Constants

Electric permittivity	$\varepsilon_0 = 8.85\ 10^{-1} \ = 1/(4\pi\ 9\ 10^9)\ F/m$	Magnetic permeability	$\mu_0 = 4\pi\ 10^{-7} N/A^2$
Electron mass	$m_e = 9.11\ 10^{-31} kg = 0.511 \frac{MeV}{c^2}$	Speed of light	$c = 2.998\ 10^8 \frac{m}{s}$
Proton mass	$m_p = 1.67\ 10^{-27} kg = 938.3\ MeV/c^2$	Speed of sound in air	$v = 343\ \frac{m}{s}$
Planck constant	$h = 6.63\ 10^{-34}\ Js = 4.14\ 10^{-15} eV\ s$	$h\ c = 1239.8\ eV\ nm$	
	$\hbar = \frac{h}{2\ \pi} = 1.05\ 10^{-34}\ Js = 6.58\ 10^{-16} eV\ s$	$\hbar\ c = 197.3\ eV\ nm$	
Bohr radius	$a = 5.29\ 10^{-11} m = 52.9\ pm$	Avogadro's number	$N_A = 6.023\ 10^{23}$
Rydberg constant	$R = 1.097\ 10^7\ m^{-1}$	Number of atoms	$N = \frac{m}{M}\ N_A$
Atomic mass unit	$1u = 1.66\ 10^{-27} kg$	Electron-volt	$1\ eV = 1.6\ 10^{-19} J$
Bohr magnetron	$\mu_B = -\frac{e}{2m}\ \hbar = 9.27\ 10^{-24}\ A\ m^2 = 5.788\ 10^{-5} \frac{eV}{T}$	Conversion	$c^2 = 931.5 \frac{MeV}{u}$
Integration	$\int x^2 e^{-2x/a} dx = -\frac{a}{4}(2x^2 + 2\alpha x + a^2) e^{-2x/a}$		$\int sin^2 x\ dx = \frac{x}{2} - \frac{\sin 2x}{4}$

Chapters 15-16 Mechanical Waves-Sound

Traveling wave equation $y(x,t) = A\sin(\omega t \mp kx \mp \varphi) = A\sin\left(\frac{2\pi}{T} t \mp \frac{2\pi}{\lambda} x \mp \varphi\right)$

Speed of wave $v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda\ f$ Transverse velocity $v_y(x,t) = \frac{\partial y}{\partial t}$

Speed of wave on string $v = \sqrt{\frac{T}{\mu}}$ Linear mass density $\mu = \frac{M}{L}$

Wave equation $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\ \frac{\partial^2 y}{\partial t^2}$ Energy $E_\lambda = \frac{1}{2}\ \mu A^2 \omega^2 \lambda$ Power $P = \frac{energy}{time}$

Interference of waves $y(x,t) = 2\ A\cos\frac{\varphi}{2}\ \sin(kx - \omega t + \frac{\varphi}{2})$ Intensity $I = \frac{P}{A_\perp} = \frac{\frac{1}{2}\mu\ \omega^2 A^2\ v}{4\ \pi\ r^2}$

Standing wave equation $y(x,t) = 2\ A\sin(kx)\ \cos(\omega t) = 2\ A\sin\left(\frac{2\pi}{\lambda} x\right)\ \cos\left(\frac{2\pi}{T} t\right)$

Standing wave on string	$L = n\frac{\lambda}{2}$	$f_n = n\frac{v}{2L} = n\ f_1$	$n = 1,2,3 \ldots$	# antinodes
Open-open pipe resonance	$L = n\frac{\lambda}{2}$	$f_n = n\frac{v}{2L} = n\ f_1$	$n = 1,2,3 \ldots$	# nodes
Half-open pipe resonance	$L = n\frac{\lambda}{4}$	$f_n = n\frac{v}{4L} = n\ f_1$	$n\ = 1,3,5, \ldots$	
Sound level	$\beta = 10\ log\frac{I}{I_0}$	$I_0 = 10^{-12}\frac{W}{m^2}$	whisper level	

Doppler frequency $f' = \frac{v \pm v_D}{v \pm v_S}\ f$ where $(+)$ is for D toward S or S away from D

$(-)$ is for S toward D or D away from S

Chapters 32 Electromagnetic Waves

Gauss electric $\Phi_E = \oiint \vec{E} \cdot d\vec{A} = \frac{1}{\varepsilon_0} q_{enc}$ Gauss magnetic $\Phi_B = \oiint \vec{B} \cdot d\vec{A} = 0$

Maxwell-Ampere $\oint \vec{B} \cdot d\vec{s} = \varepsilon_0 \mu_0 \frac{d\Phi_E}{dt} + \mu_0\ i_{enc}$ Faraday $\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt} = \Delta V_{ind}$

Electro-magnetic waves	$\vec{E}(\vec{r},t) = E_m \sin(\kappa x - \omega t)\ \hat{\jmath}$		$\vec{B}(\vec{r},t) = B_m \sin(\kappa x - \omega t)\ \hat{k}$
Speed of light	$c = \frac{E}{B} = \frac{E_m}{B_m} = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = \frac{\omega}{\kappa} = \lambda f = 3\ 10^8 \frac{m}{s}$		$rms = \frac{max}{\sqrt{2}}$
Poynting vector	$\vec{S} = \frac{1}{\mu_0}\ \vec{E} \times \vec{B}$	Intensity	$I = \frac{power}{area} = S_{ave} = \frac{1}{c\mu_0} E^2{}_{rms}$
Radiation pressure	$p_r = \frac{I}{c}$ (total absorption)	$p_r = \frac{2I}{c}$	(perfect reflection)
Standing el.mg. waves	$x = n\frac{\lambda}{2}$ nodal planes $\vec{E}$	$x = (2n+1)\frac{\lambda}{4}$ nodal planes $\vec{B}$	
Resonance condition	$L = n\frac{\lambda}{2}$ AND	$f_n = \frac{c}{\lambda_n} = n\ \frac{c}{2L}$	

Ch.33-36 Optics

Law of reflection	$\theta_i = \theta_r$	Law of refraction	$n_1 sin\theta_1 = n_2 sin\theta_2$
Index of refraction	$n = \frac{c}{v} > 1$	Critical angle	$\theta_C = \theta_1$ when $\theta_2 = 90°$
Wavelength in medium	$\lambda_n = \frac{\lambda}{n}$	Frequency	$f_n = f$
Polarization	$I = \frac{1}{2} I_0$	for incident un-polarized	
	$I_t = I\ cos^2\theta$	for incident polarized	
Spherical mirrors	$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} = \frac{2}{R}$	Magnification	$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$
Lens-maker's formula in air	$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$	$\frac{1}{f} = \frac{2(n-1)}{R}$ for	$R_1 = R_2 = R$
Thin lens formula	$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$	Magnification	$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

Mirror Convention distances on same/opposite side as object are +/-

Thin-lens Conventions

Object distance	$d_o > 0$	
Image type	$d_i > 0$ real-image on opposite side	$d_i < 0$ virtual-image on same side
Image orientation	$h_i > 0$ upright	$h_i < 0$ inverted
Focal distance	$f > 0$ converging lens	$f < 0$ diverging lens
Radius of curvature	$R > 0$ object faces convex	$R < 0$ object faces concave refractive surface
Thin-film interference	Hard $n_1 < n_2 \rightarrow \Delta x = \frac{\lambda}{2}$	Soft $n_1 > n_2 \rightarrow \Delta x = 0$

Condition $2L = (2m+1)\frac{\lambda}{2n}$ Constructive 1 phase shift $(\lambda/2)$ OR Destructive no phase shift $(0\ or\ \lambda)$

$2L = m\frac{\lambda}{n}$ Destructive 1 phase shift $(\lambda/2)$ OR Constructive no phase shift $(0\ or\ \lambda)$

Number of rulings	$N = \frac{w}{d}$	Half-width of line at θ	$\theta_{hw} = \frac{\lambda}{N\ d\ cos\theta}$
Resolving power	$R = \frac{\lambda_{ave}}{\Delta\lambda} = m\ N$	Dispersion at angle θ	$D = \frac{\Delta\theta}{\Delta\lambda} = \frac{m}{d\ cos\theta}$
Rayleigh's Criterion for circular-opening diffraction		$sin\theta_R = 1.22\ \frac{\lambda}{D}$	$D = diameter$

	Bright	Dark	Intensity
	$\sin\theta \cong tan\theta = \frac{y}{L}$ (SAA)		
Double-slit interference DSI	$\boldsymbol{d}\, sin\theta = m\,\lambda$	$\boldsymbol{d}\, sin\theta = (2m+1)\frac{\lambda}{2}$	$I = 4I_m cos^2\beta$ $\beta = \pi\frac{\boldsymbol{d}}{\lambda}\sin\theta$
Single-slit diffraction SSD		$\boldsymbol{a}\sin\theta = m\ \lambda$	$I = I_m\left(\frac{sin\,\alpha}{\alpha}\right)^2$ $\alpha = \pi\frac{\boldsymbol{a}}{\lambda}\sin\theta$
Double-slit diffraction DSD = SSD + DSI	$\boldsymbol{d}\, sin\theta = \boldsymbol{m_i}\lambda$	$\boldsymbol{a}\sin\theta = \boldsymbol{m_d}\,\lambda$ (SSD) $\boldsymbol{d}\, sin\theta = (2\boldsymbol{m_i}+1)\frac{\lambda}{2}$ (DSI)	$I = I_m\, cos^2\beta\left(\frac{sin\,\alpha}{\alpha}\right)^2$
Diffraction grating	$\boldsymbol{d}\, sin\theta = m\lambda$		

Ch.37 Special relativity and Relativistic energy and momentum

Time dilation $\Delta t = \gamma\,\Delta t_0$ Length contraction $L = \frac{L_0}{\gamma}$

Lorentz transformation $x' = \gamma(x - u\,t)$ $x = \gamma(x' + u\,t')$

$t' = \gamma(t - \frac{u\,x}{c^2})$ $t = \gamma(t' + \frac{u\,x'}{c^2})$

$v' = \frac{v-u}{1-\frac{v\,u}{c^2}}$ $v = \frac{v'+u}{1+\frac{v'u}{c^2}}$

Kinetic energy $K = (\gamma - 1)\,E_0$ Rest energy $E_0 = m\,c^2$

Total energy $E = \gamma\,E_0 = K + E_0$ and $E^2 = p^2c^2 + {E_0}^2$

Linear momentum $p = \gamma\,m\,v$ $\gamma = \frac{1}{\sqrt{1-(v/c)^2}} = \frac{1}{\sqrt{1-\beta^2}}$ $\beta = \frac{v}{c}$

Ch.38-41 – Wave Properties and Q.M. I-II

Photon energy $E = h\,f$ Photon momentum $p = \frac{h}{\lambda} = \frac{h\,f}{c} = \frac{E}{c}$

Particle energy $E = h\,f = \hbar\,\omega$ Particle momentum $p = \frac{h}{\lambda} = \hbar\,k$ (De Broglie wave)

Stefan-Boltzmann $I = \sigma\,T^4 = \int_0^\infty I(\lambda)d\lambda$ Wien displacement $\lambda_m\,T = 2.9\;10^{-3}\;m\cdot K$

$\sigma = 5.67\;10^{-8}\,\frac{W}{m^2K^4}$ Planck distribution $I(\lambda) = \frac{2\pi\,h\,c^2}{\lambda^5\left(e^{\frac{hc}{\lambda kT}}-1\right)}$

Photoelectric effect $h\,f = \Phi + K_{max}$ $K_{max} = \frac{1}{2}\,m_e {v_{max}}^2 = e\,V_0$ and $\Phi = h\,f_0$

Compton effect $\Delta\lambda = \lambda' - \lambda = \lambda_C\,(1 - cos\varphi)$ Compton wavelength $\lambda_C = \frac{h}{m\,c} = \frac{h\,c}{E_0}$

Uncertainty principle $\Delta p_x\,\Delta x \geq \frac{\hbar}{2}$ $\Delta E\,\Delta t \geq \frac{\hbar}{2}$

Bohr quantization $L_n = r_n\,m\,v_n = n\,\hbar$ $h\,f = \frac{h\,c}{\lambda} = E_i - E_f$ $\frac{1}{\lambda} = R\left(\frac{1}{{n_{low}}^2} - \frac{1}{{n_{high}}^2}\right)$

Bohr H atom $r = a_0\,n^2$ $E_n = -\frac{13.6\,eV}{n^2}$

Schrödinger equation	$-\frac{\hbar^2}{2m}\frac{d^2\Psi(x)}{dx^2} + U(x)\,\psi(x) = E\,\psi(x)$	Free particle	$U(x) = 0$
Probability	$P(a < x < b) = \int_a^b \lvert\Psi(x,t)\rvert^2 dx$	Normalization	$\int_{-\infty}^{\infty} \lvert\Psi(x,t)\rvert^2\, dx = 1$
Infinite square well	$\psi(x) = \sqrt{\frac{2}{L}}\,\sin(\frac{n\,\pi}{L}x)$	$n = 1,2,3,\ldots$	$E_n = \frac{p^2}{2m} = n^2\frac{\pi^2\hbar^2}{2\,m\,L^2} = n^2 E_1$
Tunneling probability	$T = 16\frac{E}{U_0}\left(1-\frac{E}{U_0}\right)e^{-2\kappa\,L} \cong 2\,e^{-2\kappa\,L}$		$\kappa = \frac{1}{\hbar}\sqrt{2m\,(U_0 - E)}$
Q. harmonic oscillator	$E_n = \left(n+\frac{1}{2}\right)\hbar\,\omega$	$n = 0,1,2,3,$	
Hydrogen atom G.S. wave functions	$\psi_{100} = \frac{1}{\sqrt{\pi\,a^3}}\,e^{-\frac{r}{a}}$		$dV = 4\,\pi r^2\,dr$
Radial probability density	$P(r) = 4\,\pi r^2\lvert\psi\rvert^2 = \frac{4}{a^3}\,r^2 e^{-2\,r/a}$		$P(r)\,dr = \psi(r)^2 dV$
	$P(R) = \int_0^R P(r)dr = 1 - [1 + 2\frac{R}{a} + 2\left(\frac{R}{a}\right)^2]\,e^{-2\frac{R}{a}}$		
Hydrogen atom energy	$E_n = -\frac{13.6\,eV}{n^2}$		$n = 1,2,3,\ldots$
Selection rules energy shells	$n = 1\,(K), 2\,(L), 3\,(M), \ldots$		
orbital angular momentum	$L = \sqrt{l(l+1)}\,\hbar$	$l = 0\,(s),\ 1\,(p),\ 2\,(d),\ 3\,(f), \ldots, n-1$	
orbital magnetic quantum #	$L_z = m_l\,\hbar$	$m_l = 0,\ \pm 1, \ldots,\ \pm l$	

Ch.43 Nuclear Physics

Mass number	$A = Z + N$	Effective nuclear radius	$r = r_0\,A^{1/3}$ $\quad r_0 = 1.2\,fm$
Binding energy	$E_b = \left(Z\,m_p c^2 + N\,m_n c^2\right) - {}^A_Z M$	Binding energy per nucleon	$E_{b/n} = \frac{E_b}{A} \sim 7 - 9\,MeV$
Decay rate OR activity	$R(t) = -\frac{dN(t)}{dt} = \lambda\,N(t)$	Half-life	$T_{1/2} = \frac{\ln 2}{\lambda} = \tau\,ln2$
Decay law	$N(t) = N_0\,e^{-\lambda\,t}$ OR	$R(t) = \lambda\,N_0 = R_0\,e^{-\lambda\,t}$	
Units	$1\,Ci = 3.7\,10^{10}\,Bq$	$1\,Bq = 1\,decay/s$	
Alpha decay	${}^A_Z X \rightarrow {}^{A-4}_{Z-2}D + \alpha$	$Q = \left[M\left({}^A_Z X\right) - M\left({}^{A-4}_{Z-2}D\right) - M\left({}^4_2 He\right)\right]c^2$	
Beta decay	${}^A_Z X \rightarrow {}_{Z+1}^{\;\;A}D + \beta^- + \bar{\nu}$	$Q = \left[M\left({}^A_Z X\right) - M\left({}_{Z+1}^{\;\;A}D\right)\right]c^2$	
	${}^A_Z X \rightarrow {}_{Z-1}^{\;\;A}D + \beta^+ + \nu$	$Q = \left[M\left({}^A_Z X\right) - M\left({}_{Z-1}^{\;\;A}D\right) - 2m_e\right]c^2$	
Gamma decay	${}^A_Z X * \rightarrow {}^A_Z X + \gamma$		
Nuclear reaction	$a + X \rightarrow b + Y$	$Q = [(M_X + M_a) - (M_Y + M_b)\,c^2$	