Small x expansions to first order (use substitutions where necessary)

$$\begin{array}{cc} \frac{1}{1-x} = 1 + x + \ldots & \frac{1}{\sqrt{1-x}} = 1 + \frac{1}{2}x + \ldots \\ \sqrt{1+x} = 1 + \frac{1}{2}x + \ldots & (1+x)^2 = 1 + 2x + \ldots \\ \sin x = x + \ldots & e^x = 1 + x + \ldots \end{array} \tag{1}$$

$$x'(x,y,z,t) = \gamma(x - vt) \tag{2}$$
$$y'(x,y,z,t) = y \tag{3}$$
$$z'(x,y,z,t) = z \tag{4}$$
$$t'(x,y,z,t) = \gamma(t - \frac{vx}{c^2}) \tag{5}$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\beta^2}} \tag{6}$$

$$f_{\text{redshift}} = f_0 \sqrt{\frac{1-\beta}{1+\beta}} \tag{7}$$

$$u'_x = \frac{dx'}{dt'} = \frac{u_x - v}{1 - \frac{u_x v}{c^2}} \tag{8}$$
$$u'_y = \frac{dy'}{dt'} = \frac{u_y}{\gamma(1 - \frac{u_x v}{c^2})} \tag{9}$$

$$\Delta t = \gamma \tau \quad L = \frac{L_0}{\gamma} \tag{10}$$

$$c = \lambda f \tag{11}$$

$$(\Delta s)^2 = (c\Delta t)^2 - (\Delta x)^2 - (\Delta y)^2 - (\Delta z)^2 \tag{12}$$

$$(\Delta s')^2 = (\Delta s)^2 \tag{13}$$

$$(\text{slope of } x'\text{-axis}) = \beta \tag{14}$$
$$(\text{slope of } ct'\text{-axis}) = \frac{1}{\beta} \tag{15}$$

$$E = mc^2 + E_K = p^0 c = \frac{mc^2}{\sqrt{1 - \frac{u^2}{c^2}}} \text{ if } m \neq 0 \tag{16}$$

$$\vec{p} = \frac{m\vec{u}}{\sqrt{1 - \frac{u^2}{c^2}}} \text{ if } m \neq 0 \tag{17}$$

$$E^2 = p^2c^2 + m^2c^4 \tag{18}$$

$$ds^2 = \left(1 + \frac{2\Phi(r)}{c^2}\right)(cdt)^2 - \left(1 - \frac{2\Phi(r)}{c^2}\right)(dx^2 + dy^2 + dz^2) \tag{19}$$

$$\Phi(r) = -\frac{GM}{r} \tag{20}$$

$$\Delta\Phi(r) = gh \tag{21}$$

$$\frac{\Delta f}{f} = \frac{gh}{c^2} \tag{22}$$

$$\Delta E = nhf = n\hbar\omega \tag{23}$$

$$R_{\text{total}} = \sigma T^4 \tag{24}$$

$$\lambda_m T = 2.898\ \times 10^{-3}\ \text{m}\cdot\text{K} \tag{25}$$

$$u(\lambda) = 8\pi k_B T \lambda^{-4} \tag{26}$$

$$u(\lambda) = \frac{8\pi hc}{\lambda^5}\frac{1}{\exp\left(\frac{hc}{\lambda k_B T}\right) - 1} \tag{27}$$

$$R(\lambda) = \frac{c}{4}u(\lambda) \tag{28}$$

$$eV_0 = \left(\frac{1}{2}mv^2\right)_{\text{max}} = hf - \phi \tag{29}$$

$$n\lambda = 2d\sin\left(\frac{2\theta}{2}\right) \ \ \text{(Bragg)} \tag{30}$$

$$\lambda_f - \lambda_i = \frac{h}{mc}(1 - \cos\theta) \tag{31}$$

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \tag{32}$$

$$L_n = mvr_n = n\hbar \tag{33}$$

$$E_n = -\frac{1}{2}\left(\frac{e^2}{4\pi\epsilon_0}\right)^2 \frac{m}{\hbar^2}\frac{Z^2}{n^2} = -13.6\,\text{eV}\frac{Z^2}{n^2} \tag{34}$$

$$r_n = \frac{4\pi\epsilon_0}{e^2}\frac{\hbar^2}{m}\frac{n^2}{Z} = \frac{n^2 a_0}{Z} \tag{35}$$

$$f^{1/2} = A_n(Z - b) \tag{36}$$

$$A_n^2 = cR_\infty\left(1 - \frac{1}{n^2}\right) \tag{37}$$

$$p = \frac{h}{\lambda} = \hbar k \tag{38}$$

$$m\lambda = d\sin\theta \ \ \text{(Young)} \tag{39}$$

$$\lambda = \frac{h}{\sqrt{2mE_k}} = \frac{hc}{\sqrt{2mc^2 E_k}} \tag{40}$$

$$v_p = \frac{\omega}{k} \qquad v_g = \frac{d\omega}{dk} \tag{41}$$

$$\Delta k\,\Delta x \sim 1 \tag{42}$$

$$\Delta x\,\Delta p_x \geq \frac{1}{2}\hbar \qquad \Delta E\,\Delta t \geq \frac{1}{2}\hbar \tag{43}$$

$$P(x,t)\,dx = |\Psi(x,t)|^2\,dx \tag{44}$$

$$-\frac{\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2} + V(x,t)\Psi(x,t) = i\hbar\frac{\partial\Psi(x,t)}{\partial t} \tag{45}$$

$$x_{\text{op}} = x \tag{46}$$

$$p_{\text{op}} = \frac{\hbar}{i}\frac{\partial}{\partial x} \tag{47}$$

$$\Psi(x,t) = \sum_n A_n \psi_n(x) \Phi_n(t) = \sum_n A_n \psi_n(x) \exp\left(-i \frac{E_n t}{\hbar}\right) \tag{48}$$

$$\Psi(x,t) = A \exp(i(kx - \omega t)) \tag{49}$$

$$H\psi(x) = -\frac{\hbar^2}{2m} \frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x) \tag{50}$$

$$\int_{-\infty}^{\infty} dx\, \psi^*(x)\psi(x) = 1 \tag{51}$$

$$< B > = < \psi|B|\psi > = \int_{-\infty}^{\infty} dx\, \psi^*(x) B_{\rm op} \psi(x) \tag{52}$$

$$\psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right) \tag{53}$$

$$E_n = \frac{\hbar^2 \pi^2 n^2}{2mL^2} \tag{54}$$

$$\theta = \frac{\sqrt{2mE}\, L}{2\hbar} \quad \theta_0 = \frac{\sqrt{2mV_0}\, L}{2\hbar} \tag{55}$$

$$\tan\theta = \sqrt{\frac{\theta_0^2}{\theta^2} - 1} \quad \cot\theta = -\sqrt{\frac{\theta_0^2}{\theta^2} - 1} \tag{56}$$

$$E_n = \hbar\omega \left(n + \frac{1}{2}\right) \tag{57}$$

$$T \approx 16 \frac{E}{V_0} \left(1 - \frac{E}{V_0}\right) e^{-2\alpha L} \sim e^{-2\alpha L} \tag{58}$$

$$\alpha = \frac{\sqrt{2m(V_0 - E)}}{\hbar} \tag{59}$$

$$R(t) = R_0 \exp(-\lambda t) \tag{60}$$

$$\lambda = \frac{\ln 2}{t_{1/2}} \tag{61}$$

$$R(t) = \lambda N(t) \tag{62}$$

$$\text{Biological dose (Sv)} = Q\ \text{(Physical dose Gy)} \tag{63}$$

$c = 3.00 \times 10^8$ m/s	$h = 6.63 \times 10^{-34}$ J s
$\hbar = h/2\pi = 1.055 \times 10^{-34}$ J s	$hc = 1240$ eV nm
$\hbar c = 1973$ eV Å	$m(\text{electron}) = 9.11 \times 10^{-31}$ kg$= 5.11 \times 10^5$ eV/c^2
$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}	$k_B = 1.38 \times 10^{-23}$ J/K$= 8.63 \times 10^{-5}$ eV/K
1 eV$= 1.60 \times 10^{-19}$ J	$\frac{e^2}{4\pi\epsilon_0} = 14.4$ eV Å$= 1.44$ eV nm
$e = 1.60 \times 10^{-19}$ C	$\epsilon_0 = 8.85 \times 10^{-12}$ F/m
$R_{\rm H} = 1.0968 \times 10^7$ m^{-1}	$R_\infty = 1.0974 \times 10^7$ m^{-1}
$a_0 = 0.529$ Å$= 0.0529$ nm	1 Å=0.1 nm=10^{-10} m
1 Ci$= 3.7 \times 10^{10}$ Bq	