Formula Sheet Based on *Finn's Thermal Physics*, 4th *ed.*, by Rex

(When quoting a formula from this sheet write down **the** formula **and** its number)

1. TEMPERATURE

$$PV = nRT = Nk_BT \quad (1.1)$$

$$T(\mathrm{K}) \equiv 273.16 \lim_{P_{\mathrm{TP}}\to 0} \frac{P}{P_{\mathrm{TP}}} \quad (1.2)$$

$$t(^\circ\mathrm{C}) \equiv T(\mathrm{K}) - 273.15 \quad (1.3)$$

2. REVERSIBLE PROCESSES AND WORK

$$\alpha \equiv \frac{1}{L}\left(\frac{\partial L}{\partial T}\right)_P \quad ; \quad \beta \equiv \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P \quad (2.1)$$

$$B_T \equiv -V\left(\frac{\partial P}{\partial V}\right)_T \equiv \frac{1}{\kappa_T} \quad ; \quad Y \equiv \frac{L}{A}\left(\frac{\partial F}{\partial L}\right)_T \quad (2.2)$$

$$\begin{aligned} đW &= -PdV \quad \text{(if reversible process)} \\ &= Fdx \\ &= \Gamma \mathrm{dA} \end{aligned} \quad (2.3)$$

3. FIRST LAW OF THERMODYNAMICS

$$\Delta U = Q + W \quad ; \quad dU = đQ + đW \quad (3.1)$$

$$C \equiv \lim_{\Delta T\to 0} \frac{Q}{\Delta T} = \frac{đQ}{dT} \quad (3.2)$$

$$c = \frac{1}{m}\frac{đQ}{dT} \quad (3.3)$$

$$H \equiv U + PV \quad (3.4)$$

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V \quad ; \quad C_P = \left(\frac{\partial H}{\partial T}\right)_P \quad ; \quad \gamma \equiv \frac{C_P}{C_V} \quad (3.5)$$

$$L \equiv \frac{Q}{m} \quad (3.6)$$

$$\begin{aligned} &\tfrac{1}{2} m\overline{v^2} = \tfrac{3}{2} k_B T \quad \text{(if ideal gas)} \\ &C_P = C_V + nR \\ &PV^\gamma = \text{constant} \quad \text{(for adiabat)} \end{aligned} \quad (3.7)$$

$$\mu_{\mathrm{J}} \equiv \left(\frac{\partial T}{\partial V}\right)_U \quad ; \quad \mu_{\mathrm{JK}} \equiv \left(\frac{\partial T}{\partial P}\right)_H \quad (3.8)$$

$$\left(P + n^2 a / V^2\right)(V - nb) = nRT \quad (3.9)$$

4. SECOND LAW OF THERMODYNAMICS

$$\eta \equiv \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1} \quad (4.1)$$

$$\eta_c \equiv 1 - \frac{T_2}{T_1} \quad (4.2)$$

$$COP^{\mathrm{R}} \equiv \frac{Q_2}{W} \quad ; \quad COP^{\mathrm{HP}} \equiv \frac{Q_1}{W} \quad (4.3)$$

$$\eta = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1} \quad \text{(if ideal gas)} \quad (4.4)$$

5. ENTROPY

$$\oint \frac{đQ}{T_0} \le 0 \quad (5.1)$$

$$\oint \frac{đQ_R}{T} = 0 \;\; \text{(if reversible cycle)} \;\; \Rightarrow \;\; dS \equiv \frac{đQ_R}{T} \quad (5.2)$$

$$dS \ge \frac{đQ}{T_0} \quad (5.3)$$

$$dU = TdS - PdV \quad \text{(if work is compressive only)} \quad (5.4)$$

6. INTRO TO STATISTICAL MECHANICS

$$\Omega(N,n) = {}^N C_n = \binom{N}{n} \equiv \frac{N!}{n!(N-n)!} \quad (6.1)$$

$$\begin{aligned} &\Omega_{tot}(N,q) = q^N \quad \text{(if } N \text{ distinguishable particles)} \\ &\Omega_{tot}(N,q) = \frac{(q+N-1)!}{N!(q-1)!} \quad \text{(if } N \text{ indistinguishable particles)} \end{aligned} \quad (6.2)$$

$$S \equiv k_B \ln \Omega \quad (6.3)$$

$$Z(T) \equiv \sum_i g_i e^{-E_i/k_BT} \quad ; \quad P(E_i) = \frac{1}{Z(T)} g_i e^{-E_i/k_BT} \quad (6.4)$$

$$\begin{aligned} &f(v_x, v_y, v_z) = \left(\frac{m}{2\pi k_B T}\right)^{3/2} e^{-mv^2/2k_BT} \quad \text{(if ideal gas)} \\ &f(v) = \left(\frac{m}{2\pi k_B T}\right)^{3/2} 4\pi v^2 e^{-mv^2/2k_BT} \\ &f(E) = \frac{2}{\sqrt{\pi}} (k_B T)^{-3/2} E^{1/2} e^{-E/k_BT} \end{aligned} \quad (6.5)$$

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7. MORE ON THERMODYNAMIC POTENTIALS

$$F \equiv U - TS \quad (7.1)$$

$$G \equiv H - TS \quad (7.2)$$

8. GENERAL THERMODYNAMIC RELATIONS

$$C_p = C_V + T\beta^2 B_T V \quad (8.1)$$

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P \quad \text{(if only work is compressive)}$$

$$\left(\frac{\partial U}{\partial P}\right)_T = -\left[T\left(\frac{\partial V}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial P}\right)_T\right] \quad (8.2)$$

$$\frac{C_P}{C_V} = \frac{\kappa_T}{\kappa_S} \quad (8.3)$$

$$\mu_J = \frac{1}{C_V}\left[P - T\left(\frac{\partial P}{\partial T}\right)_V\right] \quad (8.4)$$

$$\mu_{JK} = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right] \quad (8.5)$$

9. MAGNETIC SYSTEMS

$$\chi_m = \frac{C}{T} \quad \text{(high temp approximation)} \quad (9.1)$$

$$\chi_m = \frac{C}{T - T_0} \quad (9.2)$$

$$dU = đQ - PdV + B_0 dM' \quad (9.3)$$

10. PHASE CHANGES

$$\frac{dP}{dT} = \frac{S_2 - S_1}{V_2 - V_1} = \frac{L}{T(V_2 - V_1)} \quad (10.1)$$

$$\frac{dP}{dT} = \frac{C_{P1} - C_{P2}}{TV(\beta_1 - \beta_2)} = \frac{\beta_2 - \beta_1}{\kappa_2 - \kappa_1} \quad (10.2)$$

11. OPEN SYSTEMS

$$dU = TdS - PdV + \mu dN \quad (11.1)$$

$$\mu \equiv \left(\frac{\partial U}{\partial N}\right)_{S,V} = \left(\frac{\partial F}{\partial N}\right)_{V,T} = \left(\frac{\partial G}{\partial N}\right)_{T,P}$$

$$= \frac{G}{N} \quad \text{(if only one type of particle present)} \quad (11.2)$$

APPENDIX A. SOME PHYSICAL CONSTANTS

$R = 8.314$ J/(K mol)

$N_A = 6.023 \times 10^{23}$ mol^{-1}

$k_B \equiv 1.380649 \times 10^{-23}$ JK^{-1}

$\sigma = 5.67 \times 10^{-8}$ W/(m^{2}K^4)

$h = 6.626 \times 10^{-34}$ Js

$e = 1.602 \times 10^{-19}$ C

$c \equiv 299792458$ m/s

$g = 9.81$ m/s^2

$\mu_0 \equiv 4\pi \times 10^{-7}$ NA^{-2}

$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1}

1 atomic mass unit $= 1.661 \times 10^{-27}$ kg

$P_{atm} = 1.013 \times 10^5$ Pa $= 760$ mmHg

1 cal = 4.184 J

1 Btu = 1055 J

1 hp = 746 W

1 kWh $= 3.60 \times 10^6$ J

APPENDIX B. SOME INTEGRALS

$$\int_0^\infty e^{-ax^2} dx = \frac{1}{2}\sqrt{\frac{\pi}{a}} \quad (B.1)$$

More generally:

$$\int_0^\infty x^{2n} e^{-ax^2} dx = \frac{1.3.5\ldots(\text{up through } 2n-1)}{2^{n+1} a^n}\sqrt{\frac{\pi}{a}} \quad (B.2)$$

$$\int_0^\infty x^{2n+1} e^{-ax^2} dx = \frac{n!}{2a^{n+1}} \quad (B.3)$$