Thermodynamics Formula Sheet

Chapter 1

Pressure

Constants

$$\begin{aligned}1\text{ atm} &= 101.325\text{ kPa}\\ &= 1.01325\text{ bar}\\ &= 760\text{ Torr}\\ &= 760\text{ mmHg}\\ &= 29.92\text{ inHg}\\ &= 14.696\text{ psi}\end{aligned}$$

Pressure Conversions

$1\,\text{Pa} = 1\,\text{N/m}^2$

$1\ \text{bar} = 10^5\ \text{Pa}$

$1\ \text{psi} = 6.89476 \times 10^3\ \text{Pa}$

$1\ \text{Torr} = 133.322\ \text{Pa}$

$1\ \text{mmHg} = 133.322\ \text{Pa}$

$1\ \text{inHg} = 3.38639 \times 10^3\ \text{Pa}$

Gauge vs Absolute Pressure

$P_{\text{gauge}} = P_{\text{absolute}} - P_{\text{atmospheric}}$

$P_{\text{vacuum}} = P_{\text{atmospheric}} - P_{\text{absolute}}$

Note: Generally, gauge pressures already account for atmospheric pressure, and thus reads zero when open to the atmosphere.

Formulas

$P = F/A$

$P = \rho g h$ (hydrostatic pressure)

Multi-fluid Manometer

1. Begin at a known pressure point (gauge or atmospheric pressure) and follow the fluid layers to the unknown pressure point.
2. Sign convention: add when going down, subtract when going up.
3. **Horizontal jump:** We can "jump" horizontally across bends in the tube if both sides of the jump are within the **same continuous fluid**. This is because pressure is identical at the same horizontal level within a single static fluid. *Any pressure decrease from moving upward is perfectly balanced by an equal pressure increase when moving back down to that same level on the other side.*
4. The pressure at each end of the manometer equals the total pressure obtained by summing the contributions of all fluid columns along the vertical path.

Pascal's Principle

The pressure applied to a confined fluid increases the pressure throughout the fluid by the same amount.

Note: $1\,\text{lbf} = 32.174\,\text{lbm} \cdot \text{ft/s}^2$

Temperature

Temperature Conversions

- Absolute temperature conversions
  - $T_K = T_{\circ C} + 273.15$
  - $T_{\circ R} = T_{\circ F} + 459.67$
  - $T_{\circ F} = \frac{9}{5}T_{\circ C} + 32$
  - $T_{\circ R} = \frac{9}{5}T_K$
- Temperature difference conversions
  - $\Delta K = \Delta{}^\circ C$
  - $\Delta{}^\circ R = \Delta{}^\circ F$
  - $\Delta{}^\circ F = \frac{9}{5}\Delta{}^\circ C$
  - $\Delta{}^\circ R = \frac{9}{5}\Delta K$

Note: Fahrenheit and Celsius are relative temperature scales (based on the freezing/boiling points of water), while Rankine and Kelvin are absolute temperature scales (starting at absolute zero).

SI Prefixes

$$\begin{aligned}\text{femto (f)} &= 10^{-15}\\ \text{pico (p)} &= 10^{-12}\\ \text{nano (n)} &= 10^{-9}\\ \text{micro } (\mu) &= 10^{-6}\\ \text{milli (m)} &= 10^{-3}\\ \text{centi (c)} &= 10^{-2}\\ \text{deci (d)} &= 10^{-1}\\ \text{deca (da)} &= 10^{1}\\ \text{hecto (h)} &= 10^{2}\\ \text{kilo (k)} &= 10^{3}\\ \text{mega (M)} &= 10^{6}\\ \text{giga (G)} &= 10^{9}\\ \text{tera (T)} &= 10^{12}\\ \text{peta (P)} &= 10^{15}\end{aligned}$$

Note: $1\text{Angstrom}\,(\text{Å}) = 10^{-10}$ m

System Properties

Extensive Properties	**Intensive Properties**
Temperature: T	T
Pressure: P	P
Volume: $\cancel{V}$	Specific Volume: $\cancel{v} = \cancel{V}/m$
Internal Energy: U	Specific Internal Energy: $u = U/m$
Entropy: S	Specific Entropy: $s = S/m$

Density and Specific Gravity

$$\rho = \frac{m}{\cancel{V}} \quad \text{(density)}$$

$$\cancel{v} = \frac{\cancel{V}}{m} = \frac{1}{\rho} \quad \text{(specific volume)}$$

Specific gravity is defined as a relative density compared to water (at 4°C) where $\rho_{water} = 1000\,\text{kg/m}^3$:

$$\boxed{SG = \frac{\rho_{fluid}}{\rho_{water}} \implies \rho_{fluid} = SG \cdot \rho_{water}}$$

Ideal Gas Law

$$P\cancel{V} = m\,\bar{R}\,T, \quad \bar{R} = \frac{R_u}{M} \quad \text{(specific gas constant)}$$

Where:

- P = *absolute* pressure (Pa)
- $\cancel{V}$ = volume (m^3)
- m = mass of gas (kg)
- T = *absolute* temperature (K)
- Universal gas constant: $R_u = 8.314$ J/(mol·K)
- M = molar mass of gas (kg/mol)
- $\bar{R}$ = specific gas constant (J/kg·K)