Physics 123 Formula Sheet
(2 Feb 2026 version)

Constants & Conversion Factors

$g = 9.8$ m/s^2
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
$k_B = 1.381 \times 10^{-23}$ J/K
$N_A = 6.022 \times 10^{23}$
$R = k_B \cdot N_A = 8.314$ J/mol·K
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4
$c = 3 \times 10^8$ m/s
$m_{electron} = 9.11 \times 10^{-31}$ kg
1 inch = 2.54 cm
1 m^3 = 1000 L
1 atm = 1.013×10^5 Pa = 14.7 psi
1 eV = 1.602×10^{-19} J
$T_F = \frac{9}{5}T_C + 32$
$T_C = \frac{5}{9}(T_F - 32)$
$T_K = T_C + 273.15$

Materials Parameters

ρ_{water}: 1000 kg/m^3
ρ_{air}: 1.29 kg/m^3 (at 0°C, 1 atm)
ρ_{alum}: 2700 kg/m^3
α_{alum}: 24×10^{-6} /°C
α_{copper}: 17×10^{-6} /°C
α_{steel}: 11×10^{-6} /°C
c_{water}: 4186 J/kg·°C
c_{ice}: 2090 J/kg·°C
c_{steam}: 2010 J/kg·°C
c_{alum}: 900 J/kg·°C
c_{copper}: 387 J/kg·ºC
$L_{melt,water}$: 3.33×10^5 J/kg
$L_{boil,water}$: 2.26×10^6 J/kg
$L_{boil,liquid\ nitrogen}$: 1.98×10^5 J/kg
$k_{th,alum}$: 238 J/s·m·°C
$k_{th,copper}$: 397 J/s·m·°C
$v_{sound,air}$: 343 m/s (at 20°C)
$n_{water} = 1.33$ (unless otherwise specified)
$n_{glass} = 1.5$ (unless otherwise specified)
$n_{air} = 1.0$ (unless otherwise specified)

Misc. Math

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
$A_{sphere} = 4\pi R^2$
$V_{sphere} = \frac{4}{3}\pi R^3$
$(1+x)^n \approx 1 + nx$

Fluids & Thermodynamics

$P = P_0 + \rho g\,(depth)$
B = weight of displaced fluid
$A_1 v_1 = A_2 v_2$ (if incompressible)
$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$
$\Delta L = \alpha L_0 \Delta T, \Delta V = \beta V_0 \Delta T;\ \beta = 3\alpha$
$PV = nRT = Nk_BT$ (ideal gas)
$KE_{ave} = \frac{3}{2}k_BT$ (translational only)
$m/k_B = M/R$ (M = molar mass)
$f(v) = 4\pi\left(\frac{m}{2\pi k_BT}\right)^{3/2} v^2 e^{-\frac{1}{2}mv^2/k_BT}$
$v_{most\ prob} = \sqrt{\frac{2k_BT}{m}}$
$v_{average} = \int_0^\infty v f(v)dv = \sqrt{\frac{8k_BT}{\pi m}}$
$v_{rms} = \sqrt{\int_0^\infty v^2 f(v)dv} = \sqrt{\frac{3k_BT}{m}}$
Mean free path: $\ell = \frac{1}{\sqrt{2}\pi d^2 n}$
Ave time between collisions: $\tau = \ell/v_{avg}$
$P_{cond} = \frac{k_{th}A\Delta T}{L} = \frac{A\Delta T}{R};\ R = L/k_{th}$
$P_{rad} = e\sigma A T^4$
$Q = mc\Delta T$
$\#\text{dof}_{mono} \approx 3;\ \#\text{dof}_{dia} \approx 5$ (at room temp)
$E_{int} = \frac{\#\text{dof}}{2}Nk_BT = \frac{\#\text{dof}}{2}nRT$
$Q = nC\Delta T$
$C_v = (\#\text{dof})R/2$
$E_{int} = nC_vT;\ \Delta E_{int} = nC_v\Delta T$
$Q_{added} = \Delta E_{int} + W_{by}$ (First Law)
$\Delta E_{int} = Q_{added} + W_{on}$ (First Law)
$C_p = C_v + R = (\#\text{dof} + 2)R/2$
$\gamma = C_p/C_v = (\#\text{dof} + 2)/\#\text{dof}$
isotherm: $P_1V_1 = P_2V_2$
reversible adiabatic: $P_1V_1^\gamma = P_2V_2^\gamma$
reversible adiabatic: $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$
$e_{Otto} = 1 - \frac{1}{r^{\gamma-1}};\ r = V_{max}/V_{min}$
$e_{Diesel} = 1 - \frac{1}{r^{\gamma-1}}\left(\frac{r_c^\gamma - 1}{\gamma(r_c - 1)}\right);$
$r = \frac{V_{max}}{V_{min}},\ r_c = \frac{V_{middle}}{V_{min}}$
$e_{Carnot} = 1 - T_c/T_h$
$\Delta S_{12} = \int_{\text{state 1}}^{\text{state 2}} QdT,$
integral done over any reversible path
$S = k_B \ln W$
(W = #microstates with the given energy)
$\#\text{microstates} = \binom{N}{k} = \frac{N!}{k!(N-k)!}$ (e.g. coins)
$\#\text{macrostates} = 2^N$ (e.g. coins)

Waves & Sound

$P_{string} = \frac{1}{2}\mu\omega^2A^2v$
$r_{string} = \frac{v_2 - v_1}{v_2 + v_1};\ t_{string} = \frac{2v_2}{v_2 + v_1}$
$R = |r|^2;\ T = 1 - R$
$v_{string} = \sqrt{T/\mu};\ \mu = m/L$
$v_{rod} = \sqrt{Y/\rho};\ Y = \frac{stress}{strain} = \frac{F/A}{\Delta L/L}$
$v_{sound} = \sqrt{B/\rho} = 343\,\frac{\text{m}}{\text{s}}\sqrt{T/293\text{K}}$
$\beta = 10\log_{10}\left(\frac{I}{I_0}\right);\ I = I_0 10^{\frac{\beta}{10}};$
$I_0 = 10^{-12}$ W/m^2
$f' = f\,\frac{v \pm v_{obs}}{v \pm v_{source}}$
$\sin\theta_{boom} = 1/\text{Mach\#}$

Optics

$n = v/c$
$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$\tan\theta_{Brewster} = n_2/n_1$
$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$
$f_{mirror} = R/2$
$\frac{1}{f_{lens}} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right);$
(R_1 = pos, R_2 = neg for convex-convex)
$\phi = 2\pi\Delta PL/\lambda$
$E = E_0\left(e^{i\phi_1} + e^{i\phi_2} + \cdots\right)$
$I \sim |E|^2$
2 narrow slits: $I = I_0\cos^2\left(\frac{\pi}{\lambda}d\sin\theta\right)$
$m\lambda = d\sin\theta_{max};\ m = 0, \pm1, \pm2, \ldots$
1 wide slit: $I = I_0\,\text{sinc}^2\left(\frac{\pi}{\lambda}a\sin\theta\right)$
$m\lambda = a\sin\theta_{min};\ m = \pm1, \pm2, \ldots$
circular slit: $\theta_{min} = 1.22\lambda/D$
grating: $m\lambda = d\sin\theta$
$R = \frac{\lambda_{ave}}{\Delta\lambda} = \#\text{slits} \times m$
Bragg: $m\lambda = 2d\sin\theta$