Modern Physics SH1011 formulas and constants, 2022-08-26

$\gamma = \frac{1}{\sqrt{1-\frac{u^2}{c^2}}}$

Time dilation $\Delta t = \gamma \Delta t_0$

Length Contraction $l = \frac{l_0}{\gamma}$

Lorentz Transformations
$x' = \gamma(x - ut)$ $y' = y$ $z' = z$
$t' = \gamma(t - \frac{ux}{c^2})$
$v'_x = \frac{v_x - u}{(1-\frac{uv_x}{c^2})}$
$v_x = \frac{v'_x + u}{(1+\frac{uv'_x}{c^2})}$

Doppler shift $f = \sqrt{\frac{c+u}{c-u}} f_0$

Relativistic energy and momentum
$\vec{p} = \gamma m \vec{v}$
$K = (\gamma - 1)mc^2$
$E = K + mc^2 = \gamma mc^2$
$E^2 = (mc^2)^2 + (pc)^2$

Photon Energy $E = hf = \frac{hc}{\lambda}$
Photon momentum $E = pc$
Photoelectric Effect $eV_0 = hf - \phi$
Atomic Line Spectra $hf = E_i - E_f$
X-ray production $E_{max} = eV_{AC} = \frac{hc}{\lambda_{min}}$
Compton scattering: $\lambda' - \lambda = \frac{h}{mc}(1 - \cos\phi)$
Stefan-Boltzmann law $I = \sigma T^4$
Wien Displacement law $\lambda_m T = 2.9 \cdot 10^{-3}$ m·K
Planck Radiation Law $I(\lambda) = \frac{2\pi hc^2}{\lambda^5(e^{\frac{hc}{\lambda kT}} - 1)}$

de Broglie Waves $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV_{ba}}}$

Heisenberg's uncertainty principle
$\Delta x \Delta p_x \geq \frac{\hbar}{2}$ $\Delta E \Delta t \geq \frac{\hbar}{2}$

Stationary state wave function
$\Psi(x,y,z,t) = \psi(x,y,z)e^{iEt/\hbar}$

Schrödinger equation
$(-\frac{\hbar^2}{2m}\frac{d^2}{dx^2} + U(x))\psi(x) = E\psi(x)$

Particle in a box
$E_n = \frac{p_n^2}{2m} = \frac{n^2\pi^2\hbar^2}{2mL^2}$
$\psi_n(x) = \sqrt{\frac{2}{L}} \sin\frac{n\pi x}{L}$
$n = 1, 2, 3....$

Wave function normalization
$\int_{-\infty}^{\infty} |\psi(x)|^2 \, dx = 1$
$P(r)dr = |\psi(r)|^2 \, dV = |\psi(r)|^2 \, 4\pi r^2 dr$

Atomic Energy Levels
$E_n = -\frac{1}{(4\pi\epsilon_0)^2}\frac{me^4}{2n^2\hbar^2} = -\frac{13.6eV}{n^2}$
$E_n = -\frac{Z_{eff}^2}{n^2} 13.6eV$
$a = \frac{4\pi\epsilon_0\hbar^2}{me^2} = 5.3 \cdot 10^{-11}\ m$

Moseley's law $f = (2.48 \cdot 10^{15} Hz)(Z-1)^2$

Angular momentum
$L = \sqrt{l(l+1)}\hbar$ $L_z = m_l \hbar$

Spin
$S = \sqrt{s(s+1)}\hbar = \sqrt{\frac{1}{2}(\frac{1}{2}+1)}\hbar$ $S_z = \pm\frac{1}{2}\hbar$

Zeeman effect
$U = -\mu_z B = m_l \frac{e\hbar}{2m} B = m_l \mu_B B$

Exclusion Principle, Quantum numbers
$n \geq 1$
$0 \leq l \leq n - 1$
$|m_l| \leq l$
$m_s \pm \frac{1}{2}$

Molecules
$E_l = l(l+1)\frac{\hbar^2}{2I}$ $l = 0, 1, 2, 3...$
$I = m_r r_0^2$ $m_r = \frac{m_1 m_2}{m_1 + m_2}$
$E_n = (n + \frac{1}{2})\omega\hbar = (n + \frac{1}{2})\sqrt{\frac{k'}{m_r}}\hbar$
$n = 0, 1, 2, 3...$

Free Electron Model
$g(E) = \frac{(2m)^{\frac{3}{2}} V}{2\pi^2\hbar^3} E^{\frac{1}{2}}$
$f(E) = \frac{1}{e^{\frac{E-E_F}{kT}} + 1}$

p-n junction diode
$I = I_S(e^{\frac{eV}{kT}} - 1)$

Nuclear Radius
$R = R_0 A^{\frac{1}{3}}$ $R_0 = 1.2 \cdot 10^{-15}\ m$

Nuclear Binding Energy
$E_B = (ZM_H + Nm_n - {}^A_Z M)c^2$

Radioactive Decay
$N(t) = N_0 e^{-\lambda t}$

Speed of light
$c = 3 \cdot 10^8\ m/s$

Elementary Charge
$e = 1.6 \cdot 10^{-19}\ C$

Gravitational constant
$G = 6.67 \cdot 10^{-11}\ N \cdot m^2/kg^2$

Planck's constant
$h = 6.626 \cdot 10^{-34}\ Js$

Boltzmann's constant
$k = 1.38 \cdot 10^{-23}\ J/K$

Electron rest energy
$m_e c^2 = 511\ keV$
Proton rest energy
$m_p c^2 = 938.3\ MeV$
Neutron rest energy
$m_n c^2 = 939.6\ MeV$