Constants: $c = 2.998\times10^8$ m/s $\quad e = 1.602\times10^{-19}$ C $\quad N_\mathrm{A} = 6.02\times10^{23}$

$k_\mathrm{B} = 1.38\times10^{-23}$ J/K $\quad m_\mathrm{e} = 511$ keV/c^2 $\quad \frac{1}{4\pi\epsilon_0} = 8.99\times10^9$ N·m^2/C^2

$h = 6.626\times10^{-34}$ J·s $\quad \hbar = h/2\pi \quad$ 1 eV $= 1.602\times10^{-19}$ J $\quad R = 1.09737\times10^7$/m

$hc = 1240$ eV·nm $\quad \frac{e^2}{4\pi\epsilon_0} = 1.44$ eV·nm $\quad$ 1u $= 931.5$ MeV/c^2 $\quad a_0 = 0.0529$ nm

$\mu_B = \frac{e\hbar}{2m_e} = 5.788\times10^{-5}$ eV/T $\quad m_\mathrm{p} = 938.272$ MeV/c^2 $\quad m_\mathrm{n} = 939.566$ MeV/c^2

Classical Physics:

$$\vec{F} = m\vec{a} \qquad K = \frac{1}{2}mv^2 \qquad a = \frac{v^2}{r} \qquad F_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2} \qquad V_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$$

Modern Physics:

$$\gamma = \frac{1}{\sqrt{1-v^2/c^2}} \qquad \Delta t = \gamma\Delta t_p \qquad L = L_0/\gamma \qquad f_\mathrm{obs} = \frac{\sqrt{1+v/c}}{\sqrt{1-v/c}}\,f_\mathrm{source}$$

$$x' = \gamma(x-vt) \qquad y' = y \qquad z' = z \qquad t' = \gamma(t - \frac{vx}{c^2})$$

$$u'_x = \frac{u_x - v}{1-u_xv/c^2} \qquad u'_y = \frac{u_y}{\gamma(1-u_xv/c^2)} \qquad u'_z = \frac{u_z}{\gamma(1-u_xv/c^2)}$$

$$\vec{p} = \gamma m\vec{v} \qquad K = (\gamma-1)mc^2 \qquad E_0 = mc^2 \qquad E_\mathrm{tot} = \gamma mc^2 \qquad E^2 = (pc)^2 + (mc^2)^2$$

$$n_i = A\,g_i\,e^{-E_i/kT} \qquad n(v) = 4\pi\frac{N}{V}\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} v^2 e^{-mv^2/2kT}$$

$$e_\mathrm{total} = \sigma T^4 \qquad \lambda_\mathrm{max}T = 2.898\times10^{-3}\ \mathrm{m\cdot K} \qquad J(f) = \frac{c}{4}\,u(f) \qquad u(f) = \frac{8\pi hf^3}{c^3}\frac{1}{e^{hf/kT}-1}$$

$$K_\mathrm{max} = hf - \phi \qquad \lambda' = \lambda + \frac{h}{m_ec}(1-\cos\theta)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right) \qquad d_\mathrm{min} = \frac{zZe^2}{4\pi\epsilon_0}\frac{1}{E} \qquad \Delta n = n\,N\left(\frac{A}{R^2}\right)\left(\frac{zZe^2}{4\pi\epsilon_0}\frac{1}{4E}\right)^2\frac{1}{\sin^4\theta/2}$$

$$\text{Bohr}: \qquad L = n\hbar \qquad r_n = \frac{4\pi\epsilon_0}{e^2}\frac{\hbar^2}{m}n^2 = a_0n^2 \qquad E_n = -\frac{1}{2}\left(\frac{e^2}{4\pi\epsilon_0}\right)^2\frac{m}{\hbar^2}\frac{1}{n^2}$$

$$p = \frac{h}{\lambda} = \hbar k \qquad E = hf = \hbar\omega \qquad v_{\text{phase}} = \frac{\omega}{k} \qquad v_{\text{group}} = \frac{d\omega}{dk} \qquad a_0 = \frac{4\pi\epsilon_0}{e^2}\frac{\hbar^2}{m}$$

$$\Delta p\ \Delta x \geq \frac{\hbar}{2} \qquad \Delta E\ \Delta t \geq \frac{\hbar}{2} \qquad \Delta x = \left[\langle x^2\rangle - \langle x\rangle^2\right]^{1/2}$$

$$-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) + V(x)\Psi(x,t) = i\hbar\frac{\partial}{\partial t}\Psi(x,t) \qquad P(x) = |\Psi(x,t)|^2 = \Psi^*(x,t)\,\Psi(x,t)$$

$$-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x) + V(x)\psi(x) = E\psi(x) \qquad \Psi(x,t) = \psi(x)e^{-iEt/\hbar} \qquad \int_{-\infty}^{\infty} P(x)\,dx = 1$$

$$\langle x\rangle = \int_{-\infty}^{\infty}\psi^*(x)\,x\,\psi(x)\,dx \qquad \langle f(x)\rangle = \int_{-\infty}^{\infty}\psi^*(x)\,f(x)\,\psi(x)\,dx \qquad \langle p\rangle = \int_{-\infty}^{\infty}\psi^*(x)\,\frac{\hbar}{i}\frac{d}{dx}\psi(x)\,dx$$

$$\text{Square Well}:\ \psi_n = \sqrt{\frac{2}{L}}\,\sin\frac{n\pi}{L}x\ ;\quad E_n = \frac{n^2\pi^2\hbar^2}{2mL^2} \qquad \text{Oscillator}:\ E_n = (n+\tfrac{1}{2})\hbar\omega$$

$$T = \left[1 + \frac{V_0^2}{16E(V_0-E)}(e^{\alpha L} - e^{-\alpha L})^2\right]^{-1} \qquad T \simeq e^{-2G} \qquad G = \sqrt{\frac{2m}{\hbar^2}}\int [V(x)-E]^{\frac{1}{2}}\,dx$$

$$\psi_{n,\ell,m} = R_{n,\ell}(r)\,Y_\ell^m(\theta,\phi) \qquad E_n = -\frac{1}{2}\left(\frac{e^2}{4\pi\epsilon_0}\right)^2\frac{m}{\hbar^2}\frac{1}{n^2} = -\frac{13.6\,\text{eV}}{n^2} \qquad P(r) = r^2R_{n,\ell}^2$$

$$\ell = 0,1,2,\ \ldots,n-1 \qquad m = -\ell,-\ell+1,\ \ldots,\ell \qquad L = \sqrt{\ell(\ell+1)}\hbar \qquad L_z = m\hbar$$

$$W_{\text{mag}} = -\vec{\mu}\cdot\vec{B} \qquad \vec{\mu}_{\text{orbit}} = -\frac{e}{2m}\vec{L} \qquad \vec{\mu}_{\text{spin}} = -2\frac{e}{2m}\vec{S} \qquad S_z = m_s\hbar$$

$$\vec{J} = \vec{L} + \vec{S} \qquad J = \sqrt{j(j+1)}\hbar \qquad j = \ell \pm \tfrac{1}{2}\ \ (\text{except for } \ell = 0)$$

$$E_{\text{rot}} = \frac{\ell(\ell+1)\hbar^2}{2I} \qquad I = \mu R_0^2 \qquad \mu = \frac{m_1m_2}{m_1+m_2} \qquad E_{\text{vib}} = (\nu + \tfrac{1}{2})\hbar\sqrt{k/\mu}$$

$$G(E) = \frac{8\sqrt{2}\pi m_e^{3/2}}{h^3}VE^{1/2} \qquad E_F = \frac{h^2}{8m_e}\left[\frac{3n}{\pi}\right]^{\frac{2}{3}} \qquad n(E) = \frac{G(E)}{e^{(E-E_F)/kT}+1}$$

$$I = neAv_d \qquad \sigma = \frac{e^2}{m_ev_F}nL \qquad K = \frac{\pi^2}{3}\left(\frac{k^2T}{m_ev_F}\right)nL$$

$$R = 1.2\,A^{\frac{1}{3}}\ \text{fm} \qquad M = Nm_n + Z(m_p+m_e) - B/c^2 \qquad m_ic^2 = m_fc^2 + Q$$

$$\mathcal{A} = \lambda N \qquad \tau = \frac{1}{\lambda} \qquad T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \qquad N = N_0\,e^{-\lambda t}$$