Chapter 7 — Conservation of Energy

1. Define, illustrate, and compare and contrast the following terms and concepts:

Work-Energy Principle
- relation to conservation of linear momentum

Energy
- internal energy
  - specific internal energy: u
- mechanical energy
- gravitational potential energy
  - specific gravitational potential energy: gz
- kinetic energy
  - specific kinetic energy: $V^2/2$
- spring energy

Work
- mechanism for transferring energy
- mechanical work vs. thermodynamic work
- work (W) vs. power ($\dot{W}$)
- path function
- reversible (quasiequilibrium) work vs. irreversible work
- types
  - compression/expansion (pdV) work
  - shaft work
  - elastic (spring) work
  - electric work/power
    - dc power
    - ac power:
      - effective vs maximum values
      - power factor

Heat transfer
- mechanism for transferring energy
- heat transfer (Q) vs. heat transfer rate ($\dot{Q}$)
- adiabatic surface or boundary
- path function
- types of heat transfer
  - conduction
  - convection
    - Newton's law of cooling
    - convection heat transfer coefficient
  - thermal radiation

Application of Accounting Principle to Energy

rate of accumulation of energy within the system

amount of energy $E_{sys} = \int_V e\,\rho dV$

where the specific energy is defined as $e = u + (V^2)/2 + gz$

transport rate of energy by heat transfer: $\dot{Q}$ ---- Heat transfer rate

transport rate of energy by work at non-flow boundaries: $\dot{W}$ -------- Power

transport rate of energy by work at flow boundaries:

$$\sum (pv)\dot{m}_{in} - \sum (pv)\dot{m}_{out}$$ ------------ Flow Power

transport rate of energy mass flow: $\sum \dot{m}(u + \frac{V^2}{2} + gz)_{in} - \sum \dot{m}(u + \frac{V^2}{2} + gz)_{out}$

Rate form of Conservation of Energy

$$\frac{dE_{sys}}{dt} = \dot{Q}_{Net,in} + \dot{W}_{Net,in} + \sum (h + \frac{V^2}{2} + gz)\dot{m}_{in} - \sum (h + \frac{V^2}{2} + gz)\dot{m}_{out}$$

where $h = u + pv$ is a new property called enthalpy

Substance models
- Ideal gas with room-temperature specific heats
- Incompressible substance with room-temperature specific heats

Thermodynamic cycles
- Definition (three parts)
- Classifications
  - Working fluid: single vs two-phase
  - Structure: Closed, periodic vs Closed-loop, steady-state
  - Purpose: Power vs Refrigeration vs Heat Pump cycles
- Measures of Performance
  - General definition
  - Power cycles → Thermal efficiency – η
  - Refrigeration cycle → Coefficient of Performance – COP_{ref}
  - Heat pump cycles → Coefficient of Performance – COP_{hp}

2. Given a mechanical system consisting of particles, apply the Work-Energy Principle where appropriate to solve problems where changes in mechanical energy (kinetic, potential, and spring) can be balanced with mechanical work done on the system.

3. Given a closed or open system and sufficient information about the properties of the system, apply conservation of energy to determine changes in energy (rates of change) within the system and heat transfers (heat transfer rates) and work transfers of energy (power) with the surroundings.

4. Given sufficient information, determine the change in specific internal energy Δu and the change in Δh for a substance that can be modeled using one of the following substance models:

    Ideal gas with room-temperature specific heats

    Incompressible substance with room-temperature specific heats

    and use this information in conjunction to meet Objective 3 above.

5. Given the indicated information, calculate the magnitude and the direction of the associated work transfer of energy or power for the system:
    - Given a relation between system pressure and system volume, calculate the compression/expansion work for the system.
    - Given a torque and a rotational speed for a shaft, calculate the shaft power transmitted by the shaft.
    - Given an electric current and the corresponding voltage difference across the terminals, calculate the electric power supplied to or by the system. (You should be able to perform this calculation for both DC and AC systems.)

6. Given a numerical value for a typical energy or power quantity, make the appropriate unit conversions to change the units to the requested values, e.g. convert ft^2/s^2 to Btu/lbm.

7. Given a device that operates in a closed-periodic cycle or a closed-loop, steady-state cycle,
    - determine whether the device operates as a power cycle (heat engine) or a refrigerator or heat pump, and
    - calculate the appropriate measure of performance for the specific device, i.e. a thermal efficiency for a power cycle and a coefficient of performance (COP) for a refrigerator or heat pump.

8. List the appropriate assumptions to recover the mechanical energy balance from the general conservation of energy equation.