

my study notes, thermodynamics UCI 91, summer 2004

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1 questions

1. 8/28/04, 8:20 pm. page 284 in book, the formulas for ds are NOT for polytrpic process, but for general ideal gas process (no n in the formula). So, how to determine ds for the 4 different polytropic processes? In particular how to find ds for const T ($n = 1$) process? The other book has it, but do not see it now in our text book.
2. page 284, equation for $s_2 - s_1$ for ideal gas, why does book write C_{p0} but only C_{v0} for the next equation below it? Should not they both be for ideal gas, i.e. with a '0' in the subscript?
3. $K - P$ statment of second law basically says that it is impossible to reach $T_L = 0$, right? becuae when $T_L = 0$ then $W = Q_H$ for an ideal cycle.
4. 8/28/04, 9:20 pm. What about shaft work for non-steady state flow? Do not need to worry about it in this course.
verify what it will be for $n = \infty$, ie. Constant V

$$\begin{aligned}
 w &= \frac{n}{1-n} (P_e v_e - P_1 v_1) \\
 &= \frac{nR}{1-n} (T_e - T_1)
 \end{aligned}$$

5. Since Gibbs equations were derived assuming a reversible process and compressible substance, then I assume we can't use these for solids/liquids? Verify.
6. How do we derive $ds = \frac{C}{T}dT$ for solids?, I see we can get it Gibbs equation by setting $dv = 0$ for solids, But Gibbs equations were derived for incompressible substances??
answer: do not use Gibbs. always start from basic laws to be safe. use entropy equation $ds = \frac{dq}{T} = \frac{C}{T}dT$. simple.
7. In deriving the entropy change equation for ideal gas, the book for some reason ignores the term $v dP$, why?? see page 263. see my derivation below
8. Why is $\delta w = Pdv$ only and not $\delta w = P dv + v dP$

2 To investigate

Model carnot cycle as water flow and using flywheel. Then translate the 2nd law statments to this model.

$$h_2 - h_1 = C_p \ln \frac{T_2}{T_1}$$

entropy change for ideal gas:

$$\begin{aligned}
 ds &= \frac{dq}{T} \quad (\text{by definition, entropy law}) \\
 &= \frac{dw + du}{T} = \frac{dw}{T} + \frac{du}{T} \\
 &= \frac{1}{T} d(Pv) + \frac{1}{T} d(C_v T) \\
 &= \frac{1}{T} (P dv + v dP) + \frac{C_v}{T} dT \\
 &= \frac{P}{T} dv + \frac{v}{T} dP + C_v \frac{dT}{T}
 \end{aligned}$$

but $Pv = RT$, hence

$$\begin{aligned}
 ds &= R \frac{dv}{v} + R \frac{dP}{P} + C_v \frac{dT}{T} \\
 s_2 - s_1 &= R \ln \frac{v_2}{v_1} + R \ln \frac{P_2}{P_1} + C_v \ln \frac{T_2}{T_1} \quad (1)
 \end{aligned}$$

entropy change for Solids/liquids:

$$\begin{aligned}
ds &= \frac{dq}{T} \quad (\text{by definition, entropy law}) \\
&= \frac{dw + du}{T} = \frac{dw}{T} + \frac{du}{T} \\
&= \frac{1}{T} d(Pv) + \frac{1}{T} d(C T) \\
&= \frac{1}{T} (P dv + v dP) + \frac{C_v}{T} dT \\
&= \frac{P}{T} dv + \frac{v}{T} dP + C_v \frac{dT}{T}
\end{aligned}$$

but $dP = 0$ since incompressible,
and dv is very small, so

$$\begin{aligned}
ds &= C \frac{dT}{T} \\
s_2 - s_1 &= C \ln \frac{T_2}{T_1}
\end{aligned} \tag{1}$$

Now, for constant P we get from equation (1)

$$\begin{aligned}
s_2 - s_1 &= R \ln \frac{v_2}{v_1} + C_v \ln \frac{T_2}{T_1} \\
&= R \ln \frac{v_2}{v_1} + (C_p - R) \ln \frac{T_2}{T_1} \\
&= R \ln \frac{v_2}{v_1} + C_p \ln \frac{T_2}{T_1} - R \ln \frac{T_2}{T_1} \\
&= R \left(\ln \frac{v_2}{v_1} - \ln \frac{T_2}{T_1} \right) + C_p \ln \frac{T_2}{T_1} \\
&= R \left(\ln \frac{\frac{v_2}{T_2}}{\frac{v_1}{T_1}} \right) + C_p \ln \frac{T_2}{T_1} \\
&= R \left(\ln \frac{v_2 T_1}{v_1 T_2} \right) + C_p \ln \frac{T_2}{T_1}
\end{aligned}$$

But $\frac{v_2}{T_2} = \frac{R}{P_2}$ and $\frac{v_1}{T_1} = \frac{R}{P_1}$ so

$$\begin{aligned}
s_2 - s_1 &= R \left(\ln \frac{R P_1}{P_2 R} \right) + C_p \ln \frac{T_2}{T_1} \\
&= R \left(\ln \frac{P_1}{P_2} \right) + C_p \ln \frac{T_2}{T_1}
\end{aligned}$$

so, for constant P , for ideal gas

$$s_2 - s_1 = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

but if constant P , then $s_2 - s_1 = C_p \ln \frac{T_2}{T_1}$??

Process that causes irreversibility

1. Friction
2. Unrestrained expansion
3. Heat transfer from hot to cold body
4. Mixing of 2 different substances
5. i^2R loss in electric circuits
6. Hystereris effects
7. Ordinary combustion

First Law, non-flow

$$\delta Q = \delta W + dE$$

$$\dot{Q} = \dot{W} + \frac{dE}{dt}$$

where $E = U + KE + PE$

$$Q_{1,2} = W_{1,2} + m(u_2 - u_1)$$

$$\dot{Q}_{C.V.} + \dot{m}_i(h + KE + PE)_i = \dot{W}_{C.V.} + \dot{m}_e(h + KE + PE)_e + \frac{dE}{dt}$$

$$Q_{C.V.} + m_i(h + KE + PE)_i = W_{C.V.} + m_e(h + KE + PE)_e + (m_2u_2 - m_1u_1)$$

$$Q_{C.V.} + m_i h_i = W_{C.V.} + m_e h_e + (m_2u_2 - m_1u_1)$$

$$Q_{C.V.} + m(h + KE + PE)_i = W_{C.V.} + m(h + KE + PE)_e$$

$$Q_{C.V.} + m h_i = W_{C.V.} + m h_e$$

$$Q_{C.V.} = W_{C.V.} + m(h_e - h_i)$$

$$q = w + (h_e - h_i)$$

steady state. $m_i = m_e = m$

$$m(s_2 - s_1) = \frac{\delta Q}{T} + S_{gen}$$

$$s_2 - s_1 = \frac{\delta q}{T} + s_{gen}$$

$$0 = m_i s_i - m_e s_e + \frac{\delta Q}{T} + S_{gen}$$

$$0 = s_i - s_e + \frac{\delta q}{T} + s_{gen}$$

$$m_2 s_2 - m_1 s_1 = m_i s_i - m_e s_e + \frac{\delta q}{T} + s_{gen}$$

3 Chapter 5. First law of thermodynamics

This law is the conservation of energy law.

It says that change of internal energy of a system equals the difference between the heat energy entering the system and the work produced by the system.

In symbols, let E be the energy of the control mass or volume, W , work produced, Q is the heat energy gained. Then

$$\Delta E = \Delta Q - \Delta W$$

Usually we have a process from one state to the next, so the above is written as

$$Q_{1-2} - W_{1-2} = E_2 - E_1$$

energy is $E = U + PE + KE$

enthalpy

$$H = U + PV$$

$$h = u + Pv$$

$$\delta Q - \delta W = m(u_2 - u_1)$$

$$\delta Q - \int P dV = m(u_2 - u_1)$$

$$\delta Q - P(V_2 - V_1) = m(u_2 - u_1)$$

$$\delta q = P(v_2 - v_1) + (u_2 - u_1)$$

$$\delta q = (Pv_2 + u_2) - (Pv_1 + u_1)$$

$${}_1q_2 = h_2 - h_1$$

C_v C_p

$$C_v = \left(\frac{\partial u}{\partial T} \right)_v$$

$$C_p = \left(\frac{\partial h}{\partial T} \right)_p$$

$$C_p = \left(\frac{\partial h}{\partial T} \right)_p$$

3.1 Solids and liquids equations

$C_v \approx C_p$ For solids and liquids

Now, by definition, C is the heat energy

to raise

Hence for solids/liquids, $dh \approx du \approx C dT$

$$du = C dT$$

$$du = C_{v0} dT$$

$$dh = C_{p0} dT$$

$$C_{p0} - C_{v0} = R$$

$$dh = du + d(Pv)$$

$$dh = du + (v dP + P dv)$$

For solids and liquids, $dv = 0$ since almost incompressible, hence

$$dh \approx du + (v dP) \quad \text{For Solids and Liquids}$$

Also for solids and liquids, v is very small, hence

$$dh \approx du \quad \text{For Solids and Liquids}$$

3.2 Signs for energy and work

Q in is +

W out is +

$$Q_{in} + W_{in} + m_i (h + PE + KE)_i =$$

$$Q_{out} + W_{out} + m_e (h + PE + KE)_e + (m_2 u_2 - m_1 u_1)$$

$$W_{net} = h_e - h_i$$

$$S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + S_{gen}$$

$$S_{gen} \geq 0$$

$$S_{gen} = 0 \Rightarrow \text{reversible process}$$

$$\delta Q = 0 \Rightarrow \text{adiabatic process}$$

Hence, $S_2 = S_1$ for a reversible adiabatic process

$$W_{lost} = \int T dS_{gen}$$

$$\text{Actual boundary work } W_{1-2} = \int P dV - W_{lost}$$

4 Gibbs relations

$$T ds = du + P dv$$

$$T ds = dh - v dp$$

$$s_2 - s_1 = C \ln \frac{T_2}{T_1}$$

$$s_T^0 = \int_{T_0}^T \frac{C_{p0}}{T} dT$$

$$s_2 - s_1 = s_{T_2}^0 - s_{T_1}^0 - R \ln \frac{P_2}{P_1} \quad \text{Using table A.7 or A.8}$$

$$s_2 - s_1 = C_{p0} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1} \quad \text{Constant } C_p, C_v$$

$$s_2 - s_1 = C_v \ln \frac{T_2}{T_1} - R \ln \frac{v_2}{v_1} \quad \text{Constant } C_p, C_v$$

$$k = \frac{C_{p0}}{C_{v0}}$$

5 Polytropic process

$$PV^n = \text{constant}$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2} \right)^n$$

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1} \right)^{\frac{n}{n-1}}$$

specific work (work is moving boundary work, $\int P dv$)

$$w_{1-2} = \frac{1}{1-n} (P_2 v_2 - P_1 v_1) = \frac{R}{1-n} (T_2 - T_1) \quad n \neq 1$$

$$w_{1-2} = P_1 v_1 \ln \frac{v_2}{v_1} = RT_1 \ln \frac{v_2}{v_1} = RT_1 \ln \frac{P_1}{P_2} \quad n = 1$$

6 study agenda notes

6.1 Monday August 30, 2004

12 midnight. Working on derivation of the entropy change equations. Putting the questions I have into separate file (pdf, html).

Spend more time going over the conceptual questions for each chapter. These are good. finished chp 8. now doing chp 9.

3:10 AM. Done. Finished chp9 conceptual questions, and went over 1st and 2nd laws and few things. Updated the diagram. Now at 11x17 paper size, need to figure how/where to print it.

6.2 Sunday August 29, 2004

3:40 PM. Sitting down to try to do some studying. Where does time go?

6.3 Saturday August 28, 2004

Working on this diagram, which does better classifications of the different processes involved. I am finding it hard to put everything in one place, because we have 2 main classifications, Gasses and Solids/liquids, and then we have to classify based on the process type (including ideal vs not ideal cases for Gasses), then we have the reversible vs. irreversible process to classify on, and then we have the flow vs non-flow process.

doing this diagram is helping me better figure where to use which law than I did before.

Got my final grade not including the final exam, which is 53.6/60, this is 89.4%.

Since finals has 40 points, then I need to get 40/40 in the finals to get 93.6% final grade to get a chance of an A. Not sure I can get it. So may be I'll get an A- or a B+.

I have decided that our text book is not well organized. The author does not classify different things using tables or diagrams.

I am now studying from text book called "Elements of applied thermodynamics" by Johnston and Brockett. I really like the polytropic process discussion there and how they show the different cases for different n values. Much clearer than our textbook.

10:43 PM. Just learned a cool trick to remember the P-v and T-s diagrams. They all are clock-wise 0,1,k,infinity. For P-v, draw the straight lines first (const P, $n=0$) and const v ($n=\infty$). Then using the clock-wise direction the rest follow. For T-s diagram, again draw the straight lines, const T ($n=1$) and const s ($n=k$), and the rest follows.

Wish I learned this before that quiz which asked about this!

If a process is irreversible, then only end points are known. So use a dotted line to draw such a process on P-v or T-s. reversible processes are known at each point between the end states. Use solid line.

Area under irreversible process on P-v or T-s diagram has NO SIGNIFICANCE.

Only area under reversible process. For a reversible process, area under T-s is the heat energy, while under the P-v is the work.

2nd law statements: No engine, actual or ideal, when operating in a cycle, can convert all the heat supplied to it into mechanical work.

Clausius statement: "it is impossible for a self-acting machine, unaided by an external agency, to transfer heat continuously from one body to another at a higher temp".

Basically this says that work is needed to force heat to travel from a lower temp body to a higher temp body.

See if I can get the Carnot book "Reflections on the motive power of heat" on amazon. Originally French, may be there is a translation.

Carnot principle: "The motive power of heat is independent of the agents employed to realize it; its quantity is fixed solely by the temp. of the bodies between which is effected, finally, the transfer of heat"

The efficiency of a reversible heat engine cycle depends only of the temp. of the heat energy source and sink.

1:20 AM. Go to sleep. Tomorrow need to start working on solving actual problems.

6.4 Sunday August 22, 2004

11:30 PM, Working on last HW. 4 problems done, this HW is taking long time.

Spend time doing this visio diagram, was getting lost with all the relations and not being clear when to use which under what conditions. Still can not see my grades by looking at e3.uci.edu, a bug in the system.