ABE 201
Biological Thermodynamics 1

Module 9:

1st Law of Thermodynamics

Energy Balances and

Enthalpy

Outline

- Continuity equation and energy balances
- Types of energy that can accumulate in a system
- Closed versus Open systems
- First law of thermodynamics energy balance equations

Properties of State

- We've examined T, P, V, n, and phase as state properties so far.
- Energy is another important state property that affects all others.
- Energy comes in different "flavors"
- Enthalpy is an important flavor of energy

Thermodynamics

- You can't win
- You can't break even
- You can't even get out of the game

Isaac Asimov

Law of Conservation of Energy

(First Law of Thermodynamics)

- Like mass, energy cannot be created or destroyed, it can only change form.
- Generation = consumption = 0
- General Balance becomes:

Accum. = input – output

Accumulation is defined as the difference between final and initial values therefore replace the left hand side of the above eqn.

Final System Energy	-	Initial System Energy	= Net energy transferred (input – output) for the system

What are the components of Energy?

- ***Potential Energy:*** Energy due to position of the system in a potential field.

- ***Kinetic Energy:*** Energy due to the translational motion of the system.

- ***Internal Energy:*** All energy possessed by a system other than kinetic and potential energy. (Usually rotational, vibrational or electromagnetic, often related to a temperature or phase change or chemical reaction – condition of the molecules must change.)

Examples:

- Pool balls moving on a table?
- Aggregation of proteins to clot blood?
- My location on top of a roof?
- After I jump off of the roof?
- Vaporization of hot water?
- A system with no acceleration has no…
- A relative location that does not have the ability to rise or fall….

Net Positive or Negative?

- Net potential energy is positive (gained) when…

  $mg(z_2 - z_1)$

- Net kinetic energy is positive (gained) when…

  $\frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2$

- Internal energy is positive for $U_f > U_i$

Energy Transfer Across Boundaries

- ***Heat (Q):*** Energy that flows as a result of temperature difference.

- ***Work (W):*** Energy that flows in response to any driving force other than a temperature difference.

- ***Adiabatic:*** perfectly insulated, allowing no heat exchange, ($Q = 0$)

Closed System Energy Balance

$$\Delta U + \Delta E_k + \Delta E_p = Q - W$$

- What do these terms mean?

$$Accumulation = In - Out$$

$$Final - Initial = In - Out$$

$$\Delta(Internal) + \Delta(Kinetic) + \Delta(Potential) =$$

$$(In - Out)_{heat} - (Out - In)_{work}$$

Example: Write the simplified closed- system energy balances

- A tray of water at 20°C is put in the freezer.

$$U+\cancel{E_k}+\cancel{E_p}=Q-\cancel{W}$$

- A balloon near a heater expands.

$$U+\cancel{E_k}+\cancel{E_p}=Q-W$$

- A weight pushes a piston down on an insulated, sealed vessel

$$U+\cancel{E_k}+\cancel{E_p}=\cancel{Q}-W$$

Open System Energy Balance

$$\Delta \dot{H} + \Delta \dot{E}_k + \Delta \dot{E}_p = \dot{Q} - \dot{W}_s$$

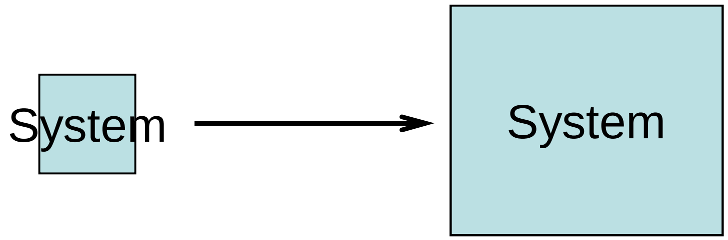
- What do the dots mean?
- Why have I used shaft work in this equation?
- What happened to final minus initial internal energy?

Shaft and Flow Work

- Shaft Work: Rate of work done by the process fluid on a moving part within the system

- Flow Work: Rate of work done by the fluid at the system outlet minus the rate of work done on the fluid at the system inlet.

Flow Work Example



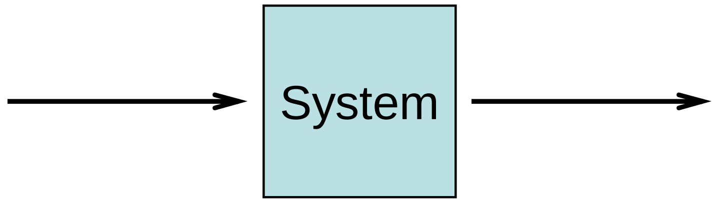
Work = force x distance

$$= N * m = \left(kg \frac{m}{s^2} \right) * m = kg * \frac{m^2}{s^2} = J$$

= pressure x volume =

$$= Pa * m^3 = \left(\frac{N}{m^2} \right) * \left(m^3 \right) = \left(\frac{kg * \frac{m}{s^2}}{m^2} \right) * \left(m^3 \right) = \left(kg * \frac{m^2}{s^2} \right) = J$$

Flow Work Example



- Work in:

  The fluid entering the system has work done on it by the fluid pushing it into the system.

- Work out:

  The fluid leaving the system does work on the surroundings as it exits the system.

$$W_{fl} = P_{out}\,V_{out} - P_{in}\,V_{in} = J/s = W$$

Enthalpy/Specific Enthalpy

- Enthalpy (H) = U + PV
- Enthalpy is a convenience term, defined because both U and PV (flow work) are necessary parts of the open system balance.
- Specific Enthalpy = Enthalpy / mass
- Why use specific enthalpy?

Example: Write the open-system energy balances

- Steam enters a rotary turbine and turns a shaft connected to a generator. Inlet and outlet are at the same height. Some energy is transferred to the surroundings as heat.

$$\hat{H} + \cancel{\hat{E}_k} + \cancel{\hat{E}_p} = \dot{Q} - \dot{W}_s$$

Example: Write the open-system energy balances

- A liquid stream flows through a heat exchanger where it is heated from 25 to 80 degrees C. The inlet and outlet pipes have the same diameter, and there is no change in elevation between these points.

$$\hat{H} + \cancel{\hat{E}_k} + \cancel{\hat{E}_p} = \dot{Q} - \cancel{\dot{W}_s}$$

Summary

- Energy balances follow continuity equation
- Accumulation is often <u>non zero</u>
- Accumulation is split into “types” of energy
  - Kinetic energy
  - Potential energy
  - Everything else
- Enthalpy is a term of convenience that combines internal energy and flow work into a single number