

*****BASIC *****EQUATIONS

(1) Work and Energy Relations

$$W_b = \int pdV \quad W_e = VI\Delta t \quad W_{\text{spring}} = \frac{k_s}{2}(x_2^2 - x_1^2)$$

$$W_{\text{rot}} = 2\pi n\tau \quad w_{\text{cv}} = -\int_1^2 vdp + (V_1^2 - V_2^2)/2 + g(z_1 - z_2)$$

$$\Delta KE = 0.5m(V_2^2 - V_1^2) \quad \Delta PE = mg(z_2 - z_1) \quad F_{\text{spring}} = k_s x$$

(2) First Law Relations and Mass Conservation

$$Q - W = \Delta U + \Delta KE + \Delta PE$$

$$\dot{Q}_{\text{cv}} - \dot{W}_{\text{cv}} - \sum_e \dot{m}_e (h + V^2/2 + gz)_e + \sum_i \dot{m}_i (h + V^2/2 + gz)_i = \frac{dE_{\text{cv}}}{dt}$$

$$\dot{m} = \rho VA \quad \dot{m} = \dot{V}/v \quad \sum_i \dot{m}_i - \sum_e \dot{m}_e = \frac{dm_{\text{cv}}}{dt}$$

(3) Second Law Relations

$$\Delta S = \int_1^2 \left[\frac{\delta Q}{T} \right]_b + \sigma \quad \Delta S = \int_1^2 \left[\frac{\delta q}{T} \right]_{\text{int rev}} \quad \frac{dS}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \dot{\sigma}$$

$$-\sum_e \dot{m}_e s_e + \sum_i \dot{m}_i s_i + \sum_j \frac{\dot{Q}_j}{T_j} + \dot{\sigma}_{\text{cv}} = \frac{dS_{\text{cv}}}{dt} \quad \oint \left(\frac{\delta Q}{T} \right)_b = -\sigma \leq 0$$

*****PROPERTY *****RELATIONS

(4) Pressure, Temperature and Energy Relations

$$p_{\text{abs}} = p_{\text{atm}} \pm p_{\text{gage}} \quad p - p_{\text{atm}} = \rho gL \quad m = V/v$$

$$pV = n\bar{R}T \quad pV = mRT \quad R = \bar{R}/M \quad Pv = ZRT$$

$$p_R = p/p_c \quad T_R = T/T_c \quad v_R = v p_c / RT_c \quad k = C_p / C_v$$

$$x = m_g / (m_f + m_g) \quad y = (1-x)y_f + xy_g = y_f + xy_{fg} \quad y_{fg} = y_g - y_f$$

$$h = u + Pv \quad \Delta u = \int c_v dT \quad \Delta h = \int c_p dT \quad C_p - C_v = R$$

$$\Delta u = \int cdT \quad \Delta h = \Delta u + v\Delta p \quad h(T,p) \cong h_f(T) + v_f(T)[p - p_{\text{sat}}(T)]$$

$$u(T,p) \cong u_f(T) \quad v(T,p) \cong v_f(T) \quad s(T,p) \cong s_f(T)$$

(5) Entropy Relations (and isentropic processes)

$$Tds = du + pdv \quad Tds = dh - vdp$$

$$\Delta s = c_v \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1} \quad \Delta s = c_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1}$$

$$\Delta s = s_2^\circ - s_1^\circ - R \ln(p_2/p_1) \quad \Delta s = c \ln(T_2/T_1)$$

$$T_2/T_1 = (p_2/p_1)^{(k-1)/k} = (v_1/v_2)^{k-1} \quad (p_2/p_1)_s = p_{r2}/p_{r1} \quad (v_2/v_1)_s = v_{r2}/v_{r1}$$

*****EFFICIENCY *****AND *****CYCLE *****RELATIONS

(6) Device Efficiencies and Cycle Analyses

$$\eta_{\text{turbine}} = w_{\text{act}}/w_{\text{isen}} \quad \eta_{\text{compressor}} = \eta_{\text{pump}} = w_{\text{isen}}/w_{\text{act}}$$

$$\eta_{\text{th}} = \frac{W_{\text{net,out}}}{Q_{\text{in}}} \quad \text{COP}_R = \frac{Q_{\text{in}}}{W_{\text{net,in}}} \quad \text{COP}_{\text{HP}} = \frac{Q_{\text{out}}}{W_{\text{net,in}}} \quad \text{BWR} = \frac{|w_{\text{pump}}|}{w_{\text{turbine}}}$$

$$\eta_{\text{th,rev}} = 1 - \frac{T_C}{T_H} \quad \text{COP}_{R,\text{rev}} = \frac{T_C}{T_H - T_C} \quad \text{COP}_{\text{HP,rev}} = \frac{T_H}{T_H - T_C} \quad \frac{T_C}{T_H} = \left(\frac{Q_C}{Q_H} \right)_{\text{rev}}$$

UNITS CONVERSION TABLE

Mass and Density	$1 \text{ kg} = 2.2046 \text{ lb}$ $1 \text{ g/cm}^3 = 10^3 \text{ kg/m}^3$ $1 \text{ g/cm}^3 = 62.428 \text{ lb/ft}^3$; $1 \text{ ft} = 0.3048 \text{ m}$	$1 \text{ lb} = 0.4536 \text{ kg}$ $1 \text{ lb/ft}^3 = 0.016018 \text{ g/cm}^3$ $1 \text{ lb/ft}^3 = 16.018 \text{ kg/m}^3$
Length	$1 \text{ cm} = 0.3937 \text{ in}$ $1 \text{ m} = 3.2808 \text{ ft}$	$1 \text{ in} = 2.54 \text{ cm}$ $1 \text{ ft} = 0.3048 \text{ m}$
Velocity	$1 \text{ km/h} = 0.62137 \text{ mile/h}$	$1 \text{ mile/h} = 1.6093 \text{ km/h}$
Volume	$1 \text{ cm}^3 = 0.061024 \text{ in}^3$ $1 \text{ m}^3 = 35.315 \text{ ft}^3$ $1 \text{ L} = 10^{-3} \text{ m}^3$ $1 \text{ L} = 0.0353 \text{ ft}^3$	$1 \text{ in}^3 = 16.387 \text{ cm}^3$ $1 \text{ ft}^3 = 0.028317 \text{ m}^3$ $1 \text{ gal} = 0.13368 \text{ ft}^3$ $1 \text{ gal} = 3.7854 \times 10^{-3} \text{ m}^3$
Force	$1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2$ $1 \text{ N} = 0.22481 \text{ lbf}$	$1 \text{ lbf} = 32.174 \text{ lb} \cdot \text{ft/s}^2$ $1 \text{ lbf} = 4.4482 \text{ N}$
Pressure	$1 \text{ Pa} = 1 \text{ N/m}^2 = 1.4504 \times 10^{-4} \text{ lbf/in}^2$ $1 \text{ bar} = 10^5 \text{ N/m}^2$ $1 \text{ atm} = 1.01325 \text{ bars}$	$1 \text{ lbf/in}^2 = 6894.8 \text{ Pa}$ $1 \text{ lbf/in}^2 = 144 \text{ lbf/ft}^2$ $1 \text{ atm} = 14.696 \text{ lbf/in}^2$
Energy and Specific Energy	$1 \text{ J} = 1 \text{ N} \cdot \text{m} = 0.73756 \text{ ft} \cdot \text{lbf}$ $1 \text{ kJ} = 737.56 \text{ ft} \cdot \text{lbf}$ $1 \text{ kJ} = 0.9478 \text{ Btu}$ $1 \text{ kJ/kg} = 0.42992 \text{ Btu/lb}$	$1 \text{ ft} \cdot \text{lbf} = 1.35582 \text{ J}$ $1 \text{ Btu} = 778.17 \text{ ft} \cdot \text{lbf}$ $1 \text{ Btu} = 1.0551 \text{ kJ}$ $1 \text{ Btu/lb} = 2.326 \text{ kJ/kg}$ $1 \text{ kcal} = 4.1868 \text{ kJ}$
Energy Transfer Rate	$1 \text{ W} = 1 \text{ J/s} = 3.413 \text{ Btu/h}$ $1 \text{ kW} = 1.341 \text{ hp}$	$1 \text{ Btu/h} = 0.293 \text{ W}$ $1 \text{ hp} = 2545 \text{ Btu/h}$ $1 \text{ hp} = 550 \text{ ft} \cdot \text{lbf/s}$ $1 \text{ hp} = 0.7457 \text{ kW}$ $1 \text{ ton} = 12,000 \text{ Btu/h} = 3.517 \text{ kW}$
Specific Heat	$1 \text{ kJ/kg} \cdot \text{K} = 0.238846 \text{ Btu/lb} \cdot \text{°R}$ $1 \text{ kcal/kg} \cdot \text{K} = 1 \text{ Btu/lb} \cdot \text{°R}$	$1 \text{ Btu/lb} \cdot \text{°R} = 4.1868 \text{ kJ/kg} \cdot \text{K}$
Universal Gas Constant		$\bar{R} = \begin{cases} 8.314 \text{ kJ/kmol} \cdot \text{K} \\ 1545 \text{ ft} \cdot \text{lbf/lbmol} \cdot \text{°R} \\ 1.986 \text{ Btu/lbmol} \cdot \text{°R} \end{cases}$
Standard Acceleration of Gravity		$g = \begin{cases} 9.80665 \text{ m/s}^2 \\ 32.174 \text{ ft/s}^2 \end{cases}$
Standard Atmospheric Pressure		$1 \text{ atm} = \begin{cases} 1.01325 \text{ bars} \\ 14.696 \text{ lbf/in}^2 \end{cases}$
Temperature Relations		$T(\text{°R}) = 1.8T(\text{K})$ $T(\text{°C}) = T(\text{K}) - 273.15$ $T(\text{°F}) = T(\text{°R}) - 459.67$