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THE FIRST LAW SELF STUDY MODULE

Objective

The objective of this module is to derive the first law of thermodynamics from the basic principles.

Reading assignment

Chapter 3 of Sandler's book. Any edition is ok. When reading, make sure to mark the sentences that bother you the most and also that you are most comfortable with. These will guide your learning as you advance in the chapter. Make sure that you take notes while reading. Solve the example problems.

Derive

The first law of thermodynamics is also called the conservation of energy. The details of the derivation can be found anywhere, here I will give brief descriptions:

$$\frac{dU}{dt} = \sum_{all\ of\ the\ streams} \dot{m}_i \widehat{H}_i + \dot{Q} + \dot{W}_s - P\frac{dV}{dt}$$

$\frac{dU}{dt}$: The time rate of change of the internal energy within the system boundary.

$\dot{Q}$: Heat flux across the system boundary. Heat is energy in transit due to a temperature gradient, and it is a path function.

W_s: Shaft work, work done due to an impeller in motion, work is energy in transit due to motion and is a path function

$P\frac{dV}{dt}$: Work due to a surface boundary movement.

$\sum_{all\ of\ the\ streams} \dot{m}_i \hat{H}_i$: The energy carried through the system boundaries, due to the mass crossing the boundaries. The term H has arisen due to the summation of the internal energy and the PV terms associated with the process. The PV term due to flow is due to the high pressure fluid forcing its way through the system boundaries.

Derive/Calculate/Compute

1. Simplify the first law for the following situations:
    a. The process is at steady state. You do not know whether the terms related to heat, or work are negligible. Therefore, you must maintain them in your equation until further information becomes available.
    b. The system is kept isothermal. You do not know whether the terms related to heat, or work are negligible. Therefore, you must maintain them in your equation until further information becomes available.
    c. The system and the surroundings are in equilibrium. When the system and the surroundings are in equilibrium, what do you conclude in terms of heat, mass and work flows through the system boundaries?
    d. The system is at steady state, and the process is adiabatic.
2. Simplify the energy balance for a process that is conducted in a closed system, and isothermal. Nothing is known in terms of work interactions. Therefore, it is better to maintain them in the general balance equation until you have more information.
3. Calculate the work done on an ideal gas confined in a piston and cylinder arrangement which is kept at a constant temperature of 300 K. What is the amount of heat that needs to be transferred?

4. Using MATLAB or EXCEL or equivalent, plot a number of isotherms for an ideal gas at 300, 320 and 350 K on a PV diagram. Select your own pressure- volume ranges.
5. Using the plots you have generated in question 4, show the amount of isothermal work that can be obtained within two different volumes you have selected.
    a. Graphically integrate the area under the curve you selected for each temperature to determine the amount of work.
    b. Based on the results you obtained in part a, discuss how the amount of work and the temperature are related for the same initial and final volumes.

Evaluate yourself

Self reflect about your progress and make a short list of things that you are confident, things that needs your attention, things that you need to discuss with your friends or the instructor for clarification.