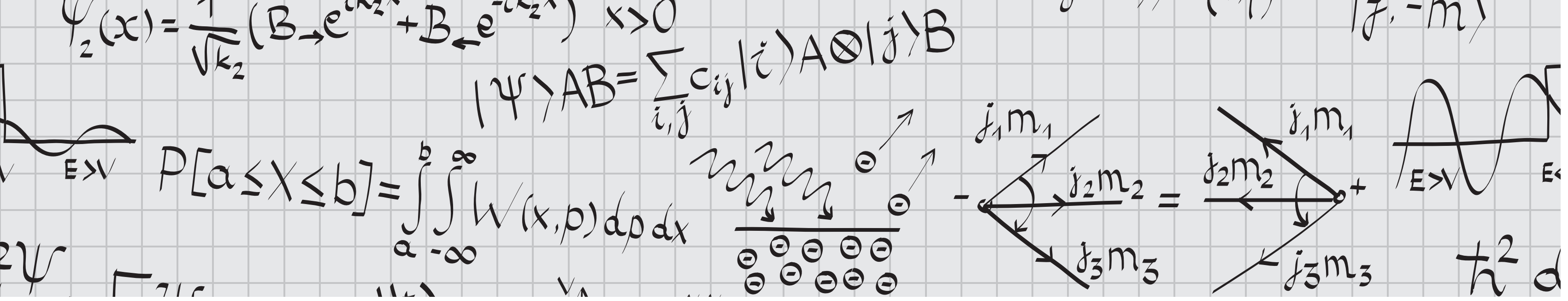

EQUATION INDEX

Classical Mechanics

(1.41) $x(t) = Ae^{i\omega t}$ (p. 22)

(1.42) $q_k(t) = a_k e^{i\omega t}$ (p. 23)

(1.43) $\det(A_{jk} - \omega^2 m_{jk}) = 0$ (p. 23)

(1.44) $m\ddot{x} + b\dot{x} + kx = 0$ (p. 25)

(1.45) $\omega_R = \sqrt{\omega_0^2 - 2\beta^2}$ (p. 25)

(1.46) $m\ddot{x} = -mgx/L$ (p. 25)

(1.47) $\omega = \sqrt{\frac{g}{L}}$ (p. 25)

(1.48) $\omega = \sqrt{\frac{mgR}{I}}$ (p. 26)

(1.49) $\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$ (p. 27)

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(2.3) $\mathbf{F}_E = q\mathbf{E}$ (p. 35)

(2.4) $\mathbf{E} = -\nabla V$ (p. 35)

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(2.6) $\nabla^2 V = -\frac{\rho}{\epsilon_0}$ (p. 36)

(2.7) $\nabla^2 V = 0$ (empty space) (p. 36)

(2.8) $V(\mathbf{r}) = \frac{1}{4\pi\epsilon_0} \int \frac{\rho(\mathbf{r'})}{|\mathbf{r} - \mathbf{r}'|} d^3\mathbf{r'}$ (p. 36)

(2.9) $\oint_S \mathbf{E}(\mathbf{r}) \cdot d\mathbf{S} = \frac{Q_{\text{enc}}}{\epsilon_0}$ (p. 36)

(2.10) $\oint_C \mathbf{E}(\mathbf{r}) \cdot d\mathbf{l} = 0$ (electrostatics) (p. 36)

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(2.16) $W = \frac{1}{2}\sum_{i=1}^{n} q_i V(\mathbf{r}_i)$ (p. 42)

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(2.20) $C = \frac{\epsilon_0 A}{d}$ (parallel-plate capacitor) (p. 44)

(2.21) $U_C = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$ (p. 44)

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(2.29) $\mathbf{B}(\mathbf{r}) = \frac{\mu_0 I}{4\pi}\int \frac{d\mathbf{l} \times \hat{\mathbf{r}'}}{r'^2}$ (p. 46)

(2.30) $|\mathbf{B}|(2\pi r) = \mu_0 I \implies \mathbf{B} = \frac{\mu_0 I}{2\pi r}\hat{\boldsymbol{\phi}}$ (p. 47)

(2.31) $B = \mu_0 n I$ (solenoid) (p. 47)

(2.32) $B = \frac{\mu_0 N I}{2\pi r}$ (toroid) (p. 47)

(2.33) $B_{\text{out}}^{\perp} - B_{\text{in}}^{\perp} = 0$ (p. 48)

(2.34) $\mathbf{B}_{\text{out}}^{\parallel} - \mathbf{B}_{\text{in}}^{\parallel} = \mu_0 \mathbf{K} \times \hat{\mathbf{n}}$ (p. 48)

(2.35) $U_B = \frac{1}{2\mu_0}\int |\mathbf{B}|^2\, d^3\mathbf{r}$ (p. 48)

(2.36) $R = \frac{mv}{qB}$ (p. 48)

(2.37) $\omega = \frac{qB}{m}$ (p. 49)

(2.38) $\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$ (p. 49)

(2.39) $\nabla \cdot \mathbf{B} = 0$ (p. 49)

(2.40) $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$ (p. 49)

(2.41) $\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0\epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$ (p. 49)

(2.42) $\mathcal{E} = -\frac{d\boldsymbol{\Phi}_B}{dt}$ (p. 50)

(2.43) $\Phi_{21} = M_{12}I_1$ (p. 50)

(2.44) $\Phi_B = LI$ (p. 50)

(2.45) $\mathcal{E} = -L\frac{dI}{dt}$ (p. 51)

(2.46) $L = \frac{\mu_0 N^2 A}{l}$ (solenoid) (p. 51)

(2.47) $U_L = \frac{1}{2}LI^2$ (p. 51)

(2.48) $\mathbf{p} = q\mathbf{r}_1 - q\mathbf{r}_2 = q\mathbf{d}$ (p. 52)

(2.49) $\mathbf{p} = \int \mathbf{r}\rho(\mathbf{r})d^3\mathbf{r}$ (p. 52)

(2.50) $V(\mathbf{r}) = \frac{1}{4\pi\epsilon_0}\frac{\mathbf{p}\cdot\hat{\mathbf{r}}}{r^2}$ (p. 52)

(2.51) $\mathbf{N} = \mathbf{p} \times \mathbf{E}$ (p. 52)

(2.52) $U = -\mathbf{p}\cdot\mathbf{E}$ (p. 52)

(2.53) $\mathbf{m} = I\mathbf{A}$ (p. 52)

(2.54) $\mathbf{N} = \mathbf{m} \times \mathbf{B}$ (p. 53)

(2.55) $U = -\mathbf{m}\cdot\mathbf{B}$ (p. 53)

(2.56) $\sigma_b = \mathbf{P}\cdot\hat{\mathbf{n}}$ (p. 54)

(2.57) $\rho_b = -\nabla\cdot\mathbf{P}$ (p. 54)

(2.58) $\epsilon_0 \mapsto \epsilon = \kappa\epsilon_0$ (p. 54)

(2.59) $C = \frac{\epsilon A}{d} = \kappa\frac{\epsilon_0 A}{d}$ (p. 54)

(2.60) $c = 1/\sqrt{\epsilon_0\mu_0}$ (p. 55)

(2.61) $\tilde{\mathbf{E}}(\mathbf{r}) = \tilde{E}_0 e^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)}\hat{\mathbf{n}}$ (p. 55)

(2.62) $\tilde{\mathbf{B}}(\mathbf{r}) = \frac{1}{c}\tilde{E}_0 e^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)}(\hat{\mathbf{k}}\times\hat{\mathbf{n}})$ (p. 55)

(2.63) $\mathbf{S} = \frac{1}{\mu_0}(\mathbf{E}\times\mathbf{B})$ (p. 55)

(2.64) $\mathbf{S} = \frac{1}{2\mu_0}\mathrm{Re}(\tilde{\mathbf{E}}\times\tilde{\mathbf{B}}^*)$ (p. 55)

(2.65) $I = \langle S\rangle = \frac{1}{2}c\epsilon_0 E_0^2$ (p. 55)

(2.66) $P = \frac{q^2a^2}{6\pi\epsilon_0 c^3} = \frac{\mu_0 q^2 a^2}{6\pi c}$ (p. 56)

(2.67) $\langle S\rangle = \left(\frac{\mu_0 p_0^2\omega^4}{32\pi^2 c}\right)\frac{\sin^2\theta}{r^2}$ (p. 56)

(2.68) $\langle P\rangle_E = \frac{\mu_0 p_0^2\omega^4}{12\pi c}$ (p. 56)

(2.69) $\langle P\rangle_B = \frac{\mu_0 m_0^2\omega^4}{12\pi c^3}$ (p. 56)

(2.70) $V_R = IR$ (p. 57)

(2.71) $V_C = \frac{Q}{C}$ (p. 57)

(2.72) $V_L = L\frac{dI}{dt}$ (p. 57)

(2.73) $R_{\mathrm{eq}} = \sum_i R_i$ (series) (p. 57)

(2.74) $\frac{1}{C_{\mathrm{eq}}} = \sum_i \frac{1}{C_i}$ (series) (p. 57)

(2.75) $L_{\mathrm{eq}} = \sum_i L_i$ (series) (p. 57)

(2.76) $\frac{1}{R_{\mathrm{eq}}} = \sum_i \frac{1}{R_i}$ (parallel) (p. 57)

(2.77) $C_{\mathrm{eq}} = \sum_i C_i$ (parallel) (p. 57)

(2.78) $\frac{1}{L_{\mathrm{eq}}} = \sum_i \frac{1}{L_i}$ (parallel) (p. 57)

(2.79) $R = \frac{\rho\ell}{A}$ (p. 57)

(2.80) $\sum_k I_k = 0$ (p. 57)

(2.81) $\sum_k V_k = 0$ (p. 57)

(2.82) $P = IV = \frac{V^2}{R} = I^2R$ (p. 57)

(2.83) $\tau_{RL} = L/R$ (p. 58)

(2.84) $\tau_{RC} = RC$ (p. 58)

(2.85) $\omega_0 = \frac{1}{\sqrt{LC}}$ (p. 58)

Optics and Waves

(3.1) $\frac{\partial^2 f}{\partial t^2} = v^2\frac{\partial^2 f}{\partial x^2}$ (p. 63)

(3.2) $f(x,t) = A\cos(kx - \omega t + \delta)$ (p. 63)

(3.3) $\lambda = \frac{2\pi}{k}, \quad T = \frac{2\pi}{\omega}, \quad \omega = 2\pi f$ (p. 64)

(3.4) $\omega = vk$ (p. 65)

(3.5) Phase velocity: $\frac{\omega}{k}$ (p. 65)

(3.6) Group velocity: $\frac{d\omega}{dk}$ (p. 65)

(3.7) $v = \sqrt{\frac{T}{\mu}}$ (p. 65)

(3.8) $\omega/k = c/n$ (for light waves) (p. 65)

(3.9) $\lambda \to \frac{\lambda}{n}$ (p. 65)

(3.10) $I = I_0 \cos^2\theta$ (p. 66)

(3.11) $\theta_B = \arctan\left(\frac{n_2}{n_1}\right)$ (p. 66)

(3.12) Constructive interference $\iff$ phase difference of $2m\pi$ (p. 67)

(3.13) Destructive interference $\iff$ phase difference of $(2m+1)\pi$ (p. 67)

(3.14) $\delta = k\Delta x$ (p. 67)

(3.15) Maxima: $d\sin\theta = m\lambda$ (p. 67)

(3.16) Minima: $d\sin\theta = (m + 1/2)\lambda$ (p. 67)

(3.17) $a\sin\theta = m\lambda, \quad m = 1, 2, \ldots$ (p. 68)

(3.18) $\Delta x = nd$ (optical path length) (p. 69)

(3.19) $n_2 > n_1$: phase shift of π (p. 69)

(3.20) $n_2 < n_1$: *no* phase shift (p. 69)

(3.21) First circular diffraction minimum: $D\sin\theta = 1.22\lambda$ (p. 70)

(3.22) Maxima: $d\sin\theta = n\lambda/2$ (p. 70)

(3.23) Reflection: $\theta_i = \theta_r$ (angle of incidence equals angle of reflection) (p. 71)

(3.24) Refraction: $n_1\sin\theta_1 = n_2\sin\theta_2$ (Snell's law) (p. 71)

(3.25) $c_2\sin\theta_1 = c_1\sin\theta_2$ (p. 71)

(3.26) $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ (p. 71)

(3.27) $f = R/2$ (p. 71)

(3.28) $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ (p. 71)

(3.29) Positive distances $\iff$ same side as light rays (incoming for s, outgoing for s') (p. 71)

(3.30) Negative distances $\iff$ opposite side as light rays (incoming for s, outgoing for s') (p. 71)

(3.31) $I \propto I_0\,\lambda^{-4}\,a^6$ (p. 72)

(3.32) $f = \left(\frac{v + v_r}{v - v_s}\right) f_0$ (p. 73)

Thermodynamics and Statistical Mechanics

(4.1) $p_i = \frac{e^{-\beta E_i}}{\sum_j e^{-\beta E_j}}$ (p. 78)

(4.2) $\beta = \frac{1}{k_B T}$ (p. 78)

(4.3) $\langle\mathcal{O}\rangle = \sum_i p_i \mathcal{O}_i$ (p. 79)

(4.4) $p_i = \frac{e^{-\beta E_i}}{Z}$ (p. 79)

(4.5) $Z = \sum_j e^{-\beta E_j}$ (p. 79)

(4.6) $\langle E\rangle = \sum_i p_i E_i = \frac{\sum_i E_i e^{-\beta E_i}}{Z} = -\frac{\partial}{\partial\beta}\ln Z$ (p. 79)

(4.7) $S = k_B \ln\Omega$ (p. 79)

(4.8) $S = -k_B \sum_i p_i \ln p_i = \frac{\partial}{\partial T}(k_B T\ln Z)$ (p. 79)

(4.9) $S = Nk_B\left(\ln\frac{V}{N} + \frac{3}{2}\ln T + \frac{5}{2} + \frac{3}{2}\ln\frac{2\pi m k_B}{h^2}\right)$ (p. 80)

(4.10) $S = Nk_B \ln\frac{VT^{3/2}}{N} + \text{constants}$ (p. 80)

(4.11) $Z_N = \frac{1}{N!h^{3N}}\int e^{-\beta H(\mathbf{p}_1,\ldots\mathbf{p}_n;\mathbf{x}_1,\ldots\mathbf{x}_n)} d^3\mathbf{p}_1 \cdots d^3\mathbf{p}_n d^3\mathbf{x}_1 \cdots d^3\mathbf{x}_n$ (p. 80)

(4.12) $\binom{N}{M} = \frac{N!}{(N-M)!M!}$ (p. 80)

(4.13) $\ln(n!) \approx n\ln n - n$ (p. 80)

(4.14) $\Delta U = Q - W$ (p. 81)

(4.15) $\Delta S \geq \int \frac{\delta Q}{T}$ (p. 82)

(4.16) $PV = Nk_B T$ (p. 82)

(4.17) $\delta W = P\,dV$ (reversible) (p. 83)

(4.18) $\delta Q = T\,dS$ (reversible) (p. 83)

(4.19) $\Delta S = \int \frac{\delta Q}{T}$ (p. 83)

(4.20) $PV^\gamma = \text{constant}$ (p. 83)

(4.21) $dU = TdS - PdV$ (p. 84)

(4.22) $T = \left(\frac{\partial U}{\partial S}\right)\Big|_V$ (p. 84)

(4.23) $P = -\left(\frac{\partial U}{\partial V}\right)\Big|_S$ (p. 84)

(4.24) $\left(\frac{\partial P}{\partial S}\right)\Big|_V = -\left(\frac{\partial T}{\partial V}\right)\Big|_S$ (p. 84)

(4.25) $dH = TdS + VdP$ (p. 84)

(4.26) $dA = -SdT - PdV$ (p. 84)

(4.27) $dG = -SdT + VdP$ (p. 84)

(4.28) $\left(\frac{\partial T}{\partial P}\right)\Big|_S = \left(\frac{\partial V}{\partial S}\right)\Big|_P$ (p. 84)

(4.29) $\left(\frac{\partial S}{\partial V}\right)\Big|_T = \left(\frac{\partial P}{\partial T}\right)\Big|_V$ (p. 84)

(4.30) $-\left(\frac{\partial S}{\partial P}\right)\Big|_T = \left(\frac{\partial V}{\partial T}\right)\Big|_P$ (p. 84)

(4.31) $\left(\frac{\partial Q}{\partial T}\right)_V = C_V$ (p. 84)

(4.32) $\left(\frac{\partial Q}{\partial T}\right)_P = C_P$ (p. 84)

(4.33) $\left(\frac{\partial Q}{\partial T}\right)_V = \frac{\partial U}{\partial T}$ (p. 85)

(4.34) $C_P - C_V = Nk_B$ (p. 85)

(4.35) $Q = mc\Delta T$ (p. 85)

(4.36) $e = 1 - \left|\frac{Q_C}{Q_H}\right|$ (p. 85)

(4.37) $e = 1 - \frac{T_C}{T_H}$ (p. 85)

(4.38) $U = \frac{3}{2}Nk_BT$ (p. 86)

(4.39) $v_{\rm rms} = \sqrt{\frac{3k_BT}{m}}$ (p. 87)

(4.40) $c = \sqrt{\gamma\frac{P}{\rho}}$ (p. 87)

(4.41) $c = \sqrt{\gamma\frac{k_BT}{m}}$ (p. 87)

(4.42) $F_{\rm FD}(\epsilon_i) = \frac{1}{e^{(\epsilon_i-\mu)/k_BT}+1}$ (p. 88)

(4.43) $F_{\rm BE}(\epsilon_i) = \frac{1}{e^{(\epsilon_i-\mu)/k_BT}-1}$ (p. 88)

(4.44) $\langle N\rangle = \sum_i g(\epsilon_i)F(\epsilon_i)$ (p. 88)

(4.45) $\langle N\rangle = \int \rho(\epsilon)F(\epsilon)\,d\epsilon$ (p. 88)

Quantum Mechanics and Atomic Physics

(5.1) $\langle A\rangle = \int_{-\infty}^{\infty}\Psi^*\hat{A}\Psi\,dx$ (p. 92)

(5.2) $\int_{-\infty}^{\infty}|\Psi(x,t)|^2\,dx = 1$ (p. 92)

(5.3) $\int_{-\infty}^{\infty}f(x)^*(\hat{A}g(x))\,dx = \int_{-\infty}^{\infty}(\hat{A}f(x))^*g(x)\,dx$ (p. 93)

(5.4) $\hat{x} = x, \quad \hat{p} = -i\hbar\frac{\partial}{\partial x}$ (p. 93)

(5.5) $c_n = \int_{-\infty}^{\infty}f_n(x)^*\,\Psi(x,t)\,dx$ (p. 94)

(5.6) $\langle A\rangle = \sum_k \lambda_k|c_k|^2$ (p. 94)

(5.7) Inner product of $|a\rangle$ and $|b\rangle \equiv \langle b|a\rangle$ (p. 94)

(5.8) $\langle a|b\rangle := \langle b|a\rangle^*$ (p. 94)

(5.9) $\langle a|\hat{A}b\rangle := \langle \hat{A}^\dagger a|b\rangle$ (p. 94)

(5.10) $\langle x|f\rangle := f(x)$

(5.11) $\langle f|g\rangle := \int_{-\infty}^{\infty}f(x)^*g(x)\,dx$ (p. 94)

(5.12) $i\hbar\frac{\partial}{\partial t}\Psi(x,t) = \hat{H}\Psi(x,t)$ (p. 95)

(5.13) $\hat{H} = \frac{\hat{p}^2}{2m} + \hat{V}(x) = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + \hat{V}(x)$ (p. 95)

(5.14) $i\hbar\frac{\partial}{\partial t}\Psi(x,t) = E_n\Psi(x,t)$ (p. 95)

(5.15) $[\hat{x}\hat{p}] = i\hbar$ (p. 96)

(5.16) $\sigma_A^2\sigma_B^2 \geq \left(\frac{1}{2i}\langle[\hat{A},\hat{B}]\rangle\right)^2$ (p. 97)

(5.17) $\sigma_A^2 := \langle A^2\rangle - \langle A\rangle^2$ (p. 97)

(5.18) $\sigma_x\sigma_p \geq \frac{\hbar}{2}$ (p. 97)

(5.19) $\Delta x\Delta p \approx \hbar$ (p. 97)

(5.20) $\Delta E\Delta t \approx \hbar$ (p. 97)

(5.21) $H = \frac{\hat{p}^2}{2m} + \frac{1}{2}m\omega^2\hat{x}^2$ (harmonic oscillator) (p. 99)

(5.22) $H = \hbar\omega\left(a^\dagger a + \frac{1}{2}\right)$ (p. 99)

(5.23) $[a,a^\dagger] = 1$ (p. 99)

(5.24) $H|n\rangle = \hbar\omega\left(n+\frac{1}{2}\right)|n\rangle, \quad n = 0,1,2,\ldots$ (p. 99)

(5.25) $\langle T\rangle = \langle V\rangle = \frac{E_n}{2}$ (p. 100)

$\psi_N(x,y,z) = \psi_{n_1}(x)\psi_{n_2}(y)\psi_{n_3}(z);\quad E_N = \left(N+\frac{3}{2}\right)\hbar\omega$ with

(5.26) $N = n_1 + n_2 + n_3$ (p. 100)

(5.27) $\psi(x) = e^{\pm ikx},\quad E = \frac{\hbar^2 k^2}{2m}$ (p. 102)

(5.28) $p = \hbar k$ (p. 102)

(5.29) $E = \hbar\omega$ (p. 102)

(5.30) $H = -\frac{\hbar^2}{2m}\nabla^2 + V(\mathbf{r})$ (three dimensions) (p. 105)

(5.31) $[\hat{x},\hat{p}_x] = i\hbar,\quad [\hat{y},\hat{p}_y] = i\hbar,\quad [\hat{z},\hat{p}_z] = i\hbar$ (p. 105)

(5.32) $[\hat{x},\hat{y}] = 0,\quad [\hat{x},\hat{p}_y] = 0,\quad [\hat{x},\hat{p}_z] = 0,\ldots$ (p. 105)

(5.33) $\int_0^\infty |R(r)|^2 r^2\,dr = 1,\ \int_0^{2\pi}\int_0^\pi |Y(\theta,\phi)|^2\,\sin\theta\,d\theta\,d\phi = 1$ (p. 105)

(5.34) $\hat{L}_x = \hat{y}\hat{p}_z - \hat{z}\hat{p}_y$ (p. 105)

(5.35) $\hat{L}_y = \hat{z}\hat{p}_x - \hat{x}\hat{p}_z$ (p. 105)

(5.36) $\hat{L}_z = \hat{x}\hat{p}_y - \hat{y}\hat{p}_x$ (p. 105)

(5.37) $[\hat{L}_x,\hat{L}_y] = i\hbar\hat{L}_z$, and cyclic permutations of x,y,z (p. 105)

(5.38) $\hat{L}^2 := \hat{L}_x^2 + \hat{L}_y^2 + \hat{L}_z^2$ (p. 105)

(5.39) $\hat{L}_z Y_l^m = m\hbar\, Y_l^m$ (p. 106)

(5.40) $\hat{L}^2 Y_l^m = l(l+1)\hbar^2\, Y_l^m$ (p. 106)

(5.41) $m = l, l-1, l-2, \ldots, -l$ (p. 106)

(5.42) $\int_0^{2\pi}\int_0^\pi (Y_l^m(\theta\phi))^* Y_{l'}^{m'}(\theta\phi)\sin\theta\,d\theta\,d\phi = \delta_{ll'}\delta_{mm'}$ (p. 106)

(5.43) $H = -\frac{\hbar^2}{2\mu}\nabla^2 - \frac{e^2}{4\pi\epsilon_0}\frac{1}{r}$ (hydrogen atom) (p. 106)

(5.44) $a = \frac{4\pi\epsilon_0\hbar^2}{\mu e^2}$ (p. 107)

(5.45) $\psi_1(r) \propto e^{-r/a}$ (p. 107)

(5.46)

$$-E_1 = \frac{\hbar^2}{2\mu a^2} = \frac{\mu e^4}{2(4\pi\epsilon_0)^2\hbar^2} = 13.6 \text{ eV for hydrogen}$$ (p. 107)

(5.47) $-E_n = \frac{\hbar^2}{2\mu a^2}\frac{1}{n^2},\quad n = 1,2,3,\ldots$ (p. 107)

(5.48) $\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} \approx 1/137$ (p. 108)

(5.49) $|\uparrow\rangle_x = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\1\end{pmatrix},\quad |\downarrow\rangle_x = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\-1\end{pmatrix}$ (p. 109)

(5.50) $|\uparrow\rangle_y = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\i\end{pmatrix},\quad |\downarrow\rangle_y = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\-i\end{pmatrix}$ (p. 109)

(5.51) $\hat{S}_+ := \hat{S}_x + i\hat{S}_y,\quad \hat{S}_- := \hat{S}_x - i\hat{S}_y$ (p. 109)

(5.52) $\hat{S}_+|\uparrow\rangle = 0,\quad \hat{S}_-|\uparrow\rangle = \hbar|\downarrow\rangle$ (p. 109)

(5.53) $\hat{S}_+|\downarrow\rangle = \hbar|\uparrow\rangle,\quad \hat{S}_-|\downarrow\rangle = 0$ (p. 109)

(5.54) Spin s and spin s' : $s_{\text{tot}} = s + s'$,
$s+s'-1, s+s'-2, \ldots, |s-s'|$ (p. 110)

(5.55) $m_{\text{tot}} = m_s + m'_{s'}$ (p. 110)

(5.56) $s = 0, m_s = 0 : \frac{1}{\sqrt{2}}(|\uparrow\rangle|\downarrow\rangle - |\downarrow\rangle|\uparrow\rangle)$ (p. 111)

(5.57) $E_n = E_n^0 + \lambda\langle\psi_n^0|H'|\psi_n^0\rangle$ (p. 113)

(5.58) $E_n = E_n^0 + \lambda^2\sum_{m\neq n}\frac{|\langle\psi_m^0|H'|\psi_n^0\rangle|^2}{E_n^0 - E_m^0}$ (p. 113)

$$\begin{aligned} J^2 &= (\mathbf{L}+\mathbf{S})^2 \\ &= L^2 + 2\mathbf{L}\cdot\mathbf{S} + S^2 \end{aligned}$$

(5.59) $\implies \mathbf{L}\cdot\mathbf{S} = \frac{1}{2}(J^2 - L^2 - S^2)$ (p. 115)

(5.60) $\Delta H = e\mathbf{E}\cdot\mathbf{r}$ (p. 116)

(5.61) $\Delta H = \frac{e}{2m}(\mathbf{L}+2\mathbf{S})\cdot\mathbf{B}$ (p. 116)

(5.62) $I(\omega) \propto \frac{h\omega^3}{c^2}\frac{1}{e^{\hbar\omega/k_BT}-1}$ (p. 118)

(5.63) $\frac{dP}{dA} \propto T^4$ (p. 118)

(5.64) $\lambda_{\max} = (2.9\times 10^{-3}\text{K}\cdot\text{m})\,T^{-1}$ (p. 118)

Special Relativity

(6.1) $t' = \gamma\left(t - \frac{v}{c^2}x\right)$ (p. 123)

(6.2) $x' = \gamma(x - vt)$ (p. 123)

(6.3) $\gamma = \frac{1}{\sqrt{1-v^2/c^2}}$ (p. 124)

(6.4) $t = \gamma\left(t' + \frac{v}{c^2}x'\right)$ (p. 124)

(6.5) $x = \gamma(x' + vt')$ (p. 124)

(6.6) $\Delta t = \gamma\Delta t'$ (fixed x') (p. 124)

(6.7) $L' = \gamma L$ (fixed t) (p. 125)

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(6.8) $w = \dfrac{v+u}{1+vu/c^2}$ (p. 125)

(6.9) $x^0 = ct, \quad x^1 = x, \quad x^2 = y, \quad x^3 = z$ (p. 125)

(6.10) $x^\mu = (x^0, x^1, x^2, x^3) = (ct, x, y, z)$ (p. 125)

(6.11) $\beta = v/c$ (p. 125)

(6.12) $\begin{pmatrix} x^{0\prime} \\ x^{1\prime} \\ x^{2\prime} \\ x^{3\prime} \end{pmatrix} = \begin{pmatrix} \gamma & -\gamma\beta & 0 & 0 \\ -\gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x^0 \\ x^1 \\ x^2 \\ x^3 \end{pmatrix}$ (p. 125)

(6.13) Energy–momentum: $p^\mu = (E/c, \mathbf{p})$ (p. 126)

(6.14) Current density: $j^\mu = (c\rho, \mathbf{J})$ (p. 126)

(6.15) Wavevector: $k^\mu = (\omega/c, \mathbf{k})$ (p. 126)

(6.16) $\mathbf{p} = \gamma m \mathbf{v} = \dfrac{m\mathbf{v}}{\sqrt{1-|\mathbf{v}|^2/c^2}}$ (p. 126)

(6.17) $E_0 = mc^2$ (p. 126)

(6.18) $T = E - mc^2$ (p. 126)

(6.19) $E = \gamma mc^2$ (p. 126)

(6.20) $T = (\gamma - 1)mc^2$ (p. 126)

(6.21) $a \cdot b \equiv a^0 b^0 - a^1 b^1 - a^2 b^2 - a^3 b^3$ (p. 126)

(6.22) Timelike: $(\Delta x)^2 > 0$ (p. 127)

(6.23) Spacelike: $(\Delta x)^2 < 0$ (p. 127)

(6.24) Lightlike or null: $(\Delta x)^2 = 0$ (p. 127)

(6.25) $E^2 = \mathbf{p}^2 c^2 + m^2 c^4$ (p. 127)

(6.26) $\sum_i p_i^\mu = \sum_f p_f^\mu$ (p. 127)

(6.27) $\dfrac{\lambda'}{\lambda} = \sqrt{\dfrac{1+\beta}{1-\beta}}$ (p. 129)

(6.28) $\beta = 0.6 \implies \gamma = 1.25$ (p. 129)

(6.29) $\beta = 0.8 \implies \gamma = 5/3$ (p. 129)

Laboratory Methods

(7.1) $\sigma_S^2 = \dfrac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2$ (p. 135)

(7.2) $\sigma_{\text{tot}} = \sqrt{\sigma_{\text{stat}}^2 + \sigma_{\text{sys}}^2}$ (p. 135)

(7.3) $\sigma_z^2 = \sum_{i=1}^{n}\left(\dfrac{\partial z}{\partial x_i}\right)^2 \sigma_{x_i}^2$ (p. 135)

(7.4) $X = \dfrac{x/\sigma_x^2 + y/\sigma_y^2}{1/\sigma_x^2 + 1/\sigma_y^2}$ (p. 136)

(7.5) $\sigma_{\text{tot}}^2 = \dfrac{1}{1/\sigma_x^2 + 1/\sigma_y^2}$ (p. 136)

(7.6) $P(n) = \dfrac{\lambda^n e^{-\lambda}}{n!}$ (p. 136)

(7.7) Capacitor: $Z = \dfrac{1}{i\omega C}$ (p. 137)

(7.8) Inductor: $Z = i\omega L$ (p. 137)

(7.9) Resistor: $Z = R$ (p. 137)

(7.10) Series: $Z_{\text{tot}} = Z_1 + Z_2 + \cdots Z_n$ (p. 137)

(7.11) Parallel: $Z_{\text{tot}}^{-1} = Z_1^{-1} + Z_2^{-1} + \cdots Z_n^{-1}$ (p. 137)

(7.12) $\overline{A \cdot B} = \overline{A} + \overline{B}$ (p. 139)

(7.13) $\overline{A + B} = \overline{A} \cdot \overline{B}$ (p. 139)

(7.14) $E_{\text{max}} = E_\gamma - \phi$ (p. 140)

(7.15) $\lambda = \dfrac{h}{mc}$ (p. 140)

(7.16) $\Delta\lambda = \dfrac{h}{mc}(1 - \cos\theta)$ (p. 140)

(7.17) $N = N_0 e^{-t/\tau}$ (p. 141)

(7.18) $t_{1/2} = \tau \ln 2$ (p. 141)

(7.19) $\dfrac{1}{\tau} = \dfrac{1}{\tau_1} + \dfrac{1}{\tau_2} + \cdots$ (p. 141)

Specialized Topics

(8.1) $k_F = (3\pi^2 n)^{1/3}$ (p. 151)

(8.2) $E_F = \dfrac{\hbar^2}{2m}(3\pi^2 n)^{2/3}$ (p. 151)

(8.3) $\rho(E) = \dfrac{V\sqrt{2}}{\pi^2\hbar^3} m^{3/2}\sqrt{E}$ (p. 151)

(8.4) $N = \int_0^{E_F} \rho(E)\, dE$ (p. 151)

(8.5) $\rho(E_F) = \dfrac{3}{2}\dfrac{N}{E_F}$ (p. 151)

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(8.6) $N_C \approx \rho(E_F)(k_B T) \sim N \dfrac{k_B T}{E_F}$ (p. 151)

(8.7) $\dfrac{\lambda_0}{\lambda_T} = \dfrac{a(\text{today})}{a(T)}$ (p. 152)

(8.8) $v = H_0 D$ (p. 152)

(8.9) $z(T) = \dfrac{\lambda_0}{\lambda_T} - 1$ (p. 152)