Stars Level 2, Durham University Physics

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These equations are given to provide an alternative overview of the concepts that we explored in the stars lectures. Use these to help your understanding rather than as a list to learn by rote. Refer to the lecture notes for the context and usage of these equations.

Equation 1 $L = 4\pi R^2 \sigma T_e^4$

Equation 2 $\frac{N_b}{N_a} = \frac{g_b}{g_a} e^{-(E_b - E_a)/kT}$

Equation 3 $P^2 = \frac{4\pi^2 a^3}{G\left(m_1 + m_2\right)}$

Equation 4 $\frac{m_1}{m_2} = \frac{\alpha_2}{\alpha_1} = \frac{a_2}{a_1} = \frac{v_2}{v_1}$

Equation 5 $\frac{L}{L_{sun}} = \left(\frac{M}{M_{sun}}\right)^{\alpha}$

Equation 6 $\frac{dP}{dr} = -\frac{GM_r}{r^2}\rho$ **[SHORT DERIVATION]**

Equation 7 $\frac{dM_r}{dr} = 4\pi r^2 \rho$

Equation 8 $P_c = \frac{3}{8\pi}\frac{GM^2}{R^4}$ **[DERIVATION]**

Equation 9 $T_c = \frac{1}{2}\frac{GM}{R}\frac{\mu m_H}{k}$ **[DERIVATION]**

Equation 10 $K = -\frac{1}{2}U$ **[DERIVATION]**

Equation 11 $E = -\frac{3}{10}\frac{GM^2}{R}$ **[DERIVATION]**

Equation 12 $T_{classical} = \frac{Z_1 Z_2 e_c^2}{6\pi\varepsilon_0 kr}$ **[SHORT DERIVATION]**

Equation 13 $T_{quantum} = \frac{Z_1^2 Z_2^2 e_c^4 \mu_m}{12\pi^2 \varepsilon_0^2 kh^2}$ **[DERIVATION]**

Equation 14 $\varepsilon_{ix} = \varepsilon_0' X_i X_x \rho^{\alpha} T^{\beta}$

Equation 15 $\frac{dL}{dr} = 4\pi r^2 \rho \varepsilon$

Equation 16 $\frac{dT}{dr} = -\frac{3}{4ac}\frac{\kappa\rho F_{rad}}{T^3} = -\frac{3}{16\pi ac}\frac{\kappa\rho}{T^3}\frac{L_r}{r^2}$ **[SHORT DERIVATION]**

Equation 17 $\ell = \frac{1}{n\sigma}$

Equation 18 $N = \left(\frac{d}{\ell}\right)^2$

Equation 19 $I_{\lambda} = I_{\lambda,0} e^{-\kappa_{\lambda}\rho s}$ **[DERIVATION]**

Equation 20 $\kappa = \kappa_0 \rho^{\alpha} T^{\beta}$

Equation 21 $\left|\frac{dT}{dr}\right|_{sur} > \left(\frac{\gamma_{ad}-1}{\gamma_{ad}}\right)\frac{T}{P}\left|\frac{dP}{dr}\right|_{sur}$ **[DERIVATION]**

Equation 22 $\ell = \alpha H_P$

Equation 23 $\Pi \approx \sqrt{\frac{3\pi}{2\gamma G\rho}}$ **[DERIVATION]**

Equation 24 $\frac{M_{max}}{M_{sun}} = \sqrt[\alpha-1]{\frac{4\pi c G M_{sun}}{\kappa L_{sun}}}$ **[DERIVATION]**

Equation 25 $M_J \cong \left(\frac{5kT}{G\mu m_H}\right)^{3/2}\left(\frac{3}{4\pi\rho_0}\right)^{1/2}$ **[SHORT DERIVATION]**

Equation 26 $t = \frac{X\xi M c^2}{L}$

Equation 27 $t = 10^{10}\left(\frac{M_{Sun}}{M}\right)^{\alpha-1}$

Equation 28 $P = \frac{\hbar^2}{m_e}\left[\left(\frac{Z}{A}\right)\frac{\rho}{m_H}\right]^{5/3}$ **[DERIVATION]**

Equation 29 $P_{\min} = \left(\frac{3\pi}{G\rho}\right)^{\frac{1}{2}}$ **[SHORT DERIVATION]**

Equation 30 $R = \frac{2GM}{c^2} = 2.96\left(\frac{M}{M_{Sun}}\right)km$

Associated non-numbered equations (which you should know):

Ideal gas law: $P = nKT$ **so** $P = \frac{\rho kT}{\mu m_H}$

Radiation pressure: $P = \frac{1}{3} a T^4$

Adiabatic pressure: $P = K_a \rho^\gamma$

Adiabatic Sound speed: $v_s = \sqrt{\frac{\gamma P}{\rho}}$

Kinetic energy: $E = \frac{1}{2} m V^2$

Gravitational potential energy: $U = -\frac{GMm}{r}$

Gravitational force: $g = \frac{GM}{r^2}$

Momentum: $p = mv$

Magnitude system: $m = const - 2.5 \times \log(f)$

Parallax: $d(pc) = \frac{1}{\phi(arc\sec)}$

Wein displacement law: $\lambda_{\max} T = 2.9 \times 10^{-3} mK$