# 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 "$1\times 2$" to "$2\times 1$".
- page 44, Eq. (2.50): Change the "+" superscript in the 2nd and 3rd lines to the proper adjoint symbol "$\dagger$":

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

- 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:

$$\begin{aligned} |\psi(0)\rangle = |-\rangle &= \left(|+\rangle_{y\,y}\langle+| + |-\rangle_{y\,y}\langle-|\right)|-\rangle \\ &= |+\rangle_{y\,y}\langle+|-\rangle + |-\rangle_{y\,y}\langle-|-\rangle \\ &= {}_y\langle+|-\rangle|+\rangle_y + {}_y\langle-|-\rangle|-\rangle_y \\ &= \tfrac{-i}{\sqrt{2}}|+\rangle_y + \tfrac{i}{\sqrt{2}}|-\rangle_y \end{aligned} \tag{3.65}$$

- 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 "π/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 $2\pi$ :

$$\begin{aligned} f_{ij} &= \frac{\omega_{ij}}{2\pi} = \frac{E_i - E_j}{h} \\ \lambda_{ij} &= \frac{c}{f_{ij}} = \frac{hc}{E_i - E_j} \end{aligned} \tag{5.1}$$

- page 117, Eq. (5.37): Change the " $\varphi$ " symbol to the " $\phi$ " symbol all 3 places:

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

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

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

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

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

- 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 $\varphi$ symbols inside kets to $E$:

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

- page 157, Problem 5.7: Change $\varphi$ symbols inside kets to $E$:

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

- 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:

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

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

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

- 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 | $\lvert x_0\rangle \doteq \delta(x-x_0)$ | $\lvert x_0\rangle \doteq \frac{1}{\sqrt{2\pi\hbar}}e^{ipx_0/\hbar}$ |
| Momentum eigenstate | $\lvert p_0\rangle \doteq \frac{1}{\sqrt{2\pi\hbar}}e^{ip_0x/\hbar}$ | $\lvert p_0\rangle \doteq \delta(p-p_0)$ |

(6.75)

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

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

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

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

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

- 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:

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

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

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

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

$$\mathcal{P}_{L_z=m\hbar} = \sum_{\ell=|m|}^{\infty} \left|\langle \ell m|\psi\rangle\right|^2 \tag{7.170}$$

- 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):

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

$$|\psi\rangle = -\frac{1}{\sqrt{2}}|21\rangle + \frac{1}{\sqrt{2}}|2,-1\rangle \tag{7.174}$$

$$c_{\ell m} = \langle \ell m|\psi\rangle = -\frac{1}{\sqrt{2}}\delta_{\ell 2}\delta_{m1} + \frac{1}{\sqrt{2}}\delta_{\ell 2}\delta_{m,-1} \tag{7.175}$$

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

*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:

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

- 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:

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

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

$$\begin{aligned}\psi(r,\theta,\phi,t) &= \tfrac{1}{\sqrt{2}}\psi_{200}(r,\theta,\phi)e^{-iE_2t/\hbar} + \tfrac{1}{\sqrt{2}}\psi_{210}(r,\theta,\phi)e^{-iE_2t/\hbar}\\ &= \frac{1}{4\sqrt{\pi a_0^3}}\left(1 - \frac{r}{2a_0}\right)e^{-r/2a_0}e^{-iE_2t/\hbar} + \frac{1}{\sqrt{\pi a_0^3}}\frac{r\cos\theta}{8a_0}e^{-r/2a_0}e^{-iE_2t/\hbar}\\ &= \frac{1}{4\sqrt{\pi a_0^3}}e^{-iE_2t/\hbar}\left(\left(1 - \frac{r}{2a_0}\right)e^{-r/2a_0} + \frac{z}{2a_0}e^{-r/2a_0}\right)\end{aligned} \tag{8.97}$$

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

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

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

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

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

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

- page 302, last line: Insert spaces on either side of "$\langle p\rangle$".
- page 303, last paragraph, end of 4[th] 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 "$nn$":

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

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

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

- page 323, 2[nd] 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:

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

- 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:

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

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

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

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

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

- 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:

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

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

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

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

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

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

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

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

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

- 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 "$\mp$".

$$\begin{aligned}\left|200\right\rangle &\doteq \psi_{200}^{(0)}(r,\theta,\phi) = R_{20}(r)Y_0^0(\theta,\phi) = \frac{2}{(2a_0)^{3/2}}\left(1-\frac{r}{2a_0}\right)e^{-r/2a_0}\frac{1}{\sqrt{4\pi}} \\ \left|210\right\rangle &\doteq \psi_{210}^{(0)}(r,\theta,\phi) = R_{21}(r)Y_1^0(\theta,\phi) = \frac{1}{\sqrt{3}(2a_0)^{3/2}}\frac{r}{a_0}e^{-r/2a_0}\sqrt{\frac{3}{4\pi}}\cos\theta \\ \left|21,\pm1\right\rangle &\doteq \psi_{21\pm1}^{(0)}(r,\theta,\phi) = R_{21}(r)Y_1^{\pm1}(\theta,\phi) = \frac{\mp1}{\sqrt{3}(2a_0)^{3/2}}\frac{r}{a_0}e^{-r/2a_0}\sqrt{\frac{3}{8\pi}}e^{\pm i\phi}\sin\theta\end{aligned} \qquad (10.142)$$

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

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

- 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 $4\pi$ denominator before integral; (iv) 2nd line: Change denominator before square brackets to $12a_0^4$:

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

- 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 362, first line after Eq. (11.33): Change subscript of second "$I_x$" to "$I_y$".
- 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):

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

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

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

- 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:

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

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

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

- 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:

$$E^{(1)}_{1s,2\ell} = \iint \tfrac{1}{\sqrt{2}}\left[\psi^*_{100}(\mathbf{r}_1)\psi^*_{2\ell m}(\mathbf{r}_2) \pm \psi^*_{100}(\mathbf{r}_2)\psi^*_{2\ell m}(\mathbf{r}_1)\right]\frac{e^2}{4\pi\varepsilon_0|\mathbf{r}_1-\mathbf{r}_2|} \\ \tfrac{1}{\sqrt{2}}\left[\psi_{100}(\mathbf{r}_1)\psi_{2\ell m}(\mathbf{r}_2) \pm \psi_{100}(\mathbf{r}_2)\psi_{2\ell m}(\mathbf{r}_1)\right]d^3\mathbf{r}_1 d^3\mathbf{r}_2 \tag{13.79}$$

- 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 "$i$":

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

- 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:

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

- page 467, Problem 14.3: Change starting time from "$t = 0$" to "$t = -\infty$".
- page 468, Problem 14.12: Change "l = 3" to "$\ell = 3$".
- 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 $0.5a \le x \le 8.5a$ (given that we are using periodic boundary conditions).
- page 485, Eq. (15.43): Insert absolute value symbols:

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

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

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

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

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

- 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 $\kappa$ term in exponents (4 times):

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

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

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

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

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

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

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

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