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SELF STUDY MODULE System and its Surroundings Review

Objective

This module can be used as a review guideline after completing the first law analysis.

Reading assignment

Chapter 1 and 2 of recommended texts. Explore other reading materials as well.

Vocabulary

System is defined as the part of the universe that we are interested in. We define the rest of the universe as the **surroundings**. System and the surroundings are connected through a real of a hypothetical boundary. The boundary connecting (or separating) the system and the surroundings is called the **control volume** or sometimes **control surface**.

The system can be open, closed or isolated. The open and closed systems definitions is towards mass exchange. If a system allows mass exchange it is called an **open** system. If a system does not allow mass exchange, the system is **closed**.

Derive

First we will derive a general balance equation for the conserved quantities. Within the context of the course, we define the conserved quantities as mass and energy.

The open system general balance equation

$$\begin{bmatrix} time\ rate\ of\ change \\ of\ the\ conserved \\ quantity\ within\ the \\ system\ boundaries \end{bmatrix} = \begin{bmatrix} rate\ at\ which \\ conserved\ quantity \\ enters\ through\ the \\ system\ boundaries \end{bmatrix} - \begin{bmatrix} rate\ at\ which \\ conserved\ quantity \\ leaves\ through\ the \\ system\ boundaries \end{bmatrix}$$

The first term defines the unsteady state changes that can take place within the system boundaries. For example, we can be filling a bucket with water, and the amount of water in the bucket is changing with respect to time. Or conversely, we could be emptying a tank and the mass in the tank could change with respect to time.

The second term defines the rate at which the conserved quantity enters through our system such as the flow rate of water with which we are filling the bucket. The final term is a term for the rate at which the conserved quantity leaves our system boundaries.

As a result, the general mass conservation law can be written as

$$\frac{dm}{dt} = \sum_{in} m_i - \sum_{out} m_j$$

Similarly in its simplified form, the general conservation of energy can be written as

$$\frac{dU}{dt} = \sum_{in} m_i h_i - \sum_{out} m_j h_j + \dot{Q} + \dot{W} - P\frac{dv}{dt}$$

Calculate

1. Derive the appropriate balance equations for water evaporating from a teapot. Leave your equations general enough to account for the change in the rate of evaporation at different temperatures.
2. Derive a balance equation for a mobile phone, while its battery is charging.
3. Derive an energy balance of a mobile phone in use. If you define the battery and the rest of the phone as two separate systems, does your analysis change?
4. Do you keep a journal about yourself? Some people are very observant about what they eat, how much they exercise, they keep track of their weight. Usually, we lose weight during our sleep. What is the reason of the weight change during your sleep?
5. Write down the unsteady state material balance around the ventricle and atrium of the heart both in the right and in the left. Stepwise include the blood circulation system in your analysis as well as the lungs.

6. How much time is needed to evaporate water in a tea glass (approximately 100 ml capacity) at room temperature, if the rate of evaporation is considered as constant at 1 ml/hour? List all the assumptions you make.
7. How much energy is required to evaporate all of the water in the tea glass at room temperature?

Compute

1. Select an intensive variable (for example, specific volume) from the steam table and generate a plot of that variable as a function of temperature keeping pressure constant for at least two different values, i.e. two isobars. Make sure to choose the parameters in a relatively broad range of values.
2. Generate a similar plot of that intensive variable as a function of pressure at constant temperatures. Make sure to include a relatively broad range of values.
3. Discuss the validity of linear interpolation, after you examined the results of the plots above.

References

S. I. Sandler Chemical, Biochemical and Engineering thermodynamics, 5th edition, Wiley, 2017, NY.

M. Koretsky, Engineering and Chemical Thermodynamics, 2nd edition, Wiley, 2013, NY.

M.J. Moran, H. N. Shapiro, D.D. Boettner, M.B. Bailey, Principles of Engineering Thermodynamics, 7th edition, John Wiley and Sons, 2012, NY.