(P3.1)

(a) the number of microstates is 2^N (pg 91, typo in given answer, printings 1-3)

(b) 3 particles total

$\Rightarrow p_{\{2H,1T\}} = \frac{3!}{2!*1!} = 3$ number microstates of specific arrangement (macrostate)

probability = (# microstates of specific arrangement)/(total # of microstates)

$$prob = \frac{3}{2^3} = \frac{3}{8}$$

(c) # microstates.

$$p_{\{2H,2T\}} = \frac{4!}{2!*2!} = 6$$

$$p_{\{3H,2T\}} = \frac{5!}{3!*2!} = 10$$

$$p_{\{4H,2T\}} = \frac{6!}{4!*2!} = 15$$

$$p_{\{3H,3T\}} = \frac{6!}{3!*3!} = 20$$

(d)

macrostate		# of microstates*
H	T	
0	8	1
1	7	8
2	6	28
3	5	56
4	4	70
5	3	56
6	2	28
7	1	8
8	0	1

* number of microstates = $\frac{8!}{m!(8-m)!}$

total number of microstates is 2^8 = 256, which is the same as the sum from the table.

portion of microstates (probability) for requested configurations:

{5:3} = 56/256 = 0.219 = 22%

{4:4} = 70/256 = 0.273 = 27%

{3:5) = 22% like {5:3}

probability of any one of the three most evenly distributed states = 22% + 27% + 22% = 71%

(e) for 8 particle system, Stirling's approx will not apply

$\Delta \underline{S}/k$ = ln(p{4:4}/p{5:3}) = ln (70/56) = 0.223

(P3.3) 15 molecules in 3 boxes, molecules are identical

$$p_j = \frac{N!}{\prod_{i=1} m_{ij}!}$$ ……………………………………....Eqn. 3.4

$$p_1 = \frac{15!}{9!4!2!} = 75075$$

$$p_2 = \frac{15!}{(5!)^3} = 756756$$

$$\frac{\Delta \underline{S}}{k} = \ln\left[\frac{p_2}{p_1}\right] = 2.31$$

(P3.4) two dices.

$\frac{\Delta \underline{S}}{k} = ??$ for going from double sixes to a four and three.

$\Rightarrow$ for double sixes, we have probability of 1/6 for each dice.

$$\Rightarrow p_1 = \frac{2!}{\left(1/6\right)*\left(1/6\right)}$$

for one four and one three $\Rightarrow$ probability applied for 1/6 for each one in each dice,

$$\Rightarrow p_2 = \frac{2!}{\left(1/6\right)*\left(1/6\right)}*2$$

$$\frac{\Delta \underline{S}}{k} = \ln\left(\frac{p_2}{p_1}\right) = \ln 2 = 0.693$$

(P3.5) ΔS = ??

Assume Nitrogen is an Ideal gas $\Rightarrow$ $PV = RT$ ……………. Eqn. 1.15

$$\Rightarrow P_1 = \frac{8.314\left(cm^3 * MPa/mole - K\right)*300K}{23\left(L/mole\right)*(1000cm^3/1L)} = 0.108MPa$$

Similarly $\Rightarrow P_2 = 0.00723MPa$

$$\Delta S = Cp \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$$ ……………………………………… Eqn. 3.23

$$Cp = \frac{7R}{2}$$ …..(ig)

$$\Delta S = \frac{7R}{2}*\ln\frac{400}{300} - 8.314*\ln\frac{0.00723}{0.108} = 30.88J/mole - K = 1.07kJ/kg - K$$

(P3.6) (a) m-balance: $dn^{in} = -dn^{out}$

S-balance:

$$\frac{d(nS)^{in}}{dt} = -S^{out}\frac{dn^{out}}{dt} \Rightarrow n^{in}dS^{in} + S^{in}dn^{in} = -S^{out}dn^{out}$$

But physically, we know that the leaking fluid is at the same state as the fluid in the tank; therefore, the S-balance becomes:

$(ndS + Sdn)^{inside} = -(Sdn)^{out}$, and $dn^{inside} = -dn^{out}$ so $\Delta S = 0$

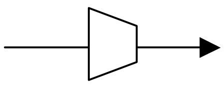
from the steam table .

State	P(Mpa)	T°C	H(kJ/kg)	S(kJ/kg*K)
1(in)	1	400	3264.5	7.4669
2 (out)	0.1	***120.8***	2717.86	7.4669

At 1 bar =	**0.1 MPa**
T	**S**
100	7.361
120.8	**7.4669**
150	7.6148

By interpolation, implies **T = 120.8°C**

(P3.7) (a) Steady-state flow, ΔH = Ws



Start 1 mole basis:

$x_1 = 0.333, x_2 = 0.667, adiabatic, Cp = x_1Cp_1 + x_2Cp_2$, Cp for each is the same anyway.

$$MW = x_1MW_1 + x_2MW_2 = 0.333(12+16) + 0.667*2 = 10.66(g/mole)$$

R = 1.987BTU/lbmol-R.

$$\Delta H = W_S = \int_{T_1}^{T_2} CpdT = \frac{7}{2}*R*(1100-100)^{\circ}R$$

$$\Rightarrow \Delta H = 6954.5 BTU/lbmol$$

$$\& \dot{m} = 1ton/h = 2000lb/h.$$

$$\& MW = 10.66lb/lbmol$$

$$\Rightarrow \Delta H = \frac{2000lb}{h}*\frac{lbmol}{10.66lb}*\frac{6954.5BTU}{lbmol}$$

$$\Rightarrow \Delta H = W_S = 1{,}305{,}000 = 1.3*10^6 BTU/h$$

(b) $\eta = ??$ of the compressor.

To find the efficiency of the compressor, ⇒ $S_1 = S_2$

But the enthalpy and the internal energy will change which gives a change in the

Work. $\Rightarrow \eta = \frac{W_S^{'}}{W_S} = ??$

$$\Delta S = 0 = Cp\ln\frac{T_2'}{T_1} - R\ln\frac{P_2}{P_1}$$

$$\Rightarrow Cp\ln\frac{T_2'}{T_1} = R\ln\frac{P_2}{P_1}$$

$$\Rightarrow \left(\frac{T_2'}{T_1}\right)^{Cp} = \left(\frac{P_2}{P_1}\right)^{R}$$

$$\Rightarrow T_2' = \left(\frac{P_2}{P_1}\right)^{\frac{R}{Cp}} * T_1$$

$$\Rightarrow T_2' = \left(\frac{100}{5}\right)^{\frac{2}{7}} * 559R$$

$$T_2' = 1315R$$

$$\& \ \Delta H' = Cp(T_2' - T_1) = 6.95(1315 - 559) \quad \Rightarrow \eta = \frac{\Delta H'}{\Delta H} = \frac{5258}{6955} = 0.76$$

$$\Rightarrow \Delta H' = 5258 BTU/lbmol$$

(P3.8) Adiabatic, steady-state open system ⇒ Q = 0, &(Cp/R = 7/2)………………………… ig

$$W = \int_{300}^{625} Cp dT = \frac{7R}{2} * (625 - 300) = 9457.175 kJ/kmole * \frac{1 kmole}{28 kg} = 337.76 kJ/kg$$

$$\eta = ??$$

$$\Delta S = 0 \Rightarrow \frac{T_2'}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{R}{Cp}}$$

$$\Rightarrow T_2' = 533.5K$$

$$\Rightarrow \Delta H' = Cp(T_2' - T_1) = \left(\frac{7 * 8.314}{2}\right) * (533.5 - 300)$$

$$\Rightarrow \Delta H' = 6794.77 kJ/mol$$

$$\Rightarrow \eta = \frac{\Delta H'}{\Delta H} = \frac{6794.77 kJ/kmol}{337.76 kJ/kg * 28 kg/kmol} = 0.718$$

$$\Rightarrow \eta = 71.8\%$$

(P3.9) work required per kg of steam through this compressor?
By looking at the steam table in the back of the book

P(MPa)	T(^{O}C)	H(kJ/kg)	S(kJ/kg-K)
0.8	200	2839.7	6.8176
4	500	3446	7.0922

$$W = \Delta H = 3446 - 2839.7 = 606.3 kJ/kg$$

now find W’ = ??

ΔS = 0 (reversible), ⇒ look in the steam table (@P = 4.0MPa) to find a similar value for S = 6.8176kJ/kg-K, if this value is not available so find it by interpolation.

H(kJ/kg)	S(kJ/kg-K)
3214.5	6.7714
H' = ??	S' = 6.8176
3331.2	6.9386

$$\Rightarrow \frac{3331.5 - H'}{3331.2 - 3214.5} = \frac{6.9386 - 6.8176}{6.9386 - 6.7714}, \Rightarrow H' = 3246.7$$

$$\Rightarrow \Delta H' = W' = 3246.7 - 2839.7 = 407 kJ/kg$$

$$\Rightarrow \eta = \frac{407}{606.3} = 0.67, \Rightarrow \eta = 67\%$$

(P3.10)@ P = 2.0 MPa & T = 600^{O}C, ⇒ H = 3690.7 kJ/kg, S = 7.7043kJ/kg-K (Steam table)

	T^{O}C	H_L(kJ/kg)	ΔH^{vap}(kJ/kg)
steam table	20	83.91	2453.52
Interpolation	**24**	**100.646**	**2444.098**
steam table	24	104.83	2441.68

$$H = H_L + q(\Delta H^{Vap}) = 1006.46 + 0.98*(2441.68) = 2493k.49 J/kg$$

$$\Rightarrow W_S = \Delta H = 3690.7 - 2493.49 = 1197.21 kJ/kg$$

$$\eta = ?? \ , \quad \eta = \frac{\Delta H}{\Delta H'} = \frac{W}{W'},$$

⇒ ΔS = 0 (reversible), ⇒look for S in the sat'd temp. steam table and find H by interpolation, ⇒ $W' = 1408.0 kJ/kg$

$$\Rightarrow \eta = \frac{1197.2}{1408.0} = 0.8503, \Rightarrow \eta = 85\%$$

(P3.11)

$$P_1 = 0.1 MPa, Sat'd_{vap}$$

$$P_2 = 10 MPa$$

$$T_2 = 1100^O C$$

State	P(MPa)	T(^{O}C)	H(kJ/kg)	S(kJ/kg-K)
1	0.1	99.61	2674.95	7.3589
2'	10		**4062.53**	*7.3589*
2	10	1100	4870.3	8.0288

interpolation for above table:

H'_2 = 4062.53	(interpolation)
H(kJ/kg)	**S(kJ/kg-K)**
3992	7.2916
4062.53	*7.3589*
4114.5	7.4085

$\Rightarrow \Delta H = W_S = 4870.3 - 2674.95 = 2195.35 kJ/kg$

mass flow rate = 1 kg/s

$\Rightarrow \dot{W}_S = 2195.35 kJ/s = 2195350 watt$

$\& 1 watt = 0.001341022 hp$

$\Rightarrow \dot{W}_S = 2944.01 hp$

$\& \Delta H' = 4062.53 - 2674.95 = 1387.58 kJ/kg$

$$\Rightarrow \eta = \frac{\Delta H'}{\Delta H} = \frac{1387.58}{2195.35} = 0.63$$

$\Rightarrow \eta = 63.2\%$

(P3.13) Through the valve $\Rightarrow H^{in} = H^{out}$

$P^{in} = 3MPa \quad P^{out} = 0.1MPa \qquad T_{out} = 110^O C = 383.15K$

(By interpolation) Find H^{out} from steam table.

$$\frac{150-110}{150-100} = \frac{2776.6 - H^{out}}{2776.6 - 2675.8}$$

$\Rightarrow$ H^{out} **= 2695.96 kJ/kg**

At 3MPa table use same value for $\boldsymbol{H^{in}}$ to find $\boldsymbol{S^{in}}$

$$\Rightarrow \text{By interpolation } \frac{2856.5 - 2695.96}{2856.5 - 2803.2} = \frac{6.2893 - S^{in}}{6.2893 - 6.1856}$$

$\Rightarrow$ S^{in} = 5.976kJ/kg-K

The process should be irreversible. To find S^{out}, interpolate using temperature at 0.1 MPa:

$$\frac{150-110}{150-100} = \frac{7.6148 - S^{out}}{7.6148 - 7.3610}$$

S^{out} = 7.4118 kJ/kg-K, since $S^{out} > S^{in}$ entropy has been generated. The entropy balance is:

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