Unit Seven Quiz Solutions and Unit Eight Goals

Mechanical Engineering 370
Thermodynamics

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March 25, 2003

Outline

- Solution to quiz seven
- Review previous topics
  - Properties
  - First law
  - Introduction to second law and cycles
- Goals for unit eight
- Use of entropy to find maximum work in an adiabatic process
- Other calculations with entropy

Review of Properties

- Get property data, depending on state
- Look at compressed liquid, mixed region and gas (superheat) region
- Simple if T and P are given
- If T or P and one other property (v, h, s, u) are given find region
  - compare given (v, h, s, u) to properties of saturated liquid and vapor

Always Use the First Law

- Closed system
- Steady open system
- Unsteady open system
- $Q = \Delta E + W +$ Outlet flow – Inlet flow
- Flow terms are $m(h + V^2/2 + gz)$
- Also as rate equation (applied to steady systems in this course)

The Second Law

- There exists an extensive thermodynamic property called the entropy, S, defined as follows:

$$dS = (dU + PdV)/T$$

- For any process $dS \quad dQ/T$
- For an isolated system $dS \quad 0$
- T must be absolute temperature

Approach to Second Law

- Started with mathematical statement on previous chart
- Proved that heat flows from higher to lower temperature
- Proved that reversible (Carnot) cycle is most efficient
  - Highest engine efficiency
  - Highest coefficient of performance for refrigeration cycles

Entropy is a Property

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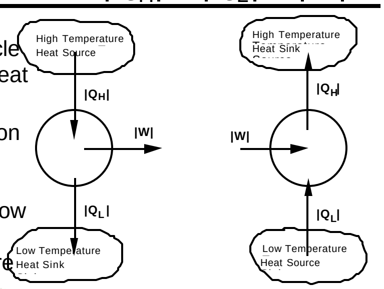
Entropy is a Property

- If we know the state of the system, we can find the entropy
- We can use the entropy as one of the properties to define the state
- Use the following if we are given a value of s and a value of T or P
  - if $s < s_f$(T or P) => compressed liquid
  - if $s > s_g$(T or P) => gas (superheat) region
  - otherwise in mixed region

Cycles with $|Q_H| = |Q_L| + |W|$

- Engine cycle converts heat to work
- Refrigeration cycle transfers heat from low to high temperature



Engine Cycle   Refrigeration Cycle

Cycle Parameters

- Engine cycle efficiency $h = \frac{|W|}{|Q_H|}$
- Refrigeration cycle COP (coefficient of performance) $b = \frac{|Q_L|}{|W|}$
- General definitions, valid for any cycle
- Engine efficiency always less than one
- COP can be greater than one

Reversible Process

- In a reversible process it is possible to return a system to its initial state with no changes in the surroundings
- This is an idealization; we cannot do better than a reversible process
- This is the = part of the sign in dS dQ/T and $dS_{isolated\ system}$ 0
- For a reversible process dS = dQ/T and $dS_{isolated\ system} = 0$

Unit Eight Goals

- As a result of studying this unit you should be able to
  - feel more comfortable with the notion of entropy as property
  - find entropies in property tables
  - use entropy and one other property to define a state that you find in a table

More Unit Eight Goals

- understand the meaning of equations for a reversible process
- recognize that the maximum work is done in a reversible process
- compute $\Delta S = \int dQ/T$ for a reversible process since $dS = dQ/T$ for reversible processes
- compute $\Delta s_{surr} = Q_{surr}/T_{surr} = -Q_{syst}/T_{surr}$
- prove that a process in an isolated system satisfies the second law because $\Delta S \geq 0$

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Still More Unit Eight Goals

- recognize that finding the maximum work for an adiabatic process is the same as finding the work in a constant entropy (isentropic) process
- be able to solve the following class of problems
  - **Given**: Initial Conditions, and one final property
  - **Find**: Maximum work for adiabatic process
  - **Solution:** Compute isentropic process

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Maximum Work

- $dS \geq dQ/T$; if reversible $dS = dQ/T$
- Compare two processes with between same states ($dU = dU_{rev}$)
- $dS = dQ_{rev}/T = [dU_{rev} + dW_{rev}]/T \geq dQ/T$
- $[dU_{rev} + dW_{rev}]/T \geq [dU + dW]/T$
- $dW_{rev} \geq dW$
- Maximum work in a reversible process

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Maximum Adiabatic Work

- From given inlet conditions, find the initial state properties including $s_{initial}$
- The maximum work in an adiabatic process occurs when $s_{final} = s_{initial}$
- From $s_{final} = s_{initial}$ and one other property of final state get all final state properties
- Find work from first law
- Last week's exercise is an example

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Checking the Second Law

- Ten kilograms of a fluid having a heat capacity, c_p = 3 kJ/kg•K is cooled from 500 to 300 K at constnat pressure with heat rejected to the surroundings at 310 K
- Is this process possible?
- Answer is found by seeing if ΔS of isolated system consisting of fluid plus surroundings is greater than zero

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Computing $\Delta S_{isolated\ system}$

- $\Delta S_{fluid} = m \int c_p dT/T = mc_p \ln(T_2/T_1)$
- $\Delta S_{fluid} = (10\text{ kg})(3\text{ kJ/ kg}\bullet\text{K})\ln(300/500)$
- $\Delta S_{surr} = Q_{surr}/T_{surr} = -Q_{fluid}/T_{surr}$
- $Q_{fluid} = m \int c_p dT = mc_p(T_2 - T_1)$
- $Q_{fluid} = (10\text{ kg})(3\text{ kJ/kg}\bullet\text{K})(300 – 500)\text{K}$
- $\Delta S_{surr} = -(-6000\text{ kJ})/(310\text{ K}) = 19.35\text{ kJ/K}$
- $\Delta S_{isol\ syst} = \Delta S_{fluid} + \Delta S_{surr} = (-15.32 +19.35)\text{ kJ/K} = 4.03\text{ kJ/K}$

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