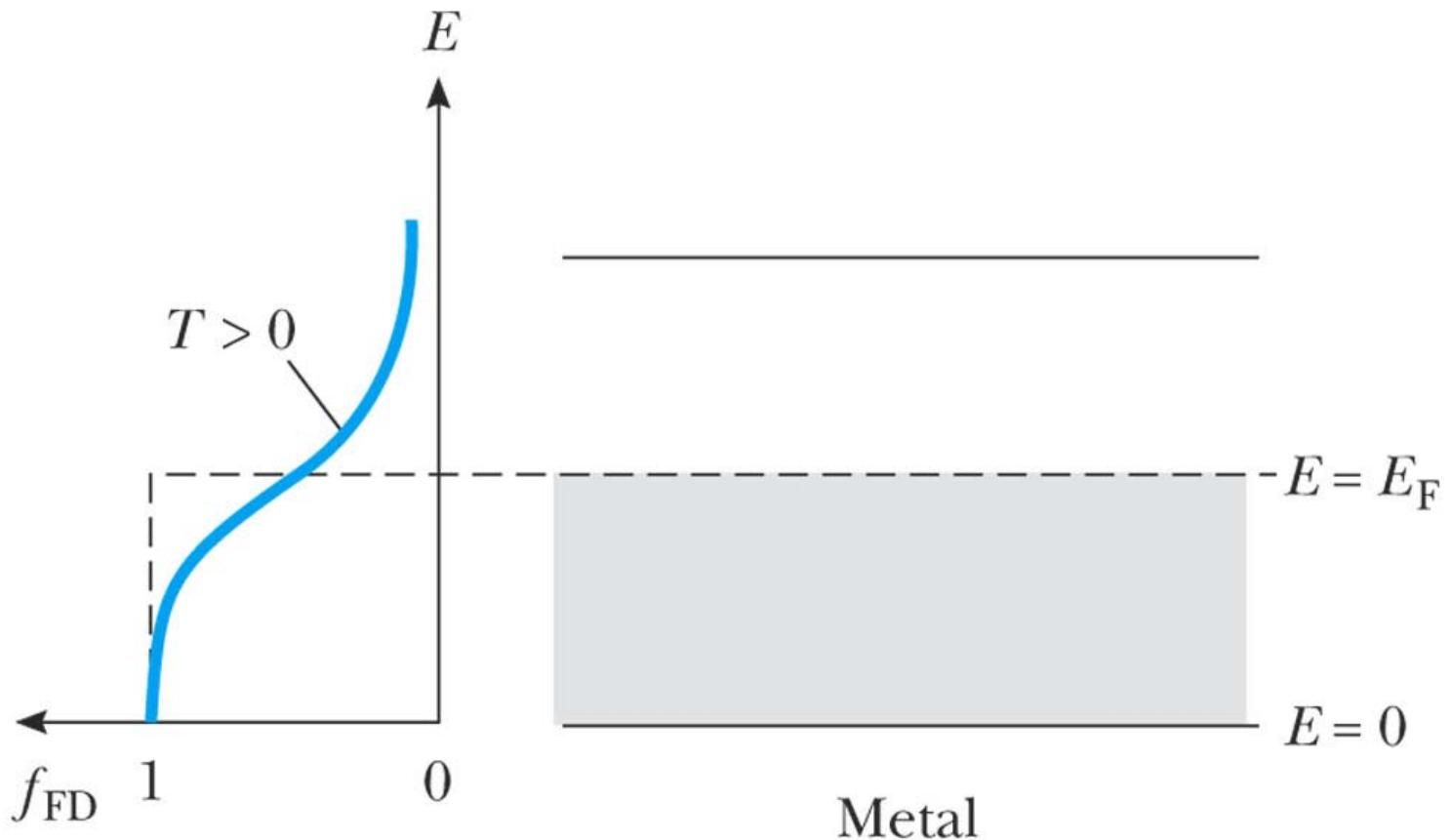
Fig. 12-18, p.426



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Metal



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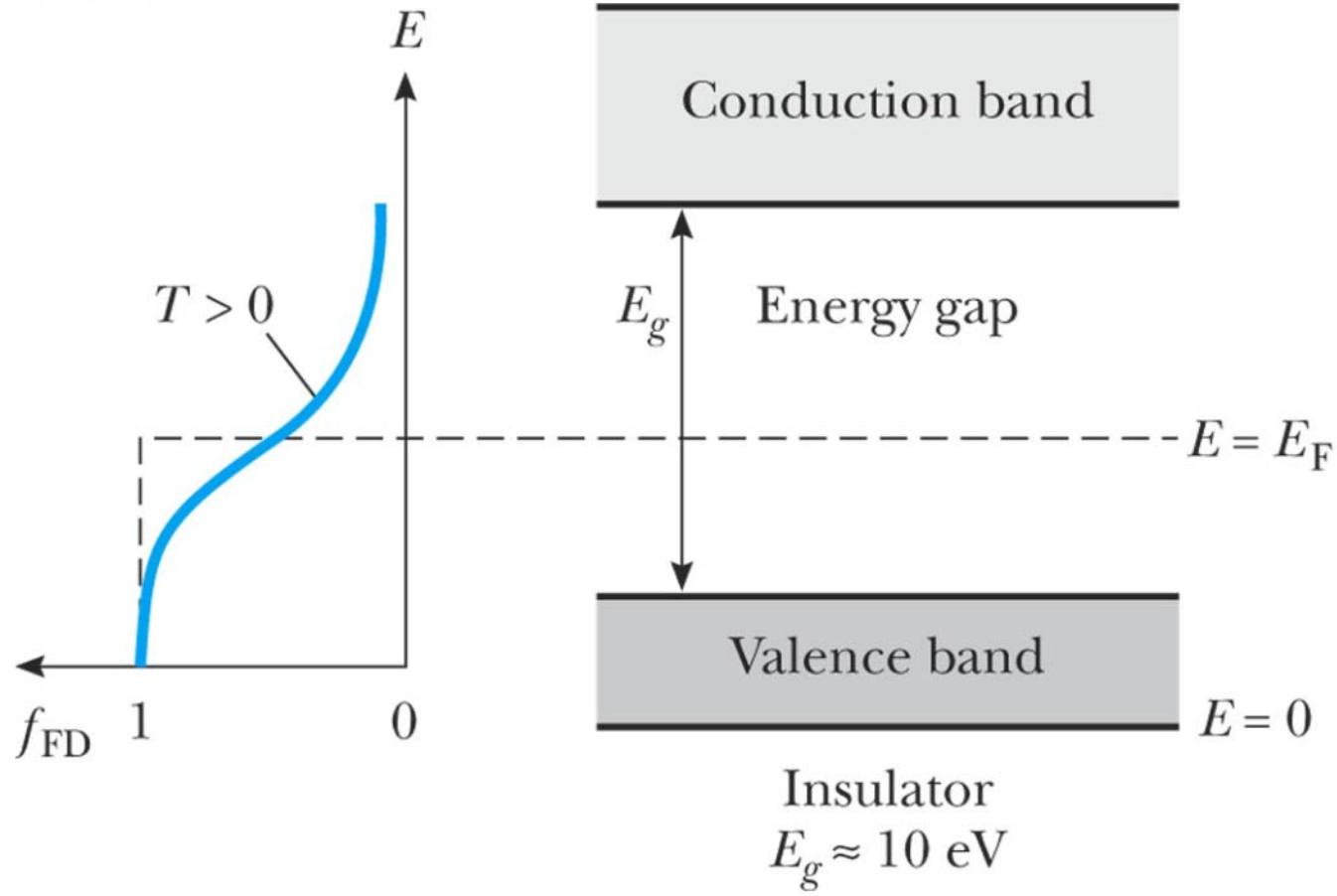
Fig. 12-19, p.427



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Insulator



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Fig. 12-20, p.428



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**Table 12.8 Energy-Gap
Values for Some
Semiconductors***

Crystal	$E_g(\text{eV})$	
	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

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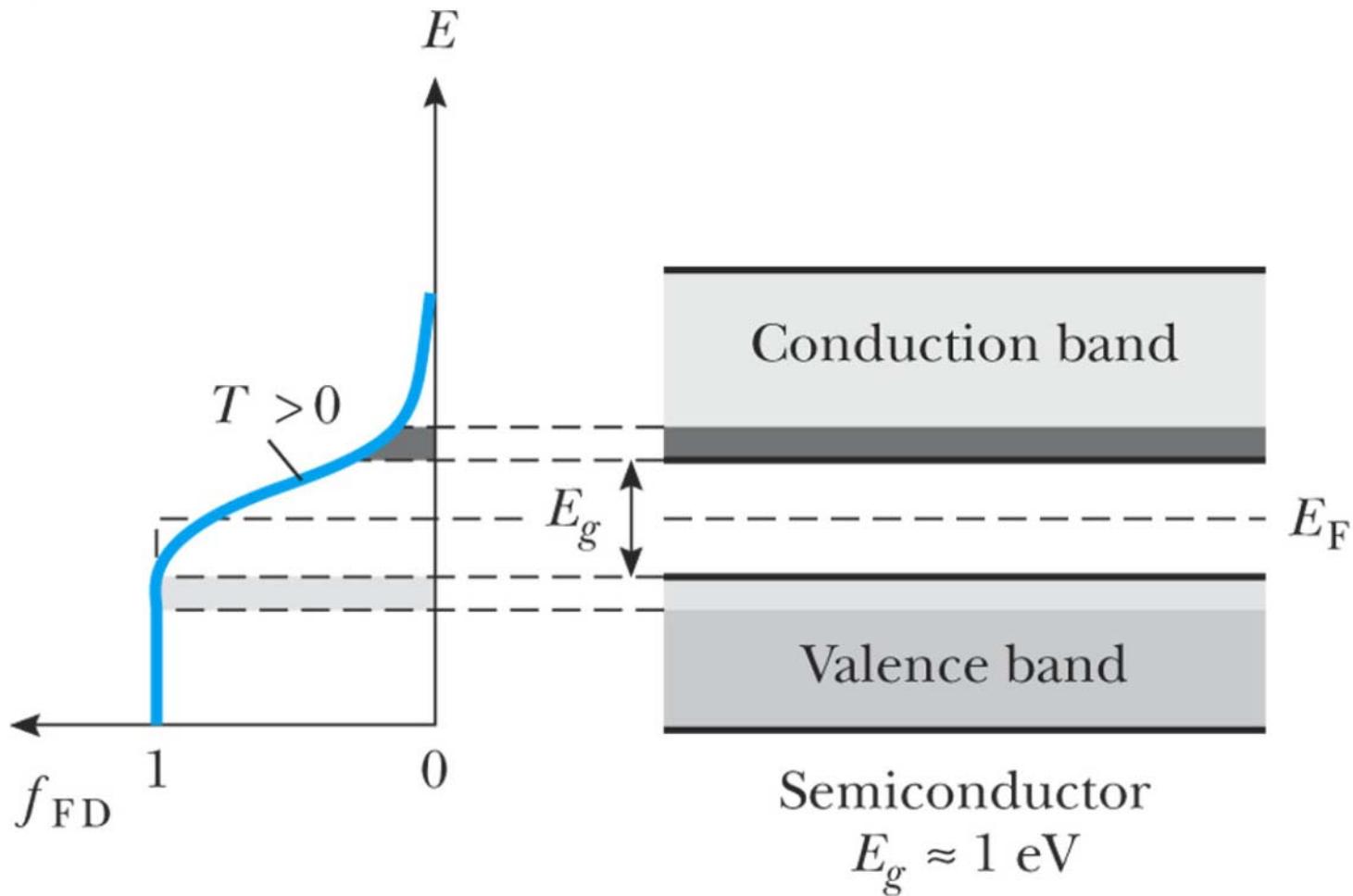
Table 12-8, p.428



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Semiconductor

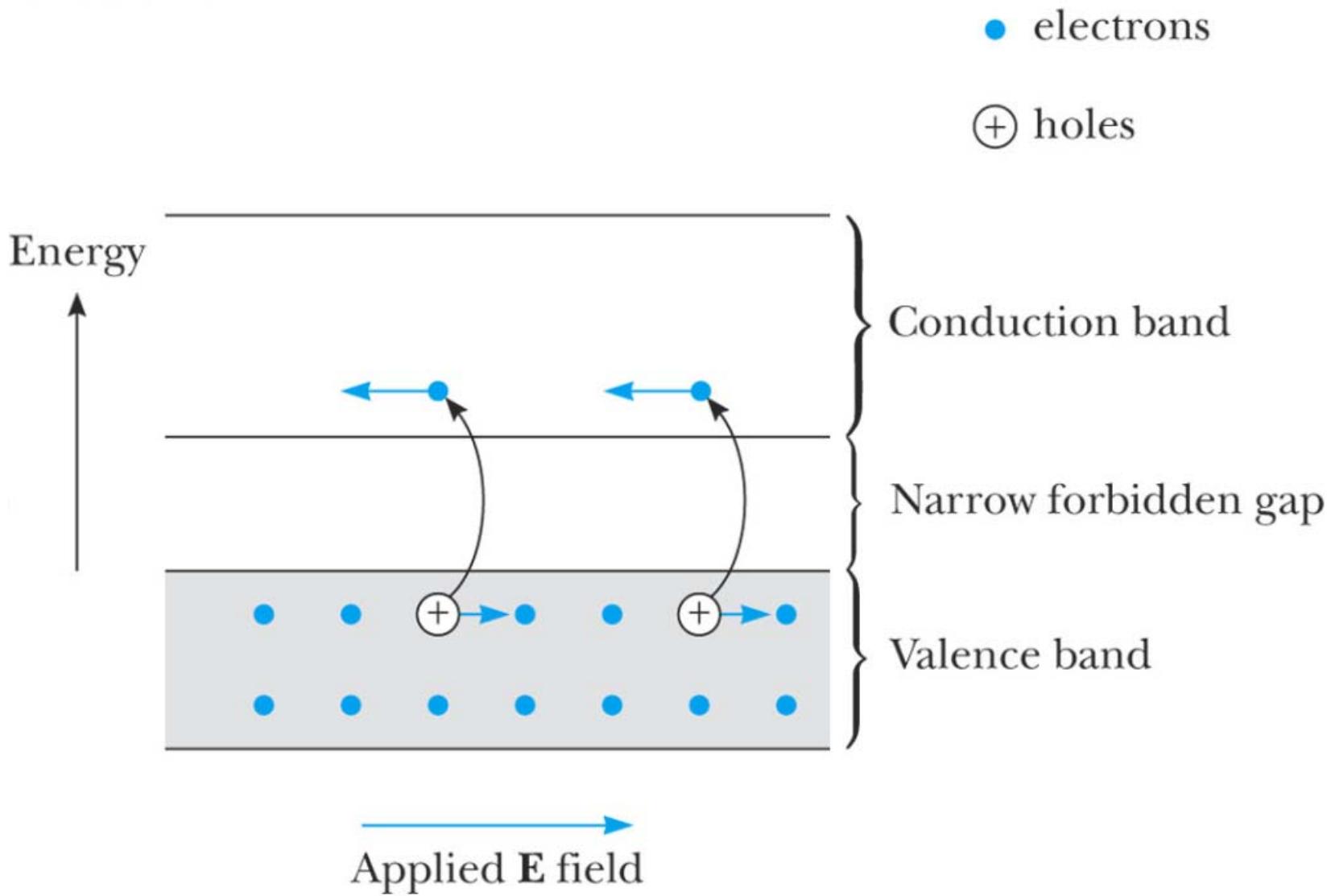


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Fig. 12-21, p.428



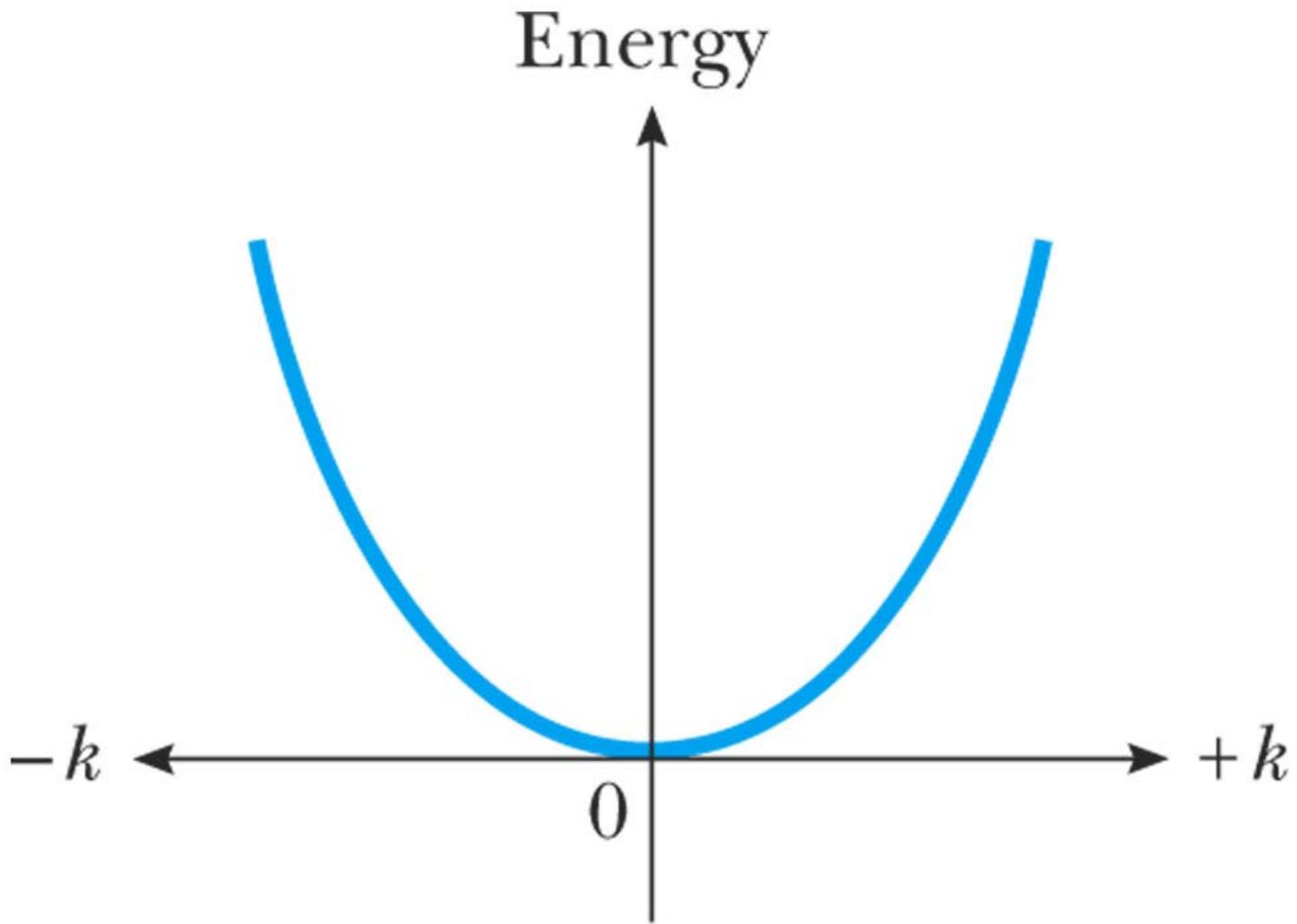
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Fig. 12-22, p.429



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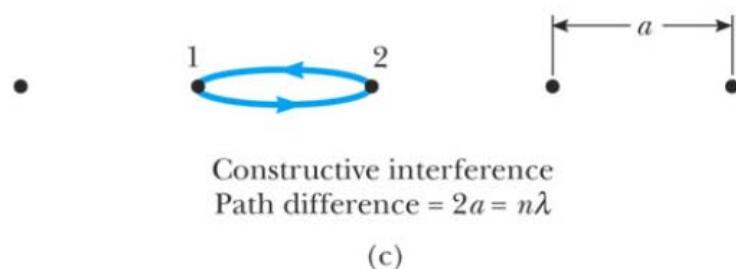
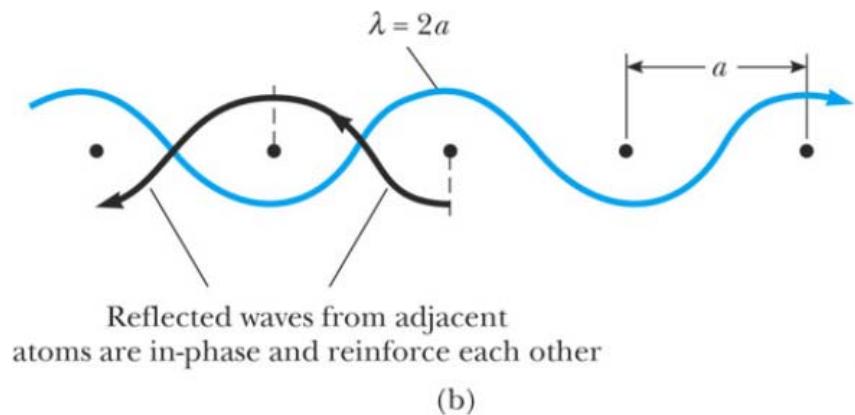
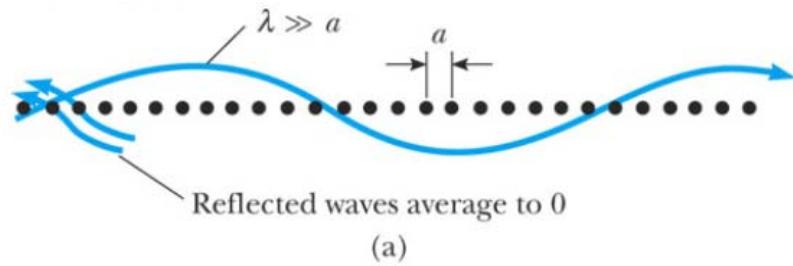
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Fig. 12-23, p.430



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$$2a = \pm n\lambda \quad n = 1, 2, 3, \dots$$

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

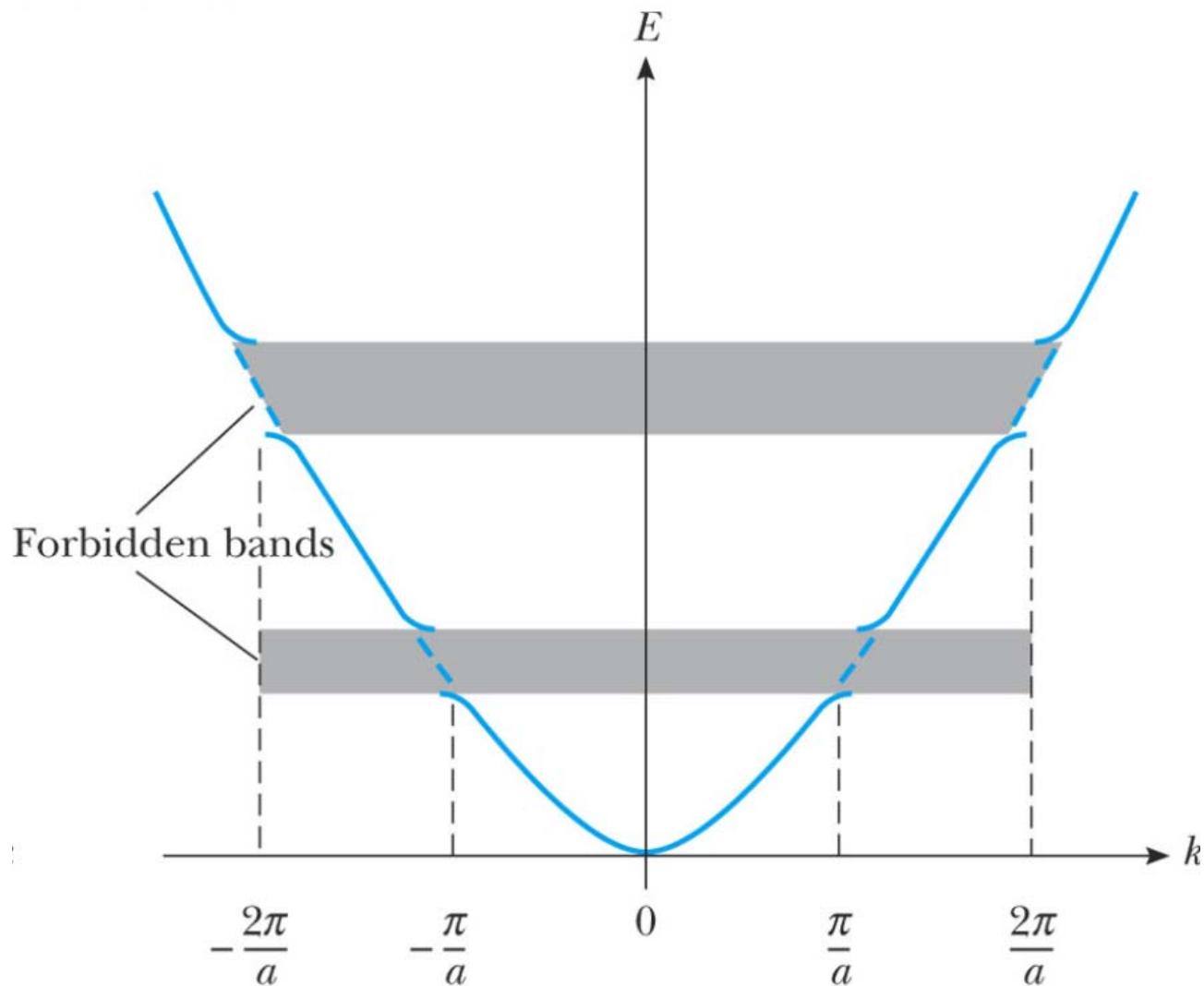
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Fig. 12-24, p.430



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

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

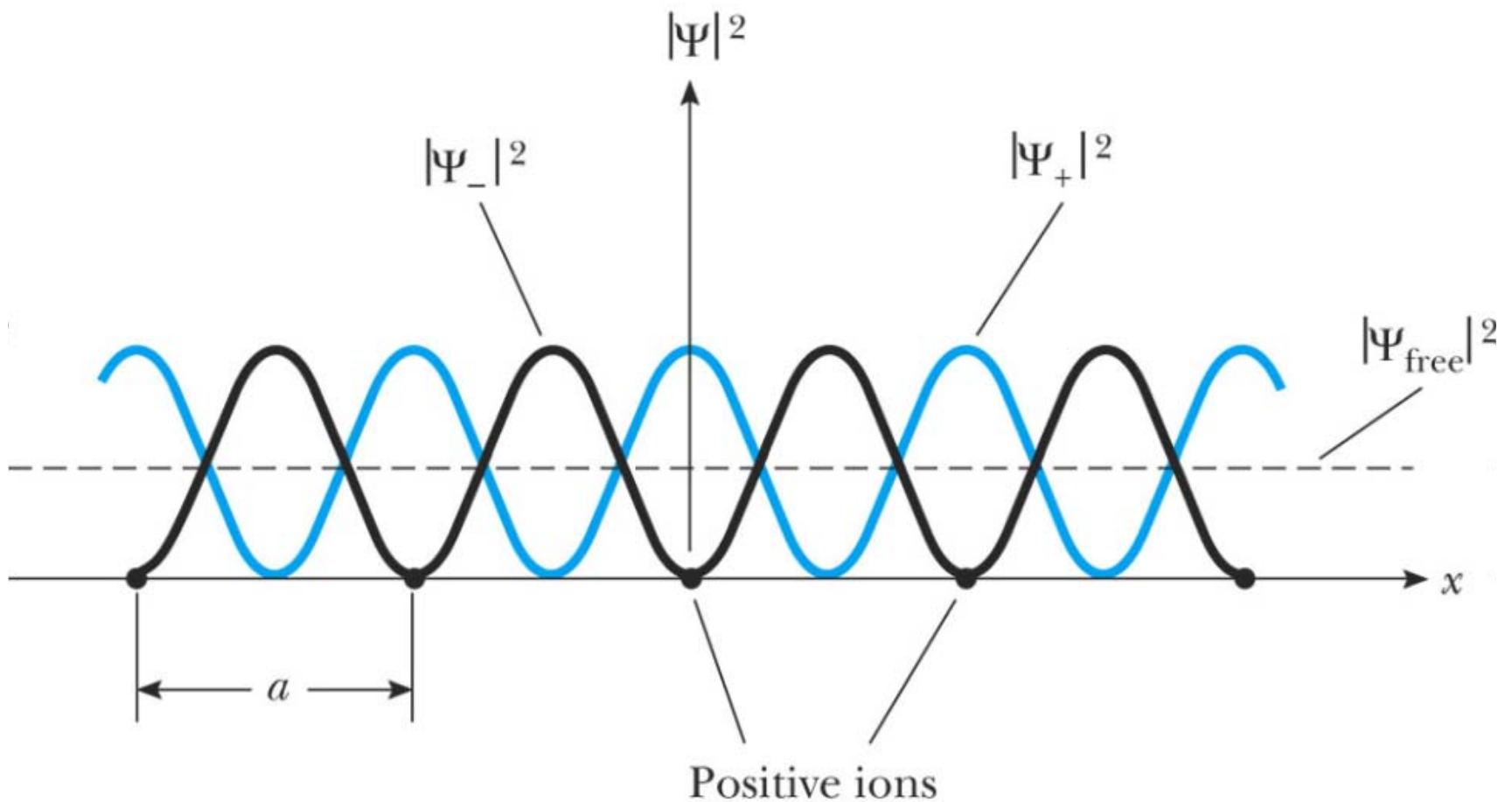
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Fig. 12-25, p.432



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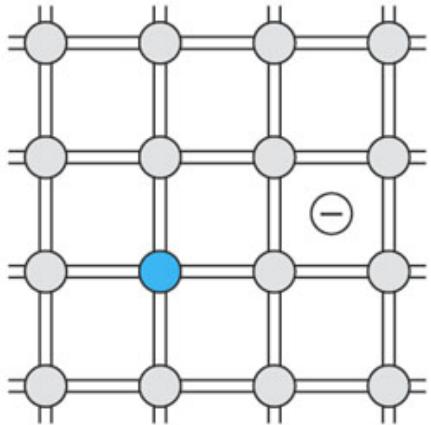
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Fig. 12-26, p.432



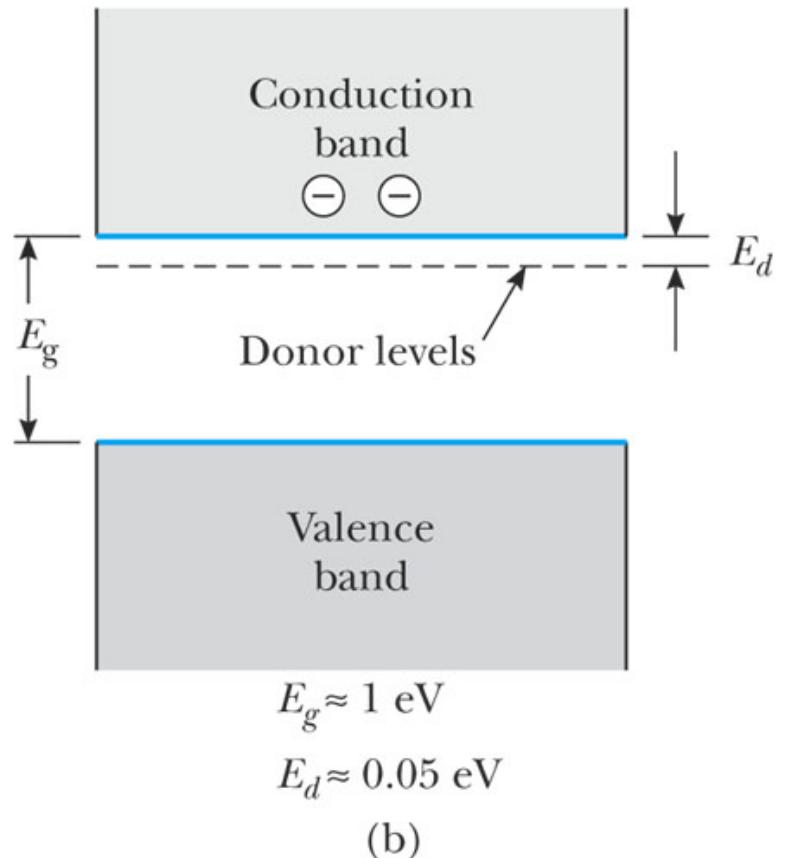
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- = Semiconductor atoms
- = Impurity atom with five valence electrons
- ⊖ = Extra electron from impurity atom

(a)



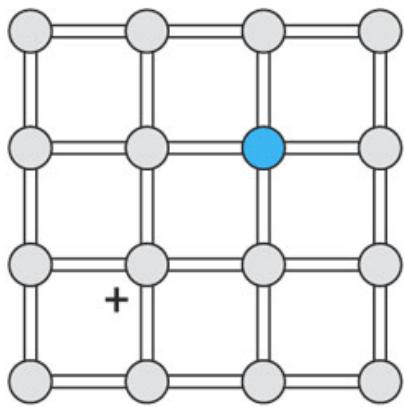
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Fig. 12-27, p.433



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○ = Semiconductor atoms

● = Impurity atom with
three valence electrons

⊕ = Hole, or electron
deficiency in a bond

(a)

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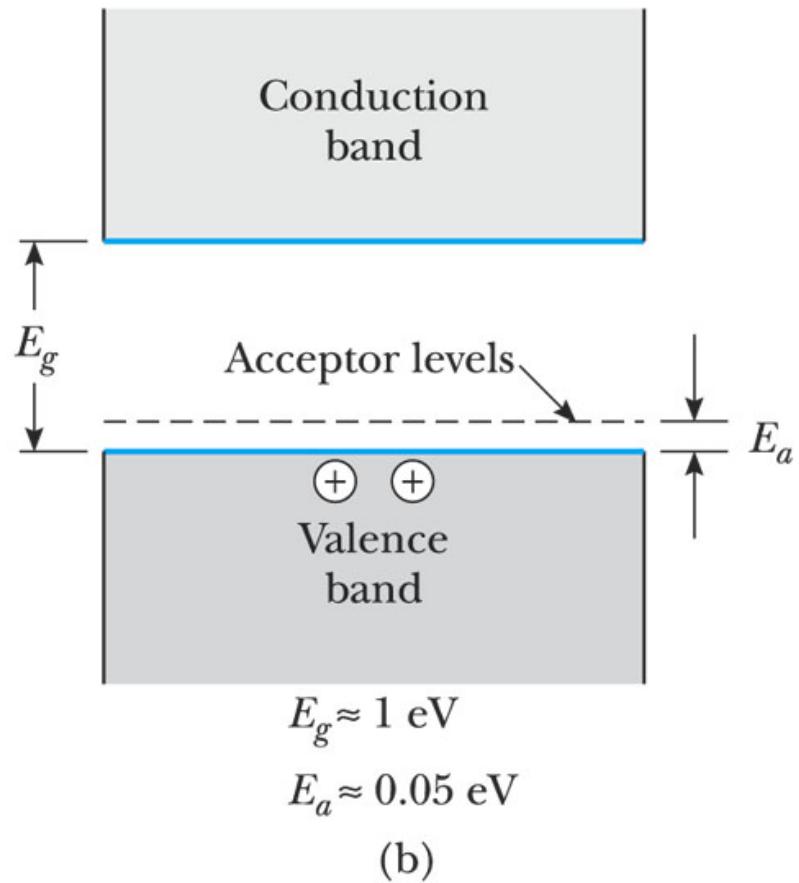


Fig. 12-28, p.434



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