# Teaching and Learning Objectives of Lecture 20 – 25 & Lab 5

1. Explain the physical significance of each of the terms in the conservation of mass and conservation of energy equations and in the entropy accounting equation.
2. Explain what if any limitations apply to the entropy generation term in the entropy accounting equation. Pay special attention to what the value of this term says about the reversibility, irreversibility or impossibility of a particular process.
3. Know and understand the *operating* and *design* assumptions for the following steady-state devices:
   - Nozzles and diffusers
   - Turbines, pumps, compressors, fans, and blowers
   - Throttling devices
   - Heat exchangers with and without mixing.
4. Define, Illustrate, and Compare and Contrast the following terms and concepts:
   - State Principle
     - properties
       - intensive vs. extensive
     - intensive state of a system
     - simple substance
       - simple compressible substance
         - state principle for a simple compressible substance
         - Gibbs (*T ds*) equations for a simple, compressible substance
         - specific heat definition: $c_P = \left(\partial h / \partial T\right)_P$ and $c_\upsilon = \left(\partial u / \partial T\right)_\upsilon$
   - Property Surface
     - *P*-*v*-*T* surface for a simple compressible substance
     - single-phase regions: solid, liquid, vapor
       - compressed (subcooled) liquid
       - compressed (subcooled) solid
       - superheated vapor
     - two-phase regions (vapor dome)
       - quality (for liquid-vapor mixture)
       - phase change:
         - liquid-vapor: condensation vs. evaporation (boiling)
     - saturated state and saturation lines
       - saturated liquid $(\;)_f$
       - saturated vapor $(\;)_g$ ,
     - critical point: critical temperature $T_c$ and critical pressure $P_c$
     - triple line (triple point)
   - Property Diagrams (Projections of the property surface)
     - phase diagram: *P*-*T* projection
     - process diagrams: *P*-*v* and *T*-*v* projections
     - constant property lines (isolines): isobars, isotherms, isentropes, constant volume

- Property Tables for numerical values
  - saturation, superheated vapor, and compressed liquid tables
- Specific Heats (or heat capacities)
  - specific heat at constant pressure and constant volume: $c_p$ and $c_v$
- Equation of State
  - universal vs. specific gas constant $R_u$ vs. $R$
  - compressibility factor $Z \equiv Pv/(RT)$
- Substance Models
  - principle of corresponding states
    - generalized compressibility chart
      - reduced temperature ($T_r = T/T_c$)
      - reduced pressure ($P_r = P/P_c$)
    - used to relate $P$-$\upsilon$ - $T$ and test applicability of ideal gas model
  - ideal gas model
    - key assumptions and consequences
      - relating $P$, $\upsilon$, and $T$
      - ideal-gas (zero-pressure) specific heats
    - calculating $\Delta s$, $\Delta u$, and $\Delta h$ using
      - average specific heats or
      - the ideal gas property tables
  - incompressible substance model
    - key assumptions and consequences
      - relating $P$, $\upsilon$, and $T$
      - specific heat for an incompressible substance
    - calculating $\Delta s$, $\Delta u$, and $\Delta h$ using average specific heats

5. Given a description of a process and/or the state of a system, carefully sketch the process and/or locate the state on a phase or process diagram. Sketches should accurately show the relative position of process lines and states with respect to saturation lines, pertinent isobars and isotherms, the triple line, and the critical point. (In other words, show some “road signs” on your “property map.”)

6. Given any two independent, intensive properties selected from the following list ($P$, $T$, $h$, $u$, $v$, $x$, and $s$) and a set of property tables or charts, determine
   1) the physical phase of the substance: compressed liquid (or solid); saturated liquid, saturated vapor, or saturated solid; superheated vapor; or two-phase mixture,
   2) the numerical values for the remaining properties in the list, and
   3) the location of the state on a *process* or *phase* diagram.

7. Given an ideal gas, use the ideal gas tables OR the average-specific-heat concept and a table of specific heat values to determine all pertinent properties and property changes. Know the difference between these two approaches and be able to use either approach if requested.

8. Given two of the three properties *P*, $\upsilon$ and *T*, use the generalized compressibility chart to
   1) estimate the accuracy of the ideal gas model for a specific set of conditions, and
   2) estimate the value of *P*, $\upsilon$ or *T* given values for the other two.

9. Given a problem statement that requires that you find thermodynamic properties, (a) determine which of the following approaches is best for accurately evaluating the required thermodynamic properties, and then (b) use the selected approach to determine the necessary information:
   1) the *property tables and charts* for the substance (no model),
   2) the *compressed liquid approximation* using saturated liquid/solid data to estimate the properties of a compressed liquid/solid,
   3) the *incompressible substance model*,
   4) the *generalized compressibility chart* to predict the relationship between *P*, $\upsilon$, and *T* or
   5) the *ideal gas model*.

10. Given a steady-state device and sufficient information to define its operating conditions, *i.e.* inlet/outlet conditions, adiabatic efficiency, *etc.*, apply the conservation of mass, conservation of energy, and entropy accounting principles along with appropriate property information to answer questions about the system operation, such as (but not limited to)

    Determine the work/heat transfer for the device, in kJ/kg.
    Determine the rate of entropy production, in kJ/(K-kg).
    Determine the mass flow rate for the device.
    Determine the exit velocity.

    Note any of the property information/models discussed to date in this course may be required to answer these questions.