Physics 122 Fall 2025 — Jacks

General Equations Guide

("≡" means "is defined as")

Heat, First Law, Heat Engines and Heat Pumps

$$e \equiv \frac{\text{what you get}}{\text{what you paid}} \tag{1}$$

$$\Delta E_{\text{th}} = W + Q \tag{2}$$

$$Q_{\text{in}} = W_{\text{out}} + Q_{\text{out}} \tag{3}$$

$$e_{\text{HE}} = \frac{W_{\text{out}}}{Q_{\text{in}}} \tag{4}$$

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

$$Q_{\text{in}} + W_{\text{in}} = Q_{\text{out}} \tag{6}$$

$$\text{COP}_{\text{HP}} = \frac{Q_{\text{in}}}{W_{\text{in}}} \tag{7}$$

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

Conversions, Pressure, and Ideal Gas Law

$$n = \frac{N}{N_A} \tag{9}$$

$$K_{\text{avg}} = \frac{3}{2} k_B T \tag{10}$$

$$E_{\text{th}} = \frac{3}{2} N k_B T \tag{11}$$

$$\Delta E = \frac{3}{2} N k_B \Delta T \tag{12}$$

$$v_{\text{rms}} = \sqrt{\frac{3 k_B T}{m}} \tag{13}$$

$$p \equiv \frac{F}{A} \tag{14}$$

$$p_{\text{gauge}} = p_{\text{actual}} - p_{\text{atm}} \tag{15}$$

$$pV = N k_B T \tag{16}$$

$$pV = nRT \tag{17}$$

Thermal Expansion

$$\frac{\Delta L}{L} = \alpha \Delta T \tag{18}$$

$$\frac{\Delta V}{V} = \beta \Delta T \tag{19}$$

Heat Capacity, Calorimetry and Emissivity

$$C \equiv \frac{Q}{\Delta T} \tag{20}$$

$$c \equiv \frac{C}{m} \tag{21}$$

$$Q = mc\Delta T \tag{22}$$

$$Q_{\text{melt}} = mL_f \tag{23}$$

$$Q_{\text{freeze}} = -mL_f \tag{24}$$

$$Q_{\text{boil}} = mL_v \tag{25}$$

$$Q_{\text{condense}} = -mL_v \tag{26}$$

$$Q_{\text{into 1}} + Q_{\text{out of 2}} = 0 \tag{27}$$

$$Q_V = mc_V \Delta T \tag{28}$$

$$Q_P = mc_P \Delta T \tag{29}$$

$$\frac{Q}{\Delta t} = e\sigma A T^4 \tag{30}$$

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

Fluids

$$\rho = \frac{m}{V} \tag{32}$$

$$p = p_0 + \rho_\ell g h \tag{33}$$

$$p_0 = \rho g h \tag{34}$$

$$p_{\text{gas}} = p_0 + \rho g h \tag{35}$$

$$\|F_B\| = \rho_\ell V_\ell g \tag{36}$$

$$A_1 v_1 = A_2 v_2 \tag{37}$$

$$p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 = p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 \tag{38}$$

Oscillations

$$f \equiv \frac{1}{T} \tag{39}$$

$$\vec{F}_s = -kx\,\hat{x} \tag{40}$$

$$\Delta\ell = \frac{mg}{k} \tag{41}$$

$$\sin\theta \approx \theta \tag{42}$$

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

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

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

$$x_{\max} = A \tag{46}$$

$$v_{\max} = 2\pi f A \tag{47}$$

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

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \tag{49}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}} \tag{50}$$

Energy in SHM

$$U_{\text{spring}} = \frac{1}{2}kx^2 \tag{51}$$

$$KE = \frac{1}{2}mv^2 \tag{52}$$

$$E_{\text{total}} = KE_{\max} = U_{\max} \tag{53}$$

$$E_x = KE_x + U_x \tag{54}$$

Traveling Waves

$$\mu = \frac{m}{\ell} \tag{55}$$

$$v_{\text{string}} = \sqrt{\frac{T}{\mu}} \tag{56}$$

$$v = \lambda f \tag{57}$$

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

$$I \equiv \frac{P}{A} \tag{59}$$

Doppler Effect

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

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

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

Standing Waves

Open–Open or Closed–Closed

$$\lambda_n = \frac{2L}{n}, \quad n = 1, 2, 3, \ldots \tag{63}$$

$$f_n = \frac{nv}{2L} \tag{64}$$

Open–Closed

$$\lambda_n = \frac{4L}{n}, \quad n = 1, 3, 5, \ldots \tag{65}$$

$$f_n = \frac{nv}{4L} \tag{66}$$

Interference and Beats

$$\Delta d = n\lambda \tag{67}$$

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

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

$$f_{\text{beat}} = \|f_1 - f_2\| \tag{70}$$

Light and Optics

$$n \equiv \frac{c}{v} \tag{71}$$

$$\lambda_{\text{med}} = \frac{\lambda_0}{n} \tag{72}$$

Young's Double Slit

$$m\lambda = d\sin\theta_m \tag{73}$$
$$m\lambda = d\theta_m \tag{74}$$
$$y_m \approx \frac{m\lambda L}{d} \tag{75}$$
$$\Delta y = \frac{\lambda L}{d} \tag{76}$$
$$y_p = \left(p + \frac{1}{2}\right)\frac{\lambda L}{d} \tag{77}$$

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

$$2d = m\frac{\lambda_0}{n} \tag{78}$$
$$2d = \left(m + \frac{1}{2}\right)\frac{\lambda_0}{n} \tag{79}$$

Diffraction

$$d\sin\theta_m = m\lambda \tag{80}$$
$$y_m = L\tan\theta_m \tag{81}$$
$$\theta_p = \frac{p\lambda}{a} \tag{82}$$
$$y_p = \frac{p\lambda L}{a} \tag{83}$$
$$w = \frac{2\lambda L}{a} \tag{84}$$
$$w \approx 2.44\frac{\lambda L}{D} \tag{85}$$

Ray Optics

$$\theta_i = \theta_r \tag{86}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2 \tag{87}$$
$$\theta_c \geq \arcsin\left(\frac{n_1}{n_2}\right), \quad n_2 > n_1 \tag{88}$$

Lenses and Instruments

$$s' = s\frac{n_2}{n_1} \tag{89}$$

$$m \equiv \pm\frac{s'}{s} \tag{90}$$

$$\frac{1}{\pm f} = \frac{1}{s} + \frac{1}{s'} \tag{91}$$

$$P = \frac{1}{f} \tag{92}$$

$$M \equiv \frac{\theta}{\theta_0} \tag{93}$$

$$M = \frac{25\text{ cm}}{f} \tag{94}$$

$$M_o \approx -\frac{L}{f_o} \tag{95}$$

$$M_e = \frac{25\text{ cm}}{f_e} \tag{96}$$

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

$$M = -\frac{f_o}{f_e} \tag{98}$$

$$\alpha = 1.22\frac{\lambda}{D} \tag{99}$$