Equations for Calculus Based Physics 53
Modern Physics

$x = x' + ut,\ \ y = y',\ \ z = z',\ \ v_x = \frac{dx}{dt},\ \ \Delta t = \gamma \Delta t_0,\ \ \gamma = \frac{1}{\sqrt{1-u^2/c^2}},\ \ l = \frac{l_0}{\gamma},\ \ x' = \gamma(x-ut),\ y' = y,$

$z' = z,\ \ t' = \gamma\left(t - ux/c^2\right), v_x' = \frac{v_x - u}{1 - uv_x/c^2},\ \vec{p} = \gamma m\vec{v},\ f = f_0\sqrt{\frac{c+u}{c-u}},\ K = (\gamma - 1)mc^2,$

$E = K + mc^2 = \gamma mc^2,\ E^2 = \left(\mathrm{mc}^2\right)^2 + (\mathrm{pc})^2,\quad (1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \ldots,$

$E = hf = h\frac{c}{\lambda},\ \ p = \frac{E}{c},\ \ p = \frac{h}{\lambda},\ \ eV_0 = K_{\max} = hf - \phi =,\ K_{\max} = \frac{1}{2}mv_{\max}{}^2,\ \ hf = E_i - E_f,$

$E_n = -\frac{hcR}{n^2};\ \mathrm{n}=1,2,\ldots,\ r_n = \varepsilon_0\frac{n^2h^2}{\pi me^2} = n^2a_0,\ \ v_n = \frac{1}{\varepsilon_0}\frac{e^2}{2nh},\ \ a_0 = \varepsilon_0\frac{h^2}{\pi me^2},\ \mathrm{eV_{AC}} = hf_{m\max} = \frac{hc}{\lambda_{\min}},$

$\lambda' - \lambda = \frac{h}{mc}(1-\cos\phi),\ \ I = \sigma T^4,\ \ \lambda_{\mathrm{m}}T = 2.90\times10^{-3}m.K,\ \ I(\lambda) = \frac{2\pi hc^2}{\lambda^5\left(e^{hc/\lambda kT} - 1\right)},\ \ n_i = Ae^{-E_i/kT},$

$\lambda = \frac{h}{p} = \frac{h}{mv},\ \ mvr = n\frac{h}{2\pi} = n\hbar,\ \ p = \sqrt{2meV_{ab}},\ \Delta x\Delta p_x \geq \hbar,\ \Delta E\Delta t \geq \hbar,\ \ \psi(\mathrm{x,y,z,t}) = \psi(x,y,z)e^{-iEt/\hbar},$

$\left|\Psi(x,y,z,t)\right|^2 = \left(\psi(x,y,z)e^{-iEt/\hbar}\right)\ \left(\psi^*(x,y,z)e^{+iEt/\hbar}\right),\ \ -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x) + U(x)\psi(x) = E\psi(x),$

$E_n = \frac{n^2h^2}{8mL^2} = \frac{n^2\pi^2\hbar^2}{2mL^2},\ \ \psi_n(x) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}\ \ \ n = 1,2,3,\ldots,\ \ \int_{-\infty}^{\infty}\left|\psi(x)\right|^2 dx = 1,$

$T = Ge^{-2\kappa L},\ \ G = 16\frac{E}{U_0}\left(1 - \frac{E}{U_0}\right),\ \kappa = \frac{\sqrt{2m(U_0 - E)}}{\hbar},$

$-\frac{\hbar^2}{2m}\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)\psi(x,y,z) + U(x,y,z)\psi(x,y,z) = E\psi(x,y,z);\ \ U(r) = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r};$

Hydrogen: $E_n = -\frac{1}{\left(4\pi\varepsilon_0\right)^2}\frac{m_re^4}{2n^2\hbar^2} = -\frac{13.6eV}{n^2}$; Hydrogenlike: $E_n = -\frac{Z_{eff}{}^2}{n^2}(13.6eV); n = 1,2,3,\ldots,$

$L = \sqrt{l(l+1)}\hbar; l = 0,1,2,\ldots, L_z = m_l\hbar, m_l = 0,\pm1,\pm2,\ldots,\ S = \sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)}\hbar = \sqrt{\frac{3}{4}}\hbar, S_z = m_s\hbar; m_s = \pm\frac{1}{2}$

$\vec{J} = \vec{L} + \vec{S}; J = \sqrt{j(j+1)};\ j = \left|l \pm \frac{1}{2}\right|,\ \ a = \frac{\varepsilon_0h^2}{\pi m_re^2} = 5.29\times10^{-11}m,\ \ P(r)dr = |\psi|^2\,dV = |\psi|^2\,4\pi r^2dr,$

$U = -\mu_BB = m_l\frac{e\hbar}{2m}B = m_l\mu_BB;\ m_l = 0,\pm1,\pm2,\ldots,\quad n \geq 1;\ 0 \leq l \leq n-1;\ |m_l| \leq l;\ m_s = \pm\frac{1}{2},$

$f = \left(2.48\times10^{15}Hz\right)(Z-1)^2,\ \ E_l = l(l+1)\frac{\hbar^2}{2I};\ I = m_rr_0^2;\ m_r = \frac{m_1m_2}{m_1+m_2};\ E_n = \left(n + \frac{1}{2}\right)\hbar\sqrt{\frac{k'}{m_r}}$

$g(E) = \frac{(2m)^{3/2}V}{2\pi^2\hbar^3}E^{1/2},\ \ f(E) = \frac{1}{e^{\left(E-E_f\right)/KT} + 1},\ I = I_s\left(e^{eV/KT} - 1\right)$

$R = R_0A^{1/3},\ R_0 = 1.2\times10^{-15}m,\quad \mathrm{E_B} = \left(ZM_H + Nm_n - {}^{A}_{Z}M\right)c^2,\ N(t) = N_0e^{-\lambda t};\ T_{mean} = \frac{1}{\lambda} = \frac{T_{1/2}}{\ln 2}$

$E_B = C_1A - C_2A^{2/3} - C_3\frac{Z(Z-1)}{A^{1/3}} - C_4\frac{(A-2Z)^2}{A} \pm C_5A^{-4/3}$

Constants: $C_1 = 15.75\ MeV;\ C_2 = 17.80MeV;\ C_3 = 0.7100MeV;\ C_4 = 23.69MeV;\ C_5 = 39MeV$

Some Physical Constants, Conversion Factors, and Experimental Data

Decimal prefixes

$centi \to 10^{-1}$ $deca \to 10^{1}$

$deci \to 10^{-2}$ $hecta \to 10^{2}$

$mili \to 10^{-3}$ $kilo \to 10^{3}$

$micro \to 10^{-6}$ $mega \to 10^{6}$

$nano \to 10^{-9}$ $giga \to 10^{9}$

$pico \to 10^{-12}$ $tera \to 10^{12}$

$femto \to 10^{-15}$ $peta \to 10^{15}$

Some unit conversion factors

$1atm = 1.01325 \times 10^{5} Pa$

$1cal = 4.186 J$

$1km = 0.621 mi$

$1N = 0.225 lb$

$1gal = 3786L = 0.003786 m^{3}$

$1.0\ mole\ ideal\ gas = 22.4\ L$

$1eV = 1.602 \times 10^{-19} J$

$1u = 1.66053886 \times 10^{-27} kg$

Some experimental data

$\rho_{water} = 1000 kg/m^{3}$

$\rho_{air} = 1.20 kg/m^{3}$

$C_V^{air} = 20.8 J/mol.K$

$p_0 = 1.01 \times 10^{5} Pa$

$m_e c^2 = 0.5109989 MeV$

$n_{air} = 1.00$

$n_{water} = 1.33$

Fundamental constants

$c = 2.99792458 \times 10^{8} m/s$

$e = 1.6022 \times 10^{-19} C$

$G = 6.6742 \times 10^{-11} N.m^2/kg^2$

$g = 9.80665\ m/s^2$

$h = 6.6261 \times 10^{-34} J.s$

$h = 4.136 \times 10^{-15} eV$

$k = 1.3807 \times 10^{-23} J/K$

$N_A = 6.0221 \times 10^{23} molecules/mol$

$a_0 = 5.29 \times 10^{-11} m,$

$\sigma = 5.67 \times 10^{-8} W/m^2.K^4$

$R = 8.3145\ J/mol.K$

$R = 0.082 (L.atm)/(mol.K)$

$m_e = 9.1093826 \times 10^{-31} kg$

$m_p = 1.67262171 \times 10^{-27} kg$

$m_n = 1.67492728 \times 10^{-27} kg$

$q_e = -1.60 \times 10^{-19} C,$

$\mu_0 = 4\pi \times 10^{-7} Wb/A.m$

$\varepsilon_0 = 1/\mu_0 c^2 = 8.8541 \times 10^{-12} C^2/N.m^2$

$1/4\pi\varepsilon_0 = 8.98755 \times 10^{9} N.m^2/C^2$