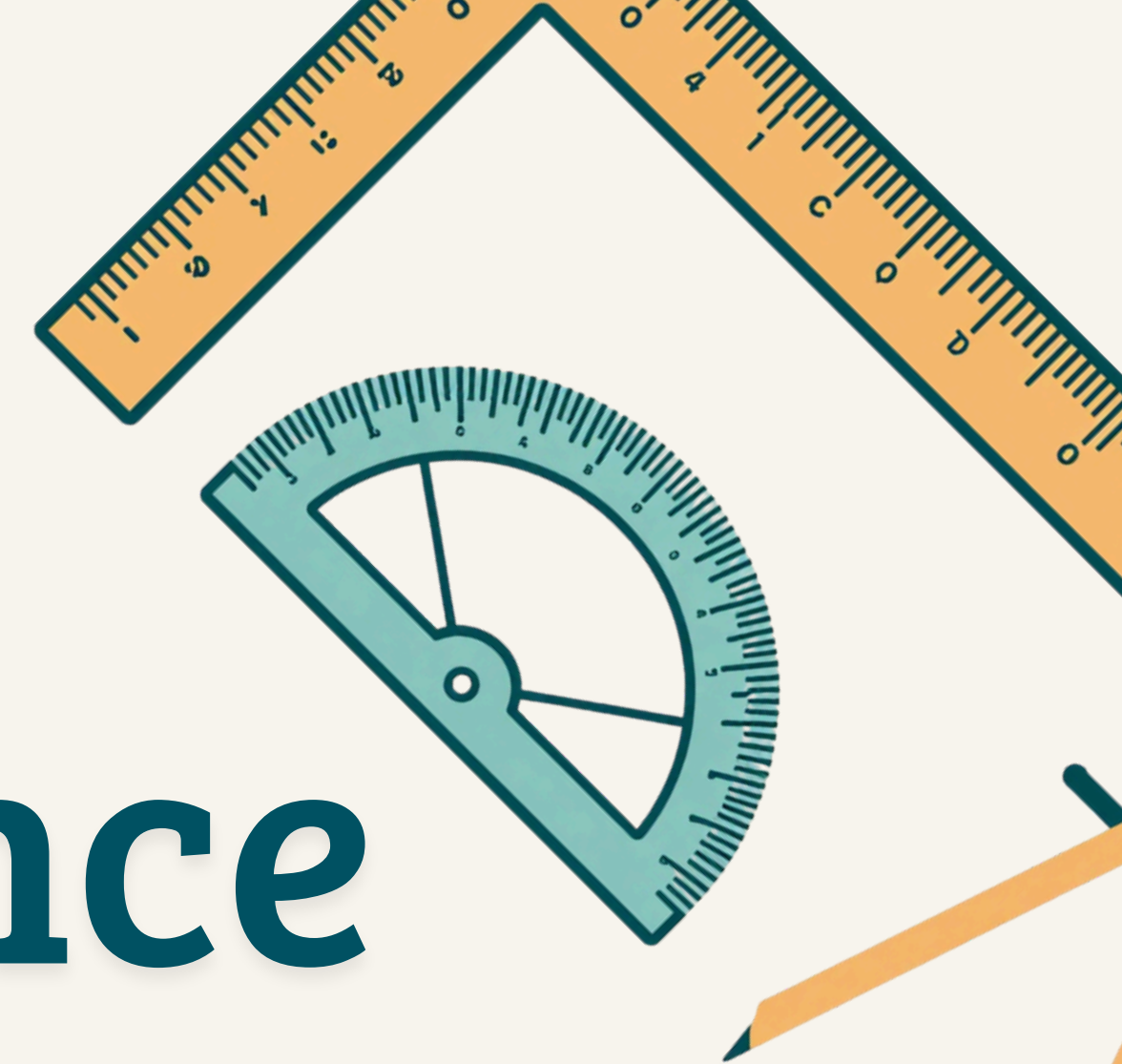
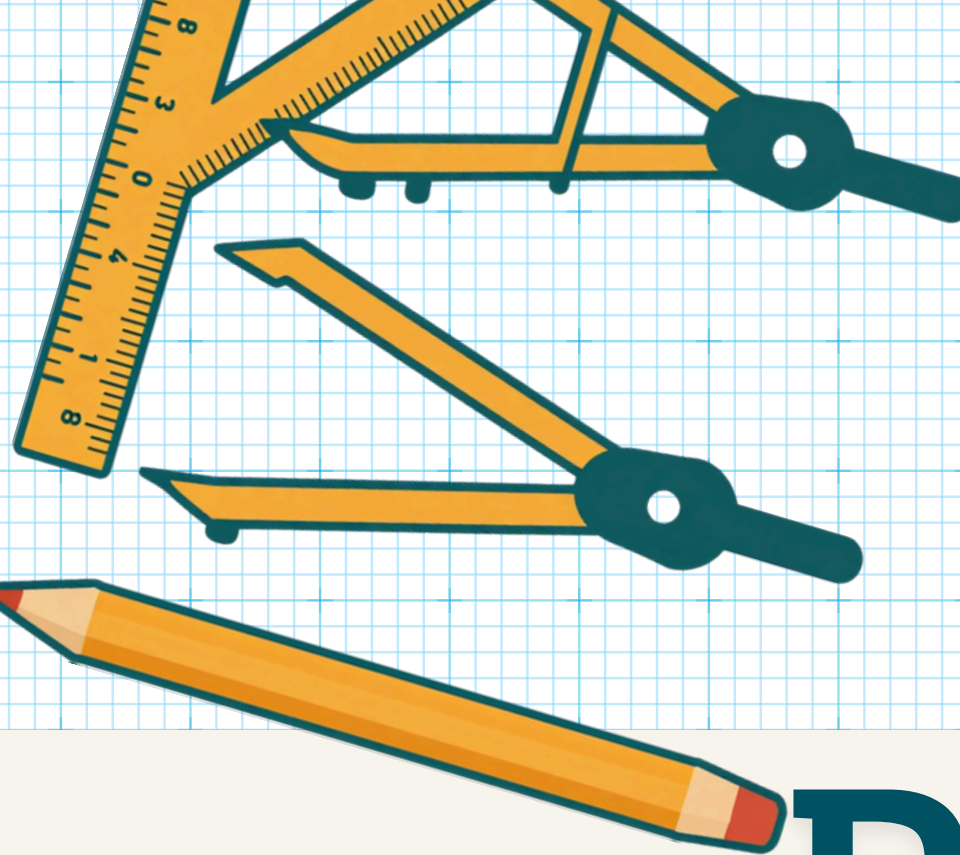
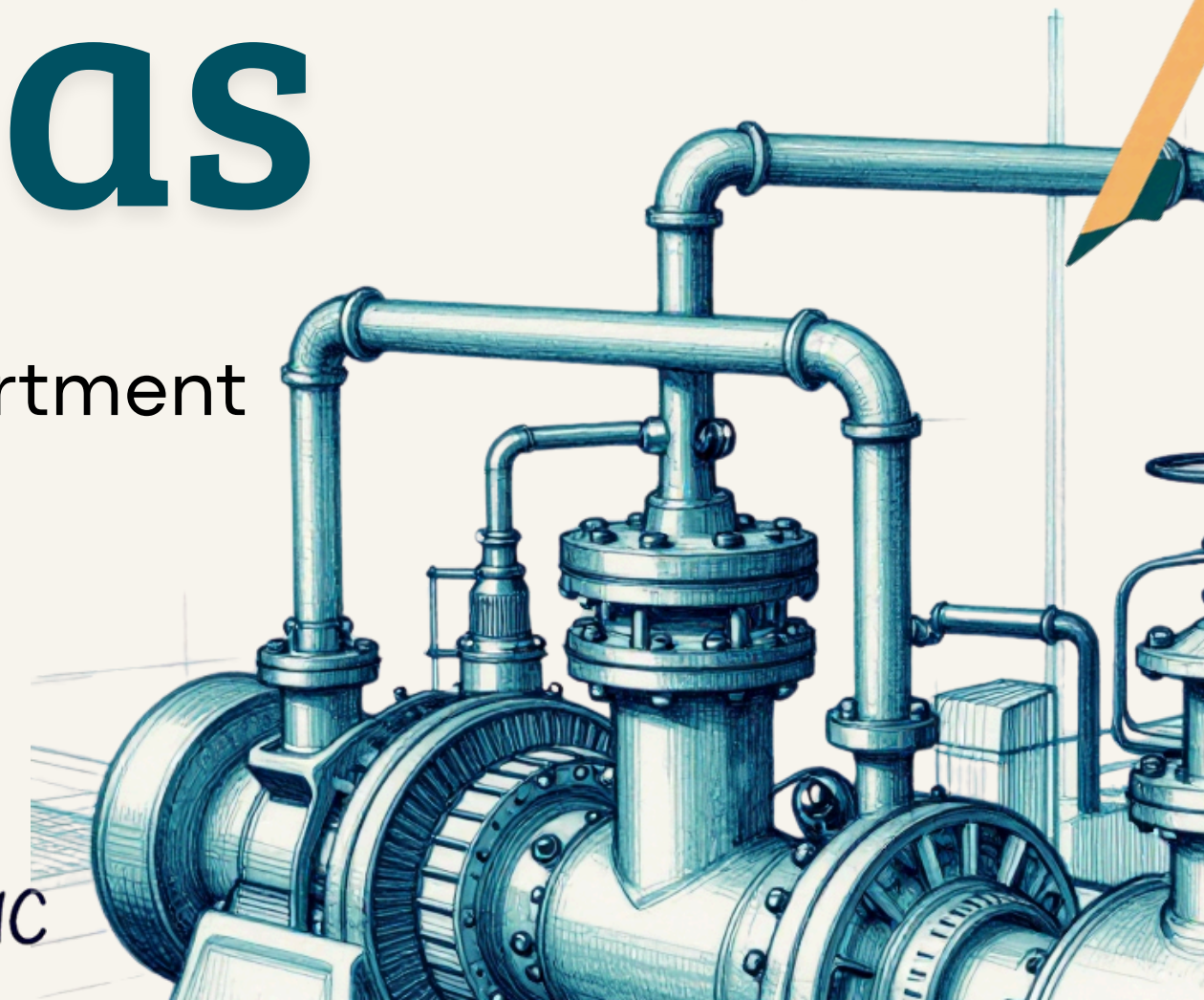
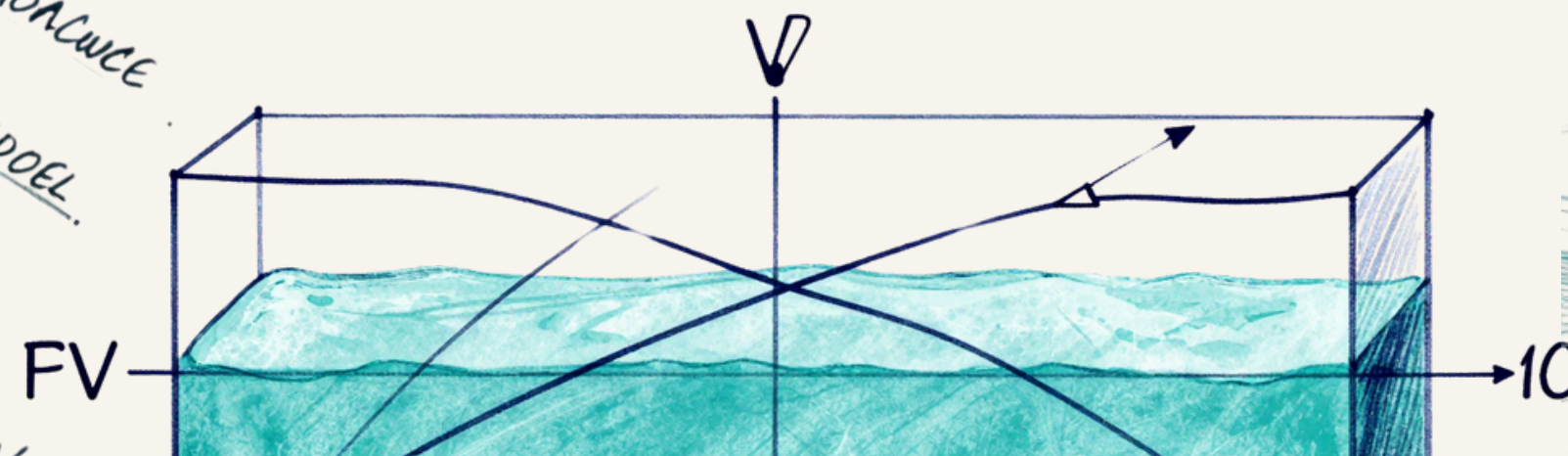
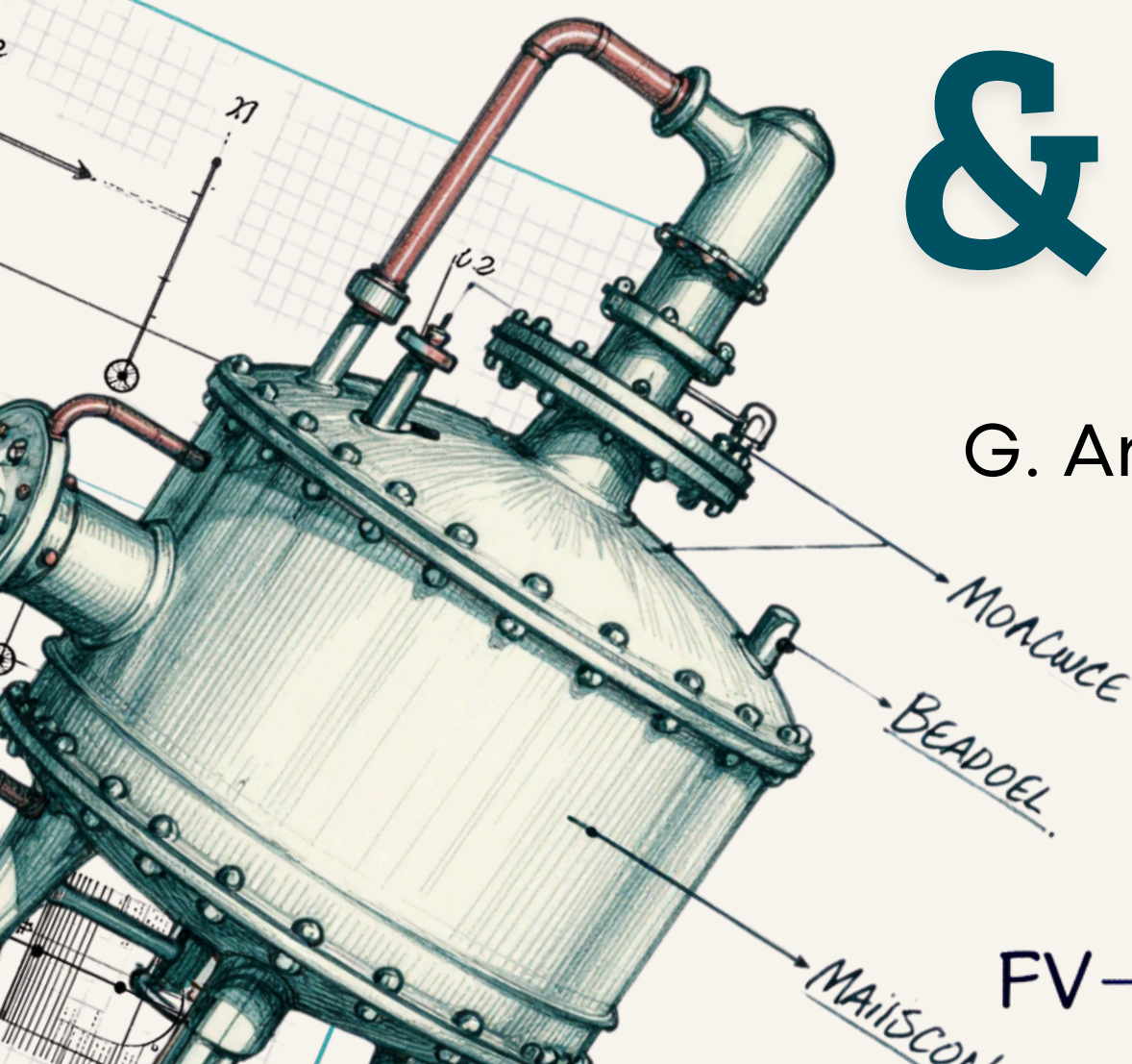


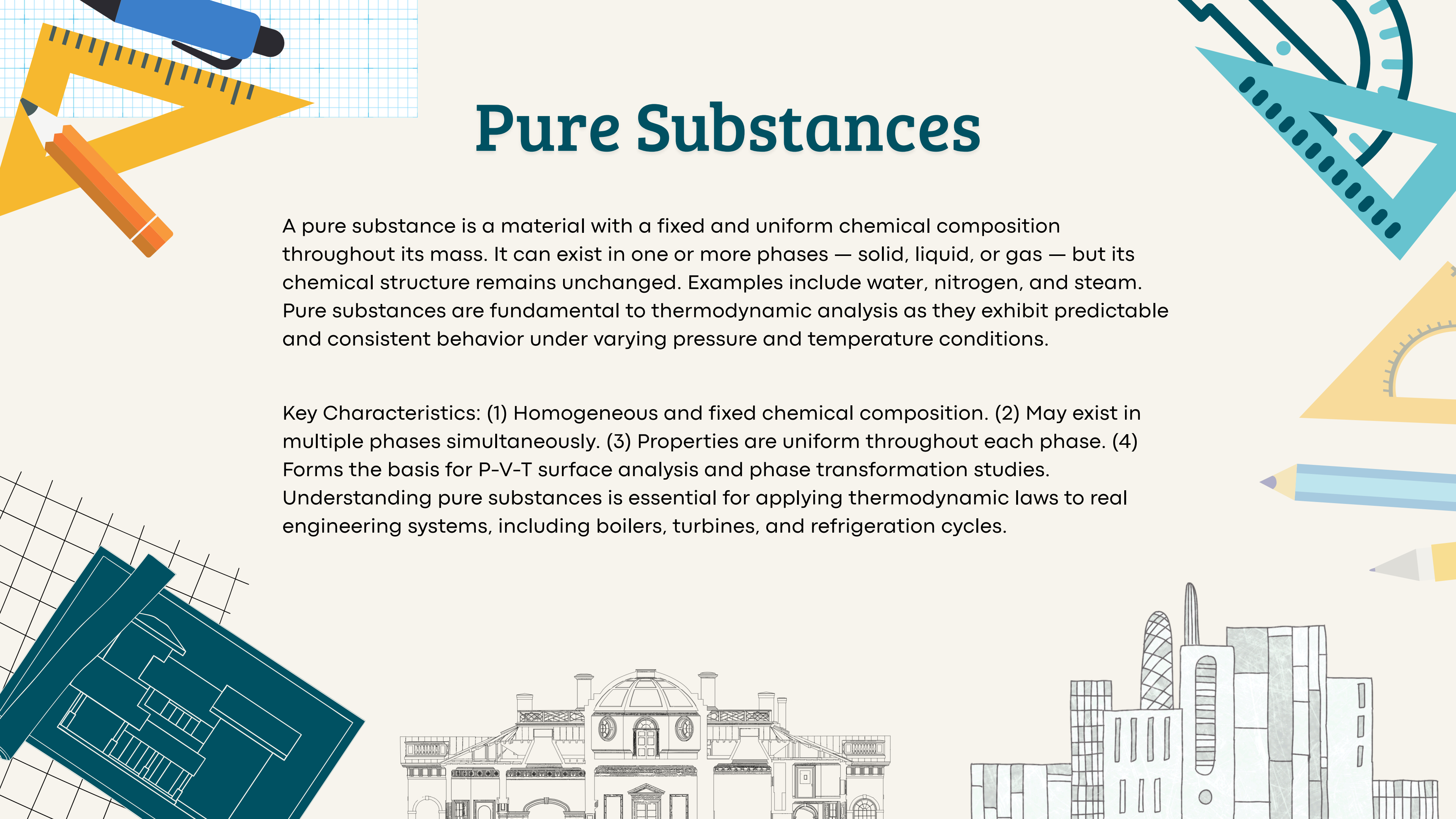


UNIT - III

Pure Substance & Perfect Gas

G. Anitha | Asst. Prof. | Mechanical Department





Pure Substances

A pure substance is a material with a fixed and uniform chemical composition throughout its mass. It can exist in one or more phases — solid, liquid, or gas — but its chemical structure remains unchanged. Examples include water, nitrogen, and steam. Pure substances are fundamental to thermodynamic analysis as they exhibit predictable and consistent behavior under varying pressure and temperature conditions.

Key Characteristics: (1) Homogeneous and fixed chemical composition. (2) May exist in multiple phases simultaneously. (3) Properties are uniform throughout each phase. (4) Forms the basis for P-V-T surface analysis and phase transformation studies. Understanding pure substances is essential for applying thermodynamic laws to real engineering systems, including boilers, turbines, and refrigeration cycles.

P-V-T Surfaces & Phase Diagram

P-V-T Surface

A P-V-T surface is a 3D representation showing the relationship between Pressure (P), Volume (V), and Temperature (T) for a pure substance.

Key regions include:

- Solid, Liquid & Vapor phases
- Two-phase regions (solid-liquid, liquid-vapor)
- Triple point line
- Critical point
- Sublimation region

The projection of the P-V-T surface onto the P-T plane gives the phase diagram.

Ennpel

T-S & h-s Diagrams

T-S Diagram (Temperature-Entropy):

- Shows thermodynamic processes as area under curve = heat transfer
- Saturation dome separates liquid and vapor regions

- Useful for cycle analysis

h-s Diagram (Mollier Chart):

- Enthalpy vs Entropy plot
- Widely used for steam turbine analysis
- Isentropic processes appear as vertical lines
- Dryness fraction lines shown within wet region

Molier h-s enthalpy ensetr

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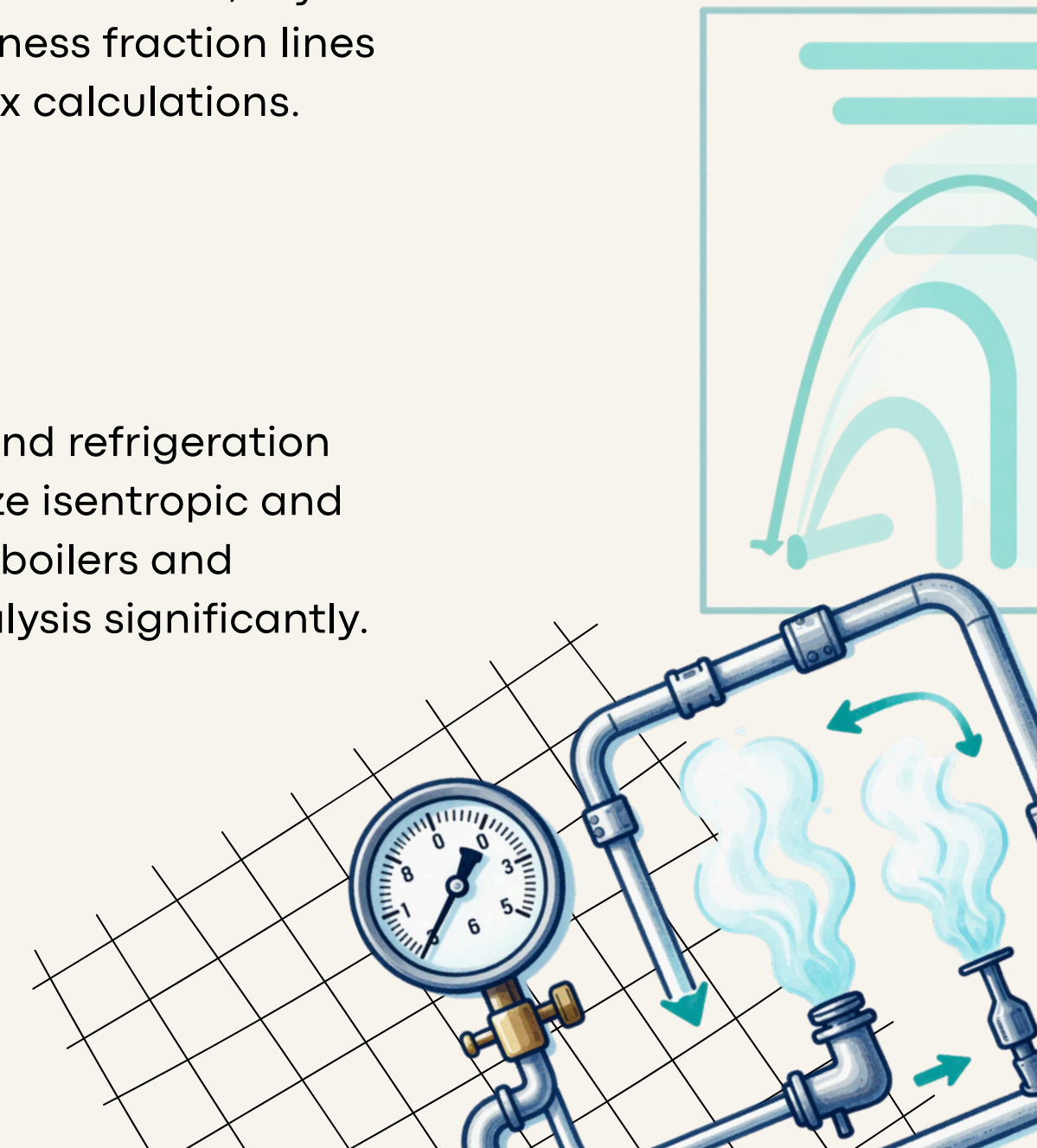
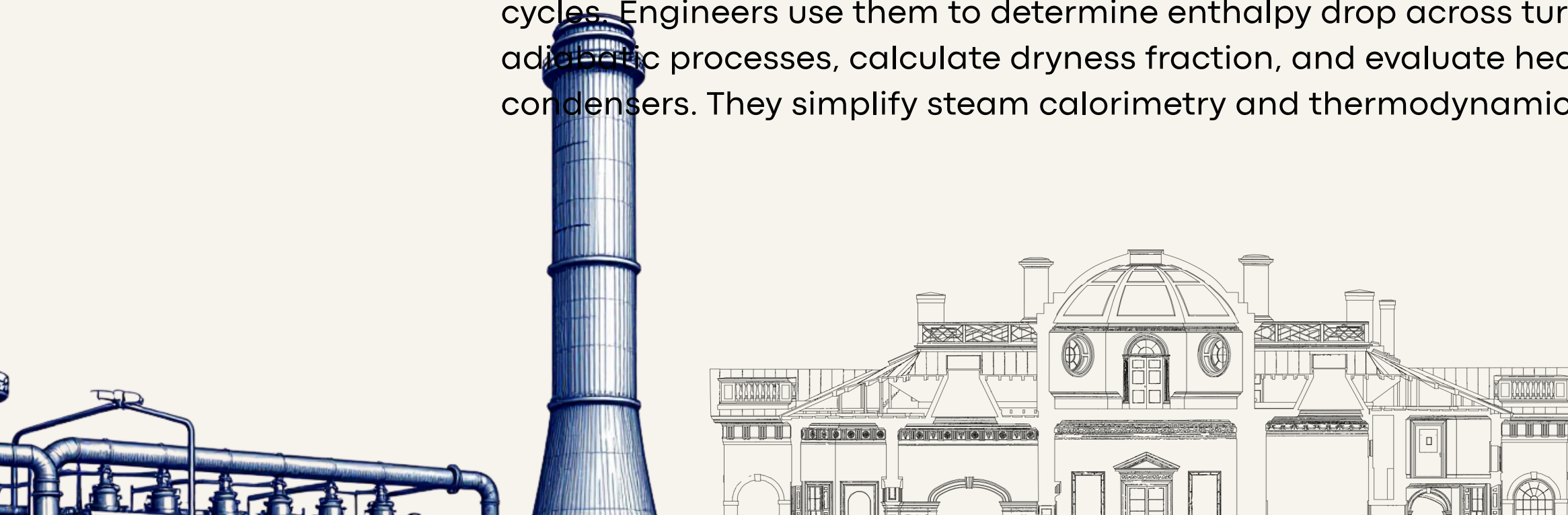
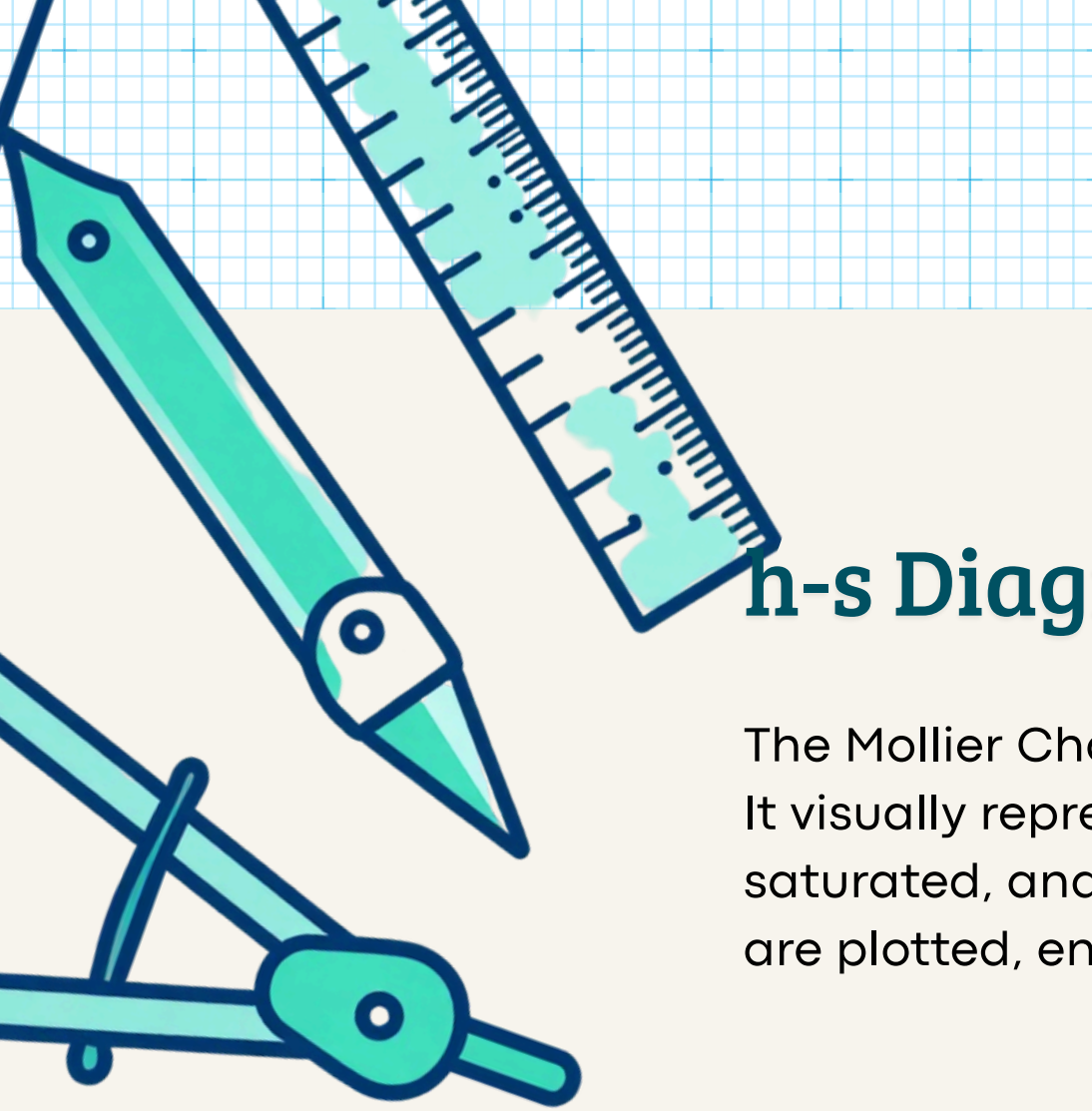
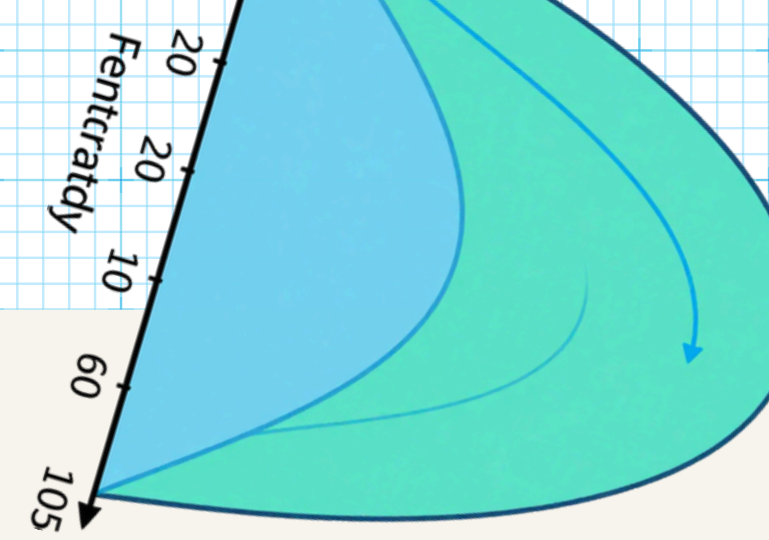
Mollier Charts

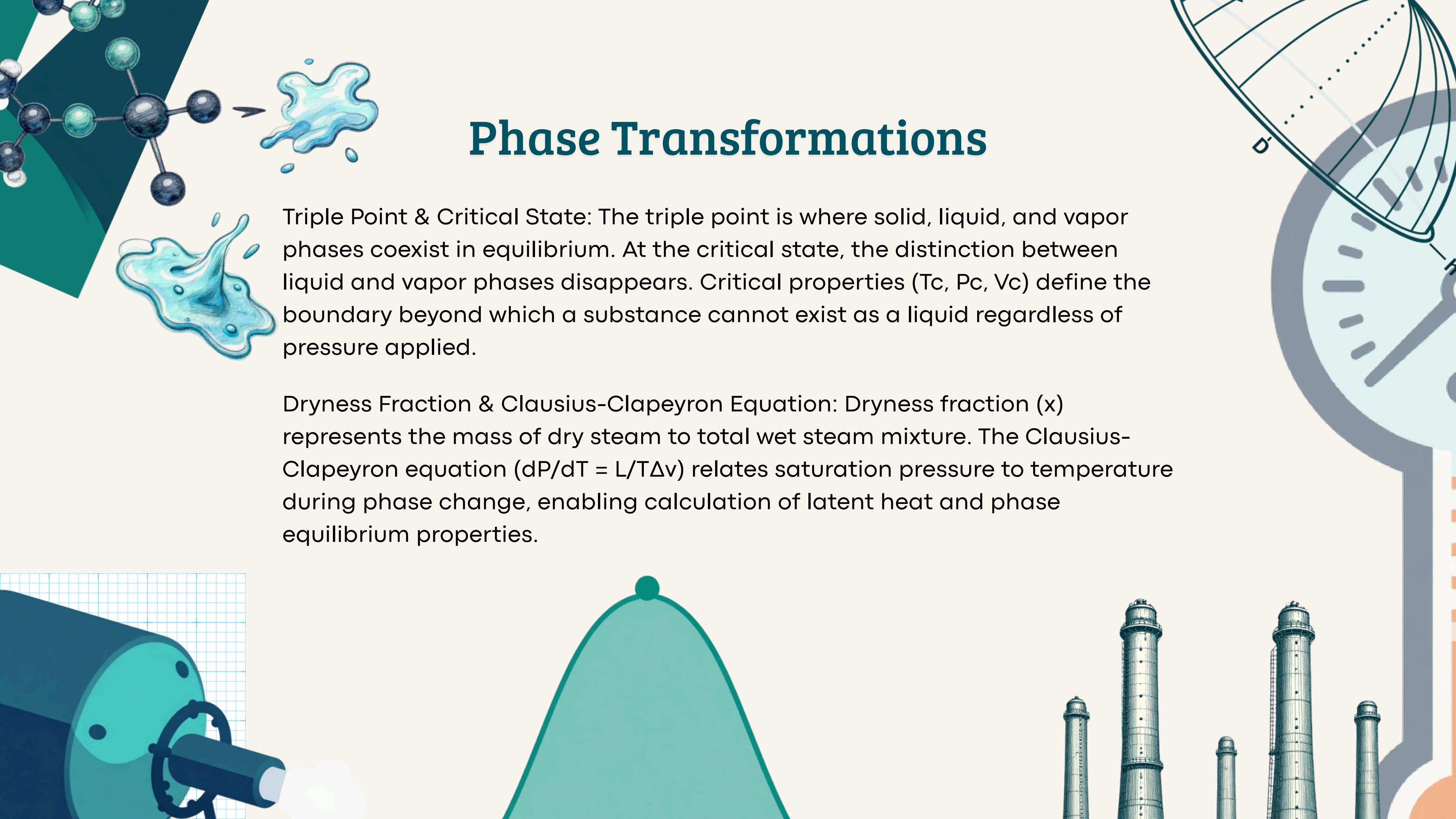
h-s Diagram Overview

The Mollier Chart (h-s diagram) plots enthalpy (h) on the Y-axis against entropy (s) on the X-axis. It visually represents thermodynamic states of steam: the saturation curve separates wet, dry saturated, and superheated regions. Constant pressure, temperature, and dryness fraction lines are plotted, enabling quick determination of steam properties without complex calculations.

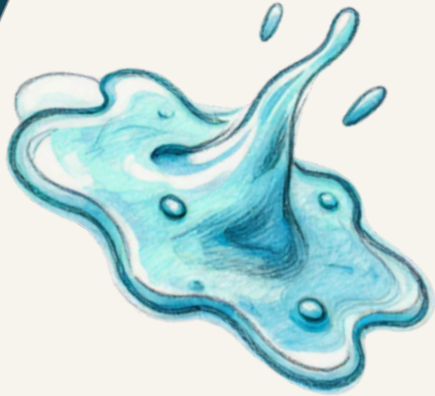
Practical Applications

Mollier Charts are widely used in steam power plant analysis, turbine design, and refrigeration cycles. Engineers use them to determine enthalpy drop across turbines, analyze isentropic and adiabatic processes, calculate dryness fraction, and evaluate heat transfer in boilers and condensers. They simplify steam calorimetry and thermodynamic process analysis significantly.





Phase Transformations

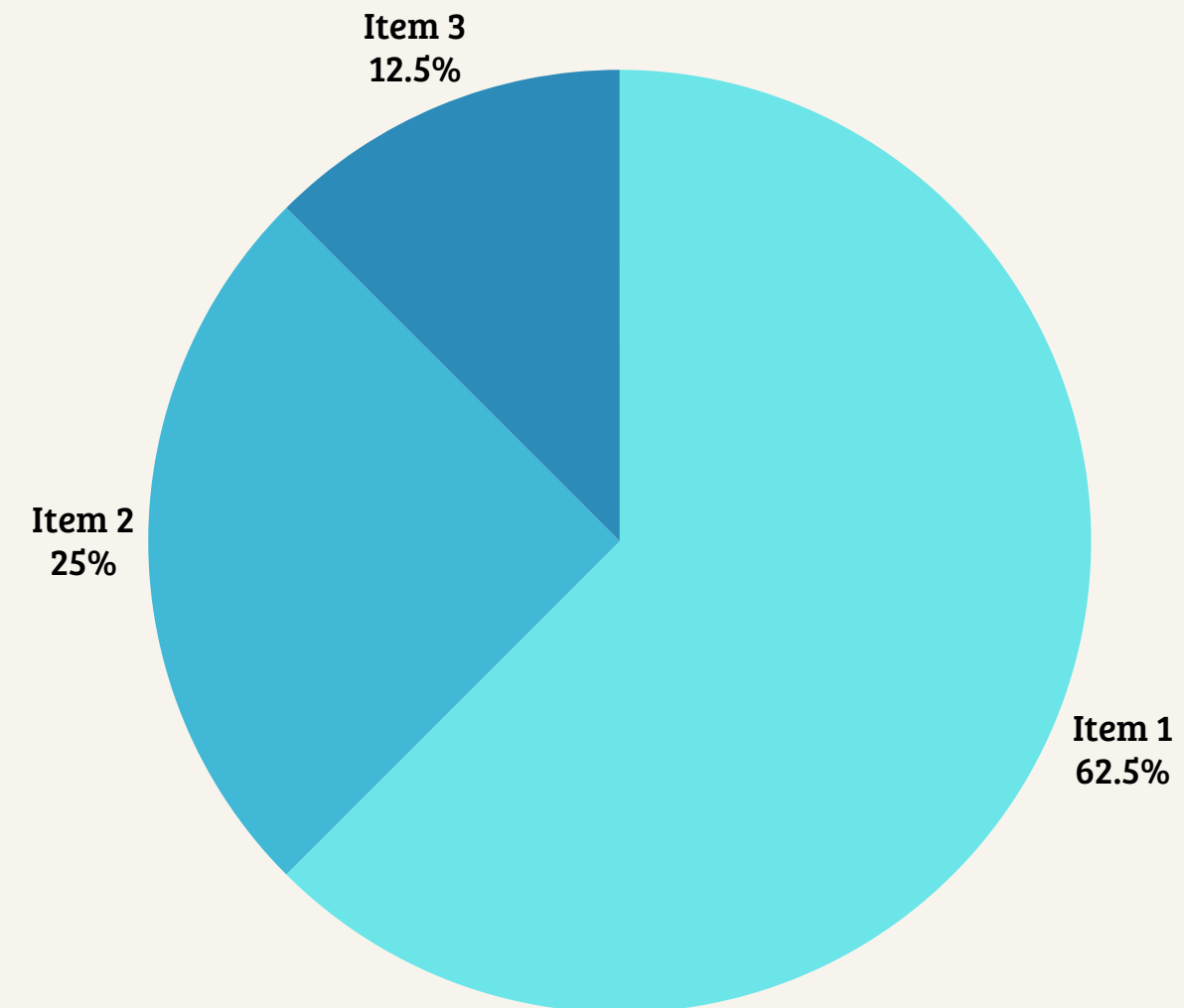


Triple Point & Critical State: The triple point is where solid, liquid, and vapor phases coexist in equilibrium. At the critical state, the distinction between liquid and vapor phases disappears. Critical properties (T_c , P_c , V_c) define the boundary beyond which a substance cannot exist as a liquid regardless of pressure applied.

Dryness Fraction & Clausius-Clapeyron Equation: Dryness fraction (x) represents the mass of dry steam to total wet steam mixture. The Clausius-Clapeyron equation ($dP/dT = L/T\Delta v$) relates saturation pressure to temperature during phase change, enabling calculation of latent heat and phase equilibrium properties.

Dryness Fraction

Dryness Fraction (x) defines steam quality in a wet steam mixture. It is the ratio of dry steam mass to total mixture mass: $x = m_{\text{steam}} / (m_{\text{steam}} + m_{\text{water}})$. Range: 0 (saturated liquid) to 1 (dry saturated steam). Measured using throttling calorimeter, separating calorimeter, or combined methods. Higher x means better steam quality and greater energy content. Used in turbine efficiency, heat exchanger design, and steam power cycle analysis.



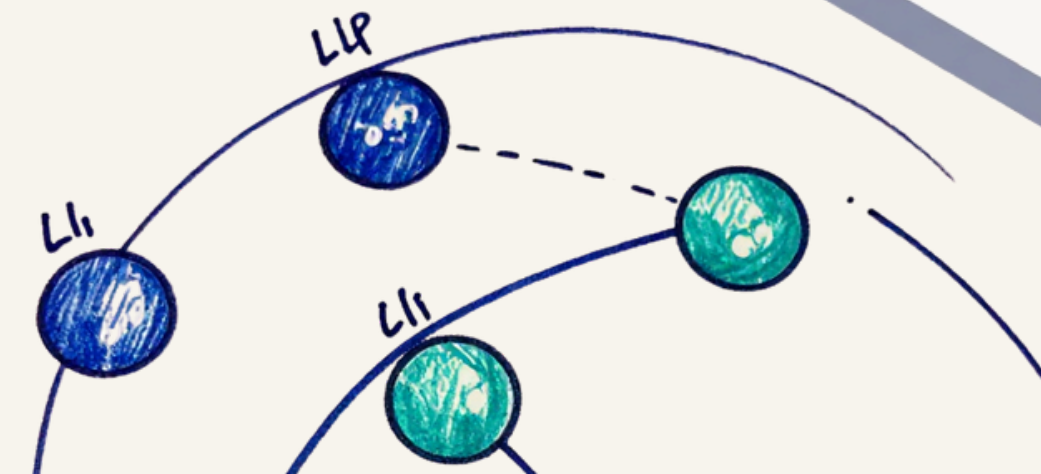
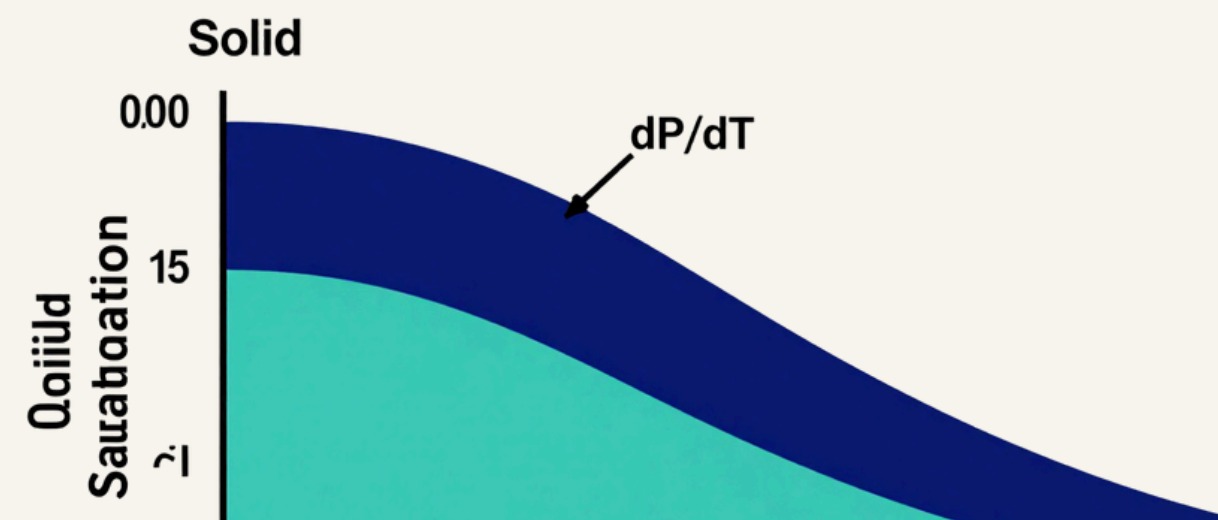
Clausius-Clapeyron Equation

The Clausius-Clapeyron equation relates the slope of the saturation curve on a P-T diagram to the latent heat of phase transformation:

$$dP/dT = L / (T \cdot \Delta v)$$

Where L is the latent heat, T is the absolute temperature, and Δv is the change in specific volume during phase change. It describes the rate of change of saturation pressure with temperature.

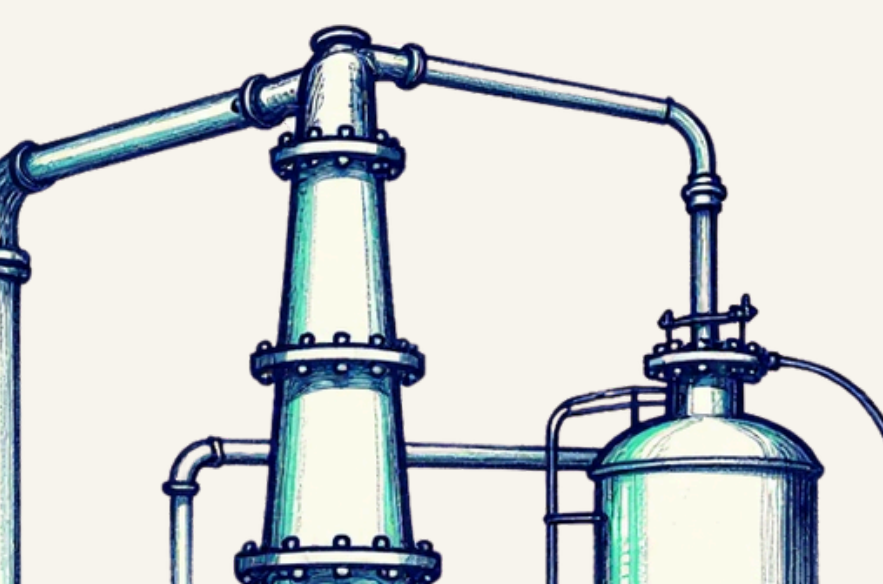
Significance & Applications: The equation predicts how saturation pressure varies with temperature during phase transitions (liquid-vapor, solid-liquid). It is used in steam tables construction, refrigeration cycle analysis, and meteorology. For ideal gas approximation: $dP/dT \approx (P \cdot L) / (R \cdot T^2)$, enabling estimation of vapor pressure at various temperatures and analysis of boiling point elevation.



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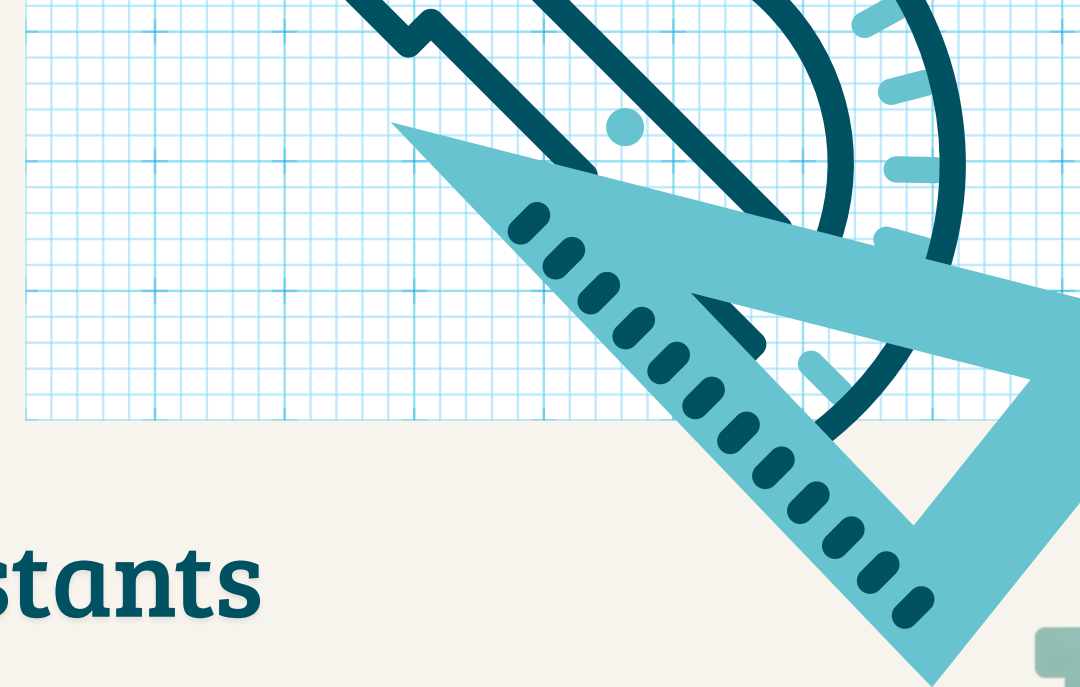
A stylized illustration of a pressure gauge with a white face and black markings, connected to a teal pipe. The gauge needle points to a value between 10 and 20. The pipe has several flange-like connections. To the right, a portion of a teal tank or container is visible.

A detailed illustration of a steam boiler or pressure vessel. The boiler is a large, rounded metal container with a thick, flanged top. A thick, dark pipe extends vertically from the center of the top flange, with a large, billowing cloud of white steam rising from it. To the right of the boiler, a circular pressure gauge is mounted on a horizontal pipe. The gauge has a white face with black markings and a black needle. The entire assembly is supported by a network of pipes and valves. The background features a light blue grid pattern, suggesting a technical or scientific context. The style is a detailed line drawing with cross-hatching for shading.



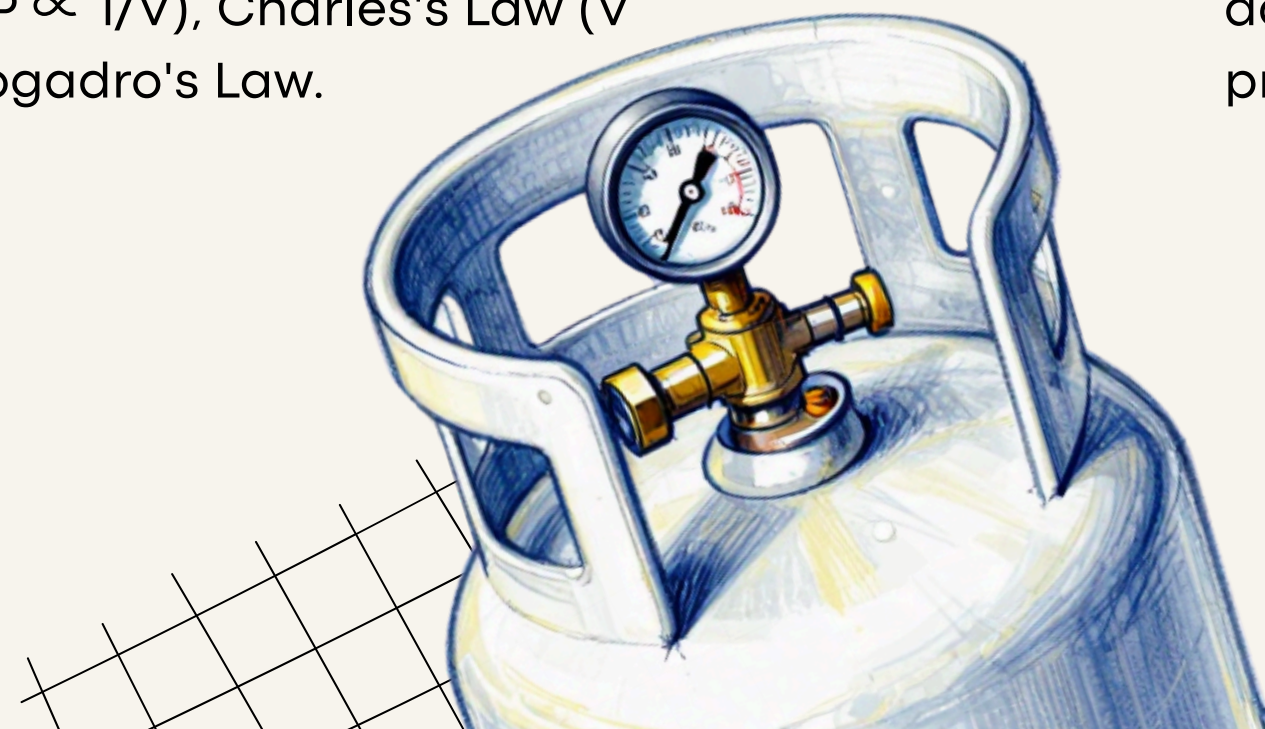


Perfect Gas Laws



Equation of State

A perfect gas obeys the ideal gas equation of state: $PV = nRT$. Here, P is pressure, V is volume, n is the number of moles, R is the universal gas constant, and T is absolute temperature. This equation describes the relationship between macroscopic properties of an ideal gas, assuming no intermolecular forces and negligible molecular volume. It is derived from Boyle's Law ($P \propto 1/V$), Charles's Law ($V \propto T$), and Avogadro's Law.



Gas Constants

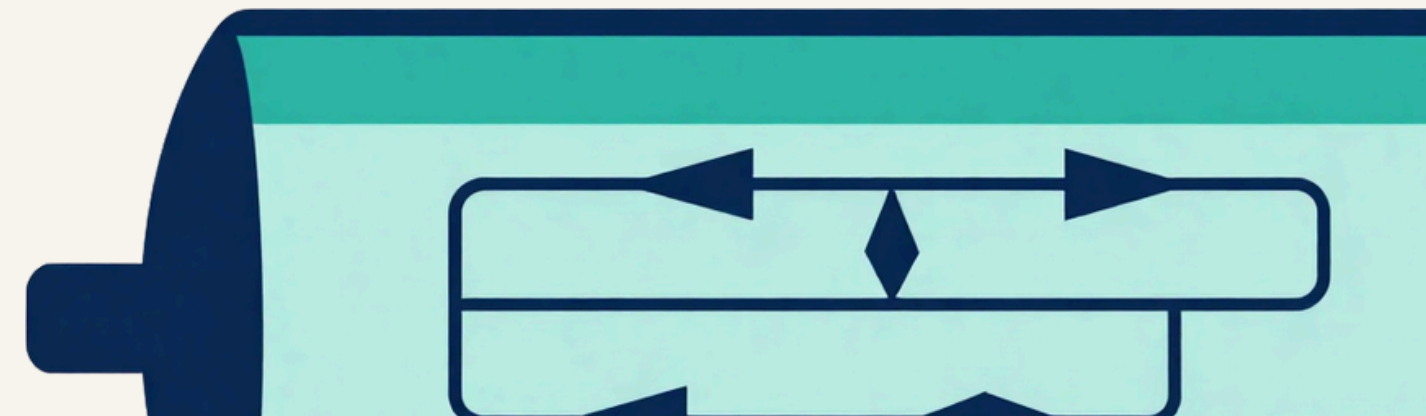
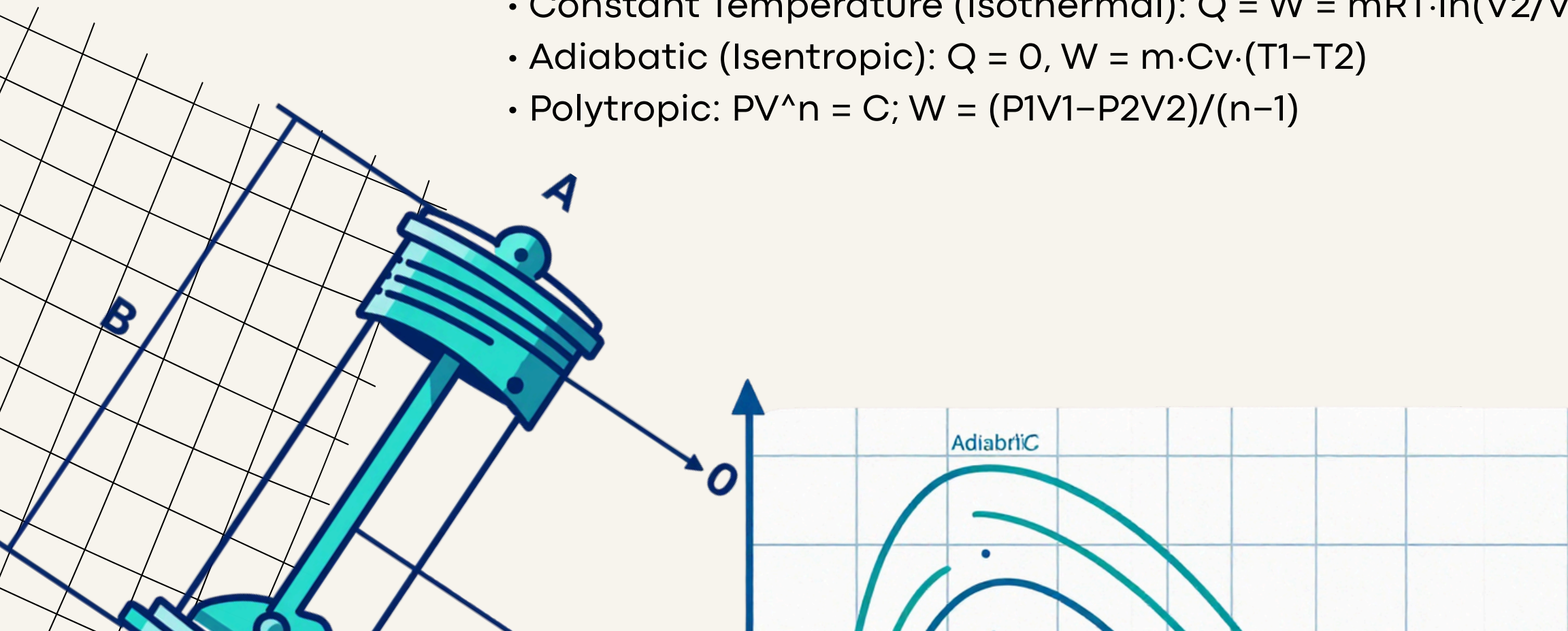
Universal Gas Constant: $R = 8.314$ J/mol·K, applicable to all ideal gases.
Specific Gas Constant: $R_s = R/M$, where M is the molar mass of the gas (unique to each gas). For air: $R_s = 287$ J/kg·K.
The equation of state for a specific gas: $PV = mR_sT$, where m is mass in kg. These constants are fundamental in thermodynamic calculations involving non-flow processes such as isothermal, adiabatic, polytropic, and isochoric processes.

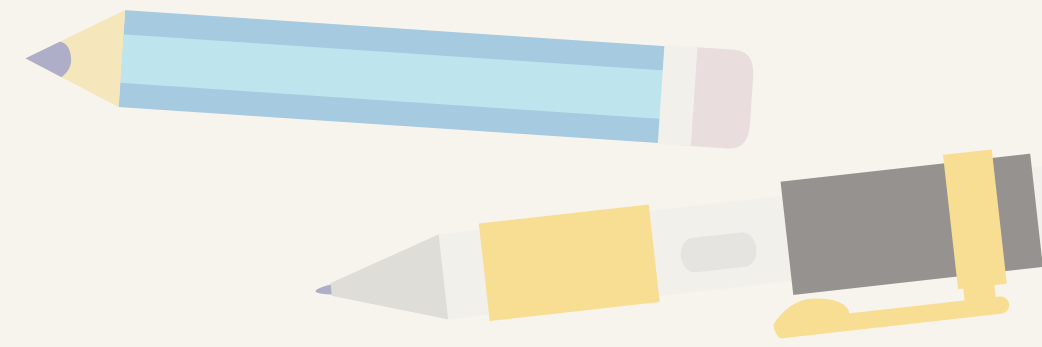


Non-flow Processes

A Non-flow Process occurs in a closed system where the working fluid does not cross the system boundary. Key properties defining the end states include pressure (P), volume (V), temperature (T), internal energy (U), enthalpy (H), and entropy (S). The initial and final states are determined using the equation of state and property tables.

- Constant Volume (Isochoric): $W = 0$, $Q = m \cdot C_v \cdot (T_2 - T_1)$
- Constant Pressure (Isobaric): $W = P \cdot (V_2 - V_1)$, $Q = m \cdot C_p \cdot (T_2 - T_1)$
- Constant Temperature (Isothermal): $Q = W = mRT \cdot \ln(V_2/V_1)$
- Adiabatic (Isentropic): $Q = 0$, $W = m \cdot C_v \cdot (T_1 - T_2)$
- Polytropic: $PV^n = C$; $W = (P_1V_1 - P_2V_2)/(n-1)$





Thank You! Questions & Discussion

