THERMODYNAMICS I: BASICS, ENERGY, & THERMAL EFFICIENCY

Introduction:

- There are seven basic properties to describe a state: enthalpy, entropy, internal energy, temperature, pressure, density, and specific volume. If two are known, the others can be calculated.
- Intensive properties are independent of amount of mass, denoted with lowercase.
- Extensive properties are dependent on the amount of mass, denoted with uppercase.
- The four tools used in introductory thermodynamics are the 1st and 2nd laws of thermodynamics, conservation of mass, and equations of state.
- Temperature scale conversions are as follows:
  \[ T(\text{°C}) = \left(\frac{5}{9}\right) \times [T(\text{°C}) - 32] \]
  \[ T(K) = T(\text{°C}) + 273.15 \]
  \[ T(\text{°R}) = T(\text{°F}) + 459.12 \]

Energy:

- There are 5 forms of energy: kinetic (KE), potential (PE), internal (U), work (W), and heat (Q)
- A change in energy of a system occurs through work done or heat transferred
- Energy sign convention:
  - \( W > 0 \) positive Work done by the system
  - \( W < 0 \) negative Work done on the system
  - \( Q > 0 \) positive Heat transferred into system
  - \( Q < 0 \) negative Heat transferred out of system

- Energy balance equation:
  \[ \Delta E = E_2 - E_1 = \Delta U + \Delta KE + \Delta PE = (Q_{in} + W_{in} - Q_{out} - W_{out}) + \Delta KE + \Delta PE \]

Rates of Change:

The energy balance equation also applied to rates of change of energy, with a superscript dot centered over a letter signifying the derivative with respect to time:

\[ \dot{E} = \frac{dE}{dt} \]

The subscript "cv" is used to notate the system is a control volume (\( \Delta V = 0 \)).

- Mass balance:
  \[ \frac{dm_{cv}}{dt} = \sum_{in} \dot{m}_{in} - \sum_{exit} \dot{m}_{exit} \]
• Energy balance:

\[
\frac{dE_{cv}}{dt} = E_{in} - E_{out} = Q - W + \dot{m}_m \left( h_{in} + \frac{v_{in}^2}{2} + gz_{in} \right) - \dot{m}_o \left( h_{out} + \frac{v_{out}^2}{2} + gz_{out} \right)
\]

Based on the assumptions of a given problem, many terms will cancel out to simplify the equation. For example, \(\frac{v_{in}^2}{2} - \frac{v_{out}^2}{2}\) and \(gz_{in} - gz_{out} = 0\) when changes kinetic and potential energy are assumed to be zero. It is good practice to start every relevant problem with the entire equation before cancelling out any terms.

**Thermal Efficiency:**

The following table notes three types of thermal processes and their respective thermal efficiencies. Carnot refers to a perfectly reversible processes, such that \(\Delta s = 0\)

<table>
<thead>
<tr>
<th>Type</th>
<th>C.O.P</th>
<th>General</th>
<th>Expansion</th>
<th>Carnot Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Cycle</td>
<td>(\eta)</td>
<td>(\frac{w_{cycle}}{Q_{in}})</td>
<td>(1 - \frac{Q_{out}}{Q_{in}})</td>
<td>(1 - \frac{T_C}{T_H})</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>(\beta)</td>
<td>(\frac{Q_{in}}{w_{cycle}})</td>
<td>(\frac{Q_{in}}{Q_{out} - Q_{in}})</td>
<td>(\frac{T_C}{T_H - T_C})</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>(\gamma)</td>
<td>(\frac{Q_{out}}{w_{cycle}})</td>
<td>(\frac{Q_{out}}{Q_{out} - Q_{in}})</td>
<td>(\frac{T_H}{T_H - T_C})</td>
</tr>
</tbody>
</table>