ME 433 Week #1 STUDY GUIDE

Polytropic Processes - notes

- **The ideal gas law applies to a gas consisting of point particles that experience no intermolecular forces other than at the instant of collision**
- The ideal gas law can be expressed on a molar basis: pV = nRT
- Here n is the number of moles and R is the universal gas constant (8.314 kJ/kgmol-K)
- The ideal gas law can also be expressed on a mass basis: pV = m **R** T
- Here **R** = R/MW and MW is the molecular weight; **R** is different for different gases
- The ideal gas law can also be expressed on a specific volume basis: pv=**R** T
- Here v is the specific volume and it has units of volume/kg

- **All variables in ideal gas and polytropic equations are absolute quantities**
- Remember to use the correct pressure (typically kPa) and temperature units (typically K)!
- Degrees K = Degrees C +273; Degrees R = Degrees F + 460

- A variety of different processes are described by different values of n
  n=0 => isobaric
  n=1 => isothermal
  n=cp/cv => isentropic
  n=infinity => isochoric

- **Work is the area underneath a P-V process path on a pressure-volume diagram**
  when V increases, work is positive (provides work output)
  when V decreases, work is negative (requires work input)

- The equations for entropy, s(T,V) and s(P,V), use both the ideal gas law and caloric equation

Polytropic Processes – study questions

1) How do you find the molecular weight of a substance? Where can you get this information?
2) If you are working with the ideal gas law in moles, is it the same for all gases? Why?
3) If you are working with the ideal gas law in mass is it the same for all gases? Why?
4) What is the meaning absolute pressure? How do you find this?
5) What is the meaning of absolute temperature? How do you find this?
6) What is the difference between volume and specific volume?
7) What do process paths look like on a PV diagram for the following processes (Isobaric, Isothermal, Isentropic, and Isochoric)? How do you know your reasoning is correct?
8) What is the meaning of positive work (i.e. is this work leaving or entering the system)?
9) What is the meaning of negative work (i.e. is this work leaving or entering the system)?
10) How does the equation for ideal gas entropy change if cv and cp are functions of temperature?

Caloric Equation of State – notes

- **Entropy, enthalpy, and internal energy can all be expressed on an extensive or intensive basis**
- Capital letters (S, H, and U) designate extensive properties
- Lowercase letters (s, h, and u) designate intensive properties
- Extensive entropy in the SI system has units J/K; Likewise, intensive entropy has units J/kg-K
- Extensive energies in the SI system have units J; Likewise, intensive energies have units J/kg

- Heat capacity can also be extensive (i.e. Cp and Cv) or intensive (i.e. cp and cv)
- Intensive heat capacities in the SI system have units of kJ/kg-K
- For an ideal gas $du = cv\ dT$ and $dh = cp\ dT$
- For an ideal gas $R = cp - cv$

Caloric Equation of State – study questions

1) Is temperature an extensive or intensive property? Why?
2) Why is it convenient to express thermodynamic calculations in terms of intensive quantities?
3) Why might you express the results of thermodynamic calculations in extensive quantities?
4) If cp(T) and cv(T), does the gas constant R change?
5) How do you find the change in enthalpy for an ideal gas undergoing an isobaric process?
6) How do you find the change in internal energy for an ideal gas undergoing an isochoric process?
7) What do you get if you follow a process path on a TS diagram and find the area under the curve?
8) What are the units of quantity produced in question 6?
9) What does it physically mean if this quantity is positive?
10) What does it physically mean if this quantity is negative

Laws of Thermodynamics

Mass Conservation – study questions

1) What does this equation reduce to for in-cylinder processes with intake and exhaust values closed?

2) Under what cylinder conditions would you want to consider mass exchange?

Energy Conservation – study questions

3) What do each of the terms in the equation represent?

4) Which quantities are intensive? Which quantities are extensive?

5) What does this equation look like for an open system?

6) What does this equation reduce to for a closed system?

7) Under what conditions of engine operation would you want to use the closed system form?

8) Under what conditions of engine operation would you want to use the open system form?

9) How do you reduce heat and work terms into intrinsic quantities?

10) How do you find the change in energy for a process using this equation?

Entropy Balance – study questions

11) Is the change in entropy of the system always positive? Why or why not?

12) What has to happen to the surroundings to decrease the entropy of a system?

13) What are three different ways to increase the entropy of a system?

14) What are two different ways to decrease the entropy of a system?

15) What does this equation reduce to for a close system?

16) What does this equation reduce to for an adiabatic process?

17) What does this equation reduce to for an isentropic process?

Carnot Engine – Study Questions

1) What does a Carnot cycle look like on a TS diagram?
2) What is meant by a Carnot engine?
3) How do you find the maximum efficiency of a Carnot engine using data on a TS diagram?
4) Can other thermodynamic cycles have the same efficiency as the Carnot engine? Why?
5) Can other thermodynamic cycles have higher efficiency than the Carnot engine? Why?
6) What provisions are need for using the relations in these slides with respect to temperature?
7) How could you use Carnot engine efficiency to evaluate claims about a new engine design?
8) How do you measure Carnot refrigerator performance?
9) How do you measure Carnot heat pump performance?
10) Can a refrigerator be more efficient than the same device operating as a heat pump?

Isentropic Efficiency – Study Questions

11) What is the relationship between ideal work and real work for a turbine?
12) What is the relationship between ideal work and real work for a compressor?
13) What is the relationship between ideal work and real work for a pump?
14) What does an ideal process path for expansion look like on a TS diagram?
15) What does a real process path for expansion look like on a TS diagram?
16) What does an ideal process path for compression look like on a TS diagram?
17) What does a real process path for compression look like on a TS diagram?
18) Can entropy decrease during compression? How can this happen?

Balancing Chemical Reactions – Study Questions

19) What is the chemical difference between paraffin, olefin, acetylene, and alcohol fuels?
20) How is chemical energy stored in fuels? Which bonds are most significant?
21) Which fuels contain oxygen? What do you think this means in terms of fuel heat release per kg?
22) What is the typical fraction of oxygen in a mole of air?
23) What is the typical fraction of nitrogen in a model of air?
24) What is meant by a stoichiometric reaction balance?
25) What information is needed to find the stoichiometric air/fuel ratio?