Thermo

PERFECT EDGE ® MICRO PERFORATED FOR CLEAN TEAR-OUTS

GRAPH NOTEBOOK

100 SHEETS

4X4 QUAD RULED

Norcom, Inc. Griffin, GA 30224
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	due	read	problems	
	1-25	165-177	4-6, 11, 29.	
	2-1	178-191	4-133, 147, 152	
	2-8	221-239	5- 54, 59	
	2-15	240-248	5- 69, 78, 87	
TEST	2-10-10	Chap. 4 & 5		* needs review
	2-17	249-253 284-297	5-121 * 6-52, 54	
	2-17	Quiz 4		like 5-59
	3-1-10	298-305 309-315	6-83 E, 98	
	2-24	Quiz 5		like 5-78
	3-8	338-346	7-25, 35E, 37	
	3-3	Quiz 6		like
Test 2	3-10	chapters 5 & 6		
	3-15	349-352		
	3-22	356-361	7-52, 72, 83	
	4-5	review ch7 to p 362	7-128, 147, 152	
	3-23	Quiz 7		Ch 7, work, enthalpy, quality x, steady flow
	4-5	Review ch 7 beyond p 362		
	4-19	Read 434-444	8-51, 54, 65	
	4-14	Exam 3 Chapter 7		
	4-26	445-454	8-16 E 8-24, 32	
	5-3	455-474		
	5-5	Exam 4 Chapter 8		

due 1/20 (Not collected) read 111-139   prob 3-27, 33, 39E

P112 phases S, L, V (solid, liquid vapor)
properties:

- P pressure
- T temp
- v specific volume, m^3/kg or ft^3/lb
- $P_{sat}\langle T\rangle$ saturation presure for given temp
  (press. which allows liq & vapor to both exist
- $T_{sat}\langle P\rangle$ saturation temp

P120 T-V diagram, use fig 3-18

u: internal energy   h: enthalpy   s: entropy

P916 H_2O SI units sat table temperature table
918 saturated H_2O pressure table
920 superheated vapor
924 compressed liquid

R134a: refrigerant
p129 for a mix of vapor, x = 'quality' = $\frac{m_g}{m_\ell + m_g}$ mass fraction of gas

$$v = (1-x)\, v_f + x\, v_g$$
$$u = (1-x)\, u_f + x\, u_g$$

Ex 3-9

part d $T = 75°C$ phase? $P_{sat}\langle 75°\rangle = 38.597$ kPa
$P = 500$ kPa u? compressed liquid
$u \approx u_f\langle 75°C\rangle$ dont say $u \approx u_f\langle 500\text{kPa}\rangle$
$u = 313.99 \frac{kJ}{kg}$
$h \equiv u + Pv$

e) $P = 850$ kPa p919
$x = 0 \Rightarrow$ saturated liquid $T = T_{sat}\langle 850\text{ kPa}\rangle = 172.94$
$u = u_f = 731.00$

P137 § 3-6 ideal gas a gas that closely follows following relation.
$PV = mRT$
P = absolute pressure
V = volume
m = mass
R = gas constant, get values P961 British, 911 (SI units)

- any gas behaves as an I.G. if pressure is lowered sufficiently while temp stays fixed
fig. 3-49 shows when ideal gas is good estimate for water

P961 ex a) air, 20°C, 101 kPa $\rho = ? = \frac{m}{V}$ $R_{air} = 0.287 \frac{kJ}{kg\cdot°K}$

$$\frac{m}{V} = \frac{P}{RT} \quad \frac{101\text{ kPa}\ \frac{1\text{kN/m}^2}{\text{kPa}}}{0.287\ \frac{\text{kN}\cdot\text{m}}{\text{kg}\ °\text{K}}\ (20+273)°\text{K}}$$

$= kJ$

b) 68°F 14.7 psi
$$\frac{m}{v} = \frac{14.7\ \text{lb}/\text{in}^2\ \left(12\ \frac{\text{in}}{\text{ft}}\right)^2}{0.06855\ \frac{\text{Btu}}{\text{lb}_m\ °\text{K}}\ 778\ \frac{\text{ft lb}}{\text{Btu}}\ (68+460)\ °\text{K}}$$

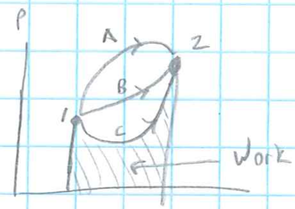
$= .0752 \frac{\text{lbm}}{\text{ft}^3}$

Notes Ch 4 ENERGY ANALYSIS OF CLOSED SYSTEM

closed system: no flow of mass across boundary

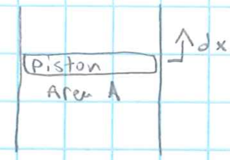
If during a process ~~of~~ volume changes then work $= \int_1^2 P\,dV$

- has built-in sign convent. that work done by system on surroundings is > 0



if path $P = C_1 + C_2 V$ (straight line)

then ${}_1W_2 = \frac{P_1 + P_2}{2} (V_2 - V_1)$



$\Delta W = \underbrace{PA}_{\text{force}} \underbrace{dx}_{\text{distance}}$

$= P\,dV$

if $PV^n = \text{const}$ $n =$ "polytropic $\underline{\text{exp. constant}}$"

then ${}_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n}$, $n \neq 1$

or ${}_1W_2 = P_1 V_1 \ln \frac{V_2}{V_1}$, $n = 1$

Conservation of energy

${}_1Q_2 =$ heat transfer from surroundings into system

$E_2 =$ energy in system at end of process (state$_2$)

$E_1 =$ energy in system at beginning (state$_1$)

${}_1Q_2 = {}_1W_2 + E_2 - E_1$ $\underline{\text{checking acc.}}$ ${}_1Q_2 =$ deposits

${}_1W_2 =$ withdrawals

$E_1, E_2 =$ balances

$E = m\left(u + \frac{V^2}{2} + gz\right)$

internal energy

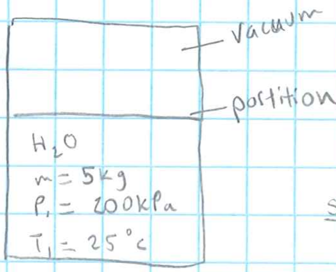
pot. energy $g =$ grav $z =$ elev

kinetic energy, velocity

ex

Notes Ch 4 p176

Ex 4-6



$${}_1W_2 = \int_1^2 P\,d\cancel{V}^{\,0} = 0$$

$${}_1Q_2 = {}_1W_2 + m(u_2 - u_1)$$

state 2   state 1

$$V_2 = 2V_1$$

p916 $P_{sat}\langle 25°C\rangle = 3.1698$ kPa $\therefore$ state 1 is compressed liquid

$v_1 = v_f\langle 25°C\rangle = .001003$ m³/kg

$u_1 = u_f\langle \quad \rangle = 104.83$ kJ/kg

$mv_1 = 5\text{kg}\,(.001003)\ \text{m}^3/\text{kg} = .005_{xx}\ \text{m}^3$ $V_{tank} = 2(.005\ \text{m}^3) = 0.01\ \text{m}^3$

$T_2 = T_1 = 25°$ p916 @ 25°C $v_f = 0.001003$

$v_2 \approx .002$ $v_g = 43.40$

$v_f < v_2 < v_g \therefore$ ② is mixture of L & V

$P_2 = P_{sat}\langle 25°C\rangle = 3.1698$ kPa

$$x_2 = \frac{m_{g2}}{5\text{kg}}$$

$$v_2 = (1-x_2)(v_f)_2 + (x_2)(v_g) \Rightarrow x_2 = 2.3\times10^{-5}$$

$$u_2 = (1-x_2)\underbrace{u_f}_{104.83} + x_2\underbrace{u_g}_{2409.1} = 104.88$$

$${}_1Q_2 = \cancel{{}_1W_2}^{\,0} + m(u_2 - u_1)$$

$$= 5\text{kg}\,(104.88 - 104.83)\ \frac{\text{kJ}}{\text{kg}}$$

$${}_1Q_2 = 0.25\text{kJ}$$

Notes

3.27 a homework problem

H_2O (a) $P = 200\,kPa$ $T = ?$ mix L & V

$x = .7$ $h = ?$ $T = T_{sat} \langle 200\,kPa \rangle$ (918) $= 120.21°C$

$h = \underset{h_f}{.3(504.71)} + \underset{h_g}{.7(2706.3)} = 2045.8 \; \frac{kJ}{kg}$

(b) $140°C$, $h = 1800$ (916) @ 140°C $h_f = 589.16$ $h_g = 2733.5$, mix L & V

$P = P_{sat} \langle 140 \rangle = 361.53\,kPa$

$1800 = (1-x)\,589.16 + x(2733.5)$ $x = 0.565$

(c) $P = 950\,kPa$ $x = 0$ saturated liquid $T = T_{sat} \langle 950\,kPa \rangle$ $h = h_f \langle 950\,kPa \rangle$

p918 $h = h_f \langle 950\,kPa \rangle = 752.74$

(d) $T = 80°C$ $P = 500\,kPa$ $P_{sat} \langle 80° \rangle = 47.416\,kPa$ compressed liquid

$\boxed{p524}$ min $P = 5\,MPa$ our P not high enough

assume the liquid is incompressible, $h \approx h_f \langle 80°C \rangle$ (916) $= 335.02$

here, don't use $h_f \langle 500\,kPa \rangle$ ← b/c the incompressible assumption, we use temp h_f is a weak relationship w/ volume

another approx = $h = h_f \langle 80°C \rangle + (500\,kPa - 47.416)\, v_f \langle 80° \rangle$

$h = u + Pv$

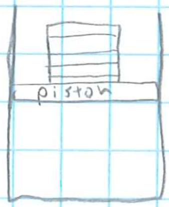
e) $P = 800\,kPa$ $h = 3162.2$ $\boxed{919}$ @ 800 kPa $h_g = 2768.3$

$h > h_g$ ∴ superheated vapor SHV p920 @ .8 MPa 5th row is our h

$T = 350°C$

Notes

3.33)



$m = 1kg$

$V_1 = .14m^3$

$T_1 = -26.4°C$

$T_2 = 100°C$

path = const pressure $V_2 = ?$

State 1 P930 sat table

P	T_{sat}	v_f	v_g
100	-26.37	.0007259	.19254

$0 < x < 1$ don't need x, only need $P_1 = P_{sat} = 100$ kPa

State 2 100°C, 100 kPa $T > T_{sat}$ ∴ SHV P931 .1MPa last row is 100°C

$v = .30138 \; m^3/kg$ $V_2 = .30138 \; m^3$

Homework 39.E)

$m = 1 lbm$

H_2O, $V = 2ft^3$ $u = ?$

$P = 100 psia$ $h = ?$

$v = \frac{V}{m} = 2 ft^3/lbm$

$x = \frac{v - v_f}{v_{fg}} = \frac{2 - .01774}{(4.4327 - .01774)} = .4490$

$x = 0.4490$

$u = (1-x) u_f + x(u_g) = (.551)(298.19) + (.4490)(1105.5) = 660.672$ Btu

$v = (1-x) h_f + x(h_g) = (.551)(298.51) + (.449)(1187.5) = 697.67$ Btu

33) rework: R134a $.14m^3$ T_1 $-26.4°C$ T_2 $100°C$

Homework 3 | 27, 33, 39E

27)

	T, °C	P, kPa	h, kJ/kg	x (gas/mix)	Phase	T_{sat}
a)	$\boxed{120.21}$	200	$\boxed{2046}$	0.7	mix liq & vap	120.21
b)	140	$\boxed{361.53}$	1800	.565	mix	
c)	177.66	950	752.74	0.0	liquid, saturated	
d)	80	500	335.02	NA or 0	compressed liquid	
e)	350°	800	3162.2	1	Superheated vapor	

a) $h = 0.7(2706.3) + 0.3(504.71) = 2045.82$

b) $1800 = (1-x)(h_f)\ (x)(h_g)$ $\quad h_f = 589.16 \quad h_g = 2733.5$

$x = 0.565$

c)

d) $u \cong u_f\ @(75) = \cancel{334.97}\ 335.02$

e) $h > h_g \therefore SV \quad 350°$

Notes

due 1/25 read 165-177 prob 4-6, 11, 29

3-39 E

$u = ?$

$H = ?$

H_2O
100 psia
2 ft^3, 1 lbm

rigid tank

$$v = \frac{V}{m} = 2\ \text{ft}^3/\text{lbm} \quad p = 100\ \text{psia} \Big\}\ \text{p968 @ 100 psia} \quad v_f = .01774 \quad v_g = 4.4327$$

$u_f = 298.19$ $\quad u_g = 1105.5$

$h_f = 298.51$ $\quad v: 2 = (1-x)v_f + x(v_g) \Rightarrow x = .4490$

$h_g = 1187.5$ $\quad u: u = (1-.4490)u_f + .4490\, u_g = 660\ \text{Btu/lbm}$

$h: h = (1-.4490)h_f + .4490\, h_g = 697.7\ \text{Btu/lbm}$

$U = u\,(1\ \text{lbm})$

$H = h\,(1\ \text{lbm})$

p181 for ideal gas

$$u_2 - u_1 = \int_1^2 c_v\, dt \qquad h_2 - h_1 = \int_1^2 c_p\, dt$$

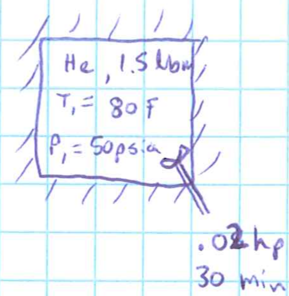
we will use average specific heats (c_p & c_v) eval at $T_{avg} = \frac{T_1 + T_2}{2}$

- dont use table A-17

Example 4-8

$T_2 = ?$ $\quad P_2 = ?$

rigid insulated tank



.02 hp
30 min

1st law $\quad {}_1\cancel{Q}_2 = {}_1W_2 + m(u_2 - u_1)$

0

$${}_1W_2 = (-.02\ \text{hp})\ \frac{550\ \text{ft lbf}}{\text{s hp}}\ \frac{30\ \text{min}\ (60)\ \frac{\text{sec}}{\text{min}}}{778\ \frac{\text{ft lbf}}{\text{btu}}}$$

$= -25.45\ \text{Btu}$ $\quad$ p961 $\quad c_v = .753\ \text{Btu/lbm}\cdot\text{R}$

$= m(u_2 - u_1)$

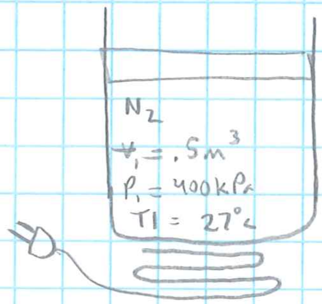
$25.45\ \text{Btu} = 1.5\ \text{lbm}\ (.753\ \frac{\text{Btu}}{\text{lbm}\cdot\text{R}})(T_2 - 80)\ {}^\circ\text{F}$ $\qquad T_2 - 80 = 22.53$

$T_2 = 102.53\ {}^\circ\text{F} = 562.5\ {}^\circ\text{R}$ $\qquad PV = NRT \quad \frac{P}{T} = \frac{mR}{V} = \text{const}$

$= m c_v (T_2 - T_1)$

$$\frac{P_2}{T_2} = \frac{P_1}{T_1} \qquad \frac{P_2}{(460^\circ + 102.5^\circ)\ {}^\circ\text{R}} = \frac{50\ \text{psia}}{460 + 80} \qquad P_2 = 52.1\ \text{psia}$$

1-22-10 Notes



ex 4.9) $\quad {}_1Q_2 = -2800\ J \qquad T_2 = ?$

elect. $\left({}_1W_2\right) = -2(120)\ \text{watts}\ \dfrac{1\ J/s}{\text{watt}}\ 300\ \text{sec}$

$= -72{,}000\ J = -72\ kJ$

$${}_1Q_2 = ({}_1W_2)_{elec} + \overbrace{\int_1^2 P\,dV}^{W_b} + U_2 - U_1$$

$$-2.8\,kJ = -72\,kJ + \underbrace{P(V_2 - V_1) + U_2 - U_1}_{m(h_2 - h_1)}$$ because $h = u + Pv$

p911 $\quad R = .2968,\ C_p = 1.039$ kJ/kg°K $\qquad PV = mRT \Rightarrow m = \dfrac{P_1 V_1}{RT_1}$

$$m = \frac{400\,kN/m^2\ (.5\,m^3)}{.2968\ \frac{kN\cdot m}{kg\,°K}\ (27+273)°K} = 2.246\ kg$$

$$69.2\ kJ = 2.246\ kg\ \left(1.039\ \frac{kJ}{kg\cdot K}\right)(T_2 - 27°C)$$

$T_2 - 27 = 29.65 \qquad T_2 = 56.65°C$

p189 change in u or h for incompressible (solids or liquids)

$u_2 - u_1 = c\,(T_2 - T_1) \qquad h_2 - h_1 = c(T_2 - T_1) + v(P_2 - P_1)$

Ex 4-11) water 100°C 15MPa $\quad P_{sat}(100°C) = 101.42\ kPa \quad$ Tabl A4, 916

compressed liquid $\quad P_1\ 101.42\,kPa \quad v_1 = .001043 \quad h_1 = 419.17$

$$h_2 - 419.17 = C(T_2 - T_1) + .001043\ \frac{m^3}{kg}\left[\begin{matrix}3500\ kN/m^2\\ -101.42\ kN/m^2\end{matrix}\right\}\ \frac{m\,kN}{kg} = kJ$$

$= 15.639$

$h_2 = 434.71\ kJ/kg$

Notes

ex 4-12   Iron 5kg $T_1 = 80°C$ liquid water $.5m^3$ 25°C   Fe & H_2O ⇒ thermal contact

find common temp. reached, $T_2 = ?$ assume pressure of water is high enough to stay liquid

1^{st} law for a system including both water & iron

$\cancel{{}_1Q_2} = \cancel{{}_1W_2} + U_2 - U_1$, $U_2 = U_1$ $50\,kg\, C_1 T_2 + M_W C_W T_2 = 50\,kg\, C_1 (80°C) + M_W C_W (25°C)$

(insulated) 0   0

$M_W = \frac{V}{v} = \frac{.5m^3}{.001 \frac{m^3}{kg}} = 500kg$ Table A.3 H_2O $C = 4.18 \frac{kJ}{kg \cdot K}$

P916 iron $C = .45$ Table A 3B $T_2 = 25.6°C$

Notes 1-25-09

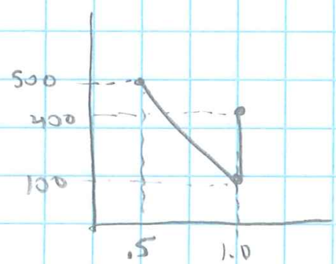
due 2-1 read 178-191   4-133, 147, 152 path: P = const.

test #1 2-10 ch 3 & 4

4-6

${}_1W_3 = ?$ ${}_1W_2 = m \int_1^2 P\,dv = \frac{P_1 + P_2}{2} (V_2 - V_1) m$

$= 300 \frac{kN}{m^2} (.5) \frac{m^3}{kg}\, 2kg = 300\, kn \cdot m = \boxed{300kJ}$



${}_2W_3 = \int_2^3 P\,dV = 0$

4-11 H_2O $m = 5kg$ path = const. pressure ① 300kPa $x_1 = 1$ ② $T_2 = 200°C$

${}_1W_2 = ?$ $m \int_1^2 P\,dv = mP(v_2 - v_1)$ $v_1 = v_g = .60582$ table A-5

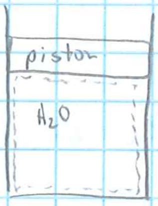
$t_{sat} = 133.52 \rightarrow$ ② in SHV $v_2 = .71643$ table A-6

${}_1W_2 = 5kg \left(300 \frac{kN}{m^2}\right)(.71643 - .60582)\, m^3/kg = 165.9\, kN \cdot m = 165.9\, kJ$

positive work, leaves the system

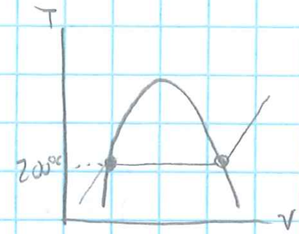
Notes 1-25

4-29)



① 200 °C $x_1 = 1$ path = const. temp

② 200 °C $x_2 = 0$ ${}_1q_2$? ${}_1w_2$?



${}_1W_2 = \int_1^2 P dv = P(v_2 - v_1)$ table A4

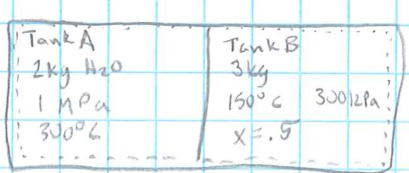
$v_1 = v_g = .12721$ $u_1 = u_g = 2594.2$ $v_2 = v_f = .001157$ $u_2 = u_f = 850.46$

$P_{sat} = 1554.9$ kPa

${}_1W_2$ $1554.9 \frac{kN}{m^2} (.001157 - .12721) m^3/kg = -196$ kJ/kg

cons. of energy ${}_1q_2 = {}_1w_2 + u_2 - u_1 = -196 + 850.46 - 2594.2 = \boxed{-1939.7 \text{ kJ/kg}}$

4-42)



↑ partition in state 1
no partition in state 2

${}_1Q_2 = ?$ $T_2 = ?$ $x_2 = ?$

${}_1Q_2 = {}_1W_2 + U_2 - U_1$ no boundary work, Pdv = 0

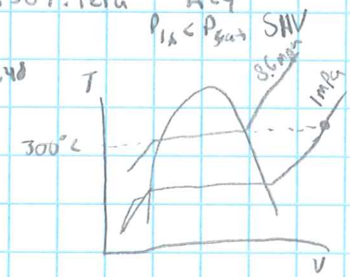
(${}_1W_2$: 0)

${}_1Q_2 = 5kg(u_2) - [2kg\, u_{A_1} + 3kg\, u_{B_1}]$ (1A) $P_{sat}(300°) = 8587.9$ kPa A-4

$P_{1A} < P_{sat}$ SHV

Table A-6 1A $v = .25799$ $u = 2793.7$ State (1B) $\xrightarrow[A4]{Table}$ $v_{1B} = \frac{.001091 + .39248}{2}$

$u_{1B} = \frac{631.66 + 2559.1}{2}$ $v_{1B} = .19679\ m^3/kg$ $u_{1B} = 1595.4$



$V_2 = 2kg(.25799\ m^3/kg) + 3kg(.19679) = 1.106 m^3$ $v_2 = .22127$

State 2 $P_2 = 300$ kPa $v_2 = .22127$ A-5 @ 300kPa $v_f = .001073$ $v_g = .60582$ $0 < x_2 < 1$

$.22127 = (1 - x_2)(.001073) + x_2(.60582)$ $x_2 = .3641$ $T_2 = T_{sat}(\ ) = 133.5$ °C

$u_2 = (1 - .3641) u_f + .3641 u_g = 1282.8$

561.11 2543.2

${}_1Q_2 = 5kg(1282.8) - [2kg(2793.7) + 3kg(1595.4)] = -3957$ kJ

✗ Notes on 2-1 ✗

165-177

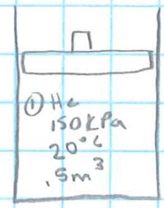
Homework due 2-1-10 4- 133, 147, 152 P=const. read 178-191

133) Polytropic $P\forall^n = \text{const}$

$C_p = 5.1926$

$C_v = 3.1156$

$R = 2.079$



$PV^n = C$

② 400kPa 140°C

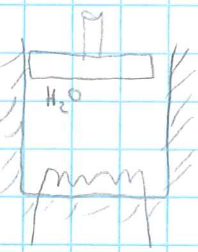
$$m = \frac{P_1 \forall_1}{R T_1} = \frac{150 \frac{kN}{m^2} \; .5m^3}{2.0769 \frac{kJ}{kg \cdot K}(20+273\ °K)}$$

$$\frac{P_1 \forall_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow V_2 = .5m^3\left(\frac{150}{400}\right)\left(\frac{140+273}{20+273}\right) = .264m^3$$

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

P200 gives $\int_1^2 P d\forall = \frac{P_2 V_2 - P_1 V_1}{1-n}$

4.152)



- insulated

$M = 1.4kg$ 200°C $x_1 = 0$ $\frac{\forall_2}{\forall_1} = 4$

path = const. pressure

$\forall_2 = ?$ $V_1 = ?$ $T_2 = ?$

916, $P_{sat}\langle 200 \rangle = 1554.9\ kPa$ $v_f = .001157 = v_1\ m^3/kg$

$h_f = 852.26\ kJ/kg \cdot k$

$\forall_1 = 1.4kg(.001157) = .00162\ m^3$ $\forall_2 = 4\forall_1 = .00463\ m^3$ $P_2 = 1554.9$

$V_2 = .00648\ m^3$ $V_g\langle 1554.9\ kPa \rangle = .12721$

${}_1Q_2 = {}_1W_2 + m(u_2 - u_1)$ don't cut through the heater wires w/ sys. boundary

$v_2 = (1-x_2)v_f + x_2 v_g \rightarrow x_2 = .0275$ $x_2 < 1$

$h_2 = (1-x_2)h_f + x_2 h_g \rightarrow h_2 = 905.65$

${}_1Q_2 = 1.4kg(905.65 - 852.26) = 74.75\ kg$ kW

$P(20min \frac{60\ sec}{min}) = 74.75\ kJ$ $P = .0623 \left(\frac{kJ}{sec}\right)$

Notes

Q	W_{out}	E_1	E_2	m	e_2-e_1
kJ	kJ	kJ	kJ	kg	kJ/kg
280	440	1020	860	3	-53.3
-350	130	550	70	5	-96
-40			0		

$e_2 - e_1 = \dfrac{E_2 - E_1}{m}$

1st law

${}_1Q_2 = {}_1W_2 + E_2 - E_1$

$280 = {}_1W_2 + \underbrace{860 - 1020}_{-160}$

${}_1W_2 = 440$

$Q = W + E_2 - E_1$

$-350 = 130 + E_2 - 550$

$E_2 = 70$

4-124 rigid tank ideal gas $C_v = .748 \frac{kJ}{kg\,°K}$ path: v = const

$Pv = RT$

① 200 kPa, 200°C

② 100 kPa, ${}_1Q_2 = ?$

$\frac{T_1}{P_1} = \frac{T_2}{P_2}$

$T_2 = (200+273)\,K \frac{100\,kPa}{200\,kPa}$

$u_2 - u_1 = C_v(T_2 - T_1)$

$= .748 \frac{kJ}{kg\,°K}(236.5 - 473)$

$= -176.9$ kJ/kg

1st law ${}_1q_2 = {}_1\cancel{w}_2^{\,0} + u_2 - u_1$

$= -176.9$ kJ/kg

Notes 1-29

4) 65

① 50 psia, $\forall = ?$, 80° F

② 100 psia

air, 20 lbm, ${}_1Q_2 = ?$ — rigid tank

$P_1\forall = mRT_1$ — $.06855 \frac{Btu}{lbm\,°R}$ p961

$C_v = .171$ @ 80°F

$$\forall = \frac{20\,lbm\,(.06855 \frac{Btu}{lbm\,°R})(80+460\,°R)}{50 \frac{lbf}{in^2}\;144 \frac{in^2}{ft^2}}\left(778 \frac{ft\,lbf}{Btu}\right) = 80\,ft^3$$

$\frac{P_1}{T_1} = \frac{mR}{\forall} = \frac{P_2}{T_2} \Rightarrow \frac{100\,psia}{50\,psia}(540°R) = 1080°R$

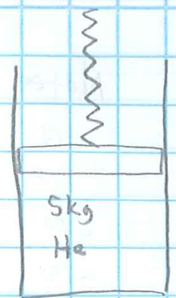
$T_{avg} = \frac{1080 + 540}{2}\,°R \approx 350°F$

p962 @ 350 F 1st law ${}_1Q_2 = {}_1\cancel{W}_2^{\,0} + U_2 - U_1 = mC_{v(avg)}(T_2 - T_1)$

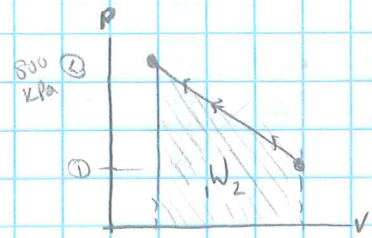
$= 20\,lbm\left(\frac{.175\,Btu}{lbm\,°R}\right)(540°R)$

Notes 1-29 4-76) Helium ① 100 kPa 20°C

$_1Q_2 = ?$ $_1W_2 = ?$ ② 800 kPa 160°C



$$_1W_2 = \int_1^2 P\,d\forall = \frac{P_1+P_2}{2}(\forall_2-\forall_1)$$



$P\forall = mRT$ $V_1 = \frac{mRT_1}{P_1}$

p 411 $R = 2.0769$ $C_v = 3.1156 \frac{kJ}{kg°K}$

$$V_1 = \frac{5kg\,(20+273)°K\,\left(2.0769 \frac{kJ}{kg°K}\right) 1 \frac{kN\cdot m}{kJ}}{100\,kPa\,\frac{1\,kN/m^2}{kPa}} = 5.621\ m^3$$

$_1W_2 = \int_1^2 P\,d\forall =$
$= 450\ kPa\,(5.621 - 30.427)\,m^3 \cdot \left(\frac{1\,kN/m^2}{kPa}\right)\left(\frac{1\,kJ}{kN\cdot m}\right)$
$= -11.163\ kJ$

$_1Q_2 = {}_1W_2 + U_2 - U_1$
$= -11{,}163 + 5kg\,\underbrace{\left(3.1156 \frac{kJ}{kg°K}\right)}_{C_v}(140°K)$

$\boxed{_1Q_2 = -8982\ kJ}$

4-89) electric iron 1000 watts → 15% leaks to room
→ 85% heats alum. plate

plate: .5cm thick, .03 m² } $\forall = .03(.005)$ $\rho = 2770\ kg/m^3$ $m = .4155\,kg$

$C\langle Al\rangle = 875 \frac{J}{kg°C}$ for solids C_v & C_p are same

$\boxed{1\ watt = 1 \frac{kJ}{s}}$

$T_1 = 22°C$ $T_2 = 140°C$ Δt = time interval?

$\left(\frac{energy}{time}\right) = 1\,kJ/s\,(.85) = .85 \frac{kJ}{s}$ $_1Q_2 = \cancel{_1W_2}^{\,0} + U_2 - U_1$

$.85 \frac{kJ}{s}(\Delta t) = .4155\,kg \cdot .875 \frac{kJ}{kg°C}(118°C)$

notes $h = u + Pv$ — 2-3-10 —

$${}_1Q_2 = {}_1W_2 + m(u_2 - u_1) = m(h_2 - h_1)$$

$$\int_1^2 P\,d\forall = P(\forall_2 - \forall_1)$$

Table A-5 p919 1000 kPa $T_{sat} \langle 179.88 \rangle$ $h_1 = (1-.88)(\underset{h_f}{762.51}) + .88(\underset{h_g}{2777.1})$

② ~~h~~ SHV Table A-6 p921

$h_2 = 3158.2$ kJ/kg

$h_1 = 2535.3 \frac{kJ}{kg}$

$${}_1Q_2 = 2kg(3158.2 - 2535.3)\frac{kJ}{kg} = \boxed{1245.8\ kJ}$$

Ch 5 conservation eqn's (CV) for control volumes

C.$\forall$. in region of space mass crosses surface of c.$\forall$.

cons. of mass $\sum_{in} \dot{m} = \sum_{out} \dot{m} + \frac{d}{dt}(m)_{c\forall}$ $\frac{d}{dt}$ = derivative qua time

pv = flow of work per unit mass

where mass comes in, pv is work by surr. on c.$\forall$. (energy in)

where mass leaves c$\forall$, pv is work done by c$\forall$ on surroundings

cons. of energy for steady state w/in c.$\forall$. steady flow at surface

$$\dot{Q} = \sum_{in}(\underbrace{u + pv}_{h} + v^2/2 + gz)\,in$$

$$= \dot{W} + \sum_{out}(h + v^2/2 + gz)\,in$$

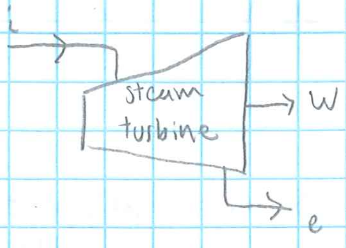
$\dot{Q}$ = heat trans. rate into c.$\forall$.

* if conditions inside c.$\forall$. vary with time but are spatially uniform, add following in term on right hand side: $\frac{d}{dt}\left[m\left(u + v^2/2 + gz\right)\right]_{c.\forall.}$

sometimes unsteady problem is specified by time interval, then

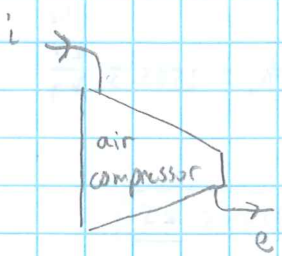
$${}_1Q_2 + \sum_{in} m(h + v^2/2 + gz) = {}_1W_2 + \sum_{out} m(h + v^2/2 + gz) + \underbrace{m(u_2 + v_2^2/2 + gz_2)\;(-m(u_1 + v_1^2/2 + gz_1))}_{\text{increase of energy inside the c.}\forall.}$$

— example —



1st law $q + h_i = w + h_e$

usually ≈ 0



1st law $h_i = w + h_e$ ← (exit)

$w > 0$

Notes ~~12~~ 2-8

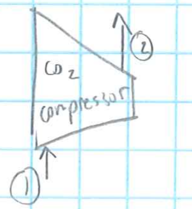
5-54) ① 10 MPa 500°c ② 10 kPa $x = .9$ $\dot{m} = ?$ (kg/s)

A-6 $h_1 = 3375.1$ kJ/kg A-5 p918 $h_2 = .1(\underset{h_f}{191.81}) + .9(\underset{h_g}{2583.9}) = 2344.7$

$w = h_1 - h_2 = 1030.4$ kJ/kg

$\dot{m} = \frac{power}{w} = \frac{500 \text{ kJ/s}}{1030.4 \text{ kJ/kg}} = 4.85$ kg/s

5-59) ① 100 kPa 300°K ② 600 kPa 450°K $\dot{m} = .5$ kg/s



$\dot{V}_1 = ?$ $\dot{W} = ?$

911 $R = .1889$ $v_1 = \frac{RT_1}{P_1} = \frac{.1889 \frac{kN \cdot m}{kg \cdot K}(300°K)}{100 \text{ kN/m}^2}$

$= .5667$ m³/kg $\dot{V} = \dot{m} v_1 = .5$ kg/s $(.5667$ m³/kg$) = 2833$

$T_{avg.} = \frac{300 + 450}{2} = 375°K$ p912 $C_p =$ specific heat $\frac{\underset{(350°K)}{.895} + \underset{(400°K)}{(.939)}}{2} = .917$

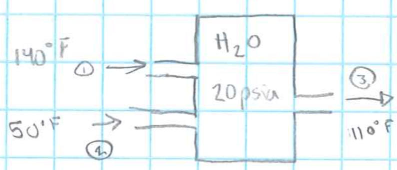
$h_2 - h_1 = (C_p)_{avg.}(T_2 - T_1) = .917 \frac{kJ}{kg \cdot K}(150°K) = 137.55 \frac{kJ}{kg}$

1st law $\cancel{q} + h_1 = w + h_2$ $w = -137.55$ kJ/kg power $= \dot{m}w = .5(-137.55) = -$

$\boxed{= -68.78 \text{ kJ/sec}}$

Test: 2 questions probably, Ch 3 & 4

Example 5-9



@ 20 psi $T_{sat} = 227.92°F$

so ① ② ③ are compressed liquid

since ①, ②, & ③ are all same pressure,

$h_1 = h_f \langle 140°F \rangle = 107.99$

$h_2 = h_f \langle 50°F \rangle = 18.07$

$h_3 = h_f \langle 110°F \rangle = 78.02$

A4E .966

rather than $h = h_f + (P - P_{sat}) v_f$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 = \dot{m}_1 h_3 + \dot{m}_2 h_3$

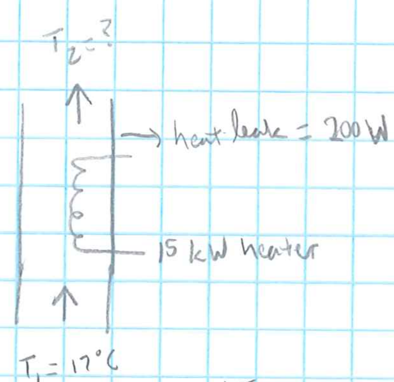
$\dot{m}_3 = \dot{m}_1 + \dot{m}_2$

$\dot{m}_1 (h_1 - h_3) = \dot{m}_2 (h_3 - h_2)$

5-10 - get it from scott.

Notes 2-12

ex 5-11



$\dot{V} = 150\ m^3/min$
$= \_\_\_\_\ m^3/s$

$v_1 = \frac{RT_1}{P_1} = \frac{kJ}{kg \cdot k} = \frac{(17+273)°K}{100\ \frac{kN}{m^2}} \left(\frac{1\ kN \cdot m}{kJ} \right)$

p911

$= .832\ m^3/kg$

$\Rightarrow \dot{m} = \frac{\dot{V}}{v} = 3.0\ kg/s$

1st law $\dot{m}h_1 + 15\ \frac{kJ}{s} = .2\ \frac{kJ}{s} + \dot{m}h_2$

300°K $C_p = 1.005\ \frac{kJ}{kg \cdot K}$

$14.8\ \frac{kJ}{s} = 30\ kg/s\ \ 1.005\ \frac{kJ}{kg \cdot K} \underbrace{(T_2 - 17°)}_{4.908}$

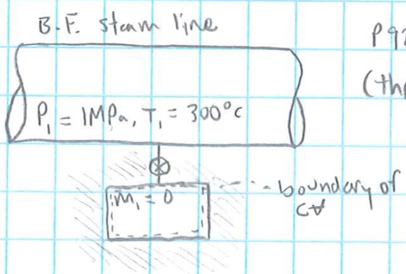
$T_2 = 21.91°C$

p 249 1st Law for unsteady C.V., no kinetic energy or potential energy written for time interval ① at start & ② at end

$${}_1Q_2 + \sum_{in} mh = {}_1W_2 + \sum_{out} mh + \underbrace{[m_2u_2 - m_1u_1]}_{\text{inside } c\forall}$$

steady or an avg.

ex 5-12



p921 $h_i = 3051.6$ no change in h across the valve (throttling process is const. h.) 1st law —

$m_ih_i = m_2u_2 \quad m_2 = m_i$ (cons. of mass)

$u_2 = 3051.6 \quad P_2 = 1MPa \quad$ p921 @ 1MPa

T	u
500	3125.0
400	2957.9
T_2	3051.6

interpolate $T_2 = 456.1$

H/W

Homework 5-69)

69) ① 2000 kPa $T_{sat} = 212.38°C$

② 100 kPa 120°C $x = ?$

$q \simeq 0,\ W = 0,\ \Delta pe = 0$

$\Delta ke \simeq 0\quad h_2 \approx h_1$ kJ/kg

h_2: 100 – 2675.8, 150 – 2776.6; 120° ⇒ 2715.42

$h_1 = 2715.4$ kJ/kg $= x(2798.3) + (1-x)(908.47)$

$1806.93 = x(2798.3 - 908.47)$

$\boxed{x = 0.956}$

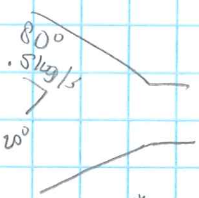
78) hot 80°C $\dot{m} = .5$ kg/s H_2O mix: 42°C P = 250 kPa example P244

cold 20°C $\dot{m} = ?$

$\Delta m_{cv} = 0\quad \Delta E_{cv} = 0$

$ke \simeq pe \simeq 0\quad \dot{Q} = 0$, no work

compressed ~~sat.~~ liquid



compressed ~~sat.~~ liquid

$h_1 = h_f = 335.02$

$h_2 = h_f = 83.915$

$h_3 = h_f(42°) = 175.89$ kJ/kg

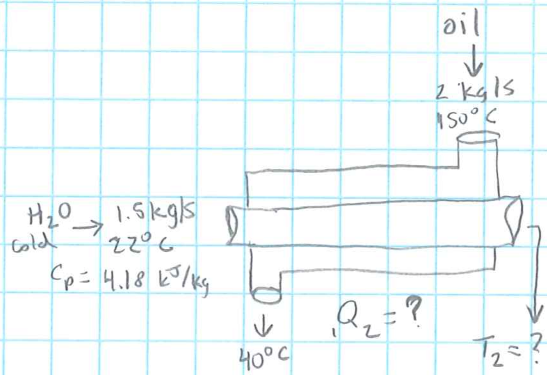
* comp. liq. can be approx. by sat. liquid

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \cancel{\dot{m}_3 h_3}\ (\dot{m}_1 + \dot{m}_2) h_3$

$\dot{m}_2 h_2 = m_1 h_3 + m_2 h_3 - m_1 h_1$

$\dot{m}_2 (h_2 - h_3) = m_1 (h_3 - h_1)$

$m_2 = \dfrac{.5(\quad)}{(\quad)} = \boxed{0.865 \text{ kg/s}}$



87) * kinetic & potential = negligible

heat loss negligible $ke \simeq 0\quad pe \simeq 0\quad \dot{Q} \simeq 0$

Oil : $C_p = 2.2$ kJ/kg·K

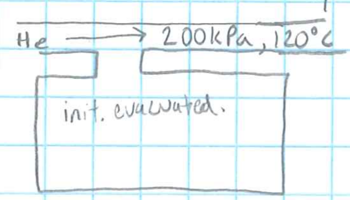
Oil: $\dot{Q} = \dot{m} c_p (T_{in} - T_{out}) = 2(2.2)(150 - 40) = 484$ kJ/s

H_2O: $\dot{Q} = \dot{m} c_p (T_{out} - T_{in})\qquad 484 = 1.5(4.18)(T_2 - 22°) = -137.94 + 6.27 T_2$

$\boxed{T_2 = 99.2°C}$

5-121) $\Delta V = 0$ $\quad {}_1Q_2 = 0$ $\quad {}_1W_2 = ?$

T_2 in tank = ?



$R = 2.0769\ kJ/kg\,K$ $\quad C_v = 3.1156$

$C_p = 5.1926\ kJ/kg\cdot K$

$v_{line} = \frac{RT_{line}}{P} = 4.081\ m^3/kg$ $\quad w_{flow} = Pv = 200\,kPa\,(4.0811\ m^3/kg) = 816.2\ kJ/kg$

$h = u + PV$

$h = u + RT$

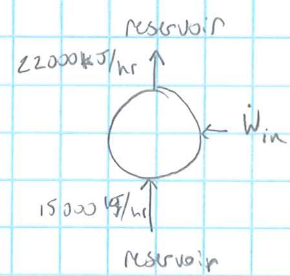
$u_{tank} = h_{line}$ $\quad h_{line} = C_p T_{line} = 5.1926(120+273) = 2040.7\ kJ/kg$

$u_{tank} = C_v T_{tank}$ $\quad 2040.7\ kJ/kg = (3.1156)T_{tank} \Rightarrow T_{tank} = 655.0°K$

6-52) 15,000 kJ/h cooling reject 22,000 kJ/hr heat find COP

1st Law $\dot{W}_{net\,in} = \dot{Q}_H - \dot{Q}_L = 22 - 15 = 7000\ kJ/h$

$COP_R = \frac{\dot{Q}_L}{\dot{W}_{net\,in}} = \frac{15000}{7000} = 2.14$



6-54) $T = 23°$ $\quad COP = 2.5 = \frac{\dot{Q}_L}{\dot{W}_{net\,in}}$

$\dot{Q}_H = 60{,}000 - 4{,}000 = 56{,}000\ kJ/h$

$\dot{W}_{net\,in} = \frac{\dot{Q}_H}{COP_{HP}}\left[\frac{1\,kW}{3600\ kJ/hr}\right] = 6.22\ kW$

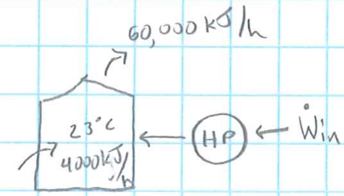
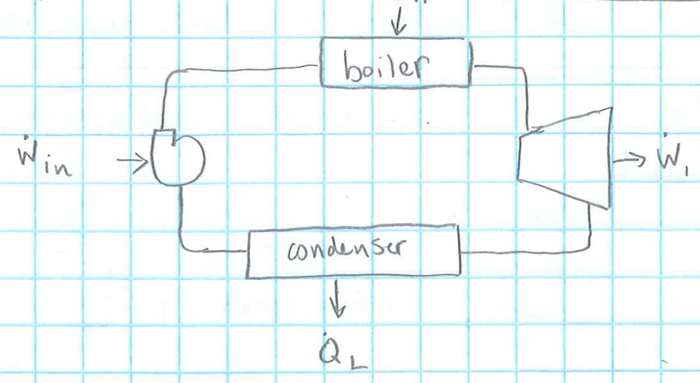


Fig 287 6-10 Steam pwr plant



$\dot{W}_{in} << \dot{W}_1$
└ backwork

— ex. $\boxed{6.1}$ & $\boxed{6.2}$ covered in class

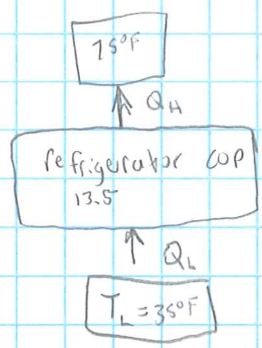
— Notes 2-19 —

ex. 6-4 & 6-5 covered

1st law ⇒ $Q_H = Q_L + W$

6-6 reversible engine ⇒ $\frac{Q_H}{Q_L} = \frac{T_H}{T_L}$

$T_H = 75°F$ $T_L = 35°F$



highest COP is for $\frac{Q_H}{Q_L} = \frac{T_H}{T_L}$

1st law $Q_L + W = Q_H$

$W = Q_H - Q_L$

$= Q_L \left(\frac{Q_H}{Q_L} - 1 \right)$

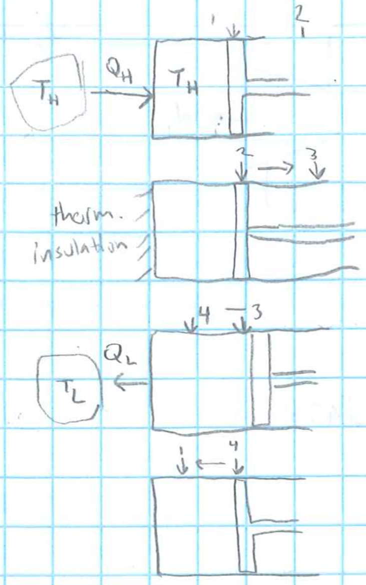
$= Q_L (.0808)$

$(COP)_{max} = \frac{\text{desired}}{\text{cost}} = \frac{Q_L}{W} = \frac{1}{.0808} = 12.38$

6-7) Q_H must = 135,000 kJ/hr $\frac{135\,000}{\dot{Q}_L} = \frac{294}{268}$

$\dot{W} + \dot{Q}_L = \dot{Q}_H$ $\dot{W} = 11939$ kJ/hr $\left(\frac{1}{3600} \frac{kW}{kJ/hr} \right) = \boxed{3.316\ kW}$

P 304 6-37 carnot heat engine Ideal gas, in cyl. piston



1-2, isothermal heat addition

adiabatic $T_2 = T_H$ $T_3 = T_L$

$P\forall^k = const$ $k = \frac{c_p}{c_v}$

isothermal $P\forall = const$

adiabatic compression

path $PV^k = const.$

6-83 E

reversible $T_H = 1500R$ $W = 5hp$

$T_L = 500R$ $\dot{Q} = ?$

efficiency $\boxed{\eta_{th,rev} = 1 - \frac{T_L}{T_H}}$

$= 1 - \frac{500}{1500} = 66.6\%$ $5hp = .667\,\dot{Q}$

$\dot{Q} = \frac{5(2544.5\ Btu/hr)}{.667} = \boxed{19084\ \frac{Btu}{hr}}$

6-98

reject 300 kJ/min

$T_L = -8°C$

$T_H = 25°C$

$Q = 2710$ kJ/min (

$COP_{r,rev} = \frac{1}{(T_H/T_L) - 1} = 8030$ $\dot{W}_{net\,in} = \frac{\dot{Q}_L}{COP_{R,max}} = \frac{300\ kJ/min}{8.03} = 37.36\ kJ/min$

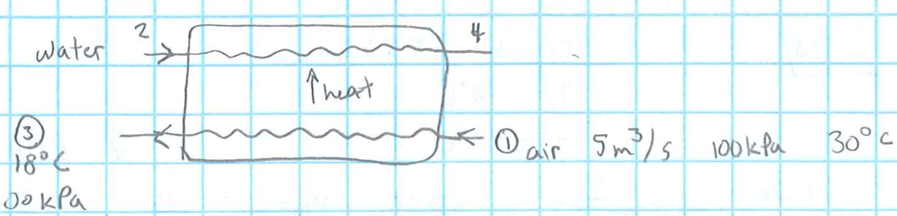
$\boxed{\dot{W}_{net\,in} = .623\ kW}$

Notes 2-24

recall $h = u + Pv$

find h without compressed liquid tables $\quad h_2 \approx h_f\langle 40°C\rangle + v_f\langle 40°C\rangle\left[5\,MPa - P_{sat}\langle 40°C\rangle\right]$

5-97)



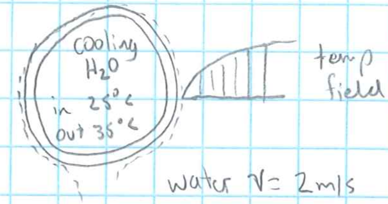
$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \underset{\dot{m}_1}{\dot{m}_3} h_3 + \underset{\dot{m}_2}{\dot{m}_4} h_4$$

air $\quad P_1 v_1 = RT_1 \Rightarrow v_1 = .8696\ m^3/kg \qquad \dot{m}_1 = \frac{\dot{V}_1}{v_1} = \frac{5\ m^3/s}{.8696\ m^3/kg} = 5.75\ kg/s$

$h_3 - h_1 = \underset{1.005\ kJ/kg\cdot K}{(C_p)_{air}}\ (18-30) \qquad$ Table A3 p914 $\qquad C_{H_2O} = 4.18\ kJ/kg\cdot K$ @ 25°C

$$2\ kg/s\left(4.18\ \frac{kJ}{kg\cdot K}\right)(8 - T_4\ °C) = 5.75\ kg/s\ \ 1.005\ kJ/kg\cdot K$$

Notes 2-26



$\boxed{5\text{-}175}$ $\dot m_{liq\ water} = \frac{2m}{s}\ \frac{\pi}{4}(.03m)^2\ \frac{1}{.001004\ m^3/kg}$

$= .00141\ m^3/s$

C.V #1 inside of tube (enclosed liq. water)

$\dot Q + \dot m h_{in} = \cancel{\dot W}^{0} + \dot m h_{out}$

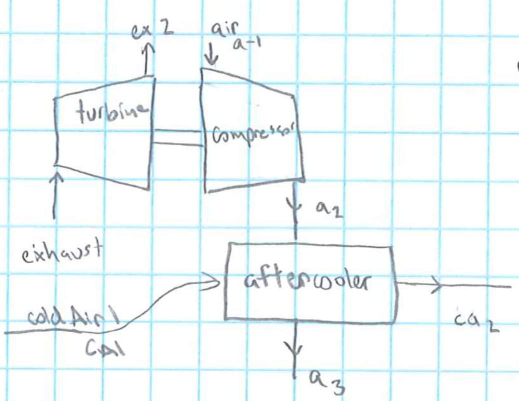
$\dot Q = 1.408\ kg/s\ C_{liquid\ water}\ (35° - 25°)\ 4.18\ kJ/kg°K = \boxed{58.86\ kJ/sec}$

C.V. all the steam (about to condense) + condensation

$\dot Q + \dot m_{cond} h_g = \dot m_{cond} h_f$

$-58.86 = \dot m\ (h_f - h_g)$ $\dot m = \frac{58.86\ kJ/s}{h_{fg} \leftarrow 2406.0\ (h_g - h_f)_{40°C}}$

5-202 turbocharger + aftercooler I.C.E.



ex_1 400°C 120 kPa .02 kg/s

ex_2 350°C

a_1 50°C 100 kPa

a_2 130 kPa T = ? ← 108.6

a_3 80°C

ca_1 $\dot V$ = ? 30°C

ca_2 40°C

C.V. around turbine $.02\ kg/s\ h_{ex_1} + \cancel{\dot Q}^{0} = \dot W_{turb} + .02\ kg/s\ h_{ex_2}$

Table A-2b C_p(air) @ (375°C + 273) (1.063)

$\dot W_{turbine} = .02\ \frac{kg}{s}\ 1.010\ \frac{kJ}{kg\cdot K}\ (400-350)°K = 1.063\ \frac{kJ}{s} = kW \approx 1hp$

C.V. around compressor $.018\ kg/s\ h_{a_1} + \cancel{\dot Q}^{0} = \dot W + .018\ kg/s\ h_2$ * $\dot W = -1.063$

C_p @ 50 + 273 = 323°K = 1.008

$.018\,(1.008)(T_{a_2} - 50°) = 1.063\ kJ/s$ $T_{a_2} - 50 = 58.59$ $\boxed{T_{a_2} = 108.6°C}$

CV ~~around~~ hot side of cooler: $.018\ \frac{kg}{s}\ C_p 108.6°C + \dot Q = .018\ C_p(80)$ $C_{p\ 368K} \approx 1.01$

$\dot Q = (-.018)(1.01)(28.6) = -.52\ kJ/s$

CV around cold side of cooler: $\dot m_{ca}\ (1.005\ kJ/kg\cdot K)(30 + 27\cancel{3.15})$ cancel $+ \dot Q\ .52\ kJ/s = \cancel{\dot W}^{0} + \dot m_{ca}(1.005)(40)$

$\dot m_{ca} = \frac{.52\ kJ/s}{1.005\ kJ/kg°K} = .10348\ kg$

$PV = \dot m RT$ $v_{ca_1} = \frac{RT}{P} = \frac{\frac{kN\cdot m}{kg\cdot K}(.287)(30 + 273.15)}{100\ kN/m^2} = .045\ m^3/s$

Notes 3-1-10

Ch 7 – Entropy

Entropy $\quad dS = \left(\frac{\delta Q}{T}\right)_{rev}$

δQ is small amount of heat transfer during a reversible process
T is abs. temp at system boundary where δQ happens
δS is change in entropy

uses: for turbo machines, ideal process is constant entropy path.

Ex 7-2

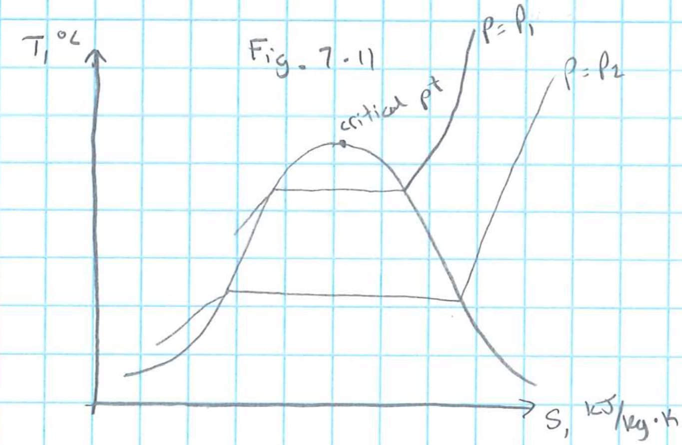
take heat source as system #1 $\quad (S_2 - S_1)_{source} = \int \frac{\delta Q}{T}$

$(S_2 - S_1)_{source} = \frac{-2000\ kJ}{800} = -2.5\ \frac{kJ}{°K}$

$(S_2 - S_1)_{sink} = \frac{2000}{500} = 4.0\ kJ/K$

$(S)_{gen} = (S_2 - S_1)_{source} + (S_2 - S_1)_{sink}$ $\quad 4 - 2.5 = \boxed{1.5\ kJ}$ part a

pt. B) $(S_2 - S_1)_{sink} = \frac{2000\ kJ}{750\ °K} = 2.66 \quad +2.66 - 2.5 = \boxed{.166\ \ kJ/°K}$



Ex 7.5

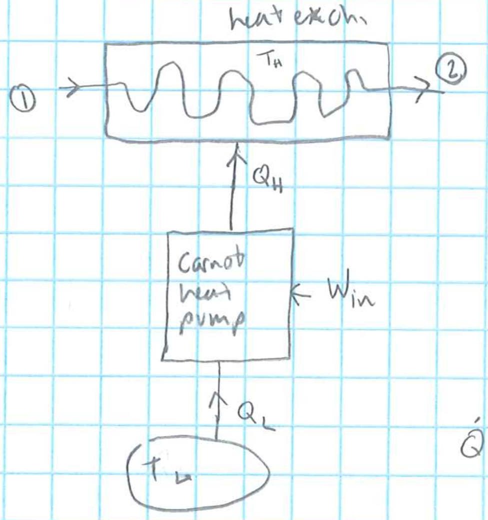
1^{st} law $\cancel{q}^{0} + h_1 = w + h_2$ $\quad ds = \left(\frac{\delta q}{T}\right)_{rev}$

$s_2 = s_1$

state 1

interpolate s vs. h to get h_2

Quiz ans



$\dot{m}h_1 + \dot{Q}_H = \dot{m}h_2$

Tsat ⟨30 psi⟩ = 250.3°F

$h_{fg} = 945.21$

$\dot{Q}_H = \frac{600\,lbm}{3600\,sec}\left(945.21\,\frac{Btu}{lbm}\right) = 157.53\,Btu/sec$

$\frac{\dot{Q}_H}{\dot{Q}_L} = \frac{T_H}{T_L} = \frac{(250.3+460)°R}{(60+460)°R}$

$\dot{Q}_L = 115.33\ Btu/sec$

1^{st} Law $\quad \dot{W} + Q_L = Q_H \Rightarrow \dot{W} = 42.2\ Btu/sec$

$= 44.5\ kW$

this = 151920 Btu/hr, same as my answer

p351 ex 7-6

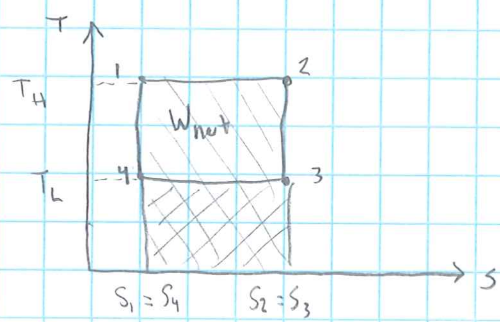
T-S diagram

1-2 isothermal heat addition

2→3 adiabatic expansion

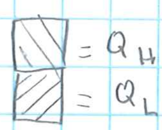
3→4 isothermal heat rejection

4-1 adiabatic compression



thermal efficiency $\eta = \frac{desired}{cost}$

$= \frac{W}{Q_H}$ ← for refrigerator



$A_{1234} = W_{net}$

Notes 3-3

T-ds relations

(7-23) $T\,ds = du + P\,dv$ * use for incompressible
(7-24) $T\,ds = dh - v\,dP$

* Notes 3-5

Chapter 5 review

p257 $\dot{m} = \rho V A$ (density · velocity · area)

$\dot{V} = VA = \dot{m} v$

Energy transfer due to mass flow into C.V. mass = $\theta = \underbrace{u + \overset{\text{flow work}}{Pv}}_{h} + \underbrace{\frac{V^2}{2} + gz}_{\text{kinetic \& potential}}$ usually neglect kinetic & potential

p258 steady state: no changes w.r.t. time inside C.V.

Steady flow: no change with time at boundary where mass crosses

$\dot{Q} + \sum_{in} \dot{m}h = \dot{W} + \sum_{out} \dot{m}h$

no kinetic or potential energy

— water that stays liquid $h_2 - h_1 = c(T_2 - T_1) + v_f\langle T_1\rangle[P_2 - P_1]$
* $h = u + Pv$ *

otherwise use a steam table

— ideal gas (air, He, N_2, etc) $h_2 - h_1 = C_p(T_2 - T_1)$
* h not a function of P, just T * — at any time

— Uniform flow $\sum m_{in} = \sum m_{out} + (m_2 - m_1)_{CV}$
— at end of time interval

☆ energy $Q + \sum_{in} hm = W + \sum_{out} mh + [m_2u_2 - m_1u_1]_{c.v.}$

Focus on steady state / steady flow probs
- do unsteady control volume problems last. (☆ energy)
- know heat engines & heat pumps

Test 2 review

Notes 3-5

$$\frac{\dot{Q}_H}{\dot{Q}_L} = \frac{T_H}{T_L}$$ ~ use absolute temperature

°R = °F + 460

°K = °C + 273.15

Test will be 2 questions

Chap 7

p-357. for liquids & solids $s_2 - s_1 = C_{avg} \ln \frac{T_2}{T_1} = 0 \Rightarrow T_2 = T_1$

p-361 for ideal gas, $s_2 - s_1 = C_{v\,avg} \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1}$

$$= C_{p\,avg} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

★ for C_{pavg}, use C_p of avg. temp

-p362 Variable specific heats - skip

Ex 7-9 pt. b air ① 100kPa 17°C ② 600kPa 57°C

Table A2-b @ 300K $C_p = 1.005$

interpo. @ 310° $C_p = 1.006$

$$s_2 - s_1 = C_{pavg} \ln \frac{57 + 273.15}{17 + 273.15} - R \ln \frac{600}{100}$$

37 + 273 = 310°

$s_2 - s_1 = -.3842 \frac{kJ}{kg \cdot K}$

if set $s_2 - s_1 = 0$ in eq 7-33 & 7-34

$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^k$ $k = c_p / c_v$ $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\left(\frac{k-1}{k}\right)}$ $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$

also 7-45, 46, 47 tell whole path pv^k = const.

reversible adiabatic ⇒ isentropic ⇒ $s_2 = s_1$

P 368 $\Delta S = \frac{Q_H}{T_H} + \frac{Q_L}{T_L}$

$W_{rev\,(out)} = -\int_1^2 v\,dP$

7-10 car engine

① air 22°C 95 kPa $\quad \frac{V_1}{V_2} = 8$

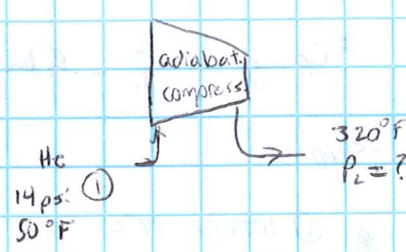
② $T_2 = ?$

$$\frac{T_2}{22 + 273.15} = (8)^{(1.4-1)} = 2.297$$

$\frac{22}{295.15}$ $\quad T_2 = 678.1°K$, $404.9°C$

$k_{He} = 1.667$

ex 7-11



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

$$\frac{P_2}{14} = {}^{.667/1.667}\sqrt{\frac{320+460}{50+460}} \qquad P_2 = 40.486$$

redo 7-10 Practice 3-16-10

① 22°C 95 kPa $\quad V_1/V_2 = 8 \quad$ adiabatic

② $T_2 = ?$

$$\frac{T_2}{(22+273)} = (8)^{k-1} \qquad k = \frac{1.005}{.718} = \frac{c_p}{c_v} = 1.40$$

$$T_2 = (8)^{.4}(295) = 678°K = \boxed{405°C}$$

7-25

"this prob is important"

1200°K

600°K

$$dS = \left(\frac{\delta Q}{T}\right)_{rev}$$

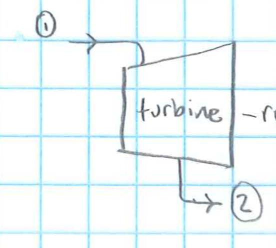
$$(S_2 - S_1)_H = \frac{-100\text{ kJ}}{1200}$$

$$(S_2 - S_1)_L = \frac{+100}{600}$$

$$(S_2 - S_1)_{univ} = 100\text{ kJ}\left(\frac{2}{1200} - \frac{1}{1200}\right) = \frac{100\text{ kJ}}{1200°K}$$

$$\boxed{8.33 \times 10^{-2}\ \frac{\text{kJ}}{°K}}$$

7-35 E R134a



– rev. adiabatic

① 250 psia 175°F

② 20°F $s_2 = s_1$

① is SHV – would need double interpolation in tables

Program: $h_1 = 130$ $s_1 = .233$

$h_2 = 107$

$h_2 - h_3 = -23$ Btu/lbm

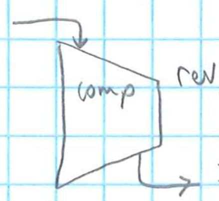
7-37 H_2O

① 35 kPa

160°K

$h = 2800.1$

$s = 8.151$



rev, adiabatic $S_2 = S_1$

300 kPa

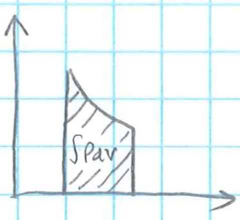
$h = 3356.8$

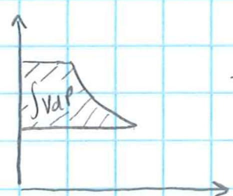
$T = 439.1$°C

① & ② are SHV again, ~~need~~ use Engineering Equation solver (EES)

P368 $w = -\int_1^2 v\,dP$

Flow Process





– this neglects ΔKE, ΔPE

example 7-12

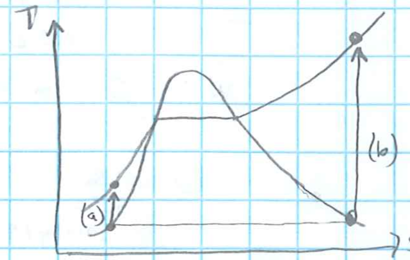
a) liquid along entire path (pump)

$$w = \int v\,dP = -v_f \langle 100kPa \rangle [1MPa - 100kPa]$$

Table A5 $v_f = .001043$

$$w_A = -.001043 \frac{m^3}{kg} [1000 - 100] \frac{kN}{m^2}$$

$$= -.9388 \frac{kN \cdot m}{kg} \Rightarrow \frac{kJ}{kg}$$



Path b) 1^{st} law $h_1 + q = w + h_2$

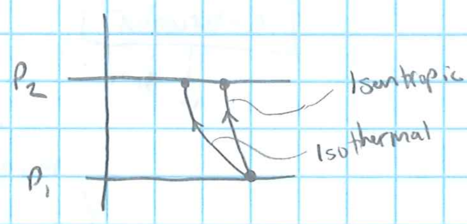
$h_1 = h_g \langle 100kPa \rangle = 2675 \frac{kJ}{kg}$

$s_1 = s_g \langle \text{"} \rangle = 7.3589$

② $P_2 = 1MPa$ $s_2 = 7.3589$ $h_2 = 3194.5$

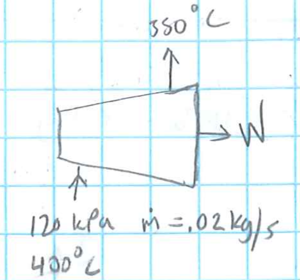
$w = h_2 - h_1 = -519.5 \, kJ/kg$

7-45



Ch 5 practice

202)

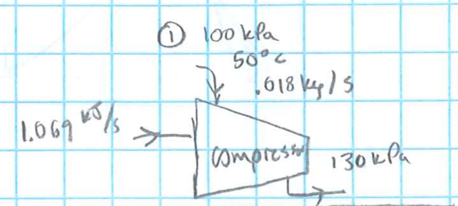


use average temp

$h_2 - h_1 = C_p (T_2 - T_1)$

$\dot{W} = \cancel{\dot{Q}}^0 - \dot{m}(h)$ $\dot{W} = .02 \ (h_2 - h_1)$

$= .02 \left(\frac{1.063 + 1.075}{2}\right)(-50°) = 1.063$ kJ/s or kWatts

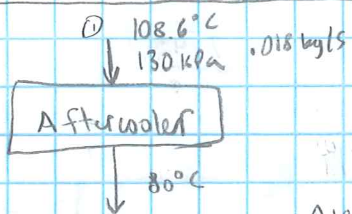


$\dot{W} = \dot{Q}^0 - \dot{m}(\Delta h)$ $\dot{m} C_p (T_2 - T_1)$

$1.063 \text{ kW} = -.018 \text{ kg/s} (1.008)(\Delta T)$

$T_2 = 50° C + 58.6°C$

$\boxed{T_2 = 108.6°C}$



compressed ambient

$\dot{m}(h_2 - h_1) = \dot{m}(h_2 - h_1)$

$.018 \text{ kg/s} (1.008)(28.6°) = \dot{m}(1.005)(10°)$

$\dot{m}(\text{ambient}) = .05163$ kg/s

$\dot{V} = \dot{m}(v)$

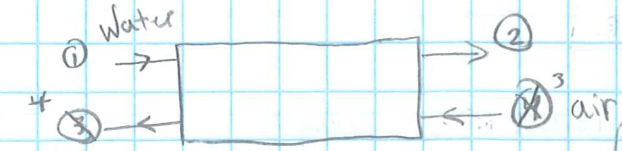
$Pv = rt$

$v = \frac{rt}{P} = \frac{.2870(303°K)}{100 \text{ kPa}} = .86961 \text{ m}^3/\text{kg}$

$\dot{V} = .8696 \text{ m}^3/\text{kg} (.05163) \text{ kg/s} = .0449 \text{ m}^3/\text{s} = \boxed{44.9 \text{ liter/sec}}$

Ch 5 practice

5-97)



① H_2O 8°C
$\dot{m} = 2\,kg/s$

③ $5\,m^3/s$ 100kPa 30°C
④ 100kPa 18°C

$\dot{m} = \frac{\dot{V}}{v}$ $\frac{5}{.8169\,m^3/kg}$

$v = \frac{RT}{P} = \frac{.2870(303°K)}{100}$

$\dot{m} = 5.7497$

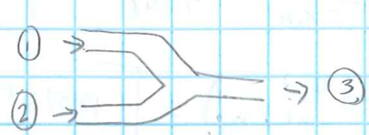
$Q = 0$ $W = 0$ $\sum_{in} \dot{m}h = \sum_{out} \dot{m}h$

$2\,kg/s\,(4.22)\,kJ/kg°C\,(\Delta T) = 5.7497\,kg/s\,(1.005)(12°)$

$\Delta T = 8.2158$ $\boxed{T_2 = 16.22°C}$

Why does book choose specific heat C_p of water to be 4.18 @ 8°C (Table A-3)

5-78)



① 80°C, $\dot{m} = .5\,kg/s$ 250 kPa ③ 42° 250 kPa
② 20°C 250kPa

$h_1\dot{m}_1 + h_2 m_2 = h_3(m_1 + m_2)$
$167.51 + 83.915 m_2 = 87.947 + 175.89 m_2$
$79.563 = 91.975 m_2$
$\boxed{= .8651\,kg/s}$ ✓ Great!

$h_1 = 335.02$ $h_2 = 83.915$
$h_3 = \frac{2}{5}(h_{45} - h_{40}) + h_{40} = 175.894$

Ch. 6 practice

52) Fridge 15,000 kJ/hr cooling
22,000 kJ/hr heat rejected $COP_R = \frac{Q_L}{W_{net\,in}}$

$$\frac{15{,}000/hr}{(22{,}000 - 15000)/hr} = \boxed{2.14}$$

54) $T_H = 23°C$ $Q_{out} = 60{,}000$ kJ/hr $Q_{in} = 4{,}000$ kJ/hr COP = 2.5

$\cancel{\frac{T_H}{T_L}}$ $\cancel{\frac{Q_H}{Q_L}}$ $\frac{Q_H}{W_{net\,in}} = 2.5$ $Q_H = -56{,}000$ kJ/hr

$W_{net} = 22{,}400$ kJ/hr $= \boxed{6.22 \text{ kJ/sec} \\ \text{kW}}$

83 E) heat engine, reversible $T_H = 1500R$ $T_L = 500R$ $P = 5hp$

$$\eta = 1 - \frac{T_L}{T_H} = 0.667 \quad \frac{W_{net}}{\eta} = \frac{5}{.667} = 7.496$$

$Q_{in} = ?$ Btu/hr $7.496\left(2544.5 \frac{Btu}{hr}/hp\right) = \boxed{19073 \text{ Btu/hr}}$

98) refrigerator remove $Q_L = 300$ kJ/min $T_L = -8°C$
$T_H = 25°C$ min power in $COP_R = \frac{Q_L}{W_{net\,in}} = \frac{1}{T_H/T_L - 1}$

$$COP_R = \frac{1}{\left(25+273/-8+273\right) - 1} = 8.0303 = \frac{300}{W_{net\,in}}$$

$W_{in} = 37.359$ kJ/min $\left(\frac{1}{60}\frac{sec}{min}\right) = \boxed{.6226 \text{ kW}}$

$h_2 \approx h_f\langle 40°C\rangle + v_f\langle 40°C\rangle\left[5MPa - P_{sat}\langle 40\rangle\right]$
$167.53 + .001008\left[5000\,kPa - 7.3851\right]$
$167.53 + 5.033$

5-200) $\eta = .90$ 50L/s ① 100kPa ② 300kPa

mechanical efficiency

$15kW \times .9 = 13.5kW$ $h_2 = 561.43$ $h_1 = 417.61$

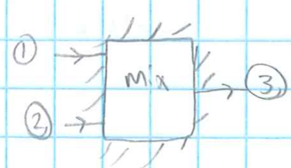
$50 L/s = .05\ m^3/s\ (1000\ kg/m^3) = 50 kg/s$

$\dot{m} = 50.00\ kg/s$

$\Delta E_{mechanical} = 50\frac{kg}{}\left(\frac{300kPa - 100}{1000\ kg/L}\right) = 10\ kJ/s$ $\boxed{\text{mech efficiency } \approx 74.07\%}$

$3.5\ kJ/s = Q_{in}$ $\Delta T = \dfrac{3.5\ kJ/s}{4.18\frac{kJ}{kg\cdot k}\left(\frac{50kg}{sec}\right)}$ $.0167°k$

Quiz 5 review



① $.5 kg/s$ 5MPa 400°C (SHV)

$h = 3196.7\ kJ/kg$

② $\dot{m} = ?$ 5MPa (comp. liquid) 40°C ③ $x = 1$ 4.5 MPa

~~$h = h_1 - 360°(4.8 kJ/kg\cdot k)$~~

~~$h_2 = 1468.7\ kJ/kg$~~

$h = h_{sat} - (T_{sat} - 40°)\,C_p$

$= \cancel{2794.2}$

$1154.5 - (263.94 - 40)(4.18)$

Ex 7-13 p 374 air compressor $1 \to 2$

① 100 kPa, 300K ② 900 kPa

a) isentropic (rev. adiabatic) $W = ?$ eq 7-56 $W = -\int_1^2 v\,dP$

eq. 7-47 $Pv^k = \text{const}$ path 7-56 perform integration

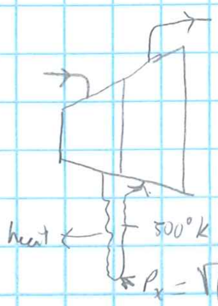
7-57a $$W = \frac{-kRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]$$

Table A-2 p 911 $k = 1.400$ $R = .2870 \frac{kJ}{kg\,°K}$

$W = -263.1$ Part b path $Pv^{1.3} = \text{const}$ $W = -246.4\ kJ/kg$

(c) isothermal $Pv = \text{const}$ $W = -\int_1^2 \frac{\text{const}\,dP}{P} = -\underset{(RT)}{\text{const}} \ln \frac{P_2}{P_1} = -.287(300)\ln 9$

$= -189.2$



$P_x = \sqrt{P_1 P_2} = 300\,kPa$

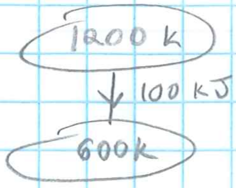
${}_1W_x = -107.65$

${}_xW_2 = -107.66$

Practice 3-16

7-25 redo

$\delta s = ?$



$\delta s_H = \frac{dQ}{T} = \frac{-100}{1200}$

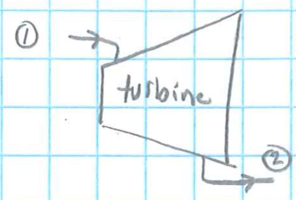
$ds_H = \frac{100}{600}$

$\delta s_{univ} = \frac{2}{12} - \frac{1}{12} = \frac{1}{12}$

$\boxed{= .08\overline{33}\ kJ/k}$

How the manual does it: $\Delta S = \frac{Q_H}{T_H} + \frac{Q_L}{T_L} = \frac{-100\ kJ}{1200\ K} + \frac{100\ kJ}{600\ K} = \boxed{.0833\ kJ/k}$

7-35E redo



① R134A 250 psia 175°F

Isentropic

② 20°F

$S/m = const$ $\Delta h = ?$

$\frac{\dot{Q}_H}{T_H} + \frac{\dot{Q}_L}{T_L} = 0$

$h_1 = 129.95$ Btu/lbm $s_1 = .23281$ Btu/lbm-R

$h_2 =$

Ex 7-9 practice

Air ① 100kPa 17°C 290°K 1.005 cp avg = 1.006

② 600kPa 57°C 330°K 1.007

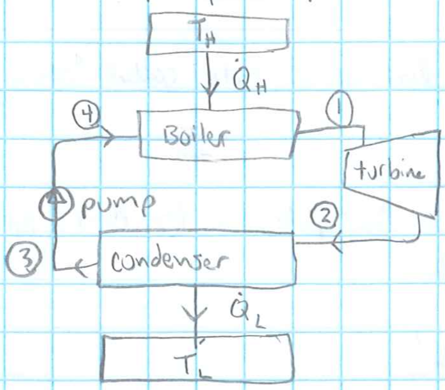
$\Delta s = C_{p\,avg} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

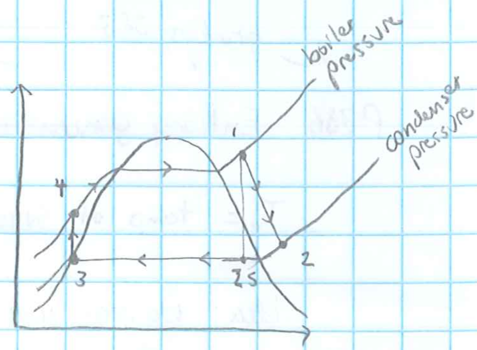
$= 1.006 \ln \frac{330}{290} - .2870 \ln \frac{600}{100}$

$= -.3842$

using $C_{p\,avg}$.

P 377 Vapor pwr cycle





$q_H = \int_4^1 T\,ds \qquad q_L = \int_2^3 T\,ds$

isentropic turbine efficiency $= \frac{{}_1W_2}{{}_1W_{2s}} = \eta_T$

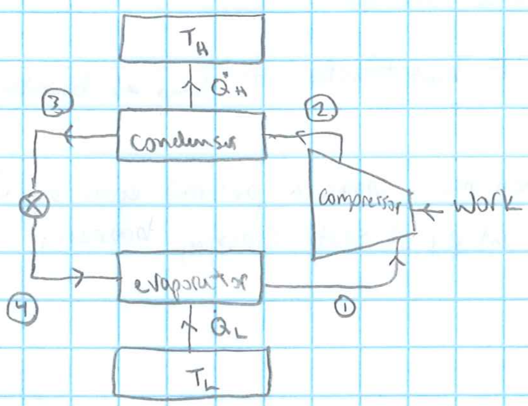
state 2s has same pressure as actual state 2

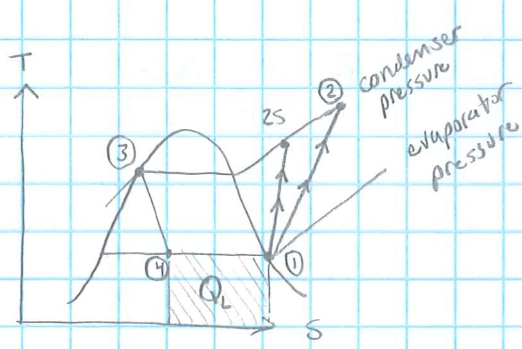
" " entropy " state 1

both ideal & real have Ø heat transfer

$\eta_T = \frac{h_1 - h_2}{h_1 - h_{2s}}$ (eq 7-61)

Vapor-Compression Refrigeration





$q_L = \int_4^1 \qquad q_H = \int_2^3 T\,ds \qquad Q_H = 1234 +$

isentropic compressor efficiency $= \frac{{}_1W_{2s}}{{}_1W_2} = \frac{h_{2s} - h_1}{h_2 - h_1}$ eq 7-63

P 386

start p. 383

Understand this Material

P386 Entropy generation (S_{gen})

lost work, later called "exergy destruction"

T_0 = temp of surroundings

idea: we can use carnot heat engines or heat pumps & free heat transfer with surroundings to get lost work

$$Work_{rev} - Work_{actual} = \text{"lost work"}$$

Eq. 7-68 System, Time interval, state 1 then state 2

$$S_{in} - S_{out} + S_{gen} = S_2 - S_1 \qquad \dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen} = \frac{ds}{dT}$$

S_{in} = entropy transferred into sys

Eq 7-71 $S_{heat} = \frac{Q}{T}$ $(T = const)$ Q = heat transfer T = temp at boundary

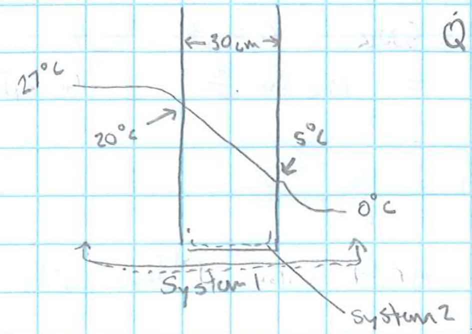
7-73 $S_{work} = 0$

7-74 $S_{Mass} = ms$ when mass comes in, put $\dot{m}s$ equal to S_{in}

s is entropy of stuff crossing boundary

Notes 3-17

P 388 Ex 7-17 'brick wall'



$\dot{Q} = 1035$ watts through 5x7m section

a) system 1 $\quad S_{in} + S_{gen} = 0 \quad \frac{1035 \text{ watt}}{27+273} - \frac{1035 \text{ watt}}{0+273°} + \dot{S}_{gen} = 0$

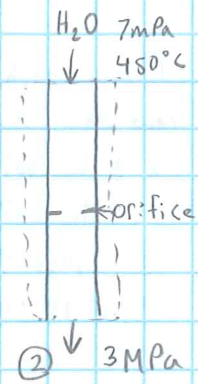
$$\boxed{\dot{S}_{gen} = .341 \frac{\text{watt}}{°K}}$$

b) Sys 2 $\quad S_{in} + S_{gen} = 0 \quad \frac{1035}{20+273} - \frac{1035}{5+273} \quad \dot{S}_{gen} = 0$

$$\boxed{\dot{S}_{gen} = .191 \text{ Watt}}$$

Notes 3-19

Ex 7-18 Throttling process



Sgen per unit mass $\quad 1^{st}$ law $h_1 = h_2$

p919 @ 700kPa $\quad t_{sat} = 285.8$ °C

∴ ① is SHV $\quad h_1 = 3288.3$

$s_1 = 6.6353 \frac{kJ}{kg \cdot k}$

② 3MPa $\quad h = 3288.3 \quad$ SHV A6 @ 3MPa

h	s
3231.7	6.9235
3288.3	s_2
3344.9	7.0856

$s_2 = 7.00455$

Entropy balance $\quad \dot{m} s_1 - \dot{m} s_2 + \dot{S}_{gen} = 0$ ← time rate of change of entropy in C.V.

$$\frac{\dot{S}_{gen}}{\dot{m}} = s_{gen} = s_2 - s_1 = .3693 \frac{kJ}{kg \cdot k}$$

Ex 7-19 drop hot metal into a lake

iron 50 kg $T_1 = 500K$ $c = .45\ kJ/kg \cdot K$

(a) $(S_2 - S_1)_{iron} = ? = mc \ln \frac{T_2}{T_1} = 50\ kJ \cdot .45\ \frac{kJ}{kg \cdot K} \ln\left(\frac{285}{500}\right)$

$= \boxed{-12.648\ kJ/°K}$

b) $(S_2 - S_1)_{lake}$ sys #1 is iron 1st law $_1Q_2 = \cancel{_1W_2}^{0} + m(U_2 - U_1)$

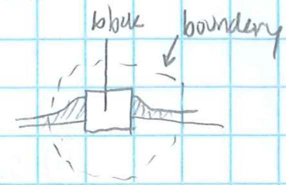
$= 50 kg\ (.45 \frac{kJ}{kg \cdot K})(285 - 500)°K$

$= -4838\ kJ$

system 2 = lake outside temp gradient in water

system 2 does not see heat transfer through gradient

$dS = \frac{\delta Q}{T} \Rightarrow (S_2 - S_1)_{lake} = \frac{4838}{285}\ kJ/°K$



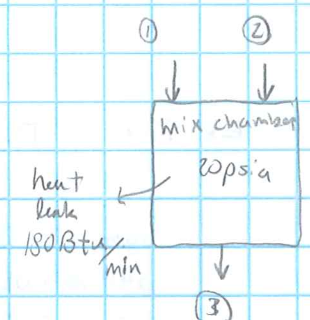
(c) entropy gen during process

$S_{gen} = (S_2 - S_1)_{iron} + (S_2 - S_1)_{lake}$

7-20 Ex

T E S T 2 P (1)

① 50°F 300 lb/min | comp liq
② 240°F | SHV
③ 130°F | comp. liq



1st law $\dot m_1 h_1 + \dot m_2 h_2 + \dot Q = \dot m_3 h_3$

cons mass $\dot m_3 = \dot m_2 + \dot m_1$

$h_1 \cong h_f \langle 50° \rangle = 18.07\ Btu/lb$ Table 9?1 $h_2 = 1162.3$

$h_3 = h_f \langle 130 \rangle = 97.99\ Btu/lb$ $s_2 = 1.7406$

$s_1 = .03609$

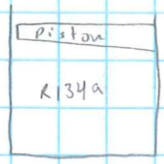
$s_3 = .18174$ plug in for 1st law, $\dot m_2 = 22.7\ lb/min$

entropy balance eq 7.77 $\dot S_{in} - \dot S_{out} + S_{gen} = \overset{0}{dS/dt}$

$300 \frac{lb}{min}\ .030609 \frac{Btu}{lbm°R} + 22.7(1.7406) - 322.7\ (.18174)$

$- \frac{180\ Btu/min}{70 + 460°R} + S_{gen} = 0 \Rightarrow S_{gen} = 8.65\ \frac{Btu}{min °R}$

7-52



① 240 kPa 20°C path: isothermal

② $x_2 = .2$ 20°C, ${}_1W_2 = ?$, ${}_1q_2 = ?$

$P_{sat}(20°C) = 572$ kPa ⇒ SHV

$u_f = 78.86$

$u_g = 241.02$ $u_2 = .8(78.86) + .2(241.02) = 111.29$

$s_f = .30063$ $s_2 = .8(.30063) + .2(.92234) = .4250$

$s_g = .92234$ $u_1 = 246.74$ (p931)

$s_1 = 1.0134$ (p931)

$ds = \frac{\delta q}{T} \Rightarrow \delta q = ds\,T$ $\int \delta q = \int T\,ds \Rightarrow$ isoth. $q = T(\Delta s)$

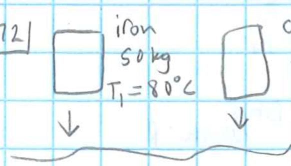
$q = (20 + 273.15)(.425 - 1.0134) = -172.5 \ \frac{kJ}{kg}$

1^{st} law ${}_1q_2 = {}_1W_2 + u_2 - u_1$ ${}_1W_2 = -172.5 + 246.74 - 111.29$

$\boxed{{}_1W_2 = -37.4 \ kJ/kg}$

$W_1 = \int_1^2 P\,dv$ true but non-constant P

7-72



$(S_2 - S_1)_{univ} = ?$

Table A 3B, 915 Iron, $C = .45$ kJ/kg·K

Cu, $C \approx .389$

1^{st} law iron ${}_1Q_2 = mc(T_2 - T_1)$

$= 50(.45)(15 - 80) = -1462$ kJ

1^{st} law Cu ${}_1Q_2 = 20(.389)(-65) = -505.7$ kJ

for lake as a system, not including temp. gradient $ds = \frac{\delta Q}{T}$

$(S_2 - S_1)_{lake} = \frac{1462 + 505.7}{15 + 273.15} = 6.829$ kJ/°K

for metals Fe $S_2 - S_1 = C_{avg} \ln\left(\frac{T_2}{T_1}\right)$ (mass) for non-specific

$= .45 \ln\left(\frac{288.15}{353.15}\right)(50kg) = -4.577$

Cu $S_2 - S_1 = .389 \ln(\text{—})\,20kg = -1.582$

$(ds_{univ}) = +.6694$ kJ/°K

Notes 3-23

Quiz answer 3-23

$ds = \left(\frac{dq}{T}\right)_{rev} \Rightarrow S_2 = S_1$

$h_1 + \cancel{q}^0 = h_2 + w$

$S_1 = .08(.01808) + .92(.22715) = .21042$

$h_1 = .08(\quad) \quad .92(\quad) = 93.537$

p979 @ 90 psia $\quad S_g = .22006 > S_2 \quad 0 > x > 1$

$.21042 = (1 - x_2)\, .07481 + x_2(.22006) \qquad x_2 = .93363$

$h_2 = 0.06637 \qquad 107.927$

$w = h_1 - h_2 = 14.39$ Btu/lbm

7-83) air, const. specific heat

① 200 psia $\quad$ 500 F $\qquad S_2 - S_1 = ?$

② 100 psia $\quad$ 50 F

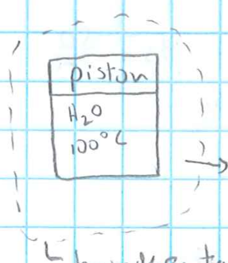
p361, eq. 7-34 $\quad S_2 - S_1 = (C_p)_{avg} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

$T_{avg} = \frac{50 + 500}{2} = 275$ F $\qquad$ p961 $\quad R = .06855$ Btu/lbm·R

p962 @ 300 $\quad C_p = .243$

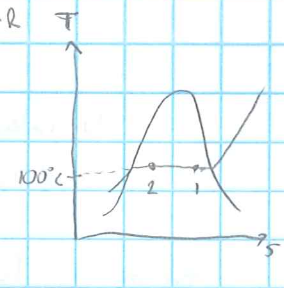
$S_2 - S_1 = -.06855$ Btu/lbm·R $\ln \frac{100}{200} = -.1062$ Btu/lbm·R

ex 7-21)



$0 < x_1 < 1$ $\quad$ const temp,

$0 < x_2 < 1$ $\quad$ const press.



a) $(S_2 - S_1)_{H_2O} = ?$

take h_2o as system

$ds = \frac{-600 \text{ kJ}}{373.15 \text{ °K}}$

b) S_{gen} (universe)

sum of sys. all @ 25°C $\quad (S_2 - S_1)_{gen} = \frac{600 \text{ kJ}}{25 + 273.15} = 2.012$

$(S_2 - S_1)_{H_2O} + (S_2 - S_1)_{surr.} = -1.61 + 2.012 = .4024 \frac{kJ}{°K} = (S_2 - S_1)_{univ.}$

$= S_{gen}$

7-95)

$M_1 = 4\,kg$

$P_1 = 450\,kPa$

$P_2 = 200\,kPa$

$M_2 = ?$

path: reversible, adiabatic

$ds = \frac{\delta Q}{T}_{rev} \Rightarrow ds = 0$

Ideal gas, const C

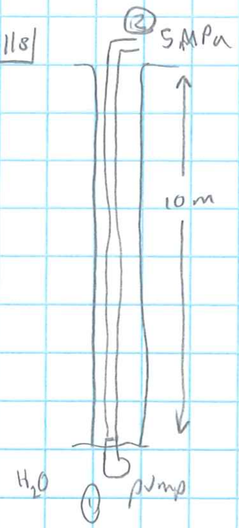
$pv^k = \text{const}$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$ $k = 1.667$ $\frac{T_2}{30 + 273.15} = \left(\frac{200}{450}\right)^{.4} = .72298$

$T_2 = 219.17\,°K$

$\frac{P_1}{P_2} = \frac{M_1 T_1}{M_2 T_2}$ $\frac{450}{200} = \frac{4\,kg}{m_2} \frac{303.15}{219.17}$ $m_2 \approx 2.46\,kg$

7-118)



"the most you can lift water by suction is 34 feet"

$\dot{W} = -7\,kW$

$\dot{m}_{max} = ?$

$\dot{m}_{max}$ is for reversible

${}_1W_2 = -\int_1^2 v\,dp$

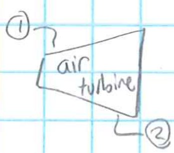
$9.81\,m/s^2 \; \frac{10\,m}{1\,kg/s^2 N}$

$\dot{W} = .001\,\frac{m^3}{kg}\; 4880\,\frac{kN}{m^2} - 98.1\,\frac{N \cdot m}{kg}\left(.001\,kN/N\right)$

$-7.00\,\frac{kJ}{sec} = \dot{m}\left(-4.978\,\frac{kJ}{kg}\right)$

$\dot{m} = 1.406\,kg/sec$

7-98)



① 150 PSIA 900°F 500 ft/s $A_1 = .5\,ft^2$

② 15 psia 100 ft/s $T_2 = ?$

isentropic

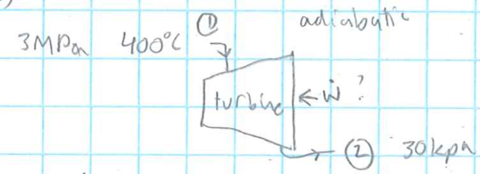
$\dot{m} = \frac{\dot{V}_1}{v_1} = \frac{A_1 V_1}{v_1}$ $P_1 v_1 = RT_1 \Rightarrow v_1 = 3.358\,ft^3/lbm$ $\dot{m} = 74.45\,\frac{lbm}{sec}$

$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$ book used $k = 1.377$ @ 600°F

we used $k = 1.4$ @ room temp

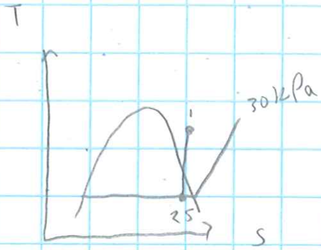
C_p @ 600°F p962 $C_p = .250\,BTU/lbm \cdot R$

7-128)



isentropic efficiency $= .92$

$\dot{m} = 2\ kg/s$



(1) SHV, $h_1 = 3231.7$

$s_1 = 6.9235$

(2s) $s_2 = s_1$

$P_2 = 30\ kPa$

$6.9235 = .9441(1 - x_{2s}) + x_{2s}(7.7675)$ $x_{2s} = .8763$

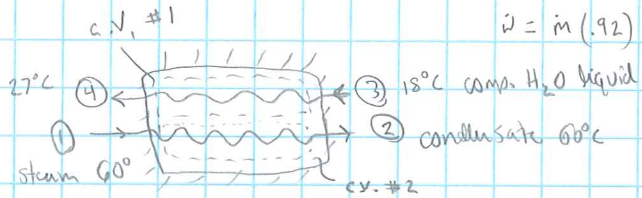
$h_{2s} = 2335.7$

1^{st} law for (1) → (2s) $h_1 + \cancel{q}^{0} = w_s + h_2$ $w_s = (3231.7 - 2335.7)\ kJ/kg$

$w = (.92)\ w_s$

$\dot{W} = \dot{m}\,(.92)\ w_s = \boxed{1649\ kW}$

7-147)



$\dot{m}_1 = ?$ $\dot{S}_{gen} = ?$

c.v. 1 : $\dot{Q} + \dot{m}_3 h_3 = \cancel{\dot{W}}^{0} + \dot{m}_3 h_4$ $\dot{Q} = 75\ kg/s\ \overset{4.18}{c}\ (T_4 - T_3) = 2822\ kg/s$

C.V. #2 : $\underset{2822}{\dot{Q}} + \dot{m}_1 h_1 = \cancel{\dot{W}} + \dot{m}_2 h_2$ $\dot{m} = \dfrac{\dot{Q}}{h_1 - h_2} = \dfrac{2822}{h_{gf}} = \dfrac{2822}{2357.7} = 1.20\ kg/s$

CV #3 whole system Entropy balance $S_{in} - S_{out} + S_{gen} = (S_2 - S_1)_{cv} = 0$ time steady

$\dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen} = 0$

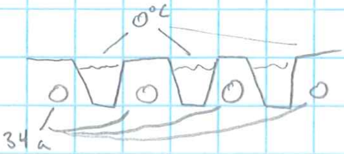
$\dot{m}_1 s_1 + \dot{m}_2 s_2 - [\dot{m}_1 s_2 + \dot{m}_3 s_4] = -\dot{S}_{gen}$ $\dot{S}_{gen} = \dot{m}_1 (s_2 - s_1) + \dot{m}_3 (s_4 - s_3)$

$s_2 - s_1 = s_f - s_g = -s_{fg} = -7.0769\ kg/kg\cdot K$

$s_4 - s_3 = \underset{4.18}{c} \ln \dfrac{T_4}{T_3} =$

$\dot{S}_{gen} = 1.06\ kW/K$

7-152) Ice making plant



C.V around all

$\dot{S}_{gen} = ?$

(R_{134a}) in $x=0$ out $x=1$

Make 4000 kg/hr.

CV #1 around Ice $\quad Q + \frac{4000}{3600} h_f = \frac{4000}{3600} h_i$

p925 @ 0°C $\quad h_i = -333.4$ kJ/kg

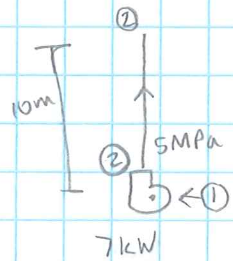
$h_1 = 2500.5$ $\quad s_i = 1.2204$

$s_g = 9.154$

P 916 .01°C $h_f = .001$ $\quad h_g = 2500.9$

7-118)

Practice 4-6-10



H_2O liquid 120 kPa

$v = .001\ m^3/kg$

max $\dot{m} = ?$ $\quad$ isentropic

$$\dot{W} = m\theta_{in} - m_{\theta\,out}$$

$$= m\left(\int_1^2 v\,dP + \cancel{\Delta ke}^{\,0} + \Delta pe\right) = \dot{m}\left[v(P_2 - P_1) + 9.81(10m)\right]$$

$$7kW = \dot{m}\left[.001\ m^3/kg\ (4.88\ MPa) + 98.1\right]$$

$$\dot{m} = 1.41\ kg/s$$

7-98) isentropic turbine

① 150 Psia 900°F = 1360 $\quad$ .5 ft^2 inlet 500 ft/s

② T = ? $\quad$ hp = ? $\quad \dot{W} = ?$ $\quad \dot{V}_{in} = 250\ ft^3/s$

15 Psia $\quad$ V = 100 ft/s

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{(k-1/k)} \qquad T_2 = 1360°R \left(\frac{15}{150}\right)^{(1.4-1)/1.4} = 704.41°R$$

$$Pv = RT$$

$$v_1 = \frac{RT_1}{P_1} = \frac{.3704\ \frac{psia \cdot ft^3}{lbm \cdot R}\ 1360°R}{150\ psia} \qquad v_1 = 3.358\ ft^3/lbm \qquad \dot{m}_{in} = \dot{m}_{out} = 74.45\ lbm/s$$

$$\dot{W} = \dot{m}(\Delta h + \Delta ke)$$

$$= \dot{m}\left[c_{p,avg}(T_2 - T_1) + \frac{(V_2^2 - V_1^2)}{2}\right] \qquad T_{avg} = \frac{900 + 244}{2} = 572 \qquad C_p = .250$$

$$= 74.45\left[.250\,(656) + \frac{100^2 - 500^2}{2}\left(\frac{1\ Btu/lbm}{25{,}037\ ft^2/s^2}\right)\right]$$

$$\dot{W}_{out} = 74.45\,(-159 \quad -2.296)$$

$$12008\ Btu/sec \left(\frac{1\ hp}{.7068\ Btu/s}\right) \qquad \boxed{\dot{W}_{out} = 16{,}989\ hp}$$

Quiz 8 answer

$_1q_2 = \int_1^2 T ds = T_{avg}(s_2 - s_1) = \frac{515.71 + 423.15}{2}[7.2810 - 6.1244]$
$= 542.9$

$_1Q_2 = m\,_1q_2 = 1085.8$

p 919) $u_1 = u_g = 2603$
$s_1 = s_g = 6.1244$
$T_1 = T_{sat} = 242.56°C = 515.71 °K$

p 920) $u_2 = 2577.1$
$s_2 = 7.2810$
$T_2 = 423.15 °K$

1st law $\quad _1q_2 = {}_1w_2 + u_2 - u_1 \qquad 542.9 = {}_1w_2 + 2577.1 - 2603$
$_1w_2 = 568.8$
$_1W_2 = m\,_1w_2 = \boxed{1138 kJ}$

7-152) remove heat of fusion using R134a

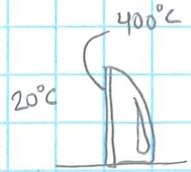
p 916 $\quad .01°C \quad u_f = 0 \quad h_f = .001\ kJ/kg \qquad u_i - u_f = -333.4\ kJ/kg$
p 925 $\quad .01°C \quad u_i = -333.4 \quad h_i = -333.4 \qquad h_i - h_f = -333.4\ kJ/kg$

$\dot{Q} = 1.111\ kg/s\ (333.4\ \frac{kJ}{kg}) = 370.4\ \frac{kJ}{s}$ leaves H_2O absorbed by R134a
C.V around refrigerant
$\underset{35.55}{\dot{m}_R(h_f)} + \underset{\dot{Q}}{370.4\ kJ/s} = \dot{m}_R h_g \qquad \dot{m}_r = 1.779 \qquad h_g = 244.51$

Notes 4-9-10

7-163

1000 W iron



CV #1 immediately around iron

$$\dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen} = \cancel{\frac{dS}{dt}}^{\,0} \text{ (steady)}$$

$S_{heat} = \frac{Q}{T}$ $S_{work} = 0$

$S_{in} = 0$

$$\dot{S}_{out} = \frac{1000\,W}{(20+273)} = 3.413 \frac{W}{°K} = \dot{S}_{gen}$$

System #2 has surface temp 20°C

$(\dot{S}_{gen})\#2 = ?$

for CV #1 $\dot{S} = \frac{1000\,W}{(400+273)} = 1.486 \frac{W}{°K}$

7-166

25,000 kg/hr

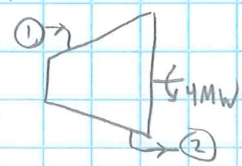
① 6 MPa 450°C steam

② 20 kPa Saturated Vapor X=1

surroundings 25°C

$\dot{W}_{out} = 4\,MW$

$\dot{S}_{gen} = ?$



① SHV $h_1 = 3302.9$ $s_1 = 6.7129$ $h_2 = 2608.9$ $s_2 = 7.9073$

1st law $\frac{25{,}000\ kg/hr}{3{,}600\ sec}(3302.9 - 2608.9) + \dot{Q} = 4000\ kJ/s$

$\dot{Q} = -819.3\ kJ/s$

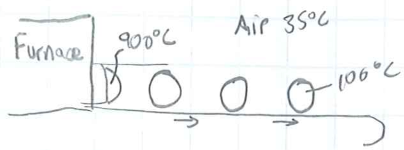
7.85 $\dot{s}_{gen} = \dot{m}(s_2 - s_1) - \Sigma\frac{\dot{Q}}{T} = \frac{25000}{3600}(7.9073 - 6.7219)\ kJ/°K + \frac{819.3\ kJ/s}{(25+273)} = 11\ \frac{kJ}{s\ °K}$

Notes 4-16-10

Thermo avg : 63.66 = 100 − 36.84

adjust 100 − $\frac{20}{36.34}$ (100−raw)

~~90~~ 90-11
80-11
70-79 11
60-69 6
<60 - 2

8-51)


balls 8mm $268.08(10^{-9})\ m^3$ mass $= \rho V = 2.0999(10^{-3})$ kg

One ball system $_1Q_2 = \cancel{W_2}^0 + U_2 - U_1$

$= mc(T_2 - T_1) = -.7811$ kJ/ball

a) $\dot{Q} = \frac{1200 \text{ balls}}{3600 \text{ sec}}\left(-.7811 \frac{kJ}{ball}\right) = -.2604$ kJ/sec

b) $\dot{X}_{dest} = ?$ one ball system + air nearby, boundary temp is 35° — both same temperature

$X_{balance}$: $X_{in} - X_{out} - X_{dest.} = (\Delta X)_{sys}$ $X_{heat} = \left(1 - \frac{T_0}{T}\right) Q = 0$

$X_{in} - X_{out} = 0$ eq 8-17 $X_2 - X_1 = U_2 - U_1 - T_0(S_2 - S_1)$

eq. 7-28 $s_2 - s_1 = c \ln \frac{T_2}{T_1} = .465 \ln \frac{\cdots}{\cdots} = -.5326 \frac{kJ}{K \cdot kg}$ $m_{ball}(s_2 - s_1) = -1.119 \times 10^{-3} \frac{kJ}{°K}$

$(X_2 - X_1)_{ball} = -.7811 - 308.15°K\left(-1.119 \times 10^{-3} \frac{kJ}{K}\right) = -.43628 \frac{kJ}{ball}\left(\frac{1200 \text{ ball}}{3600 \text{ sec}}\right) = .1454$ $\boxed{145.4 \text{ watt}}$

Ch 8 - Exergy: a measure of work potential

W_{surr} is not useful - work changing volume, done against surroundings

$W_u = W_{reversible} - W_{surr}$

I = irreversibility = $W_{rev_{in}} - W_{u\,out}$

irreversibility = "exergy destroyed", "lost work"

$X_{lost} = T_0 S_{gen}$, p 454

Closed system: $X = (U-U_0) + P_0(V-V_0) - T_0(S-S_0) + m\frac{V^2}{2} + mgz$

U is for given state U_0 is dead state (same for P, V, S)

$\phi = X/m$, exergy per unit mass

Exam 3

ideal gas
liquid } find entropy change
solid

isentrop. efficiency
energy balance
entropy gen. rate

---

3 4-12-10

Tank: comp. air, 1MPa, 300°K, $V = 200\ m^3$ — about 17' side cube

surroundings: $300°K = T_0$, $100kPa = P_0$

how much work can you get out of compressed air

$PV = mRT \quad m = \frac{PV}{RT}$

$= \frac{1000 \frac{kN}{m^2}\ 200m^3}{.287 \frac{kN\cdot m}{kg\,°K}(300°K)} = 2323\,kg$

p911

exergy $X = m\phi$

$\phi = u - u_0 + P_0(V - V_0) - T_0(s - s_0) + V^2/2 + gz$

$u - u_0 = c_v(T - T_0) = 0$

$v^2/2 = 0 \quad gz$

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

$s_0 - s = \qquad 0 \quad - R \ln \frac{P_0}{P}$

$-T_0(s - s_0) = 300°K\,(.287 \frac{kJ}{kg\cdot K}) \ln \frac{.1 MPa}{1 MPa}$

$= 300(.287)(\ln 10)$ 2.302

$= 198.25$

$P_0(v_1 - v_2) = 100 \frac{kN}{m^2} \left\{ \frac{R(300k)}{1000\ kN/m^2} - \frac{R(300k)}{100\ kN/m^2} \right\}$

$= .287(300°K)[.1 - 1] = -774.9\ kJ/kg$

$\phi = -77.49 + 198.25 = 120.76\ kJ/kg$

$X = 2.805 \times 10^5\ kJ$

4-12-10

flow exergy per unit mass X

eq. 8-21

flow exergy $\psi = h - h_0 - T_0(s - s_0) + V^2/2 \quad gz$

eq. (8-23) $\psi_2 - \psi_1$ sign error in $T_0(s_2 - s_1)$ term, also in $T_0(s - s_0)$ term Fig. 8-23b

example 8-8 do this

eq. 8-24 $X_{heat} = \left(1 - \frac{T_0}{T}\right) Q$ T = temp at boundary where heat crosses

---

4-19-10

$T_0 = 25°C$

54.)

① 8 MPa 450°C

② 6 MPa

$X_{in} - X_{out} - X_{dest} = \left(\frac{dX}{dt}\right)^0$, steady

$\bar{x}$ dest per unit mass $\dot{x}_{dest} = \frac{X_{dest}}{\dot{m}}$ $X_{heat} = 0$, $X_{work} = 0$ $X_{mass\ transfer} = \dot{m}\psi$

$\dot{m}\psi_1 - \dot{m}\psi_2 - \dot{X}_{dest} = 0$ $\dot{x}_{dest} = \dot{m}(\psi_2 - \psi_1)$

$= \dot{m}(h_2 - h_1 - T_0(s_2 - s_1))$

corrected sign p448 8-23

① SHV $h_1 = 3273.3$ $s_1 = 6.5579$

② $h_2 =$

interpolate for s_2

$X_{dest} = 298°K\ (6.6794 - 6.5579) \frac{kJ}{kg \cdot K} = 36.22\ kJ/kg$

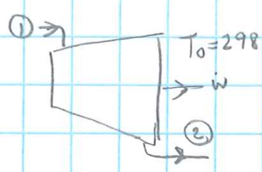
8-65)

① 80 M/s 6 MPa 600°C

SHV $h_1 = 3658.8$ $s_1 = 7.1693$

② 140 M/s 100°C 50 kPa

SHV $h_2 = 2682.4$ $s_2 = 7.6953$



$\frac{V_1^2 - V_2^2}{2} = \frac{[80^2 - 40^2]\frac{m^2}{s^2}}{2(1000\frac{kJ}{kg}/m^2/s^2)} = -6.6\ kJ/kg$

$\dot{m} = 5.1557\ kg/s$

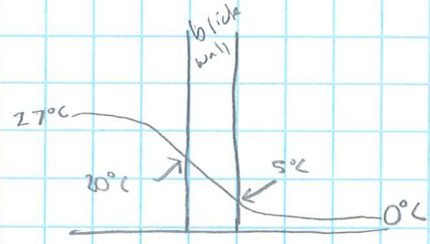
$\dot{X}_{in} = \dot{m}\psi_1$ $\dot{X}_{out} = \dot{W}_{rev}$ eq 8-26 p452 $+ \dot{m}\psi_2$ exergy bal, reversible $\dot{m}\psi_1 - (\dot{W}_{rev} + \dot{m}\psi_2) + 0 = 0$

$\dot{W}_{rev} = -5.1557 \frac{kg}{s} [\underbrace{-976.4}_{\Delta h} \underbrace{-156.74}_{T_0(\Delta s)} + \underbrace{6.6}_{kE}]$

$-5808\ kJ/s$

$\eta_{II} = \dot{w}/\dot{w}_{rev} = \frac{5000}{5808} = .8609$

Ex 8-10



$\dot{Q} = 1035$ watt

$(\dot{X}_{dest})$ in brick = ?

$(X_{dest})_{brick + imm. surroundings} = ?$

Sys 1, just brick $\dot{X}_{in} - \dot{X}_{out} - \dot{X}_{dest} = \left(\frac{dX}{dt}\right) = 0$ time steady $\qquad X_{heat} = \left(1 - \frac{T_0}{T}\right)Q$

hot side $\left(1 - \frac{0+273}{27+273}\right)(1035 \text{ watt}) =$

cold side $\left(1 - \frac{273}{5+273}\right)(-1035) =$

$70.648 - 18.615 - \dot{X}_{dest} = 0 \quad 52.03$ watt

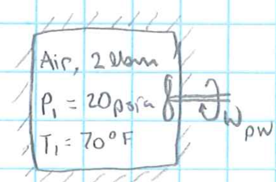
Sys. 2, whole gradient $\quad \left(1 - \frac{\overset{0}{\cancel{27}} + 273}{27+273}\right) 1035 \text{ watt} + \underbrace{\left(1 - \frac{0+273}{0+273}\right)}_{=0}(-1035) + \dot{X}_{dest} = 0$

$\dot{X}_{dest} = 93.15$ watt

Notes 4-21

Example 8-12 | p461

② $T = 130°$



$X_{dest} = ?$

$X_{work} = W \quad$ exergy bal $\quad X_{in} - X_{out} - X_{dest} = \Delta X$

$\overset{0}{\cancel{Q_2}} = {}_1W_2 + mC_v(T_2 - T_1) \Rightarrow {}_1W_2 = 2\text{ lbm}\left(.172 \frac{\text{btu}}{\text{lbm} \cdot R}\right)\underbrace{(70 - 130° R)}_{T_1 - T_2} = -20.64 \text{ Btu}$

466 $\quad X_2 - X_1 = U_2 - U_1 + \underbrace{P_0(V_2 - V_1)}_{0} - \underbrace{T_0(S_2 - S_1)}_{19.553} \qquad (70+460)(2\text{ lbm})\left(.172 \frac{\text{Btu}}{\text{lbm} \cdot R}\right) \ln \frac{590}{530} =$

$\quad + 20.64$

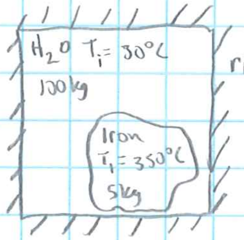
$= 1.08$ Btu

exergy bal $\quad 20.64 \text{ Btu} - X_{dest} = 1.08 \text{ Btu} \qquad \boxed{X_{dest} = 19.55 \text{ Btu}}$

$W_{rev} = ? \quad \therefore X_{dest} = 0 \qquad \underbrace{X_{in} - X_{out}}_{} + \overset{0}{\cancel{X_{dest}}} = X_2 - X_1$

$\boxed{W_{rev} = 1.08 \text{ Btu}}$

Ex 8-13



rigid tank

1^{st} Law $\quad 5kg(.45 \frac{kJ}{kg \cdot k})(350 - T_2) = 100kg(4.18)(T_2 - 30)$

$\Rightarrow T_2 = 31.71°C$

b) $X_{1,total}, X_{2,total} = ?$ $\qquad X = U - U_0 + \cancel{P_0(V - V_0)}^{0} - T_0(S - S_0)$ $\qquad T_0 = 20°C = 293\ k$

dead state for H_2O = comp. liq $\qquad P_0 = 100kPa$

$(X_1)_w = 100kg(4.18)\frac{kJ}{kg\,k}(30° - 20C) - 293°k(100kg)(4.18)(\ln \frac{303}{293})$

$= \boxed{69.748\ kJ}$

$(X_2)_w = 100(4.18)(31.7 - 20) - 293(100)(4.18)(\ln \frac{304.71}{293}) = \boxed{95.28\ kJ}$

$(X_1)_{Fe} = 5(.45)(350 - 20) - 293(5)(.45)(\ln \frac{623}{293}) = \boxed{245.2\ kJ}$

$(X_2)_{Fe} = 5(.45)(31.71 - 20) - 293(5)(.45)\ln(\frac{304.71}{293}) = \boxed{0.513}$

$(X_1)_{total} = 314.95\ kJ$

$(X_2)_{tot} = 95.793\ kJ$

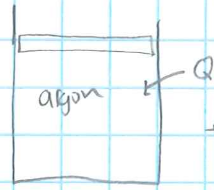
$\underbrace{X_{in} - X_{out}}_{0} - X_{dest} = \Delta X$

$X_{dest} = 219.16$

p465 ex. 8-14

$\forall_1 = .01 m^3$
$T_1 = 400k$
$P_1 = 350k$

$T_0 = 300k$
$P_0 = 100kPa$



$\forall_1 =$

1^{st} boundary inside cylinder

isothermal $\forall_2 = 2\forall_1$

a) $W_b = \int_1^2 P d\forall = P_1\forall_1 \ln \frac{\forall_2}{\forall_1} = 350 \frac{kN}{m^2}(.01m^3) \ln 2 = 2.426 \frac{kN \cdot m}{kJ}$

$W_{surr} = \int P_0 d\forall = 100 \frac{kN}{m^2}(.02 - .01)m^3 = 1 kJ$

$W_u = W_b - W_{surr} = 1.426 kJ = X_{work}$

b) $X_{dest} = ?$ X_{bal} sys 2 $X_{heat} = (1 - \frac{T_0}{T})Q = .75Q = 1.8195$

1^{st} law sys. 1 = $Q = W + mc_v \underbrace{(T_2 - T_1)}_{0} = 2.426 kJ$

X_{bal}: $X_{in} - X_{out} - X_{dest} = \Delta X$

$1.8195 - 1.426 = .3935$ eqn 8-17. $\Delta X = \cancel{U_2 - U_1} + P_0(\forall_2 - \forall_1) - T_0(S_2 - S_1)$

0, no temp change ↓ 1kJ ↓ $\cancel{C_v \ln \frac{T_2}{T_1}} + R \ln \frac{\forall_2}{\forall_1}$

$= .14424$

$\Delta X = .1442$

$.3935 - X_{dest} = -.8195$

$W_{rev} = X_2 - X_1$ $X_{in} - X_{out} - \cancel{X_{dest}}^{0} = \underbrace{X_2 - X_1}_{-.8195}$

X_{in} ↑ $(1 - \frac{T_0}{1200})Q$; X_{out} ↑ W_{rev}

$X_{heat} = 1.8195$

$1.8195 - W_{rev} = -.8195$

FINAL EXAM Tues May 11 8am - 10 am 120 civil take 4 front rows

colored paper

comprehensive, 3-4 problems

May 4 Exam 4

$\phi \geq 0 \quad \psi \geq 0$

P 8-16) H_2O flow process

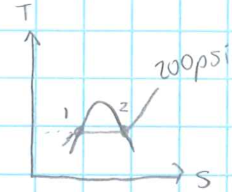
$$\dot{X}_{in} - \dot{X}_{out} - \dot{X}_{dest} = \overbrace{\left(\frac{dX}{dt}\right)_{CV}}^{zero}$$

$T_0 = 80\,F = 540\,R$

Q

combustion gasses 500°F

$$\dot{X}_{heat} = \left(1 - \frac{T_0}{T}\right)\dot{Q} = \left(1 - \frac{540}{960}\right)\dot{Q}$$
$$= .4375\,\dot{Q}$$



1st law $\dot{Q} + m_1 h_1 = m_2 h_2$

$\frac{\dot{Q}}{\dot{m}} = h_{fg}\langle 200\,psi\rangle = 843.33$ Btu/lbm

$S_2 = S_g = 1.5460 \quad S_1 = S_f = .54379 \quad S_{fg} = 1.00219$ $\frac{Btu}{lbm\,R}$

$\dot{X}_{in} = .4375\,\dot{m}\,(843.3)$ Btu/lbm $+ \dot{m}\,\psi_1 \quad X_{out} = \dot{m}\,\psi_2$

$\dot{X}_{dest} = \dot{m}\,[\,368.95\ \text{Btu} + \psi_1 - \psi_2\,] \quad \psi_1 - \psi_2 \Rightarrow$

$\psi_1 - \psi_2 = [\,h_1 - h_2 - T_0\,(s_1 - s_2) = -843.3 \quad -540(-1.002) = -302.15$

$\dot{X}_{dest} = \dot{m}\,(368.95 - 302.15)$ Btu/lbm $= \dot{m}\ 66.8$ Btu/lbm

increasing temp of combustion gasses does not influence work potential of steam.

8-24) a) $\dot{W}_{rev} = ?$ Sys 1 for outside house, sys 2 just inside

b) $\dot{I} = ?$ $(\dot{I} = \dot{X}_{dest})$

15°C

Sys 1 $\dot{X}_{heat} = \cancel{\left(1 - \frac{T_0}{T}\right)}^{0}\dot{Q} \quad \dot{X}_{work} = -80{,}000\ \frac{kJ}{hr}$

$X_{bal} \quad \dot{X}_{in} - \dot{X}_{out} - \dot{X}_{dest} = \cancel{\frac{dX}{dt}}\ 0$

$0 - (-80{,}000) - \dot{X}_{dest} = 0 \qquad \dot{X}_{dest} = \frac{80{,}000\ kJ}{3600\ sec} = \boxed{22.22\,kW}$

ON TEST:

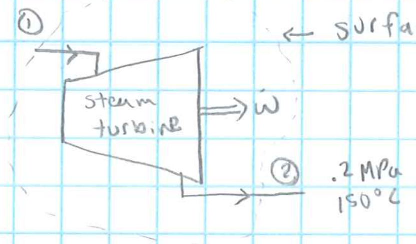
describe system or control volume for each balance

8-32) . . . . Soln. man. assumed ____ in dead state, actually it is SHV

that part is wrong

8-15) example

$\dot{m} = 8\,kg/s$



← surface temp $T_0 = 25°C$

$P_0 = 100\,kPa$

a) ① shv,

$h_1 = 3344.9$

$s_1 = 7.0856$

② SHV $h_2 = 2769.1$ $s_2 = 7.2810$

1^{st} law $\frac{8kg}{s}\left(3344.9\frac{kJ}{kg}\right) - 300\frac{kJ}{sec} = \dot{W} + 8(2769.1)$ $\boxed{\dot{W} = 4306\ \frac{kJ}{s}}$

b) max $\dot{W}$ = ? interpret as $\dot{W}_{rev}$, exergy bal with $X_{dest} = 0$ for extended C.V. with surface temp T_0

$\dot{X}_{heat} = \left(1 - \frac{T_0}{T_R}\right)\dot{Q} = 0$ $\quad T_0$ $\qquad \dot{X}_{work} = \dot{W}_{rev}$

$\dot{X}_{mass} = \dot{m}\psi \qquad \dot{X}_{in} - \dot{X}_{out} - \cancel{\dot{X}_{dest}}^{0} = \cancel{\left(\frac{dX}{dt}\right)}_{C.V.}^{0}$

$\dot{m}\psi - [\dot{m}\psi_2 + W_{rev}] = 0 \Rightarrow W_{rev} = \dot{m}(\psi_1 - \psi_2)$

$= \dot{m}[h_1 - h_2 + T_0(s_2 - s_1)]$

$= 8kg/s\,[575.8 + 298(7.281 - 7.0856)] = \boxed{5072.2\ kJ/s}$

c) $\eta_{II} = \frac{W_u}{W_{rev}} = \frac{4306}{5072.2} = .849$

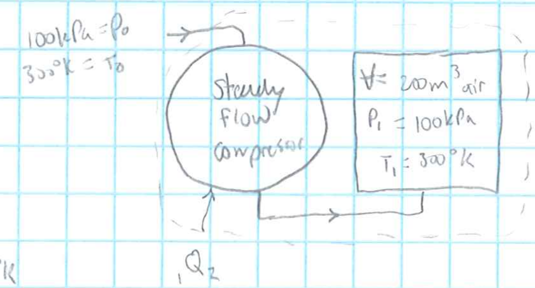
d) X_{dest} ex. bal in actual process, extended C.V. $\dot{X}_{in} - \dot{X}_{out} - \dot{X}_{dest} = 0$

$\dot{X}_{dest} = W_{rev} - W_{actual} = 5072 - 4306 = \boxed{776\ kW}$

e) $\psi_1 = ?$ $\quad h_0 = h_f\langle 25°C\rangle = 104.83 \qquad T_{sat}\langle 100kPa\rangle \approx 100°C$

$s_0 = s_f\langle 25°C\rangle = .3672 \qquad \psi_1 = 1238\ \frac{kJ}{kg} \qquad \dot{m}\psi_1 = 9904\ kW = .435\ \dot{W}$

example 8-17 p743



minimum work in = ?

state 2 in tank, 1MPa 300°K

Find W_{rev} ; $X_{dest} = 0$ $\qquad X_{in} - X_{out} - X_{dest} = (X_2 - X_1)_{cV}$

$X_{heat} = 0 \quad X_{work} = W_{rev\,(out)} \quad X_{mass} = m\psi \qquad X_{in} = m\psi = 0$, inlet is same as dead state

$-W_{rev} = X_2 - X_1 \qquad X_2 = m_2 \phi_2 = m_2 [U_2 - U_0 + P_0 (V_2 - V_0) - T_0 (S_2 - S_0)]$

$U_2 - U_0 = C_v (T_2 - T_0) = 0 \qquad V_2 = \frac{RT_2}{P_2} = \frac{.287(300)}{1000} = .0861 \quad V_0 = .861\ m^3/kg$

$P_0 (V_2 - V_0) = 100 [.0861 - .861) = -77.49 \qquad S_2 - S_1 = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$

$S_2 - S_0 = 0 - .6608 \ln 10 = -.6608 \qquad -T_0 (S_2 - S_1) = 198.25\ kJ/kg$

$m_2 = \frac{200\ m^3}{V_2} = 2322 kg \qquad X_2 = 2322 kg [-77.49 + 198.25] = 2.804(10^5)\ kJ$

$\boxed{-W_{rev} = 2.804(10^5)\ kJ}$

ex 8.7 compare

Final Exam Review

- finding states

$W = \int P d\forall$ for piston/cyl fixed mass boundary work *

$W = -\int \forall dP$ for steady flow

boundary work = like total work, where work against atmosphere is $W_{atm} = P_0(\forall_2 - \forall_1)$ for steady flow

ME 231 A Thermofluid Mechanics I Spring 2010

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Office hours: Monday through Friday, 8:00-9:00; 2:00-3:00

Grading

1. Quizzes: Average counts as 15%. Subject tends to be from recent homework. If you miss a quiz you get a 50 for that quiz; otherwise, the lowest individual quiz grade is 60.
2. Tests: There are four tests. Each counts as 15%. The dates of these are: Feb. 2, Mar. 2 , April 6, and April 27.
3. Final Exam: 20%. Comprehensive, 1:30 pm, Mon. May 10, this room.

4. Class attendance: 5%. Can miss 3 classes without penalty. Thereafter, 0.4 % per absence, until all of the 5% credit for attendance is used up.

5. Homework: Assigned and discussed, but not graded or collected.

Other points about grading:

a. Open book and class notes; for quiz, test, final. No cell phones or files from other classes.

b. Under almost all circumstances there won't be make-up tests, or quizzes. This is because it is difficult to interpret whether a make-up test is harder , easier, or the same difficulty as the test taken by the rest of the class. I do not discriminate between excused versus unexcused absences.

c. The cutoffs for letter grades of A, B, C, D, and F will be 90, 80, 70, and 60, respectively.

d. The midterm grade is just the average of tests 1 and 2.

appeal process

If the student is unsatisfied about some aspect of this course, and does not want to talk to the instructor about it, or has tried this avenue and is not satisfied, the student can appeal to the chair of the Mechanical & Aerospace Engr. & Engr Mech. Dept. (Ashok Midha, 119 Toomey Hall, phone 341-4662, e-mail: midha@mst.edu) .