

Quantum Mechanics: A Paradigms Approach

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Corrections to the 1st printing

- page xxi, last paragraph before "The End", 2nd line: Change "become" to "became".
- page 3, first line after Eq. (1.4): Change "**gyroscopic**" to "**gyromagnetic**".
- page 31, Problem 1.9, first line: Change "A pair of dice" to "Two dice".
- page 35, paragraph after Eq. (2.1), penultimate line: Change " 1×2 " to " 2×1 ".
- page 44, Eq. (2.50): Change the "+" superscript in the 2nd and 3rd lines to the proper adjoint symbol "†":

$$\begin{aligned}\langle \phi | \beta \rangle &= \langle \beta | \phi \rangle^* \\ [\langle \psi | A^\dagger] | \beta \rangle &= \{ \langle \beta | [A | \psi \rangle] \}^* \\ \langle \psi | A^\dagger | \beta \rangle &= \langle \beta | A | \psi \rangle^*\end{aligned}\tag{2.50}$$

- page 73, Eq. (3.28): Change the " $|+\rangle$ " ket in the 2nd line to " $|-\rangle$ ":

$$\begin{aligned}H|+\rangle &= \omega_0 S_z |+\rangle = \frac{\hbar \omega_0}{2} |+\rangle = E_+ |+\rangle \\ H|-\rangle &= \omega_0 S_z |-\rangle = -\frac{\hbar \omega_0}{2} |-\rangle = E_- |-\rangle\end{aligned}\tag{3.28}$$

- page 83, Eq. (3.65): In the 1st line, change the vertical bar on the 1st bra to a left angle bracket to make a proper bra symbol:

$$\begin{aligned}|\psi(0)\rangle &= |-\rangle = (|+\rangle_y \langle +| + |-\rangle_y \langle -|) |-\rangle \\ &= |+\rangle_y \langle +|-\rangle + |-\rangle_y \langle -|-\rangle \\ &= {}_y \langle +|-\rangle |+\rangle_y + {}_y \langle -|-\rangle |-\rangle_y \\ &= \frac{i}{\sqrt{2}} |+\rangle_y + \frac{i}{\sqrt{2}} |-\rangle_y\end{aligned}\tag{3.65}$$

- page 84, last sentence of paragraph after Eq. (3.68): Change sentence to read: "Neutrinos are so elusive because they interact via the **weak force** or **weak interaction**, which is much weaker than the strong nuclear force and electromagnetism, but not as weak as gravity."
- page 88, line before Eq. (3.84): Delete duplicate "the".

- page 96, Problem 3.16: (i) 1st line: After the term "Rabi oscillations", insert the parenthetic comment "(i.e., Rabi flopping)"; (ii) Part (b), Delete "complete" and after "flip" insert the parenthetic comment "(i.e., $\mathcal{P}_+(t) = \mathcal{P}_-(0)$ and $\mathcal{P}_-(t) = \mathcal{P}_+(0)$)".
- page 104, 2 lines before Eq. (4.15): Change " π -pulse" to " $\pi/2$ -pulse".
- page 106, 3rd reference (Mermin's moon article): Change issue number from "(5)" to "(4)".
- page 108, Eq. (5.1): Change \hbar to 2π :

$$f_{ij} = \frac{\omega_{ij}}{2\pi} = \frac{E_i - E_j}{h} \quad (5.1)$$

$$\lambda_{ij} = \frac{c}{f_{ij}} = \frac{hc}{E_i - E_j}$$

- page 117, Eq. (5.37): Change the " φ " symbol to the " ϕ " symbol all 3 places:

$$\mathcal{P}_{\psi \rightarrow \phi} = |\langle \phi | \psi \rangle|^2 = \left| \int_{-\infty}^{\infty} \phi^*(x) \psi(x) dx \right|^2 \quad (5.37)$$

- page 124, 2nd line: Change $x < L$ to $x > L$.
- page 136, Eq. (5.97): (i) Change φ symbols in bra-ket to E , (ii) change last subscript from " m " to " n ":

$$\langle E_m | qx | E_n \rangle = \int_{-\infty}^{\infty} \varphi_m(x) qx \varphi_n(x) d^3\mathbf{r} \quad (5.97)$$

- page 140, Example 5.4: renumber to 5.5.
- page 142, Eq. (5.123): Insert \hbar in denominator of exponent term $e^{-iE_n t/\hbar}$ in line 1:

$$\begin{aligned} \psi(x,t) &= \sum_{n=1}^{\infty} c_n \varphi_n(x) e^{-iE_n t/\hbar} = \sum_{n=1}^{\infty} c_n \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L} e^{-in^2 \pi^2 \hbar t / 2mL^2} \\ &= \sqrt{\frac{60}{L}} \sum_{n=1}^{\infty} \frac{[22 - 20(-1)^n]}{(n\pi)^3} \sin \frac{n\pi x}{L} e^{-in^2 \pi^2 \hbar t / 2mL^2} \end{aligned} \quad (5.123)$$

- page 144, 2nd line after Eq. (5.131): Change "Example 5.3" to "Example 5.4".
- page 147, 1st line after Fig. 5.24: Change "2.67 eV" to "1.42 eV – 2.14 eV".
- page 156, Problem 5.2: Change φ symbols inside kets to E :

$$|\psi(t=0)\rangle = A(|E_1\rangle - |E_2\rangle + i|E_3\rangle) \quad \text{and} \quad |E_n\rangle$$

- page 157, Problem 5.7: Change φ symbols inside kets to E :

$$|\psi(t=0)\rangle = (|E_1\rangle - 2i|E_2\rangle) / \sqrt{5} \quad \text{and} \quad |E_n\rangle$$

- page 158, Problem 5.20, end of second line: Change " $x > L$ " to " $x > a$ ".

- page 170, Eq. (6.37): Add curly brackets to match the text in the subsequent paragraph:

$$\psi(x,t) = \frac{1}{\sqrt{2\pi\hbar}} \left\{ e^{ip_0(x-p_0t/2m)/\hbar} \right\} \left[1 + \cos \left(\frac{\delta p}{\hbar} \left[x - \frac{p_0}{m} t \right] \right) \right] \quad (6.37)$$

- page 174, Eq. (6.52): Add curly and square brackets to match the text in the subsequent paragraph:

$$\psi(x,t) = \left(\frac{1}{2\pi\alpha^2} \right)^{1/4} \frac{1}{\sqrt{\gamma}} \left\{ e^{ip_0(x-p_0t/2m)/\hbar} \right\} \left[e^{-(x-p_0t/m)^2/4\alpha^2\gamma} \right] \quad (6.52)$$

- page 180, Eq. (6.75): Move zero subscript on momentum space representation of position eigenstate from p to x :

	Position space	Momentum space	
Position eigenstate	$ x_0\rangle \doteq \delta(x - x_0)$	$ x_0\rangle \doteq \frac{1}{\sqrt{2\pi\hbar}} e^{ip_0x/\hbar}$	(6.75)
Momentum eigenstate	$ p_0\rangle \doteq \frac{1}{\sqrt{2\pi\hbar}} e^{ip_0x/\hbar}$	$ p_0\rangle \doteq \delta(p - p_0)$	

- page 199, Problem 6.21, centered equation: move "x" before division symbol:

$$\psi(x) = A e^{ip_0x/\hbar} e^{-x^2/4\alpha^2}$$

- page 217, Eqs. (7.77) and (7.78): Change the sign of the second term on the left-hand side of both equations:

$$\underbrace{\frac{1}{R(r)} \frac{d}{dr} \left(r^2 \frac{dR(r)}{dr} \right) + \frac{2\mu}{\hbar^2} (E - V(r)) r^2}_{\text{function of } r \text{ only}} = \underbrace{\frac{1}{\hbar^2} \frac{1}{Y(\theta, \phi)} \mathbf{L}^2 Y(\theta, \phi)}_{\text{function of } \theta, \phi \text{ only}} \quad (7.77)$$

$$\frac{1}{R(r)} \frac{d}{dr} \left(r^2 \frac{dR(r)}{dr} \right) + \frac{2\mu}{\hbar^2} (E - V(r)) r^2 = \frac{1}{\hbar^2} \frac{1}{Y(\theta, \phi)} \mathbf{L}^2 Y(\theta, \phi) \equiv A \quad (7.78)$$

- page 225, paragraph after Eq. (7.115), penultimate line: After the word "determine", insert the parenthetic comment "(with some ambiguity)".
- page 232, Eq. (7.148): Remove "*" indicating complex conjugate:

$$\int_{-1}^1 P_k(z) P_\ell(z) dz = \frac{2}{2\ell + 1} \delta_{k\ell} \quad (7.148)$$

- page 235, Eq. (7.156): Place the normalization factor inside a square root:

$$\Theta_\ell^m(\theta) = (-1)^m \sqrt{\frac{(2\ell + 1)(\ell - m)!}{2(\ell + m)!}} P_\ell^m(\cos\theta), \quad m \geq 0 \quad (7.156)$$

- page 239, Eq. (7.170): Change lower limit of sum to absolute value of m :

$$\mathcal{P}_{L_z=m\hbar} = \sum_{\ell=|m|}^{\infty} |\langle \ell m | \psi \rangle|^2 \quad (7.170)$$

- page 240, Spherical harmonic terms throughout this example are mislabeled, so (i) change 1 to 2 in Eqs. (7.173), (7.174), (7.175), and (7.176); and (ii) change energy and angular momentum values in sentence after Eq. (7.176):

$$\psi(\theta, \phi) = -\frac{1}{\sqrt{2}} Y_2^1(\theta, \phi) + \frac{1}{\sqrt{2}} Y_2^{-1}(\theta, \phi) \quad (7.173)$$

$$|\psi\rangle = -\frac{1}{\sqrt{2}} |2, 1\rangle + \frac{1}{\sqrt{2}} |2, -1\rangle \quad (7.174)$$

$$c_{\ell m} = \langle \ell m | \psi \rangle = -\frac{1}{\sqrt{2}} \delta_{\ell 2} \delta_{m 1} + \frac{1}{\sqrt{2}} \delta_{\ell 2} \delta_{m, -1} \quad (7.175)$$

$$\begin{aligned} \mathcal{P}_{E_\ell} &= \sum_{m=-\ell}^{\ell} |\langle \ell m | \psi \rangle|^2 \\ &= \left(-\frac{1}{\sqrt{2}} \delta_{\ell 2} \right)^2 + \left(\frac{1}{\sqrt{2}} \delta_{\ell 2} \right)^2 \\ &= \delta_{\ell 2} \end{aligned} \quad (7.176)$$

New Sentence after Eq. (7.176):

The probability of measuring the energy to be $E_2 = 3\hbar^2/I$ is 100%, as is the probability for measuring $\mathbf{L}^2 = 6\hbar^2$.

- page 240, Eq. (7.177), 1st line: Change lower limit of sum to 1:

$$\begin{aligned} \mathcal{P}_{L_z=\hbar} &= \sum_{\ell=1}^{\infty} |\langle \ell 1 | \psi \rangle|^2 \\ &= \left(-\frac{1}{\sqrt{2}} \right)^2 \\ &= \frac{1}{2} \end{aligned} \quad (7.177)$$

- page 247, Problem 7.17, centered equation: Change " $2\sqrt{2}\sqrt{3}$ " to "12":

$$\mathcal{P}(\phi, t) = \frac{1}{2\pi} \left[1 - \frac{12}{13} \sin \left(3\phi + \frac{3\hbar}{2I} t \right) \right]$$

- page 248, Problem 7.26, centered equation: Change = sign to \doteq sign:

$$L_{\pm} \doteq \hbar e^{\pm i\phi} \left(\pm \frac{\partial}{\partial \theta} + i \cot \theta \frac{\partial}{\partial \phi} \right)$$

- page 253, Eq. (8.19): Change prefactors of $H'(\rho)$ and $H''(\rho)$ terms:

$$\frac{d^2 R}{d\rho^2} = \rho^{\ell-1} e^{-\gamma\rho} \left[\left(\frac{\ell(\ell-1)}{\rho} - 2\gamma\ell + \gamma^2\rho \right) H(\rho) + (2\ell - 2\gamma\rho) H'(\rho) + \rho H''(\rho) \right] \quad (8.19)$$

- page 271, Eq. (8.97), 2nd line: Change 2 in 1st denominator to 4 ; 3rd line: Change 2 in 1st denominator to 4, change exponent in e^{-r/a_0} to $e^{-r/2a_0}$, change 4 in last denominator to 2.

$$\begin{aligned} \psi(r, \theta, \phi, t) &= \frac{1}{\sqrt{2}} \psi_{200}(r, \theta, \phi) e^{-iE_2 t/\hbar} + \frac{1}{\sqrt{2}} \psi_{210}(r, \theta, \phi) e^{-iE_2 t/\hbar} \\ &= \frac{1}{4\sqrt{\pi a_0^3}} \left(1 - \frac{r}{2a_0} \right) e^{-r/2a_0} e^{-iE_2 t/\hbar} + \frac{1}{\sqrt{\pi a_0^3}} \frac{r \cos\theta}{8a_0} e^{-r/2a_0} e^{-iE_2 t/\hbar} \\ &= \frac{1}{4\sqrt{\pi a_0^3}} e^{-iE_2 t/\hbar} \left(\left(1 - \frac{r}{2a_0} \right) e^{-r/2a_0} + \frac{z}{2a_0} e^{-r/2a_0} \right) \end{aligned} \quad (8.97)$$

- page 273, Problem 8.13, both equations: Delete $n\ell m$ subscripts from wave functions:

$$\begin{aligned} \mathcal{P}(z) &= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} |\psi(x, y, z)|^2 dx dy \\ \mathcal{P}(z) &= \int_0^{2\pi} \int_0^{\infty} |\psi(\rho, \phi, z)|^2 \rho d\rho d\phi \end{aligned}$$

- page 274, Problem 8.15, centered equation: Add "x, y," to argument of function:

$$V(x, y, z) = \begin{cases} 0, & 0 < x < L, 0 < y < L, 0 < z < L \\ \infty, & \text{otherwise} \end{cases}$$

- page 275, two lines after Eq. (9.2): Delete "to" before "zero".
- page 277, penultimate paragraph, 3rd line: Delete "what" near end of line.
- page 281, Eq. (9.28), 1st line: On right-hand side of equation, delete left parenthesis and change right parenthesis to right bracket:

$$\begin{aligned} H(a|E) &= aE|E\rangle - \hbar\omega a|E\rangle \\ &= (E - \hbar\omega)(a|E\rangle) \end{aligned} \quad (9.28)$$

- page 302, last line: Insert spaces on either side of " $\langle p \rangle$ ".
- page 303, last paragraph, end of 4th line: add space to separate "of ampli-".
- page 310, Problem 9.20, part (e): Change "that" to "than".
- page 323, Eq. (10.47): Change subscript on "H" to "nn":

$$\boxed{E_n^{(1)} = H'_{nn} = \langle n^{(0)} | H' | n^{(0)} \rangle} \quad (10.47)$$

- page 323, Eq. (10.49): Insert and remove minus signs to correct sign error in energy:

$$H_0 = -\boldsymbol{\mu} \cdot \mathbf{B}_0 = -\omega_0 S_z \doteq \begin{pmatrix} -\frac{3}{2}\hbar\omega_0 & 0 & 0 & 0 \\ 0 & -\frac{1}{2}\hbar\omega_0 & 0 & 0 \\ 0 & 0 & \frac{1}{2}\hbar\omega_0 & 0 \\ 0 & 0 & 0 & \frac{3}{2}\hbar\omega_0 \end{pmatrix} \quad (10.49)$$

- page 323, 2nd line after Eq. (10.49): (i) Insert and remove minus signs to correct sign error in energy, (ii) Change "decreasing" to "increasing". New line:

$E_1^{(0)} = -\frac{3}{2}\hbar\omega_0, E_2^{(0)} = -\frac{1}{2}\hbar\omega_0, E_3^{(0)} = \frac{1}{2}\hbar\omega_0,$ and $E_4^{(0)} = \frac{3}{2}\hbar\omega_0,$ labeled in order of increasing

- page 323, Eq. (10.50): Insert and remove minus signs to correct sign error in energy:

$$H' = -\boldsymbol{\mu} \cdot \mathbf{B}' = -\omega_1 S_z \doteq \begin{pmatrix} -\frac{3}{2}\hbar\omega_1 & 0 & 0 & 0 \\ 0 & -\frac{1}{2}\hbar\omega_1 & 0 & 0 \\ 0 & 0 & \frac{1}{2}\hbar\omega_1 & 0 \\ 0 & 0 & 0 & \frac{3}{2}\hbar\omega_1 \end{pmatrix} \quad (10.50)$$

- page 324, Fig. 10.4: Insert and remove minus signs on m labels: From top, $m = -\frac{3}{2}, m = -\frac{1}{2}, m = \frac{1}{2}, m = \frac{3}{2}.$

- page 324, Eq. (10.52): Insert and remove minus signs to correct sign error in energy:

$$\begin{aligned} E_1^{(1)} &= -\frac{3}{2}\hbar\omega_1 \\ E_2^{(1)} &= -\frac{1}{2}\hbar\omega_1 \\ E_3^{(1)} &= \frac{1}{2}\hbar\omega_1 \\ E_4^{(1)} &= \frac{3}{2}\hbar\omega_1 \end{aligned} \quad (10.52)$$

- page 332, Eq. (10.82): Insert and remove minus signs to correct sign error in energy:

$$H_0 = -\boldsymbol{\mu} \cdot \mathbf{B}_0 = -\omega_0 S_z \doteq \begin{pmatrix} -\frac{3}{2}\hbar\omega_0 & 0 & 0 & 0 \\ 0 & -\frac{1}{2}\hbar\omega_0 & 0 & 0 \\ 0 & 0 & \frac{1}{2}\hbar\omega_0 & 0 \\ 0 & 0 & 0 & \frac{3}{2}\hbar\omega_0 \end{pmatrix} \quad (10.82)$$

- page 332, 2nd line after Eq. (10.82): Insert and remove minus signs to correct sign error in energy. New energies:

$$E_1^{(0)} = -\frac{3}{2}\hbar\omega_0, E_2^{(0)} = -\frac{1}{2}\hbar\omega_0, E_3^{(0)} = \frac{1}{2}\hbar\omega_0, \text{ and } E_4^{(0)} = \frac{3}{2}\hbar\omega_0$$

- page 333, first line: Change subscript on B to 2: $\mathbf{B}' = B_2 \hat{\mathbf{x}}$

- page 333, Eq. (10.83): Insert minus signs to correct sign error in energy:

$$H' = -\boldsymbol{\mu} \cdot \mathbf{B}' = -\omega_2 S_x \doteq \begin{pmatrix} 0 & -\frac{\sqrt{3}}{2} \hbar \omega_2 & 0 & 0 \\ -\frac{\sqrt{3}}{2} \hbar \omega_2 & 0 & -\frac{\sqrt{4}}{2} \hbar \omega_2 & 0 \\ 0 & -\frac{\sqrt{4}}{2} \hbar \omega_2 & 0 & -\frac{\sqrt{3}}{2} \hbar \omega_2 \\ 0 & 0 & -\frac{\sqrt{3}}{2} \hbar \omega_2 & 0 \end{pmatrix} \quad (10.83)$$

- page 333, Eq. (10.85): (i) Sum over $m \neq 1$, (ii) Insert minus signs

$$\begin{aligned} E_1^{(2)} &= \sum_{m \neq 1} \frac{|\langle 1^{(0)} | H' | m^{(0)} \rangle|^2}{(E_1^{(0)} - E_m^{(0)})} = \frac{|\langle 1^{(0)} | H' | 2^{(0)} \rangle|^2}{(E_1^{(0)} - E_2^{(0)})} \\ &= \frac{|-\frac{\sqrt{3}}{2} \hbar \omega_2|^2}{(\frac{-3}{2} \hbar \omega_0 - \frac{-1}{2} \hbar \omega_0)} \\ &= -\frac{3\hbar\omega_2^2}{4\omega_0} \end{aligned} \quad (10.85)$$

- page 333, Eq. (10.86): (i) Sum over $m \neq 2$, (ii) Insert and remove minus signs

$$\begin{aligned} E_2^{(2)} &= \sum_{m \neq 2} \frac{|\langle 2^{(0)} | H' | m^{(0)} \rangle|^2}{(E_2^{(0)} - E_m^{(0)})} = \frac{|\langle 2^{(0)} | H' | 1^{(0)} \rangle|^2}{(E_2^{(0)} - E_1^{(0)})} + \frac{|\langle 2^{(0)} | H' | 3^{(0)} \rangle|^2}{(E_2^{(0)} - E_3^{(0)})} \\ &= \frac{|-\frac{\sqrt{3}}{2} \hbar \omega_2|^2}{(\frac{-1}{2} \hbar \omega_0 - \frac{-3}{2} \hbar \omega_0)} + \frac{|-\frac{\sqrt{4}}{2} \hbar \omega_2|^2}{(\frac{-1}{2} \hbar \omega_0 - \frac{-1}{2} \hbar \omega_0)} \\ &= -\frac{\hbar\omega_2^2}{4\omega_0} \end{aligned} \quad (10.86)$$

- page 334, Eq. (10.87): Remove minus signs:

$$\begin{aligned} E_3^{(2)} &= \frac{\hbar\omega_2^2}{4\omega_0} \\ E_4^{(2)} &= \frac{3\hbar\omega_2^2}{4\omega_0} \end{aligned} \quad (10.87)$$

- page 334, Eq. (10.89): (i) Sum over $m \neq 1$, (ii) Insert minus signs in 2nd line:

$$\begin{aligned}
 |1^{(1)}\rangle &= \sum_{m \neq 1} \frac{\langle m^{(0)} | H' | 1^{(0)} \rangle}{(E_1^{(0)} - E_m^{(0)})} |m^{(0)}\rangle = \frac{\langle 2^{(0)} | H' | 1^{(0)} \rangle}{(E_1^{(0)} - E_2^{(0)})} |2^{(0)}\rangle \\
 &= \frac{-\frac{\sqrt{3}}{2} \hbar \omega_2}{(\frac{-3}{2} \hbar \omega_0 - \frac{-1}{2} \hbar \omega_0)} |2^{(0)}\rangle \\
 &= \frac{\sqrt{3} \omega_2}{2 \omega_0} |2^{(0)}\rangle
 \end{aligned} \tag{10.89}$$

- page 334, Fig. 10.8: Insert and remove minus signs on m labels: From top, $m = -\frac{3}{2}$, $m = -\frac{1}{2}$, $m = \frac{1}{2}$, $m = \frac{3}{2}$.
- page 348, Eq. (10.142): (i) 1st line: Insert "2" in denominator of wave function polynomial; (ii) 3rd line: Change " \pm " symbol in wave function amplitude to " \mp ".

$$\begin{aligned}
 |200\rangle &\doteq \psi_{200}^{(0)}(r, \theta, \phi) = R_{20}(r) Y_0^0(\theta, \phi) = \frac{2}{(2a_0)^{3/2}} \left(1 - \frac{r}{2a_0}\right) e^{-r/2a_0} \frac{1}{\sqrt{4\pi}} \\
 |210\rangle &\doteq \psi_{210}^{(0)}(r, \theta, \phi) = R_{21}(r) Y_1^0(\theta, \phi) = \frac{1}{\sqrt{3}(2a_0)^{3/2}} \frac{r}{a_0} e^{-r/2a_0} \sqrt{\frac{3}{4\pi}} \cos\theta \\
 |21, \pm 1\rangle &\doteq \psi_{21\pm 1}^{(0)}(r, \theta, \phi) = R_{21}(r) Y_1^{\pm 1}(\theta, \phi) = \frac{\mp 1}{\sqrt{3}(2a_0)^{3/2}} \frac{r}{a_0} e^{-r/2a_0} \sqrt{\frac{3}{8\pi}} e^{\pm i\phi} \sin\theta
 \end{aligned} \tag{10.142}$$

- page 349, Eq. (10.147), 2nd line: (i) Insert $1/a_0$ term before integral, (ii) Insert "2" in denominator of wave function polynomial::

$$\begin{aligned}
 \langle 200^{(0)} | H' | 210^{(0)} \rangle &= \int \psi_{200}^{(0)*}(r, \theta, \phi) e \mathcal{E} r \cos\theta \psi_{210}^{(0)}(r, \theta, \phi) r^2 \sin\theta dr d\theta d\phi \\
 &= e \mathcal{E} \frac{2}{(2a_0)^{3/2}} \frac{1}{\sqrt{4\pi}} \frac{1}{\sqrt{3}(2a_0)^{3/2}} \sqrt{\frac{3}{4\pi}} \frac{1}{a_0} \int_0^\infty \left(1 - \frac{r}{2a_0}\right) e^{-r/a_0} r^4 dr \\
 &\quad \int_0^\pi \cos^2\theta \sin\theta d\theta \int_0^{2\pi} d\phi
 \end{aligned} \tag{10.147}$$

- page 349, Eq. (10.148): (i) 1st line: Insert "(0)" superscripts in ket and bra; (ii) 1st line: Remove extraneous square right bracket before = sign; (iii) 1st line: Insert " a_0 " in 4π denominator before integral; (iv) 2nd line: Change denominator before square brackets to $12a_0^4$:

$$\begin{aligned}
 \langle 200^{(0)} | H' | 210^{(0)} \rangle &= e \mathcal{E} \frac{2}{(2a_0)^3} \frac{1}{4\pi a_0} \frac{2}{3} 2\pi \left[\int_0^\infty r^4 e^{-r/a_0} dr - \frac{1}{2a_0} \int_0^\infty r^5 e^{-r/a_0} dr \right] \\
 &= e \mathcal{E} \frac{1}{12a_0^4} \left[4! a_0^5 - \frac{1}{2a_0} 5! a_0^6 \right] \\
 &= -3e \mathcal{E} a_0
 \end{aligned} \tag{10.148}$$

- page 356, Eq. (11.4): Insert factor of $2/g_e$ before 1st term in brackets:

$$H'_{hf} = \frac{\mu_0}{4\pi} \frac{g_e \mu_B g_p \mu_N}{\hbar^2} \left[\frac{2}{g_e} \frac{1}{r^3} \mathbf{I} \cdot \mathbf{L} - \frac{1}{r^3} \mathbf{S} \cdot \mathbf{I} + \frac{3}{r^5} (\mathbf{S} \cdot \mathbf{r})(\mathbf{I} \cdot \mathbf{r}) + \frac{8\pi}{3} \mathbf{S} \cdot \mathbf{I} \delta(\mathbf{r}) \right] \quad (11.4)$$

- page 364, Eq. (11.45): Change 4/3 in top line to 2/3:

$$\begin{aligned} \Delta E_{hf} &= \frac{2\mu_0}{3} \frac{g_e \mu_B g_p \mu_N}{\pi a_0^3} = \alpha^4 m_e c^2 \frac{2}{3} g_e g_p \left(\frac{m_e}{m_p} \right) \\ &= 5.88 \times 10^{-6} eV = h \times 1420.4057517667(9) MHz \end{aligned} \quad (11.45)$$

- page 373, last paragraph: (i) 3rd line: Change "coupled" to "uncoupled", (ii) 7th line: Change "the coupled and the coupled" to " the coupled and the uncoupled".
- pages 375 & 376, Tables 11.2 – 11.5: Header symbols j and m should be capitalized J and M to be consistent with text.
- page 398, Eq. (12.63): Add minus signs to two elements of the matrix (second 1/3 and second 2/3 on diagonal):

$$L_z \doteq \hbar \begin{pmatrix} \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & \frac{1}{3} & 0 & 0 \\ 0 & 0 & -\frac{1}{3} & 0 \\ 0 & 0 & 0 & -1 \end{matrix} & \begin{matrix} 0 & 0 \\ \frac{\sqrt{2}}{3} & 0 \\ 0 & \frac{\sqrt{2}}{3} \\ 0 & 0 \end{matrix} & \begin{matrix} \frac{3}{2}, \frac{3}{2} \\ \frac{3}{2}, \frac{1}{2} \\ \frac{3}{2}, -\frac{1}{2} \\ \frac{3}{2}, -\frac{3}{2} \end{matrix} \\ \begin{matrix} 0 & \frac{\sqrt{2}}{3} & 0 & 0 \\ 0 & 0 & \frac{\sqrt{2}}{3} & 0 \end{matrix} & \begin{matrix} \frac{2}{3} & 0 \\ 0 & -\frac{2}{3} \end{matrix} & \begin{matrix} \frac{1}{2}, \frac{1}{2} \\ \frac{1}{2}, -\frac{1}{2} \end{matrix} \end{pmatrix} \quad (12.63)$$

- page 399, 1st line after Eq. (12.67): Change "play" to "plays".
- page 403, Eq. (12.86): Change exponent on 1st n to 4:

$$E_{fs}^{(1)} = \frac{1}{2} \alpha^4 m c^2 \left[\frac{3}{4n^4} - \frac{\ell(\ell+1) - m_\ell m_s}{n^3 \ell(\ell + \frac{1}{2})(\ell+1)} \right] \quad (12.86)$$

- page 408, Problem 12.14, part (b), 1st and 2nd lines: Change "the formula we derived in class" to "Eq. (12.46)".
- page 416, Eq. (13.26): Interchange last two wave functions on right hand side:

$$|\psi_{12}^{SS}\rangle \doteq \psi_{12}^S(x_1, x_2) |00\rangle = \frac{1}{\sqrt{2}} [\varphi_1(x_1)\varphi_2(x_2) + \varphi_1(x_2)\varphi_2(x_1)] |00\rangle \quad (13.26)$$

- page 425, Eq. (13.56): Interchange last two wave functions on right hand side:

$$|\psi_{12}^{AS}\rangle \doteq \psi_{12}^A(x_1, x_2) |1M\rangle = \frac{1}{\sqrt{2}} [\varphi_1(x_1)\varphi_2(x_2) - \varphi_1(x_2)\varphi_2(x_1)] |1M\rangle \quad (13.56)$$

- page 431, Eq. (13.79): Add complex conjugation symbols to two wave functions on 1st line and remove them from two wave functions on 2nd line:

$$E_{1s,2\ell}^{(1)} = \iint \frac{1}{\sqrt{2}} \left[\psi_{100}^*(\mathbf{r}_1) \psi_{2\ell m}^*(\mathbf{r}_2) \pm \psi_{2\ell m}^*(\mathbf{r}_1) \psi_{100}^*(\mathbf{r}_2) \right] \frac{e^2}{4\pi\epsilon_0 |\mathbf{r}_1 - \mathbf{r}_2|} \frac{1}{\sqrt{2}} \left[\psi_{100}(\mathbf{r}_1) \psi_{2\ell m}(\mathbf{r}_2) \pm \psi_{2\ell m}(\mathbf{r}_1) \psi_{100}(\mathbf{r}_2) \right] d^3\mathbf{r}_1 d^3\mathbf{r}_2 \quad (13.79)$$

- page 443, Problem 13.7: Delete second half of last sentence after comma (no integrals required).
- page 444, Problem 13.17: (i) part (b): Change "wave function" to "quantum state vector", (ii) part (d): Change "wave functions" to "quantum state vectors".
- page 448, Eq. (14.16): Change the subscript on the second energy from "n" to "i":

$$i\hbar \frac{dc_k^{(1)}(t)}{dt} = e^{i(E_k - E_i)t/\hbar} \langle k | H'(t) | i \rangle \quad (14.16)$$

- page 452, Figure 14.3, lower label: Insert "/" so that marked time interval is $2\pi/(\omega_{fi} - \omega)$.
- page 460, Eq. (14.69), second line: Change the first "E" symbol to a script font for electric field:

$$R_{1 \rightarrow 2} = \frac{2\pi}{\hbar} |V_{21}|^2 g(E_f) = \frac{2\pi e^2 \mathcal{E}_0^2}{\hbar} |\hat{\mathbf{e}} \cdot \langle 2 | \mathbf{r} | 1 \rangle|^2 \frac{\hbar A_{21} / 2\pi}{(E - \hbar\omega_{21})^2 + \left(\frac{\hbar A_{21}}{2}\right)^2} \quad (14.69)$$

- page 467, Problem 14.3: Change starting time from "t = 0" to "t = -∞".
- page 468, Problem 14.12: Change "l = 3" to "ℓ = 3".
- pages 482 and 483, Eqs. (15.38) and (15.39): An overall phase (which is physically meaningless) has been omitted from Eqs. (15.38) and (15.39).
- page 483, Fig. 15.12: Each wave function is defined only over the range $0.5a \leq x \leq 8.5a$ (given that we are using periodic boundary conditions).
- page 485, Eq. (15.43): Insert absolute value symbols:

$$g(E) = 2g_k(k) \left| \frac{dk}{dE} \right| = \frac{L}{\pi} \left| \frac{dk}{dE} \right| \quad (15.43)$$

- page 485, Eq. (15.44): Insert minus sign:

$$\frac{dE}{dk} = -2\beta a \sin(ka) \quad (15.44)$$

- page 485, Eq. (15.45): Insert absolute value symbol:

$$g(E) = \left| \frac{L}{2\pi\beta a \sin(ka)} \right| \quad (15.45)$$

- page 486, last line: Change "-3.6 meV" to "-3.5 meV".
- page 488, middle of last paragraph before Section 15.8.1: Change "-32 meV" to "-31 meV".
- page 490, Eq. (15.58): Change sign of κ term in exponents (4 times):

$$\begin{aligned} e^{ika}\psi_I(-b) = \psi_{II}(-b+a) &\Rightarrow Ae^{-iqb} + Be^{iqb} = e^{-ika} [Ce^{i\kappa(a-b)} + De^{-i\kappa(a-b)}] \\ e^{ika}\psi_I'(-b) = \psi_{II}'(-b+a) &\Rightarrow q[Ae^{-iqb} - Be^{iqb}] = \kappa e^{-ika} [Ce^{i\kappa(a-b)} - De^{-i\kappa(a-b)}] \end{aligned} \quad (15.58)$$

- page 490, Eq. (15.59): Change sign of κ term in exponents (4 times):

$$\begin{pmatrix} 1 & 1 & -1 & -1 \\ e^{-iqb} & e^{iqb} & -e^{-ika}e^{i\kappa(a-b)} & -e^{-ika}e^{-i\kappa(a-b)} \\ q & -q & -\kappa & \kappa \\ qe^{-iqb} & -qe^{iqb} & -\kappa e^{-ika}e^{i\kappa(a-b)} & \kappa e^{-ika}e^{-i\kappa(a-b)} \end{pmatrix} \begin{pmatrix} A \\ B \\ C \\ D \end{pmatrix} = 0 \quad (15.59)$$

- page 491, Eq. (15.61): Add absolute value symbols to κ terms (2 more times):

$$\cos(qb)\cosh(|\kappa|(a-b)) - \frac{q^2 - |\kappa|^2}{2q|\kappa|} \sin(qb)\sinh(|\kappa|(a-b)) = \cos(ka) \quad (15.61)$$

- page 523, Eq. (16.47): Insert $1/\sqrt{2}$ prefactor before last term:

$$|\psi_3\rangle = U_{CNOT} |\psi_2\rangle \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 0 \\ -1 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \\ -1 \\ 0 \end{pmatrix} \quad (16.47)$$

- page 546, First line after Eq. (D.26): Insert "we" after "if".