Formulas and constants:

$hc = 12,400 \ eV \ A$; $k_B = 1/11,600 \ eV/K$; $ke^2 = 14.4 eVA$; $m_e c^2 = 0.511 \times 10^6 eV$; $m_p/m_e = 1836$

Relativistic energy - momentum relation $\quad E = \sqrt{m^2 c^4 + p^2 c^2}$ $\qquad$; $\qquad$ $c = 3 \times 10^8 m/s$

Photons: $E = hf$; $p = E/c$; $f = c/\lambda$ $\qquad$ Lorentz force: $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$

Planck's law : $\quad u(\lambda) = n(\lambda) \bar{E}(\lambda)$; $\quad n(\lambda) = \dfrac{8\pi}{\lambda^4}$; $\quad \bar{E}(\lambda) = \dfrac{hc}{\lambda} \dfrac{1}{e^{hc/\lambda k_B T} - 1}$

Energy in a mode/oscillator : $E_f = nhf$; probability $P(E) \propto e^{-E/k_B T}$

Stefan's law : $R = \sigma T^4$; $\sigma = 5.67 \times 10^{-8} W/m^2 K^4$; $R = cU/4$, $U = \displaystyle\int_0^\infty u(\lambda)d\lambda$

Planck : $\quad u(\lambda) = n(\lambda) \bar{E}(\lambda)$; $\quad n(\lambda) = \dfrac{8\pi}{\lambda^4}$; $\bar{E}(\lambda) = \dfrac{hc}{\lambda} \dfrac{1}{e^{hc/\lambda k_B T} - 1}$; Wien : $\lambda_m T = hc/4.96 k_B$

Photoelectric effect : $eV_0 = (\dfrac{1}{2} mv^2)_{max} = hf - \phi$, $\quad \phi \equiv$ work function

Compton : $\lambda_2 - \lambda_1 = \dfrac{h}{m_e c}(1 - \cos\theta)$; $\lambda_c \equiv \dfrac{h}{m_e c} = 0.0243A$; Rutherford : $b = \dfrac{kq_\alpha Q}{m_\alpha v^2}\cot(\theta/2)$; $\Delta N \propto \dfrac{1}{\sin^4(\theta/2)}$

Electrostatics : $F = \dfrac{kq_1 q_2}{r^2}$ (force) ; $V = \dfrac{kq}{r}$ (potential) ; $U = q_0 V$ (potential energy)

Hydrogen spectrum : $\dfrac{1}{\lambda} = R(\dfrac{1}{m^2} - \dfrac{1}{n^2})$ $\qquad$; $\qquad R = 1.097 \times 10^7 \ m^{-1} = \dfrac{1}{911.3A}$

Bohr atom : $r_n = r_0 n^2$; $r_0 = \dfrac{a_0}{Z}$; $E_n = -E_0 \dfrac{Z^2}{n^2}$; $a_0 = \dfrac{\hbar^2}{mke^2} = 0.529A$; $E_0 = \dfrac{ke^2}{2a_0} = 13.6 eV$; $L = mvr = n\hbar$

$E_k = \dfrac{1}{2} mv^2$; $E_p = -\dfrac{ke^2 Z}{r}$; $E = E_k + E_p$; $F = \dfrac{ke^2 Z}{r^2} = m\dfrac{v^2}{r}$; $hf = hc/\lambda = E_n - E_m$

Reduced mass : $\mu = \dfrac{mM}{m+M}$; X - ray spectra : $f^{1/2} = A_n(Z - b)$; K : $b = 1$, L : $b = 7.4$

de Broglie : $\lambda = \dfrac{h}{p}$; $f = \dfrac{E}{h}$; $\omega = 2\pi f$; $k = \dfrac{2\pi}{\lambda}$; $E = \hbar\omega$; $p = \hbar k$; $E = \dfrac{p^2}{2m}$; $\hbar c = 1973 \ eV \ A$

Wave packets : $y(x,t) = \displaystyle\sum_j a_j \cos(k_j x - \omega_j t)$, or $y(x,t) = \displaystyle\int dk \, a(k) \, e^{i(kx - \omega(k)t)}$; $\Delta k \Delta x \sim 1$; $\Delta\omega \Delta t \sim 1$

group and phase velocity : $\quad v_g = \dfrac{d\omega}{dk}$; $v_p = \dfrac{\omega}{k}$; $\quad$ Heisenberg : $\quad \Delta x \Delta p \sim \hbar$; $\quad \Delta t \Delta E \sim \hbar$

Wave function $\qquad \Psi(x,t) = |\Psi(x,t)| e^{i\theta(x,t)}$; $\qquad P(x,t) \, dx = |\Psi(x,t)|^2 \, dx =$ probability

Schrodinger equation : $\quad -\dfrac{\hbar^2}{2m} \dfrac{\partial^2 \Psi}{\partial x^2} + V(x)\Psi(x,t) = i\hbar \dfrac{\partial \Psi}{\partial t}$; $\qquad \Psi(x,t) = \psi(x) e^{-i\frac{E}{\hbar}t}$

Time - independent Schrodinger equation : $\quad -\dfrac{\hbar^2}{2m} \dfrac{\partial^2 \psi}{\partial x^2} + V(x)\psi(x) = E\psi(x)$; $\displaystyle\int_{-\infty}^\infty dx \, \psi^* \psi = 1$

∞ square well : $\psi_n(x) = \sqrt{\dfrac{2}{L}} \sin(\dfrac{n\pi x}{L})$; $E_n = \dfrac{\pi^2 \hbar^2 n^2}{2mL^2}$; $\quad x_{op} = x$, $p_{op} = \dfrac{\hbar}{i} \dfrac{\partial}{\partial x}$; $<A> = \displaystyle\int_{-\infty}^\infty dx \psi^* A_{op} \psi$

Eigenvalues and eigenfunctions : $A_{op} \Psi = a \Psi$ (a is a constant) ; uncertainty : $\Delta A = \sqrt{<A^2> - <A>^2}$

Harmonic oscillator : $\Psi_n(x) = C_n H_n(x) e^{-\frac{m\omega}{2\hbar} x^2}$; $E_n = (n + \dfrac{1}{2})\hbar\omega$; $E = \dfrac{p^2}{2m} + \dfrac{1}{2} m\omega^2 x^2 = \dfrac{1}{2} m\omega^2 A^2$; $\Delta n = \pm 1$

Step potential : $R = \dfrac{(k_1 - k_2)^2}{(k_1 + k_2)^2}$, $\quad T = 1 - R$; $\quad k = \sqrt{\dfrac{2m}{\hbar^2}(E - V)}$

Tunneling : $\quad \psi(x) \sim e^{-\alpha x} \quad ; \quad T \sim e^{-2\alpha \Delta x} \quad ; \quad T \sim e^{-2\int_a^b \alpha(x)dx} \quad ; \quad \alpha(x) = \sqrt{\dfrac{2m[V(x) - E]}{\hbar^2}}$

3D square well : $\quad \Psi(x,y,z) = \Psi_1(x)\Psi_2(y)\Psi_3(z) \quad ; \quad E = \dfrac{\pi^2\hbar^2}{2m}\left(\dfrac{n_1^2}{L_1^2} + \dfrac{n_2^2}{L_2^2} + \dfrac{n_3^2}{L_3^2}\right)$

Spherically symmetric potential : $\quad \Psi_{n,\ell,m}(r,\theta,\phi) = R_{n\ell}(r)Y_{\ell m}(\theta,\phi) \quad ; \quad Y_{\ell m}(\theta,\phi) = f_{lm}(\theta)e^{im\phi}$

Angular momentum : $\quad \vec{L} = \vec{r} \times \vec{p} \quad ; \quad L_z = \dfrac{\hbar}{i}\dfrac{\partial}{\partial \phi} \quad ; \quad L^2 Y_{\ell m} = \ell(\ell+1)\hbar^2 Y_{\ell m} \quad ; \quad L_z = m\hbar$

Radial probability density : $\quad P(r) = r^2 \mid R_{n,\ell}(r) \mid^2 \quad ; \qquad$ Energy : $\quad E_n = -13.6eV\dfrac{Z^2}{n^2}$

Ground state of hydrogen and hydrogen - like ions : $\quad \Psi_{1,0,0} = \dfrac{1}{\pi^{1/2}}\left(\dfrac{Z}{a_0}\right)^{3/2}e^{-Zr/a_0}$

Orbital magnetic moment : $\quad \vec{\mu} = \dfrac{-e}{2m_e}\vec{L} \quad ; \quad \mu_z = -\mu_B m_l \quad ; \quad \mu_B = \dfrac{e\hbar}{2m_e} = 5.79 \times 10^{-5}eV/T$

Spin 1/2 : $\quad s = \dfrac{1}{2} \,, \quad \mid S \mid = \sqrt{s(s+1)}\hbar \quad ; \quad S_z = m_s\hbar \quad ; \quad m_s = \pm 1/2 \quad ; \quad \vec{\mu}_s = \dfrac{-e}{2m_e}g\vec{S}$

Total angular momentum : $\vec{J} = \vec{L} + \vec{S} \quad ; \quad \mid J \mid = \sqrt{j(j+1)}\hbar \quad ; \quad \mid l - s \mid \le j \le l + s \quad ; \quad -j \le m_j \le j$

Orbital + spin mag moment : $\quad \vec{\mu} = \dfrac{-e}{2m}(\vec{L} + g\vec{S}) \quad ; \quad$ Energy in mag. field : $\quad U = -\vec{\mu}\cdot\vec{B}$

Two particles : $\quad \Psi(x_1,x_2) = +/- \Psi(x_2,x_1) \quad ; \quad$ symmetric/antisymmetric

Screening in multielectron atoms : $\quad Z \rightarrow Z_{eff} \,, \quad 1 < Z_{eff} < Z$

Orbital ordering :
1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 6d ~ 5f

$f_B(E) = Ce^{-E/kT} \quad ; \quad f_{BE}(E) = \dfrac{1}{e^\alpha e^{E/kT} - 1} \quad ; \quad f_{FD}(E) = \dfrac{1}{e^\alpha e^{E/kT} + 1} \quad ; \quad n(E) = g(E)f(E)$

Rotation : $E_R = \dfrac{L^2}{2I}, \quad I = \mu R^2, \quad$ vibration : $E_v = \hbar\omega(v + \dfrac{1}{2}), \quad \omega = \sqrt{K/\mu}, \quad \mu = m_1 m_2/(m_1 + m_2)$

$g(E) = [2\pi(2m)^{3/2}V/h^3]E^{1/2}$ (translation, per spin) ; Equipartition : $< E > = k_B T/2$ per degree of freedom

Einstein coefs.: $B_{12} = B_{21} \,, \quad A_{21}/(B_{21}u(f)) = e^{hf/kT} - 1 \quad ; \quad u(f) = (8\pi hf^3/c^3)/(e^{hf/kT} - 1)$