

# Corrections 2

## Quantum Mechanics: Concepts and Applications by Nouredine Zettili

(Modified last on November 6, 2008)

**Note:** This list of corrections pertain to the book's re-prints that were produced **after 2001**.

### Physical Constants

- Back page of the front cover. Replace the proton Compton wavelength "1.321 × 10<sup>-17</sup> m" by "1.321 × 10<sup>-15</sup> m".

### Chapter 1

- Page 5, Caption of Figure 1.1, replace  $T_1 < T_2 < T_3$  by  $T_1 > T_2 > T_3$ .
- Page 8, remove the second tilde in Eq. (1.11); i.e., replace Eq. (1.11) by

$$\tilde{u}(\lambda, T) = u(\nu, T) \left| \frac{d\nu}{d\lambda} \right| = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}.$$

- Page 8, replace Eq. (1.13) by

$$\frac{\alpha}{\lambda} = 5 \left( 1 - e^{-\alpha/\lambda} \right).$$

- Page 12, replace Example 1.2 by:

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**Example 1.2** When two ultraviolet beams of wavelengths  $\lambda_1 = 80\text{nm}$  and  $\lambda_2 = 110\text{nm}$  fall on a lead surface, they produce photoelectrons with maximum energies 11.390 eV and 7.154 eV, respectively.

- Estimate the numerical value of the Planck constant.
- Calculate the work function and the cutoff frequency of lead

**Solution**

(a) From (1.21) we can write the kinetic energies of the emitted electrons as  $K_1 = hc/\lambda_1 - W$  and  $K_2 = hc/\lambda_2 - W$ ; the difference between these two expressions is given by  $K_1 - K_2 = hc(\lambda_2 - \lambda_1)/(\lambda_1\lambda_2)$ , hence

$$h = \frac{K_1 - K_2}{c} \frac{\lambda_1\lambda_2}{\lambda_2 - \lambda_1}. \quad (1)$$

Since  $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$ , the numerical value of  $h$  follows at once:

$$h = \frac{(11.390 - 7.154) \times 1.6 \times 10^{-19} \text{ J}}{3 \times 10^8 \text{ m s}^{-1}} \times \frac{(80 \times 10^{-9} \text{ m})(110 \times 10^{-9} \text{ m})}{110 \times 10^{-9} \text{ m} - 80 \times 10^{-9} \text{ m}} \simeq 6.627 \times 10^{-34} \text{ J s}. \quad (2)$$

This is a very accurate result indeed.

(b) The work function of the metal can be obtained from either one of the two data

$$\begin{aligned} W = \frac{hc}{\lambda_1} - K_1 &= \frac{6.627 \times 10^{-34} \text{ J s} \times 3 \times 10^8 \text{ m s}^{-1}}{80 \times 10^{-9} \text{ m}} - 11.390 \times 1.6 \times 10^{-19} \text{ J} \\ &= 6.627 \times 10^{-19} \text{ J} = 4.14 \text{ eV}. \end{aligned} \quad (3)$$

The cutoff frequency of the metal is

$$\nu_0 = \frac{W}{h} = \frac{6.627 \times 10^{-19} \text{ J}}{6.627 \times 10^{-34} \text{ J s}} = 1.0 \times 10^{15} \text{ Hz}. \quad (4)$$

- Page 15, first line of solution to part (c), replace  $E = 15 \text{ MeV}$  by  $E = 150 \text{ MeV}$ .
- Page 18, replace  $75 \text{ eV}$  by  $54 \text{ eV}$  in line 10 from bottom.
- Page 19, replace  $d = 9.1 \text{ nm}$  by  $d = 0.091 \text{ nm}$  in line 8 from top.
- Page 19, replace Eq. (1.47) by

$$\lambda = \frac{2d}{n} \sin \phi = \frac{2d}{n} \cos \frac{1}{2}\theta = \frac{2 \times 0.091 \text{ nm}}{1} \cos 25 = 0.165 \text{ nm}.$$

- Page 19, two lines above Eq. (1.48), replace  $\hbar c \simeq 19732.8 \text{ eV nm}$  by  $\hbar c \simeq 197.33 \text{ eV nm}$ .
- Page 19, replace Eq. (1.48) by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_e K}} = \frac{2\pi\hbar c}{\sqrt{2m_e c^2 K}} = 0.167 \text{ nm},$$

- Page 20, Footnote 12, replace  $m_e/m_b \simeq 10^{-30}$  by  $m_e/m_b \simeq 10^{-29}$ .
- Page 21, Eq. (1.51), replace  $0.01 \text{ kg}$  by  $0.1 \text{ kg}$ , and  $7.4 \times 10^{-34} \text{ m}$  by  $7.4 \times 10^{-36} \text{ m}$ .
- Page 21, line after Eq. (1.51), replace  $2.2 \times 10^{-19} \text{ m}$  by  $2.2 \times 10^{-21} \text{ m}$ .
- Page 32, first line, replace  $a_0 = 5.3 \text{ nm}$  by  $a_0 = 0.053 \text{ nm}$ .
- Page 35, line after Eq. (1.82), replace  $a_0 = 4\pi\epsilon_0\hbar^2/(m_e e^2) = 5.3 \text{ nm}$  by  $a_0 = 4\pi\epsilon_0\hbar^2/(m_e e^2) = 0.053 \text{ nm}$ .
- Page 35, part (b) in the solution of Example 1.7, replace  $r_1 = 2a_0 = 10.6 \text{ nm}$ ,  $r_2 = 8a_0 = 42.4 \text{ nm}$  and  $r_3 = 18a_0 = 95.4 \text{ nm}$  by  $r_1 = 2a_0 = 0.106 \text{ nm}$ ,  $r_2 = 8a_0 = 0.424 \text{ nm}$  and  $r_3 = 18a_0 = 0.954 \text{ nm}$ .

- Page 46, replace Eq. (1.129) by

$$\psi(x, t) = e^{ik_0(x-v_{ph}t)} f(x, t),$$

- Page 46, replace Eq. (1.130) by

$$f(x, t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} g(q) e^{iq(x-v_g t)} e^{-iq^2 \alpha t} dq,$$

- Page 56, replace Eq. (1.165) by

$$\lambda_1 = \frac{hc}{2e(V_{s_1} - V_{s_2})} = \frac{6.6 \times 10^{-34} \text{ J s} \times 3 \times 10^8 \text{ m s}^{-1}}{2 \times 1.6 \times 10^{-19} \text{ C} \times (3.2 \text{ V} - 0.8 \text{ V})} = 2.6 \times 10^{-7} \text{ m}.$$

- Page 59, replace the final result of Eq. (1.188) (i.e., 2.3 eV) by 2.3 MeV.

- Page 68, replace Eq. (1.233) by

$$r_0 = \frac{4\pi\epsilon_0 \hbar^2}{m_e e^2} = 0.053 \text{ nm}.$$

- Page 61, replace Eq. (1.193) by

$$r_{n_c} = \frac{a_0}{6} n^2, \quad E_{n_c} = -\frac{36\mathcal{R}}{n^2}$$

- Page 65, replace the solution to Problem 1.14 by

Using the relation  $\cos(\alpha \pm \beta) = \cos \alpha \cos \beta \mp \sin \alpha \sin \beta$ , we can write the superposition of  $\psi_1(y, t)$  and  $\psi_2(y, t)$  as follows:

$$\begin{aligned} \psi(y, t) &= \psi_1(y, t) + \psi_2(y, t) = 5y \cos 7t - 5y \cos 9t \\ &= 5y (\cos 8t \cos t + \sin 8t \sin t) - 5y (\cos 8t \cos t - \sin 8t \sin t) \\ &= 10y \sin t \sin 8t. \end{aligned}$$

The periods of  $10y \sin t$  and  $\sin(8t)$  are given by  $2\pi$  and  $2\pi/8$ , respectively. Since the period of  $10y \sin t$  is larger than that of  $\sin 8t$ ,  $10y \sin t$  must be the modulating function and  $\sin 8t$  the modulated function. As depicted in Figure 1.18, we see that  $\sin 8t$  is modulated by  $10y \sin t$ .

- Page 69, replace the final result (i.e.,  $1.2 \times 10^{-21}$  s) of Eq.(1.235) by  $3.2 \times 10^{-21}$  s.

- Page 70, replace Eq.(1.245) by

$$\omega_{nm} = \frac{E_n - E_m}{\hbar} = \frac{3}{2} \left( \frac{k^2}{\mu \hbar} \right)^{1/3} \left( n^{2/3} - m^{2/3} \right).$$

- Page 70, replace the final result (i.e., 0.733 fm) of Eq.(1.247) by 0.427 fm.

- Page 72, Exercise 1.13, replace 3.9 eV by 1.9 eV.

- Page 72, Exercise 1.15, replace 12 V by 1.2 V.

- Page 73, Exercise 1.24, replace 0.8nm and 17nm by 0.0008nm and 0.0017nm, respectively.

- Page 74, Exercise 1.25, replace 0.05 MeV by 0.5 MeV.

- Page 75, Problem 1.34, replace 5.3nm by 0.053 nm.

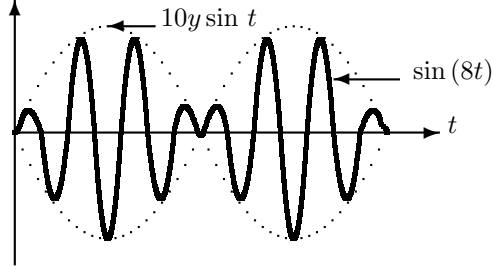


Figure 1: Shape of the wave packet  $\psi(y, t) = 10y \sin t \sin 8t$ . The function  $\sin 8t$ , the solid curve, is modulated by  $10y \sin t$ , the dashed curve.

## Chapter 2

- Page 82, replace Eq.(2.13) by

$$-a_1 + a_2 - a_3 = 0, \quad a_1 + a_2 + a_3 = 0, \quad 3a_1 + 9a_2 + 27a_3 = 0$$

- Page 83, replace Eq.(2.15) by

$$3a_1 = 0, \quad -2a_2 = 0, \quad -a_3 = 0,$$

- Page 83, Line after Eq.(2.16), replace  $a_1 = -3a_2$  by  $a_1 = a_2/3$

- Page 87, replace Eq.(2.39) by

$$\begin{aligned} |\psi + \chi\rangle &= |\psi\rangle + |\chi\rangle = (3i|\phi_1\rangle - 7i|\phi_2\rangle) + (-|\phi_1\rangle + 2i|\phi_2\rangle) \\ &= (-1 + 3i)|\phi_1\rangle - 5i|\phi_2\rangle. \end{aligned}$$

- Page 91, replace  $f(\hat{A})$  in part (b) of Example 2.4 by  $f(\hat{A}) = (1 + i\hat{A} + 3\hat{A}^2)(1 - 2i\hat{A} - 9i\hat{A}^2)/(5 + 7\hat{A})$ .

- Page 93, replace Eq. (2.86) by

$$[\hat{A}, \hat{B}^n] = \sum_{j=0}^{n-1} \hat{B}^j [\hat{A}, \hat{B}] \hat{B}^{n-j-1}$$

- Page 93, replace Eq. (2.87) by

$$[\hat{A}^n, \hat{B}] = \sum_{j=0}^{n-1} \hat{A}^{n-j-1} [\hat{A}, \hat{B}] \hat{A}^j$$

- Page 93, replace Eq. (2.90) by

$$\begin{aligned} [\hat{A}, [\hat{B}, \hat{C}]\hat{D}] &= [\hat{B}, \hat{C}][\hat{A}, \hat{D}] + [\hat{A}, [\hat{B}, \hat{C}]]\hat{D} \\ &= (\hat{B}\hat{C} - \hat{C}\hat{B})(\hat{A}\hat{D} - \hat{D}\hat{A}) + \hat{A}(\hat{B}\hat{C} - \hat{C}\hat{B})\hat{D} - (\hat{B}\hat{C} - \hat{C}\hat{B})\hat{A}\hat{D} \\ &= \hat{C}\hat{B}\hat{D}\hat{A} - \hat{B}\hat{C}\hat{D}\hat{A} + \hat{A}\hat{B}\hat{C}\hat{D} - \hat{A}\hat{C}\hat{B}\hat{D}. \end{aligned}$$

- Page 95, replace Eq. (2.103) by

$$e^{a\hat{A}} = \sum_{n=0}^{\infty} \frac{a^n}{n!} \hat{A}^n = \hat{I} + a\hat{A} + \frac{a^2}{2!} \hat{A}^2 + \frac{a^3}{3!} \hat{A}^3 + \dots$$

- Page 102, replace Eq. (2.157) by

$$\hat{U}_\alpha(\hat{G}) = \lim_{N \rightarrow \infty} \prod_{k=1}^N \left(1 + i \frac{\alpha}{N} \hat{G}\right) = \lim_{N \rightarrow +\infty} \left(1 + i \frac{\alpha}{N} \hat{G}\right)^N = e^{i\alpha\hat{G}},$$

- Page 104, replace Eq. (2.165) by

$$\begin{aligned} \langle \psi | \longrightarrow & (\langle \psi | \phi_1 \rangle \quad \langle \psi | \phi_2 \rangle \quad \dots \quad \langle \psi | \phi_n \rangle \quad \dots) \\ & = (\langle \phi_1 | \psi \rangle^* \quad \langle \phi_2 | \psi \rangle^* \quad \dots \quad \langle \phi_n | \psi \rangle^* \quad \dots) \\ & = (a_1^* \quad a_2^* \quad \dots \quad a_n^* \quad \dots). \end{aligned}$$

- Page 105, replace the statement "So a square matrix  $A$  is symmetric if it is equal to its transpose,  $A^T = -A$ " right after Eq. (2.172) by "So a square matrix  $A$  is symmetric if it is equal to its transpose,  $A^T = A$ ". (i.e., the minus sign in  $A^T = -A$  should be tossed).

- Page 106, replace the term  $B_{32}$  in Eq. (2.184) by

$$B_{32} = (-1)^5 \begin{vmatrix} 2 & 0 \\ 3 & 5 \end{vmatrix} = -10.$$

- Page 118, replace Eq. (2.263) by

$$|\psi\rangle \longrightarrow \begin{pmatrix} \vdots \\ \langle \chi_k | \psi \rangle \\ \vdots \end{pmatrix}.$$

- Page 118, replace Eq. (2.264) by

$$\langle \psi | \longrightarrow (\dots \langle \psi | \chi_k \rangle \dots).$$

- Page 119, replace Eq. (2.269) by

$$\delta(\vec{r} - \vec{r}') = \frac{1}{(2\pi)^3} \int d^3k e^{i\vec{k} \cdot (\vec{r} - \vec{r}')}.$$

- Page 136, replace Eq. (2.387) by

$$AB = \begin{pmatrix} 7 & 0 & 21 \\ 1 & 2i & -5 \\ -i & -2 & 5i \end{pmatrix}, \quad BA = \begin{pmatrix} 7 & 3i & -3 \\ 0 & 2i & 2 \\ 7i & 5 & 5i \end{pmatrix},$$

- Pages 140-141, replace the product  $AB$  in equations (2.410)–(2.413) by

$$AB = \begin{pmatrix} 0 & 1 & -2i \\ 3 & 1 & 5 \\ -2i & 1 & 0 \end{pmatrix}$$

- Page 141, replace Eq. (2.421) by

$$\begin{aligned} e^{xA} &= I \cosh x + A \sinh x = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \cosh x + \begin{pmatrix} 0 & 0 & i \\ 0 & 1 & 0 \\ -i & 0 & 0 \end{pmatrix} \sinh x \\ &= \begin{pmatrix} \cosh x & 0 & i \sinh x \\ 0 & \cosh x + \sinh x & 0 \\ -i \sinh x & 0 & \cosh x \end{pmatrix}. \end{aligned}$$

- Page 142, in the statement of Problem 2.11, replace  $A' = U^\dagger AU$  by  $A' = UAU^\dagger$ .
- Page 144, replace Eq. (2.441) by

$$\begin{aligned} A' &= UAU^\dagger = \frac{1}{4} \begin{pmatrix} -\sqrt{2} & 1 & 1 \\ 0 & \sqrt{2} & -\sqrt{2} \\ \sqrt{2} & 1 & 1 \end{pmatrix} \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} -\sqrt{2} & 0 & \sqrt{2} \\ 1 & \sqrt{2} & 1 \\ 1 & -\sqrt{2} & 1 \end{pmatrix} \\ &= \frac{1}{2} \begin{pmatrix} 1 - \sqrt{2} & -1 & 1 \\ -1 & -2 & 1 \\ 1 & 1 & 1 + \sqrt{2} \end{pmatrix}. \end{aligned}$$

- Page 144, replace the last line of Eq. (2.442) by

$$\alpha^2 (|\phi_1\rangle\langle\phi_2| + |\phi_2\rangle\langle\phi_1|).$$

- Page 145, replace the first line of Eq. (2.443) by

$$(|\phi_1\rangle\langle\phi_2| + |\phi_2\rangle\langle\phi_1|)(|\phi_1\rangle\langle\phi_2| + |\phi_2\rangle\langle\phi_1|).$$

## Chapter 3

- Page 160, replace "probability density" by "probability" in the two lines following Eq. (3.9) and in the line following Eq. (3.10).
- Page 167, replace in the upper line of Eq. (3.43) the term  $E = \frac{\langle\psi|\hat{H}|\psi\rangle}{\langle\psi|\hat{H}|\psi\rangle}$  by

$$E = \frac{\langle\psi|\hat{H}|\psi\rangle}{\langle\psi|\psi\rangle}$$

- Page 179, replace the last term of Eq. (3.114) by

$$\{q_j, p_k\} = \delta_{jk}.$$

- Page 181, replace Eq. (3.129) by

$$[\hat{\vec{P}}, \hat{V}(\vec{R}, t)] = -i\hbar \vec{\nabla} \hat{V}(\vec{R}, t),$$

- Page 181, replace Eq. (3.130) by

$$\frac{d}{dt} \langle \hat{\vec{P}} \rangle = \frac{1}{i\hbar} \langle [\hat{\vec{P}}, \hat{V}(\vec{R}, t)] \rangle = -\langle \vec{\nabla} \hat{V}(\vec{R}, t) \rangle$$

- Last line of Page 183, replace "and so do  $\hat{L}_x$ ,  $\hat{L}_y$  and  $\hat{L}_z$ ," by "and so do  $\hat{P}_x$ ,  $\hat{P}_y$  and  $\hat{P}_z$ ,".

- Page 185, line after Eq. (3.153), replace  $\exp(-iE_5t/\hbar)$  by  $\exp(iE_5t/\hbar)$ .

- Page 196, replace Eq. (3.220) by

$$|\psi(0)\rangle = \frac{1}{5} \begin{pmatrix} 3 \\ 0 \\ 4 \end{pmatrix} = \frac{2\sqrt{2}}{5} |\phi_1\rangle + \frac{3}{5} |\phi_2\rangle + \frac{2\sqrt{2}}{5} |\phi_3\rangle,$$

- Page 186, replace the first line of Eq. (3.158) by

$$\rho(x, t) = \frac{3}{10} \phi_3^2(x) + \frac{\sqrt{3}}{5} \phi_3(x) \phi_5(x) \cos\left(\frac{16E_1t}{\hbar}\right) + \frac{1}{10} \phi_5^2(x).$$

- Page 186, replace equations (3.160) and (3.161) by

$$\begin{aligned} \frac{d\psi(x, t)}{dx} &= \frac{3\pi}{a} \sqrt{\frac{3}{5a}} \cos\left(\frac{3\pi x}{a}\right) e^{-iE_3t/\hbar} + \frac{5\pi}{a} \frac{1}{\sqrt{5a}} \cos\left(\frac{5\pi x}{a}\right) e^{-iE_5t/\hbar}, \\ \frac{d\psi^*(x, t)}{dx} &= \frac{3\pi}{a} \sqrt{\frac{3}{5a}} \cos\left(\frac{3\pi x}{a}\right) e^{iE_3t/\hbar} + \frac{5\pi}{a} \frac{1}{\sqrt{5a}} \cos\left(\frac{5\pi x}{a}\right) e^{iE_5t/\hbar}. \end{aligned}$$

- Page 187, replace Eq. (3.162) by

$$\begin{aligned} \psi \frac{d\psi^*}{dx} - \psi^* \frac{d\psi}{dx} &= -2i\pi \frac{\sqrt{3}}{5a^2} \left[ 5 \sin\left(\frac{3\pi x}{a}\right) \cos\left(\frac{5\pi x}{a}\right) - 3 \sin\left(\frac{5\pi x}{a}\right) \cos\left(\frac{3\pi x}{a}\right) \right] \\ &\quad \times \sin\left(\frac{E_3 - E_5}{\hbar} t\right). \end{aligned}$$

- Page 193, replace Eq. (3.202) by

$$P(a_1) = \frac{|\langle a_1 | \psi(t) \rangle|^2}{\langle \psi(t) | \psi(t) \rangle} = \frac{36}{17} \left| \frac{1}{\sqrt{2}} \frac{1}{6} \begin{pmatrix} 0 & i & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 4 \end{pmatrix} \right|^2 = \frac{8}{17},$$

- Page 196, replace Eq. (3.220) by

$$|\psi(0)\rangle = \frac{1}{5} \begin{pmatrix} 3 \\ 0 \\ 4 \end{pmatrix} = \frac{2\sqrt{2}}{5} |\phi_1\rangle + \frac{3}{5} |\phi_2\rangle + \frac{2\sqrt{2}}{5} |\phi_3\rangle,$$

- Page 196, replace Eq. (3.221) by

$$|\psi(t)\rangle = \frac{2\sqrt{2}}{5}e^{-iE_1t}|\phi_1\rangle + \frac{3}{5}e^{-iE_2t}|\phi_2\rangle + \frac{2\sqrt{2}}{5}e^{-iE_3t}|\phi_3\rangle = \frac{1}{5} \begin{pmatrix} 3e^{-3it} \\ -4i \sin 5t \\ 4 \cos 5t \end{pmatrix}.$$

- Page 197, replace Eq. (3.222) by

$$\begin{aligned} E(0) &= \langle \psi(0) | \hat{H} | \psi(0) \rangle = \frac{8}{25} \langle \phi_1 | \hat{H} | \phi_1 \rangle + \frac{9}{25} \langle \phi_2 | \hat{H} | \phi_2 \rangle + \frac{8}{25} \langle \phi_3 | \hat{H} | \phi_3 \rangle \\ &= \frac{8}{25}(-5) + \frac{9}{25}(3) + \frac{8}{25}(5) = \frac{27}{25}. \end{aligned}$$

- Page 197, replace Eq. (3.225) by

$$\begin{aligned} E(t) &= \langle \psi(t) | \hat{H} | \psi(t) \rangle = \frac{8}{25} e^{iE_1t} e^{-iE_1t} \langle \phi_1 | \hat{H} | \phi_1 \rangle + \frac{9}{25} e^{iE_2t} e^{-iE_2t} \langle \phi_2 | \hat{H} | \phi_2 \rangle \\ &\quad + \frac{8}{25} e^{iE_3t} e^{-iE_3t} \langle \phi_3 | \hat{H} | \phi_3 \rangle = \frac{8}{25}(-5) + \frac{9}{25}(3) + \frac{8}{25}(5) = \frac{27}{25} = E(0). \end{aligned}$$

- Page 198, Problem 3.14, in the first line of part(a) solution, replace  $d\langle \hat{P} \rangle / dt = i\langle [\hat{P}, \hat{V}(x, t)] \rangle / i\hbar$  by  $d\langle \hat{P} \rangle / dt = \langle [\hat{P}, \hat{V}(x, t)] \rangle / i\hbar$ .
- Page 198, replace Eq. (3.233) by

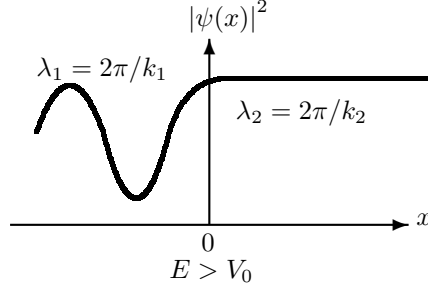
$$\langle \hat{X} \rangle(t) = \frac{p_0}{m}t + x_0.$$

- Page 201, replace the equations of Exercise 3.7 by

$$\begin{aligned} \langle \phi_1 | \psi_i \rangle &= \frac{i}{\sqrt{3}}, & \langle \phi_2 | \psi_i \rangle &= \sqrt{\frac{2}{3}}, & \langle \phi_3 | \psi_i \rangle &= 0. \\ \langle \phi_1 | \psi_f \rangle &= \frac{1+i}{\sqrt{3}}, & \langle \phi_2 | \psi_f \rangle &= \frac{1}{\sqrt{6}}, & \langle \phi_3 | \psi_f \rangle &= \frac{1}{\sqrt{6}}. \end{aligned}$$

## Chapter 4

- Page 209, third line below Eq. (4.8), replace  $E_{\pm} = \hbar k^2/2m$  by  $E_{\pm} = \hbar^2 k^2/2m$ .
- Page 211, replace the left lower plot of Fig. 4.2 by the following figure

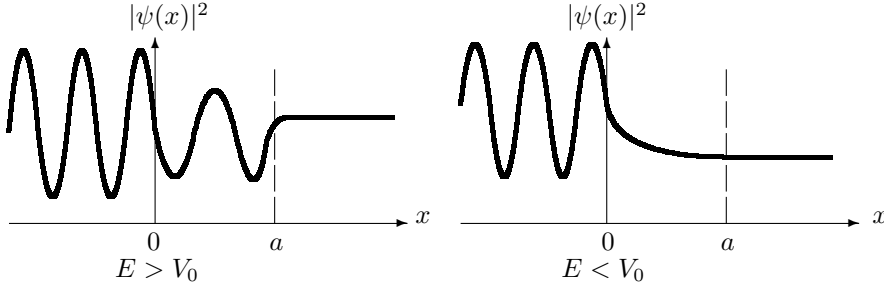


because the probability density  $|\psi(x)|^2$  shown in the lower left plot of (Figure 4.2) must be a straight line for  $x > 0$ , since  $|\psi_2(x)|^2 = |C \exp i(k_2 x)|^2 = |C|^2$ .

- Page 213, replace  $x < a$  in Eq. (4.35) by  $x > a$ , so that Eq. (4.35) should now read

$$V(x) = \begin{cases} 0 & x < 0 \\ V_0 & 0 \leq x \leq a \\ 0 & x > a. \end{cases}$$

- Page 214, replace the left two lower plots of Fig. 4.3 by the following figure



because the probability density  $|\psi(x)|^2$  shown in the lower plots of (Figure 4.3) must be straight lines for  $x > a$ , since  $|\psi_3(x)|^2 = |E \exp i(k_1 x)|^2 = |E|^2$ .

- Page 232, replace Eq. (4.149) by

$$\langle x | 2 \rangle = \frac{1}{\sqrt{2!}} \langle x | (a^\dagger)^2 | 0 \rangle = \frac{1}{\sqrt{2!}} \left( \frac{1}{\sqrt{2}x_0} \right)^2 \left( x - x_0^2 \frac{d}{dx} \right)^2 \psi_0(x),$$

- Page 233, replace Eq. (4.153) by

$$e^{-x^2/2} \left( x - \frac{d}{dx} \right) e^{x^2/2} = -\frac{d}{dx}, \quad \text{or} \quad e^{-x^2/2x_0^2} \left( x - x_0^2 \frac{d}{dx} \right) e^{x^2/2x_0^2} = -x_0^2 \frac{d}{dx},$$

- Page 235, Eq. (4.167), replace  $(\hat{a}^2 + \hat{a}^{\dagger 2} - 2\hat{a}^\dagger \hat{a} + 1)$  by  $(\hat{a}^2 + \hat{a}^{\dagger 2} - 2\hat{a}^\dagger \hat{a} - 1)$ .

- Page 238, replace the final result of Eq. (4.180) by  $7.66 \times 10^{-4} \text{ fm}^{-3}$ .
- Page 241, replace the line before last in Eq. (4.189)

$$\frac{a^2}{3} + \frac{1}{2n\pi} x^2 \sin^2 \left( \frac{2n\pi x}{a} \right) \Big|_{x=0}^{x=a} + \frac{a}{n\pi} \int_0^a x \sin \left( \frac{2n\pi x}{a} \right) dx,$$

by

$$\frac{a^2}{3} - \frac{1}{2n\pi} x^2 \sin \left( \frac{2n\pi x}{a} \right) \Big|_{x=0}^{x=a} + \frac{1}{n\pi} \int_0^a x \sin \left( \frac{2n\pi x}{a} \right) dx.$$

- Page 241, replace Eq. (4.193) by

$$\frac{1}{T} \int_0^T x^2(t) dt = \frac{v^2}{T} \int_0^T t^2 dt = \frac{1}{3} v^2 T^2 = \frac{a^2}{3}.$$

- Page 241, replace the line after Eq. (4.193) by: "where  $T$  is half of the period of the motion, with  $a = vT$ ."
- Pages 242-243, replace the energies in Eqs. (4.199), (4.200), (4.203) by:  $E_1 = \frac{\pi^2 \hbar^2}{2ma^2}$ ,  $E'_1 = \frac{\pi^2 \hbar^2}{2m(4a)^2} = \frac{\pi^2 \hbar^2}{32ma^2}$ , and  $E'_2 = \frac{\pi^2 \hbar^2}{8ma^2}$ .
- Page 246, replace Eq. (4.223) by

$$\psi_{\pm}(x) = \begin{cases} Ae^{-kx} & x > a \\ \frac{B}{2} (e^{kx} \pm e^{-kx}) & -a < x < a \\ \pm Ae^{kx} & x < -a, \end{cases} \quad (5)$$

- Page 251, replace Eq. (4.251) by

$$-2kA \sinh ka - 2kA \cosh ka + (2A) \frac{2mV_0}{\hbar^2} \sinh ka = 0.$$

- Page 254, replace Eq. (4.270) by

$$v \sim \frac{\hbar c}{mc^2 a} c \sim \frac{200 \text{ MeV fm}}{0.5 \text{ MeV} \times 10^5 \text{ fm}} c \simeq 4 \times 10^{-3} c = 1.2 \times 10^6 \text{ m s}^{-1}$$

- Page 255, replace the left-hand side of Eq. (4.275) by  $\frac{\hat{p}^2}{2m} + \frac{1}{2} m \omega^2 \hat{X}^2$
- Page 258, replace Eq. (4.293) by

$$n\pi - \frac{\pi}{2} < \frac{\sqrt{2mV_0}}{\hbar} a < n\pi + \frac{\pi}{2} \implies \text{there are } n \text{ bound states}$$

- Page 266, Exercise 4.16, the expression of  $\psi(x, 0)$ , replace the second constant  $\sqrt{\frac{3}{7a}}$  by  $\sqrt{\frac{6}{7a}}$ .

## Chapter 5

- Page 274, third line after Eq. (5.47), remove the ‘0’ from  $-5/2, -3/2, -1/2, 0, 1/2, 3/2, 5/2$ ; that is, replace “ $-5/2, -3/2, -1/2, 0, 1/2, 3/2, 5/2$ ” by “ $-5/2, -3/2, -1/2, 1/2, 3/2, 5/2$ ”.

- Page 285, replace Eq. (5.107) by

$$\hat{S}_x |\psi_x\rangle_{\pm} = \pm \frac{\hbar}{2} |\psi_x\rangle_{\pm}, \quad \hat{S}_y |\psi_y\rangle_{\pm} = \pm \frac{\hbar}{2} |\psi_y\rangle_{\pm}.$$

- Page 287, before Eq. (5.127), replace  $\langle l, m \rangle$  by  $|l, m\rangle$
- Page 290, replace the expression of  $P_3^1(\cos\theta)$  in Table 5.1 by  $P_3^1(\cos\theta) = 3\sin\theta(5\cos^2\theta - 1)/2$ .
- Page 291, replace Eq. (5.168) by

$$\frac{1}{\Theta_{ll}} \frac{\partial \Theta_{ll}(\theta)}{\partial \theta} = l \cot \theta.$$

- Page 292, first line of Eq. (5.178), replace “ $>$ ” by “ $\rangle$ ”.
- Page 293, replace the expression of  $Y_{2,\pm 2}(x, y, z)$  in Table 5.2 by  $Y_{2,\pm 2}(x, y, z) = \sqrt{\frac{15}{32\pi}} \frac{x^2 - y^2 \pm 2ixy}{r^2}$ .
- Page 295, replace “ $\hat{L}_+ Y_{30}$ ” by “ $\hat{L}_- Y_{30}$ ” in Eqs. (5.195) and (5.197).
- Page 295, Problem 2.1 Part (b), replace  $\Delta J_x \Delta J_y \geq (\hbar/2) |\langle \hat{J}_z \rangle| = \hbar/2m$  by  $\Delta J_x \Delta J_y \geq (\hbar/2) |\langle \hat{J}_z \rangle| = \hbar^2 m/2$ .
- Page 295, replace Eq. (5.200) by

$$\langle \hat{J}_y^2 \rangle = \frac{1}{4} \langle (\hat{J}_+ - \hat{J}_-)^2 \rangle = -\frac{1}{4} \langle \hat{J}_+^2 - \hat{J}_+ \hat{J}_- - \hat{J}_- \hat{J}_+ + \hat{J}_-^2 \rangle.$$

- Page 297, replace Eq. (5.209) by

$$\hat{H}\psi(\theta, \varphi) = \frac{\hat{L}^2}{2I}\psi(\theta, \varphi) = E\psi(\theta, \varphi).$$

- Page 298, between Eqs. (5.221) and (5.225), replace  $\lambda = \pm\hbar/2$  by  $\lambda = \pm 1$ .
- Page 300, between Eqs. (5.233) and (5.239), replace  $\lambda = \pm\hbar/2$  by  $\lambda = \pm 1$ .
- Page 300, replace Eqs. (5.243) and (5.244) by

$$\begin{aligned} |\lambda_+(t)\rangle &= e^{-iE_+t/\hbar} \cos \frac{1}{2}\theta \left| \frac{1}{2}, \frac{1}{2} \right\rangle + e^{i(\varphi - E_-t/\hbar)} \sin \frac{1}{2}\theta \left| \frac{1}{2}, -\frac{1}{2} \right\rangle, \\ |\lambda_-(t)\rangle &= -e^{-iE_+t/\hbar} \sin \frac{1}{2}\theta \left| \frac{1}{2}, \frac{1}{2} \right\rangle + e^{i(\varphi - E_-t/\hbar)} \cos \frac{1}{2}\theta \left| \frac{1}{2}, -\frac{1}{2} \right\rangle, \end{aligned}$$

where  $E_{\pm}$  are the energy eigenvalues corresponding to the spin-up and spin-down states, respectively.

- Page 301, replace Eq. (5.247) by

$$(\varepsilon \cos \theta - E)(-\varepsilon \cos \theta - E) - \varepsilon^2 \sin^2 \theta = 0,$$

- Page 304, first term of Eq. (5.268), replace “ $\vec{n} \cdot \vec{S}$ ” by “ $\vec{n} \cdot \vec{J}$ ”.
- Page 304, last term of Eq. (5.271), replace “ $\frac{2\sqrt{3}}{5}\hbar$ ” by “ $\frac{2\sqrt{6}}{5}\hbar$ ”.
- Page 304, third line from bottom, replace  $\hat{L}_+ |l, m\rangle = \hbar\sqrt{l(l+1) - m(m+1)} |l, m+1\rangle$  by  $\hat{L}_+ |l, m\rangle = \hbar\sqrt{l(l+1) - m(m+1)} |l, m+1\rangle$ .
- Page 305, first line from top, replace “ $\langle 10|\hat{L}_+ |1, -1\rangle = \langle 11|\hat{L}_+ |10\rangle = \sqrt{2}$ ” by “ $\langle 10|\hat{L}_+ |1, -1\rangle = \langle 11|\hat{L}_+ |10\rangle = \sqrt{2}\hbar$ ”.
- Page 308, second line from bottom, replace “(c) Since  $|\psi\rangle = (1\sqrt{5})Y_{20} + \sqrt{2/5}(Y_{2,-1} - Y_{21})$ ” by “(c) Since  $|\psi\rangle = (1/\sqrt{5})Y_{20} + \sqrt{2/5}(Y_{2,-1} - Y_{21})$ ”.
- Page 309, replace Eq. (5.308) by

$$P\left(\frac{\pi}{3}, \frac{\pi}{2}\right) = \left[ \frac{1}{4\sqrt{\pi}} \left( 3 \cos^2 \frac{\pi}{3} - 1 \right) + 0 \right]^2 (0.03)^2 \sin \frac{\pi}{3} = 9.7 \times 10^{-7}.$$

- Page 310, replace (c) including equation (5.316) at bottom of Page 310 by: Since the initial state  $|\psi_0\rangle$  can be written in terms of the eigenvectors (5.316) as follows

$$|\psi_0\rangle = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} = -\frac{\sqrt{3}}{2} |1\rangle + \frac{1}{2} |3\rangle,$$

the eigenfunction at a later time  $t$  is given by

$$\begin{aligned} |\psi(t)\rangle &= -\frac{\sqrt{3}}{2} |1\rangle e^{-iE_1 t/\hbar} + \frac{1}{2} |3\rangle e^{-iE_3 t/\hbar} \\ &= -\frac{\sqrt{3}}{4} \begin{pmatrix} -\sqrt{3} \\ 0 \\ 1 \\ 0 \end{pmatrix} \exp\left[\frac{5i\varepsilon_0 t}{2\hbar}\right] + \frac{1}{2\sqrt{12}} \begin{pmatrix} \sqrt{3} \\ 0 \\ 3 \\ 0 \end{pmatrix} \exp\left[-\frac{3i\varepsilon_0 t}{2\hbar}\right]. \end{aligned}$$

## Chapter 6

- Page 319, Eq. (6.19), replace  $\Psi_{\vec{k}}(\vec{k}, t)$  by  $\Psi_{\vec{k}}(\vec{r}, t)$
- Page 325, Eq. (6.52), replace  $\psi_{nlm}(r, \theta, \psi)$  by  $\psi_{nlm}(r, \theta, \varphi)$
- Page 327, replace Eq. (6.61) by

$$-\frac{\hbar^2}{2M} \frac{1}{r} \frac{d^2}{dr^2} (rR_{kl}(r)) + \frac{l(l+1)\hbar^2}{2Mr^2} R_{kl}(r) = E_k R_{kl}(r).$$

- Page 328, replace Eq. (6.65) by

$$j_l(\rho) \simeq \frac{2^l l!}{(2l+1)!} \rho^l, \quad n_l(\rho) \simeq -\frac{(2l)!}{2^l l!} \rho^{-l-1}.$$

- Page 328, 3rd line above and 3rd line below "Remark", replace  $E_k = \hbar k^2/(2M)$  by  $E_k = \hbar^2 k^2/(2M)$ .
- Page 330, first line above and third line below Eq. (6.73), replace the arguments  $(k_2 r)$  by  $(ik_2 r)$ .
- Page 330, replace Eq. (6.73) by

$$R_l(ik_2 r) = B [j_l(ik_2 r) \pm n_l(ik_2 r)].$$

- Page 330, replace Eq. (6.76) by  $-k_2 = k_1 \cot(k_1 a)$ .
- Page 332, second line above Eq. (6.91), replace  $r^{n'+2}$  by  $r^{n'}$ .
- Page 332, Eq. (6.95), replace  $r^{l+1}$  by  $r^l$ . That is, replace equation (6.95) by

$$\psi_{nlm}(r, \theta, \varphi) = R_{nl}(r) Y_{lm}(\theta, \varphi) = \frac{U_{nl}(r)}{r} Y_{lm}(\theta, \varphi) = r^l f(r) Y_{lm}(\theta, \varphi) e^{-M\omega r^2/2\hbar}.$$

- Page 336, remove the loose "t" at the beginning of the second line above Eq. (6.119).
- Page 338, second line from top, replace  $e^x$  by  $e^{2x}$ .
- Page 338, line after Eq. (6.136), replace  $a_{N+1}, a_{N+2}, a_{N+3}, \dots$  by  $b_{N+1}, b_{N+2}, b_{N+3}, \dots$
- Page 338, line after Eq. (6.140), replace  $a_0 = \hbar^2/(m\mu e^2)$  by  $a_0 = \hbar^2/(\mu e^2)$ .
- Page 340, replace Eq. (6.146) by

$$R_{10}(r) = A_{10} e^{-r/a_0} \sum_{k=0}^0 b_k r^k = A_{10} b_0 e^{-r/a_0},$$

- Page 340, line after Eq. (6.146), replace  $\int_0^\infty x^n e^{ax} dx$  by  $\int_0^\infty x^n e^{-ax} dx$ .
- Page 340, last fraction term in Eq. (6.147), replace  $\frac{a_0^2}{4}$  by  $\frac{a_0^3}{4}$ .
- Page 340, line after Eq. (6.148), replace  $n = 2 - 0 - 1 = 1$  by  $N = 2 - 0 - 1 = 1$ .
- Page 340, replace Eq. (6.149) by

$$R_{20}(r) = A_{20} e^{-r/2a_0} \sum_{k=0}^1 b_k r^k = A_{20} (b_0 + b_1 r) e^{-r/2a_0}.$$

- Page 344, fifth line from bottom of page 344, replace "sing-particle" by "single-particle".

- Page 345, second line from bottom of page 345, replace  $|\psi_{nlm}(r, \theta, \psi)|^2 d^3r$  by  $|\psi_{nlm}(r, \theta, \varphi)|^2 d^3r$
- Page 347, replace Eq. (6.182) by

$$g_n = \sum_{l=0}^{n-1} (2l+1) = 2 \sum_{l=0}^{n-1} l + \sum_{l=0}^{n-1} 1 = n(n-1) + n = n^2.$$

- Page 349, line above Eq. (6.197), replace  $\psi_{nlm}(r, \theta, \varphi) = R_{nl}(r)Y_{lm}(\theta, \psi)$  by  $\psi_{nlm}(r, \theta, \varphi) = R_{nl}(r)Y_{lm}(\theta, \varphi)$ .
- Page 351, first equation of Problem 6.1, replace “ $0 < x < a, 0 < y < b$ ” by “ $0 < x < a, 0 < y < a$ ”
- Page 351, part (b) of Problem 6.1, replace  $\hbar\omega > 5\pi^2\hbar^2/(ma^2)$  by  $\hbar\omega > 3\pi^2\hbar^2/(2ma^2)$ .
- Page 351, part (b) of Problem 6.1, replace  $\hbar\omega > 5\pi^2\hbar^2/(ma^2)$  by  $\hbar\omega > 3\pi^2\hbar^2/(2ma^2)$ .
- Pages 352 and 353, in Eqs. (6.204) and (6.209), replace  $\frac{5\pi^2\hbar^2}{ma^2}$  by  $\frac{5\pi^2\hbar^2}{2ma^2}$ .
- Pages 352, 2nd line below Eq. (6.204), replace  $\hbar\omega > 5\pi^2\hbar^2/(ma^2)$  by  $\hbar\omega > 3\pi^2\hbar^2/(2ma^2)$ .
- Page 353, Eq. (6.209), replace  $\frac{3\hbar\omega}{2}$  by  $\frac{\hbar\omega}{2}$ .
- Page 353, line below Eq. (6.211), replace  $E_n = \mu e^4/(2\hbar^2 n^2)$  by  $E_n = -\mu e^4/(2\hbar^2 n^2)$ .
- Page 355, replace  $k^2$  in Eq. (6.226) by 4.
- Page 356, replace Eq. (6.233) by

$$-\frac{\hbar^2}{2m} \left[ \frac{d^2 U_{nl}(r)}{dr^2} - \frac{l(l+1)}{r^2} U_{nl}(r) \right] = E U_{nl}(r),$$

- Page 359, replace  $r^3$  by  $r^4$  inside the first integral sign of Eq. (6.259).
- Page 361, line above Eq. (6.272), replace  $U_{n0}(r), U_{n0_1}(a) = U_{n0_2}(r)(a)$  by  $U_{n0}(r), U_{n0_1}(a) = U_{n0_2}(a)$ .
- Page 361, replace Eq. (6.275) by

$$-k \sinh ka - k \cosh ka + \frac{2mV_0}{\hbar^2} \sinh ka = 0,$$

- Page 362, replace the term  $(1/r)e^{-kr}$  in Eq. (6.283) by  $(1/r) \sinh(ka)e^{-k(r-a)}$ .
- Page 364, replace Eq. (6.295) by

$$E_n = - \left( \frac{\hbar^2 k^2}{2\mu} \right)^{1/3} R_n.$$

- Page 364, replace Eq. (6.297) by

$$\frac{E_n}{E_n^B} = -\frac{2}{3} \frac{R_n}{(2n^2)^{1/3}}.$$

- Page 364, replace Eqs. (6.298)–(6.299) by

$$E_1^B = \frac{3}{2} \left( \frac{\hbar^2 k^2}{\mu} \right)^{1/3} = 2.38 \text{ GeV}, \quad E_2^B = 2^{2/3} E_1^B = 3.77 \text{ GeV},$$

$$E_3^B = 3^{2/3} E_1^B = 4.95 \text{ GeV}, \quad E_4^B = 4^{2/3} E_1^B = 5.99 \text{ GeV}.$$

- Page 365, replace Eqs. (6.300)–(6.301) by

$$E_1 = \left( \frac{\hbar^2 k^2}{2\mu} \right)^{1/3} R_1 = 2.94 \text{ GeV}, \quad E_2 = \left( \frac{\hbar^2 k^2}{2\mu} \right)^{1/3} R_2 = 5.14 \text{ GeV},$$

$$E_3 = \left( \frac{\hbar^2 k^2}{2\mu} \right)^{1/3} R_3 = 6.95 \text{ GeV}, \quad E_4 = \left( \frac{\hbar^2 k^2}{2\mu} \right)^{1/3} R_4 = 8.54 \text{ GeV}.$$

- Page 368, second line above Exercise 6.2, replace “ $|n\rangle$ ” by “ $|n\rangle$ ”
- Page 370, Exercise 6.8, replace  $0 \leq x \leq a$ ,  $0 < y \leq b$  by  $0 < x < a$ ,  $0 < y < b$ .
- Page 371, second line above Exercise 6.13, replace “From (b), find the degeneracy infer the general expression for the degeneracy  $g_n$ ” by “From (b), infer a general expression for the degeneracy  $g_n$ ”.

## Chapter 7

- Page 377, replace Eq. (7. 28) by

$$\hat{R}_z(\phi) = \lim_{N \rightarrow \infty} \prod_{k=1}^N \left( 1 - \frac{i}{\hbar} \frac{\phi}{N} \hat{n} \cdot \vec{L} \right) = \lim_{N \rightarrow \infty} \left( 1 - \frac{i}{\hbar} \frac{\phi}{N} \hat{L}_z \right)^N,$$

- Page 387, replace Eq. (7. 116) by

$$\hat{J}_2^2 |j_1, j_2; j, m\rangle = j_2(j_2 + 1)\hbar^2 |j_1, j_2; j, m\rangle$$

- Page 395, line after Eq. (7. 170), replace ”As for the coefficients  $\langle \frac{1}{2}, \frac{1}{2}; \frac{1}{2}, -\frac{1}{2} | 1, 0\rangle$  and  $\langle \frac{1}{2}, \frac{1}{2}; -\frac{1}{2}, -\frac{1}{2} | 1, 0\rangle$ ,” by ”As for the coefficients  $\langle \frac{1}{2}, \frac{1}{2}; \frac{1}{2}, -\frac{1}{2} | 1, 0\rangle$  and  $\langle \frac{1}{2}, \frac{1}{2}; -\frac{1}{2}, \frac{1}{2} | 1, 0\rangle$ ,”
- Page 396, in Eq. (7. 184), replace  $\langle 0, 0 | 0, 1\rangle$  by  $\langle 0, 0 | 1, 0\rangle$ .
- Page 398, second line from top, replace  $\langle l, \frac{1}{2}; m - \frac{1}{2}, -\frac{1}{2} | l + \frac{1}{2}, m - 1\rangle$  by  $\langle l, \frac{1}{2}; m + \frac{1}{2}, -\frac{1}{2} | l + \frac{1}{2}, m - 1\rangle$ .
- Page 401 second line after Eq. (7.219), replace  $\langle j_1, j_2; m_1, m_2, m_3 | j_{12}, m_{12}\rangle$  by  $\langle j_1, j_2; m_1, m_2 | j_{12}, m_{12}\rangle$ .
- Page 401, replace Eq. (7.223) by

$$\hbar \sqrt{j_3(j_3 + 1) - m_3(m_3 \pm 1)} |j_1, j_2, j_3; m_1, m_2, (m_3 \pm 1)\rangle$$

- Page 425, last term of Eq. (7.397), replace  $\frac{\sqrt{2}}{6}$  by  $\frac{2}{\sqrt{6}}$ .

## Chapter 8

- Page 444, replace Eq. (8.36) by

$$V(\vec{r}_1, \vec{r}_2, \vec{r}_3, \dots, \vec{r}_Z) = - \sum_{i=1}^Z \frac{Z e^2}{|\vec{r}_i - \vec{R}|} + \sum_{i>j} \frac{e^2}{|\vec{r}_i - \vec{r}_j|}$$

- Page 458, replace the last term of Eq. (8.82) by  $\frac{3\pi^2\hbar^2}{ma^2}$ .
- Page 458, replace the last term of Eq. (8.84) by  $\frac{9\pi^2\hbar^2}{2ma^2}$ .
- Page 466, replace Eq. (8.131) by

$$\Psi(x_1, S_1; x_2, S_2) = \frac{1}{2} \left[ \psi_s(x_1, x_2) \chi_{singlet}(S_1, S_2) + \psi_a(x_1, x_2) \chi_{triplet}(S_1, S_2) \right],$$

## Chapter 9

- Page 473, replace Eq. (9.25) by

$$\hat{H} = -\frac{\hbar^2}{2m} \frac{d^2}{dy^2} + \frac{1}{2} m \omega^2 \hat{y}^2 - \frac{q^2 \mathcal{E}^2}{2m\omega^2}.$$

- Page 473, replace Eq. (9.26) by

$$E_n = \left( n + \frac{1}{2} \right) \hbar \omega - \frac{q^2 \mathcal{E}^2}{2m\omega^2}.$$

- Page 476, replace Eq. (9.44) by

$$\langle 100 | \hat{Z}^2 | 100 \rangle = \frac{1}{4\pi} \int_0^\infty r^4 R_{10}^2(r) dr \int_0^\pi \sin \theta \cos^2 \theta d\theta \int_0^{2\pi} d\varphi = a_0^2.$$

- Page 479, replace  $\vec{r}$  in Eq. (9.65) by  $\vec{v}$ . So Eq. (9.65) becomes

$$\vec{B} = -\frac{1}{c} \vec{v} \times \vec{E} = -\frac{1}{m_e c} \vec{p} \times \vec{E} = \frac{1}{m_e c} \vec{E} \times \vec{p},$$

- Page 482, replace  $\hat{T} = \sqrt{\hat{p}^2 c^2 - m_e^2 c^4} - m_e c^2$  by  $\hat{T} = \sqrt{\hat{p}^2 c^2 + m_e^2 c^4} - m_e c^2$ . Then replace Eq. (9.82) by

$$\sqrt{\hat{p}^2 c^2 + m_e^2 c^4} - m_e c^2 \simeq \frac{\hat{p}^2}{2m_e} - \frac{\hat{p}^4}{8m_e^3 c^2} + \dots$$

- Page 482, replace Eq. (9.85) by

$$\langle n l j m_j | \hat{p}^4 | n l j m_j \rangle = \frac{m_e^4 e^8}{\hbar^4 n^4} \left( \frac{8n}{2l+1} - 3 \right) = \frac{\alpha^4 m_e^4 c^4}{n^4} \left( \frac{8n}{2l+1} - 3 \right).$$

- Page 483, replace Eq. (9.87) by

$$E_n = Z^2 E_n^{(0)} \left[ 1 + \frac{\alpha^2}{n} \left( \frac{2}{2l+1} - \frac{3}{4n} \right) \right],$$

- Page 493, replace the first term  $\frac{15\hbar^2\alpha}{m}$  in Eq. (9.147) by  $\frac{15\hbar^2\alpha}{8m}$ .
- Page 499, replace Eq. (9.181) by

$$\psi_{2_{WKB}}(x) = \frac{C'_2}{\sqrt{p(x)}} \exp \left[ \frac{i}{\hbar} \int_x^{x_2} p(x') dx' \right] + \frac{C''_2}{\sqrt{p(x)}} \exp \left[ -\frac{i}{\hbar} \int_x^{x_2} p(x') dx' \right], \quad x_1 < x < x_2;$$

- Page 503, replace Eq. (9.211) by

$$\int_{r_1}^{r_2} dr p_r(E, r) = \int_{r_1}^{r_2} dr \sqrt{2m \left( E - V(r) - \frac{\hbar^2 l(l+1)}{2m r^2} \right)} = \left( n + \frac{1}{2} \right) \pi \hbar,$$

- Page 507, replace Eq. (9.231) by

$$\begin{aligned} \int_0^a \sqrt{2m \left( E + \frac{Ze^2}{r} \right)} dr &= \sqrt{-2mE} \int_0^a \sqrt{\frac{a}{r} - 1} dr = a\sqrt{-2mE} \int_0^1 \sqrt{\frac{1}{x} - 1} dx \\ &= \frac{\pi}{2} a\sqrt{-2mE} = -\pi Ze^2 \sqrt{-\frac{m}{2E}}. \end{aligned}$$

- Page 507, replace Eq. (9.232) by

$$E_n = -\frac{mZ^2 e^4}{2\hbar^2} \frac{1}{n^2} = -\frac{Z^2 e^2}{2a_0} \frac{1}{n^2},$$

- Page 515, replace the term "2V<sub>0</sub>" in Eqs. (9.282) and (9.283) by "V<sub>0</sub>"
- Page 516, replace the statement above Eq. (9.288) "First, V<sub>11</sub> has been calculated in (9.282); it is given by V<sub>11</sub> = 2V<sub>0</sub>/L<sup>3</sup>;" by "First, V<sub>11</sub> can be calculated in analogy to (9.282); it is given by V<sub>11</sub> = 2V<sub>0</sub>;" .
- Page 524, replace the third expression in Eq. (9.344) by  $\frac{\hbar^2}{2m} \int_0^L (L^2 - 4Lx + 4x^2) dx$ .
- Page 524, replace the third expression in Eq. (9.349) by  $\frac{\hbar^2}{2m} \int_0^L \left( 3x^2 - 3Lx + \frac{L^2}{2} \right)^2 dx$ .
- Page 526, replace the third expression in Eq. (9.349),  $\left( 2\alpha z - \frac{\alpha^2}{2} \right)$ , by  $(2\alpha z - \alpha^2 z^2)$ .
- Page 534, replace the line after Eq. (9.424) by  
"Since  $\int_0^a p dx = (n + \frac{3}{4})\pi\hbar$ , that is,  $\pi E/(2\omega) = (n + \frac{3}{4})\pi\hbar$ , we obtain"
- Page 537, line before Eq. (9.444), replace  $x = E/(Ze^2r)$  by  $x = Er/(Ze^2)$

## Chapter 10

- Page 550, replace Eq. (10.3) by

$$\hat{U}(t, t_0) = e^{-i(t-t_0)\hat{H}/\hbar}.$$

- Page 550, two lines above Eq. (10.9), replace  $\hat{U}(t) = e^{it\hat{H}/\hbar}$  by  $\hat{U}(t) = e^{-it\hat{H}/\hbar}$ .
- Page 550, replace Eq. (10.11) by

$$\hat{A}_H(t) = \hat{U}^\dagger(t)\hat{A}\hat{U}(t) = e^{it\hat{H}/\hbar}\hat{A}e^{-it\hat{H}/\hbar}.$$

- Page 563, replace in Eq. (10.77)

$$\psi'_1(x) = \sqrt{\frac{2}{a}} \sin\left(\frac{\pi x}{8a}\right) \quad \text{by} \quad \psi'_1(x) = \sqrt{\frac{2}{8a}} \sin\left(\frac{\pi x}{8a}\right)$$

- Page 565, replace Eq. (10.89) by

$$\vec{B}(\vec{r}, t) = \vec{\nabla} \times \vec{A} = i(\vec{k} \times \vec{\varepsilon})A_0 \left[ -e^{i(\vec{k}\cdot\vec{r}-\omega t)} + e^{-i(\vec{k}\cdot\vec{r}-\omega t)} \right] = \vec{n} \times \vec{E}.$$

- Page 568, replace Eq. (10.102) by

$$\hat{H}_r = \sum_{\vec{k}} \sum_{\vec{\lambda}}^2 \hbar\omega_k \left( \hat{N}_{\vec{\lambda}, \vec{k}} + \frac{1}{2} \right),$$

- Page 570, replace Eq. (10.114) by

$$\begin{aligned} \langle \Phi_f | \hat{v}_{\vec{\lambda}, \vec{k}} | \Phi_i \rangle &= \frac{e}{m_e} \sqrt{\frac{2\pi\hbar}{\omega_k V}} \langle \psi_f | e^{i\vec{k}\cdot\vec{r}} \vec{\varepsilon}_{\vec{\lambda}} \cdot \hat{\vec{P}} | \psi_i \rangle \langle n_{\vec{\lambda}, \vec{k}} - 1 | \hat{a}_{\vec{\lambda}, \vec{k}} | n_{\vec{\lambda}, \vec{k}} \rangle \\ &= \frac{e}{m_e} \sqrt{\frac{2\pi\hbar}{\omega_k V}} \sqrt{n_{\vec{\lambda}, \vec{k}}} \langle \psi_f | e^{i\vec{k}\cdot\vec{r}} \vec{\varepsilon}_{\vec{\lambda}} \cdot \hat{\vec{P}} | \psi_i \rangle. \end{aligned}$$

- Page 570, in Eq. (10.116), replace  $\Gamma_{i \rightarrow f}^{sbs}$  by  $\Gamma_{i \rightarrow f}^{abs}$ .
- Page 573, replace the last term of Eq. (10.134) by

$$\frac{1}{2\pi\hbar c^3} |\vec{\varepsilon}_{\vec{\lambda}}^* \cdot \vec{d}_{fi}|^2 d\Omega \int \omega_{fi}^2 \omega \delta(\omega_{if} - \omega) d\omega,$$

- Page 574, replace Eq. (10.144) by

$$\langle 0 | \hat{X} | n \rangle = \sqrt{\frac{\hbar}{2m\omega_0}} \langle 0 | \hat{a}^\dagger + \hat{a} | n \rangle = \sqrt{\frac{\hbar}{2m\omega_0}} [\sqrt{n+1}\delta_{0, n+1} + \sqrt{n}\delta_{0, n-1}].$$

- Page 580, replace Eq. (10.188) by

$$\begin{aligned}\langle \psi(x, t) | \hat{X} | \psi(x, t) \rangle &= \frac{1}{2} \left[ \frac{a}{2} + \frac{a}{2} - \frac{16a}{9\pi^2} \left( e^{-i(E_2 - E_1)t/\hbar} + e^{i(E_2 - E_1)t/\hbar} \right) \right] \\ &= \frac{a}{2} - \frac{16a}{9\pi^2} \cos \left( \frac{3\pi^2 \hbar t}{2ma^2} \right),\end{aligned}$$

- Page 580, line following Eq. (10.188), replace  $E_2 - E_1 = 3\pi^2 \hbar^2 t / (2ma^2)$  by  $E_2 - E_1 = 3\pi^2 \hbar^2 / (2ma^2)$ .
- Page 580, replace Eq. (10.189) by

$$\langle \phi_1 | \hat{P} | \phi_2 \rangle = -i\hbar \frac{4\pi}{a} \int_0^a \sin \left( \frac{\pi x}{a} \right) \cos \left( \frac{2\pi x}{a} \right) dx = \frac{8i\hbar}{3a} = -\langle \phi_2 | \hat{P} | \phi_1 \rangle.$$

- Page 580, replace Eq. (10.193) by

$$\langle \psi(x, t) | \hat{X}_H(t) | \psi(x, t) \rangle = \frac{a}{2} - \frac{16a}{9\pi^2} \cos \left( \frac{3\pi^2 \hbar t}{2ma^2} \right) + \frac{8\hbar t}{3ma} \sin \left( \frac{3\pi^2 \hbar t}{2ma^2} \right).$$

- Page 581, second term of Eq. (10.195), replace “>” by “)”. So, Eq. (10.195) becomes

$$P_{1 \rightarrow 2} = \frac{1}{\hbar^2} \left| \int_0^{+\infty} \langle \psi_2 | \hat{V}(t) | \psi_1 \rangle e^{i\omega_{21}t} dt \right|^2,$$

- Page 581, replace the last term in Eq. (10.197) by  $-\frac{16\epsilon_a}{9\pi^2} e^{-t^2}$ .
- Page 584, replace Eq. (10.219) by

$$\sum_{m=-1}^1 \left[ \frac{1}{2} (\epsilon_x^2 + \epsilon_y^2) (\delta_{m,-1} + \delta_{m,1}) + \epsilon_z^2 \delta_{m0} \right] = \epsilon_x^2 + \epsilon_y^2 + \epsilon_z^2 = 1,$$

## Chapter 11

- Page 606, replace Eq. (11.67) by

$$q = \left| \vec{k}_0 - \vec{k} \right| = \sqrt{k_0^2 + k^2 - 2kk_0 \cos \theta} = k\sqrt{2(1 - \cos^2 \theta)} = 2k \sin \left( \frac{\theta}{2} \right).$$

- Page 612, replace the first line of Eq. (11.101) by

$$\sigma = \int \frac{d\sigma}{d\Omega} d\Omega = \int_0^\pi |f(\theta)|^2 \sin \theta d\theta \int_0^{2\pi} d\varphi = 2\pi \int_0^\pi |f(\theta)|^2 \sin \theta d\theta$$

- Page 620, replace Eq. (11.153) by

$$k \cot(ka + \delta_0) - \frac{2mV_0}{\hbar^2} = k \cot(ka) \implies \tan(ka + \delta_0) = \left[ \frac{1}{\tan(ka)} + \frac{2mV_0}{k\hbar^2} \right]^{-1}.$$

- Page 624 replace Eq. (11.179) by

$$\int d^3r \frac{e^{i\vec{q}\cdot\vec{r}}}{r} = \int_0^\infty r dr \int_0^\pi e^{iqr \cos \theta} \sin \theta d\theta \int_0^{2\pi} d\varphi = \frac{4\pi}{q} \int_0^\infty dr \sin(qr) = \frac{4\pi}{q^2},$$

## Appendix A

- Page 629, replace Eq. (A.8) by

$$\frac{1}{2\pi} \int_{-\infty}^{+\infty} e^{ikx} dk = \frac{1}{2\pi} \lim_{\epsilon \rightarrow 0} \int_{-1/\epsilon}^{+1/\epsilon} e^{ikx} dk = \lim_{\epsilon \rightarrow 0} \frac{\sin(x/\epsilon)}{\pi x} = \delta(x).$$

- Page 631, replace Eq. (A.24) by

$$\delta(\vec{r} - \vec{r}') = \frac{1}{r^2 \sin \theta} \delta(r - r') \delta(\theta - \theta') \delta(\varphi - \varphi').$$

## Appendix B

- Page 633, replace Eq. (B.6) by

$$dy = \sin \theta \sin \varphi dr + r \cos \theta \sin \varphi d\theta + r \sin \theta \cos \varphi d\varphi.$$

- Page 634, replace Eq. (B.16) by

$$\frac{\partial}{\partial z} = \frac{\partial}{\partial r} \frac{\partial r}{\partial z} + \frac{\partial}{\partial \theta} \frac{\partial \theta}{\partial z} + \frac{\partial}{\partial \varphi} \frac{\partial \varphi}{\partial z} = \cos \theta \frac{\partial}{\partial r} - \frac{\sin \theta}{r} \frac{\partial}{\partial \theta}.$$

- Page 635, replace Eq. (B.29) by

$$\hat{L}_- = \hat{L}_x - i\hat{L}_y = -\hbar e^{-i\varphi} \left( \frac{\partial}{\partial \theta} - i \cot \theta \frac{\partial}{\partial \varphi} \right).$$