

Physics 122 Winter 2026
General Equations Guide
 (“ \equiv ” means “is defined as”)

Heat, First Law, Heat Engines and Heat Pumps

$$e \equiv \frac{\text{what you get}}{\text{what you paid}} \quad (1)$$

$$\Delta E_{\text{th}} = W + Q \quad (2)$$

$$Q_{\text{in}} = W_{\text{out}} + Q_{\text{out}} \quad (3)$$

$$e_{\text{HE}} = \frac{W_{\text{out}}}{Q_{\text{in}}} \quad (4)$$

$$e_{\text{HE,max}} = 1 - \frac{T_C}{T_H} \quad (5)$$

$$Q_{\text{in}} + W_{\text{in}} = Q_{\text{out}} \quad (6)$$

$$\text{COP}_{\text{HP}} = \frac{Q_{\text{in}}}{W_{\text{in}}} \quad (7)$$

$$\text{COP}_{\text{HP,max}} = \frac{T_C}{T_H - T_C} \quad (8)$$

Conversions, Pressure, and Ideal Gas Law

$$n = \frac{N}{N_A} \quad (9)$$

$$K_{\text{avg}} = \frac{3}{2}k_B T \quad (10)$$

$$E_{\text{th}} = \frac{3}{2}Nk_B T \quad (11)$$

$$\Delta E = \frac{3}{2}Nk_B \Delta T \quad (12)$$

$$v_{\text{rms}} = \sqrt{\frac{3k_B T}{m}} \quad (13)$$

$$p \equiv \frac{F}{A} \quad (14)$$

$$p_{\text{gauge}} = p_{\text{actual}} - p_{\text{atm}} \quad (15)$$

$$pV = Nk_B T \quad (16)$$

$$pV = nRT \quad (17)$$

Thermal Expansion

$$\frac{\Delta L}{L} = \alpha \Delta T \quad (18)$$

$$\frac{\Delta V}{V} = \beta \Delta T \quad (19)$$

Heat Capacity, Calorimetry and Emissivity

$$C \equiv \frac{Q}{\Delta T} \quad (20)$$

$$c \equiv \frac{C}{m} \quad (21)$$

$$Q = mc\Delta T \quad (22)$$

$$Q_{\text{melt}} = mL_f \quad (23)$$

$$Q_{\text{freeze}} = -mL_f \quad (24)$$

$$Q_{\text{boil}} = mL_v \quad (25)$$

$$Q_{\text{condense}} = -mL_v \quad (26)$$

$$Q_{\text{into 1}} + Q_{\text{out of 2}} = 0 \quad (27)$$

$$Q_V = mc_V\Delta T \quad (28)$$

$$Q_P = mc_P\Delta T \quad (29)$$

$$\frac{Q}{\Delta t} = e\sigma AT^4 \quad (30)$$

$$\left(\frac{Q}{\Delta t}\right)_{\text{net}} = e\sigma A (T^4 - T_0^4) \quad (31)$$

Fluids

$$\rho = \frac{m}{V} \quad (32)$$

$$p = p_0 + \rho_\ell gh \quad (33)$$

$$p_0 = \rho gh \quad (34)$$

$$p_{\text{gas}} = p_0 + \rho gh \quad (35)$$

$$\|F_B\| = \rho_\ell V_\ell g \quad (36)$$

$$A_1 v_1 = A_2 v_2 \quad (37)$$

$$p_2 + \frac{1}{2}\rho v_2^2 + \rho gy_2 = p_1 + \frac{1}{2}\rho v_1^2 + \rho gy_1 \quad (38)$$

Oscillations

$$f \equiv \frac{1}{T} \quad (39)$$

$$\vec{F}_s = -kx \hat{x} \quad (40)$$

$$\Delta\ell = \frac{mg}{k} \quad (41)$$

$$\sin \theta \approx \theta \quad (42)$$

$$x(t) = x_{\max} \cos\left(\frac{2\pi t}{T}\right) = x_{\max} \cos(2\pi f t) \quad (43)$$

$$v(t) = -v_{\max} \sin\left(\frac{2\pi t}{T}\right) = -v_{\max} \sin(2\pi f t) \quad (44)$$

$$a(t) = -a_{\max} \cos\left(\frac{2\pi t}{T}\right) = -a_{\max} \cos(2\pi f t) \quad (45)$$

$$x_{\max} = A \quad (46)$$

$$v_{\max} = 2\pi f A \quad (47)$$

$$a_{\max} = (2\pi f)^2 A \quad (48)$$

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \quad (49)$$

$$f = \frac{1}{2\pi} \sqrt{\frac{g}{\ell}} \quad (50)$$

Energy in SHM

$$U_{\text{spring}} = \frac{1}{2} k x^2 \quad (51)$$

$$KE = \frac{1}{2} m v^2 \quad (52)$$

$$E_{\text{total}} = KE_{\max} = U_{\max} \quad (53)$$

$$E_x = KE_x + U_x \quad (54)$$

Traveling Waves

$$\mu = \frac{m}{\ell} \quad (55)$$

$$v_{\text{string}} = \sqrt{\frac{T}{\mu}} \quad (56)$$

$$v = \lambda f \quad (57)$$

$$y(x, t) = A \cos\left[2\pi \left(\frac{x}{\lambda} \mp \frac{t}{T}\right)\right] = A \cos\left[2\pi \left(\frac{x \mp vt}{\lambda}\right)\right] \quad (58)$$

$$I \equiv \frac{P}{A} \quad (59)$$

Doppler Effect

$$f_{\text{obs}} = f_{\text{source}} \left(1 \mp \frac{v_{\text{source}}}{v_{\text{waves}}} \right) \quad (60)$$

$$f_{\text{obs}} = \left(1 \pm \frac{v_{\text{obs}}}{v_{\text{waves}}} \right) f_{\text{source}} \quad (61)$$

$$\Delta f = \pm 2f_{\text{source}} \frac{v_{\text{object}}}{v_{\text{waves}}} \quad (62)$$

Standing Waves

Open–Open or Closed–Closed

$$\lambda_n = \frac{2L}{n}, \quad n = 1, 2, 3, \dots \quad (63)$$

$$f_n = \frac{nv}{2L} \quad (64)$$

Open–Closed

$$\lambda_n = \frac{4L}{n}, \quad n = 1, 3, 5, \dots \quad (65)$$

$$f_n = \frac{nv}{4L} \quad (66)$$

Interference and Beats

$$\Delta d = n\lambda \quad (67)$$

$$\Delta d = \left(n + \frac{1}{2} \right) \lambda \quad (68)$$

$$f_{\text{osc}} = \frac{1}{2}(f_1 + f_2) \quad (69)$$

$$f_{\text{beat}} = \|f_1 - f_2\| \quad (70)$$

Light and Optics

$$n \equiv \frac{c}{v} \quad (71)$$

$$\lambda_{\text{med}} = \frac{\lambda_0}{n} \quad (72)$$

Young's Double Slit

$$m\lambda = d \sin \theta_m \quad (73)$$

$$m\lambda = d\theta_m \quad (74)$$

$$y_m \approx \frac{m\lambda L}{d} \quad (75)$$

$$\Delta y = \frac{\lambda L}{d} \quad (76)$$

$$y_p = \left(p + \frac{1}{2} \right) \frac{\lambda L}{d} \quad (77)$$

Thin Film ($n_{\text{film}} < n_{\text{under}}$)

$$2d = m \frac{\lambda_0}{n} \quad (78)$$

$$2d = \left(m + \frac{1}{2} \right) \frac{\lambda_0}{n} \quad (79)$$

Diffraction

$$d \sin \theta_m = m\lambda \quad (80)$$

$$y_m = L \tan \theta_m \quad (81)$$

$$\theta_p = \frac{p\lambda}{a} \quad (82)$$

$$y_p = \frac{p\lambda L}{a} \quad (83)$$

$$w = \frac{2\lambda L}{a} \quad (84)$$

$$w \approx 2.44 \frac{\lambda L}{D} \quad (85)$$

Ray Optics

$$\theta_i = \theta_r \quad (86)$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad (87)$$

$$\theta_c \geq \arcsin \left(\frac{n_1}{n_2} \right), \quad n_2 > n_1 \quad (88)$$

Lenses and Instruments

$$s' = s \frac{n_2}{n_1} \quad (89)$$

$$m \equiv \pm \frac{s'}{s} \quad (90)$$

$$\frac{1}{\pm f} = \frac{1}{s} + \frac{1}{s'} \quad (91)$$

$$P = \frac{1}{f} \quad (92)$$

$$M \equiv \frac{\theta}{\theta_0} \quad (93)$$

$$M = \frac{25 \text{ cm}}{f} \quad (94)$$

$$M_o \approx -\frac{L}{f_o} \quad (95)$$

$$M_e = \frac{25 \text{ cm}}{f_e} \quad (96)$$

$$M = -\frac{L(25 \text{ cm})}{f_o f_e} \quad (97)$$

$$M = -\frac{f_o}{f_e} \quad (98)$$

$$\alpha = 1.22 \frac{\lambda}{D} \quad (99)$$