Mec E 230 Formula Sheet

Generalized CV-CS Analysis

Conservation of mass: $\frac{dm_{CV}}{dt} = \dot{m}_{in} - \dot{m}_{out}$
Conservation of energy:

$$\frac{dE_{CV}}{dt} = (\dot{E}_{in} - \dot{E}_{out}) + (\dot{W}_{in} - \dot{W}_{out}) + \dot{Q} - \dot{W},$$

where for **Closed system** $\Rightarrow$ no mass in/out of system, **steady-state system** $\Rightarrow$ no Δ w/ time, **adiabatic system** $\Rightarrow$ no addition/removal of heat.

Work

General: $W = \int F\,dx$
Translational: $W_{M,T} = \int_{s_1}^{s_2} F\,ds$ and $\dot{W}_{M,T} = Fv$.
F, s, and v are in the same direction.
Rotational: $W_{M,R} = \int_{\theta_1}^{\theta_2} T\,d\theta$ and $\dot{W}_{M,R} = T\omega$.
Electrical: $W_E = \int_{t_1}^{t_2} \xi I\,dt$ and $\dot{W}_E = \xi I$.
Boundary: $W_B = \int_{V_1}^{V_2} p\,dV$.
Flow: $\dot{W}_F = \dot{m} w_F$, where $w_F = p\nu = \frac{p}{\rho}$

Change in the energy in a system

$$\Delta E_{CV} = \Delta KE + \Delta PE + \Delta U_T + \Delta U_L + \Delta U_C + \Delta U_N$$

where:

- $\Delta KE = \frac{1}{2}\left(m\left(v_2^2 - v_1^2\right) + I_G(\omega_2^2 + \omega_1^2)\right)$
- $\Delta PE = mg(h_2 - h_1)$
- $\Delta U_T = m\int_{T_1}^{T_2} c_v(T)\,dT$ where if c_v is constant we write $\Delta U_T = mc_v(T_2 - T_1)$
- $\Delta U_L = mu_L$ where u_L is the specific latent heat of phase change.

Random heat/pressure-related things

Adiabatic, quasi-equilibrium, ideal gas, const. c_v:
$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$; $\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$, where k is a constant from table A-8 or table B-8.
Pressure: $p = \frac{1}{3} m_p \hat{n} \left\langle v^2 \right\rangle$ where m_p is the mass of the particle, $\hat{n}$ is the number of particles per unit volume, and v is the particle's velocity.
Also, ***pressure:*** $p = \frac{F}{A}$.
Ideal Gas Law: $pV = n\bar{R}T$
Moles $\Leftrightarrow$ Mass: $m = nM$
Specific volume: $\nu = \frac{1}{\rho} = \frac{V}{m}$
Isothermal: $V_1 p_1 = V_2 p_2$ since nRT is constant.

Heat transfer

Conduction (Fourier's law (1D)): $\dot{Q}_{cond} = -kA\frac{dT}{dx}$
Then, if k and A are constant with x:
$\left|\dot{Q}_{cond}\right| = -\frac{kA}{L}\Delta T = \frac{1}{R_{cond}}\Delta T$, where $R_{cond} = \frac{L}{kA}$.
For ***heat transfer through the walls of a cylinder*** (e.g. pipe), A is not constant w.r.t. r, and $\left|\dot{Q}_{cond}\right| = \frac{1}{R_{cond}}\Delta T$ where $R_{cond} = \frac{\ln(r_{outer}/r_{inner})}{2\pi Lk}$, with L being the length of the pipe.
Equivalent resistances:
Series: $R_{eff} = R_1 + R_2$; Parallel: $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2}$.
Convective resistance: $R_{conv} = \frac{1}{hA}$

Important unit conversions

Energy, work:
$1\,\text{Btu} = 778.169\,\text{ft}\cdot\text{lbf}$
Temperature:
$T(^\circ\text{F}) = \frac{9}{5}T(^\circ\text{C}) + 32$
$T(^\circ\text{C}) = \frac{5}{9}(T(^\circ\text{T}) - 32)$
$T(\text{K}) = T(^\circ\text{C}) + 273.15$
$T(\text{R}) = T(^\circ\text{F}) + 459.67$
$T(\text{R}) = \frac{9}{5}T(\text{K})$
Volume:
$1\,\text{m}^3 = 1000\,\text{L}$
$1\,\text{cm}^3 = 1\,\text{mL}$
Mass, force:
$1\,\text{lbm} = \frac{1}{32.174}\,\text{slug} = \frac{1\,\text{lbf}}{32.174\,\frac{\text{ft}}{\text{s}^2}}$

Important constants

Universal Gas Constant:

$$\begin{aligned}\bar{R} &= 8.31434\,\text{J}/(\text{mol}\cdot\text{K})\\ &= 1.9858\,\text{Btu}/(\text{lbmol}\cdot\text{R})\\ &= 1545.35\,\text{ft}\cdot\text{lbf}/(\text{lbmol}\cdot\text{R})\\ &= 10.73\,\text{psia}\cdot\text{ft}^3/(\text{lbmol}\cdot\text{R})\end{aligned}$$

Random notes

3 (+ 1?) types of piston problems:

1. **Isothermal**: T is constant, p varies. So replace p with something like $\frac{p_1V_1}{V}$ in your W_B integral.
2. **Isobaric**: T varies, p is constant.
3. **Nothing constant, but adiabatic**: Remeber that $pV^n = constant$, where n is given to you. Should be able to derive something like $W = \frac{mc_v}{R}(p_1V_1 - p_2V_2)$.
4. **Isotropic**: Same as Isothermal, but replace p with something like $\frac{p_1V_1^n}{V^n}$ instead.

Be calm. Take your time. If you get stuck for more than ten seconds, move on and come back to it. Enjoy!