Stars Level 2, Durham University Physics

David Alexander

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 $\quad L = 4\pi R^2 \sigma T_e^4$

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

Equation 3 $\quad P^2 = \dfrac{4\pi^2 a^3}{G(m_1 + m_2)}$

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

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

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

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

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

Equation 9 $\quad P = P_{gas} + P_{rad} = nkT + \dfrac{1}{3}aT^4$

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

Equation 11 $\quad E = \dfrac{3GM^2}{10R}\left[\dfrac{1}{R} - \dfrac{1}{R_{initial}}\right]$ **[DERIVATION]**

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

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

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

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

Equation 16 $\quad \ell = \dfrac{1}{n\sigma}$

Equation 17 $\quad N = \left(\dfrac{d}{\ell}\right)^2$

Equation 18 $\quad \dfrac{dT}{dr} = -\dfrac{3}{4ac}\dfrac{\kappa\rho F_{rad}}{T^3} = -\dfrac{3}{16\pi ac}\dfrac{\kappa\rho}{T^3}\dfrac{L_r}{r^2}$ **[SHORT DERIVATION]**

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

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

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

Equation 22 $\quad \ell = \alpha H_P$

Equation 23 $\quad \dfrac{M_{max}}{M_{sun}} = {}_{\alpha-1}\sqrt{\dfrac{4\pi c G M_{sun}}{\kappa L_{sun}}}$ **[DERIVATION]**

Equation 24 $\quad \Pi \approx \sqrt{\dfrac{3\pi}{2\gamma G\rho}}$ **[DERIVATION]**

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

Equation 26 $\quad t = \dfrac{X\xi Mc^2}{L}$

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

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

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

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

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

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

Radiation pressure: $\qquad\quad P = \dfrac{1}{3}aT^4$

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

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

Kinetic energy: $\qquad\qquad E = \dfrac{1}{2}mV^2$

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

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

Momentum: $\qquad\qquad p = mv$

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

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

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