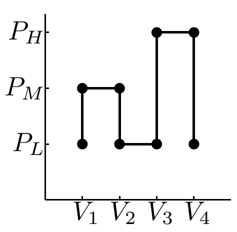
EML 3100 Exam 2 THERMODYNAMICS 3/02/10 11:45-1:00 pm
Page 1/3 Solutions (dommelen@eng.fsu.edu) series a

DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use at least 5 digits in your computations and answers where possible. You must give the units of your answers. You must write clearly. Encircle the right answer number in multiple choice. To correct, erase the wrong circle as well as you can and encircle the corrected answer number twice. Best possible answer for multiple choice. For questions asking a number, putting the clear correct formula(s) below the question might result in partial credit even if the answer is wrong. *Not following those requirements will result in reduced or no credit.*

1. (5%) Five kg of hydrogen at 100 kPa and 25°C is getting hotter at a rate of 3°C/min in an isobaric process. The hydrogen absorbs heat at a rate of 0.71045 kJ/kg-s, 3.5522 kJ/s.

2. (5%) Write the expression for the work done in the shown process, in terms of V_1, V_2, V_3, V_4, P_L, P_M, and P_H. (Do not assume the spacings are constant.)



$P_M(V_2 - V_1) + P_L(V_3 - V_2) + P_H(V_4 - V_3)$.

3. (5%) The specific heat at constant volume of hydrogen at 900K equals 10.69011 kJ/kg-K to four significant digits.

4. (5%) If 2 kg of oxygen at 100 kPa and 25°C is expanding in volume by 0.5 m^3/s in an adiabatic process, then the temperature is decreasing by 37.76 °C/s.

5. (5%) If 5 L of glycerine cools down from 100°C to 25°C, the heat lost to the surroundings is 1.143 MJ.

6. (5%) Ammonia has a pressure of 10 bar, a specific volume of 0.2 m^3/kg, and a specific enthalpy of 1800 kJ/kg. The internal energy is 1600 kJ/kg.

7. (5%) If you know the internal energy and mass of some ideal gas, it is enough to find

   (a) H and V
   (b) P and v
   [✓ (c)] T and C_v

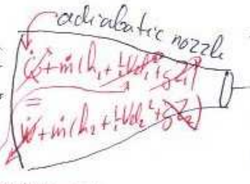
8. (32%) Oxygen at -33.15°C and 200 kPa is send into an adiabatic nozzle at low velocity. It is know that for nozzles of this type, the *absolute* temperature at the exit is 5/6 of the entrance one. Also, the exit pressure is 0.5283 times the entrance pressure.

   - Find the velocity with which the oxygen comes out of the nozzle.
   - If the desired mass flow exiting the nozzle is 0.5 kg/s, then how big should the diameter of the exit be?

   You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use the maximum number of digits in your computations.

Given: In black

O_2 T -33.15 °C
+273.15 = 240 K
I 200 kPa
low Vel



$T_2 = \frac{5}{6} T_1$ T $\dot{m}_2 = \dot{m}_1$ $T_2 = \frac{5}{6}\, 240\,K = 200\,K$

$P_2 = 0.5283 P_1$ I $P_2 = 0.5283\ 200\,kPa = 105.66\,kPa$

$\dot{m} = 0.5\ kg/s$

Asked: Vel_2, D_2 if $\dot{m} = 0.5\ kg/s$.

Solution: A.8 @ oxygen, 240 K : $\quad T = 240\,K \quad d = h_1 \qquad h_1 = d_1 + \frac{T - T_1}{T_2 - T_1}(d_2 - d_1)$

$T_1 = 200\,K \quad d_1 = 181.81\ kJ/kg \qquad = 181.81 + \frac{240-200}{250-200} \times (227.37 - 181.81)$

$T_2 = 250\,K \quad d_2 = 227.37$ "

$h_1 = 218.258\ kJ/kg$

A.8 @ oxygen, 200 K : $h_2 = 181.81\ kJ/kg$

1st law: $h_1 = h_2 + \frac{1}{2}Vel_2^2 \qquad 218.258\ \frac{kJ}{kg} = 181.81\ kJ/kg + \frac{1}{2}Vel_2^2$

$\frac{1}{2}Vel_2^2 = (218.258 - 181.81)\frac{kJ}{kg}\ \frac{1000\,m^2/s^2}{1\,kJ/kg} = 36448\ \frac{m^2}{s^2}$

$Vel_2 = \underline{\underline{269.99\ m/s}}$

$\dot{m} = \frac{A\,Vel_2}{v_2} \qquad P_2 v_2 = RT_2 \qquad 105.66\,kPa\ v_2 = 0.2598\ \frac{kJ}{kg\,K}\ 200\,K$ (from A.5 or A.8)

$v_2 = 0.491766\ \frac{m^3}{kg}$

$\dot{m} = \frac{A\,Vel_2}{v_2} \qquad 0.5\ \frac{kg}{s} = \frac{A\ 270\ m/s}{0.491766\ m^3/kg}$

$A = 0.000910670\ m^3 = \frac{\pi}{4}D_2^2 \qquad D_2 = 0.03405\,m = \underline{\underline{3.405\,cm}}$

① Know absolute T
① P_2, T_2
③ Read A.8
④ Interpolate h_1
⑤ 1st law incl. mass conservation or specific
② $\dot{Q} = 0$
② $\dot{W} = 0$
① Compute Vel_2 units!
~~$\dot{m} = A\,Vel_2/v_2$~~
~~$Pv = RT$~~
~~find R~~
~~compute v. units!~~

④ $Pv = RT$
② find R
② compute v. units! T
③ $\dot{m} = A\,Vel/v_2$
① $A = \frac{\pi}{4}D^2$
① compute D units!

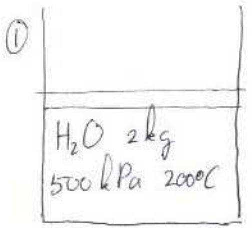
9. (33%) There is 2 kg of water at 500 kPa and 200°C in a piston/cylinder combination. The water is expanded to 100 kPa in a process that is polytropic with $n = 1.3$.

    - Construct the initial phase in a very neat Pv-diagram, marking all lines and points used to do it with their values. Do not put more info in the diagram than is needed to construct the phase. State the phase.
    - Find out enough about state 2 without assuming its phase, then construct its phase in a second Pv diagram as described above.
    - Find the work done by the water and the heat added to it during the process.

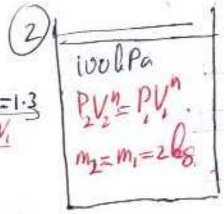
    You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use the maximum number of digits in your computations.

① $m_2 = m_1$
② B.1.3 u_1, v_1
② Conv. to extensive
② $P_1V_1^{1.3} = P_2V_2^{1.3}$
① Compute V_2
① B.1.2 u, v, f_g
③ x_2
① u_2
③ work formula
① compute $_1W_2$ units
④ 1st law
① compute $_1Q_2$ units!

Given: In black

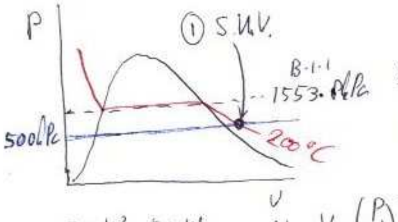


expanded
polytropic n=1.3
$_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n}$
$U_2 - U_1 = {}_1Q_2 - {}_1W_2$

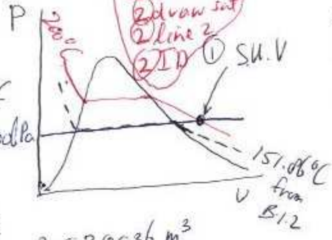


Asked phase 1 in Pv, phase 2 in Pv, $_1Q_2$, $_1W_2$

Solution



or



① diagram
② line 1
② find sat
② draw sat
② line 2
② ID

Either way, table B.1.3 applies. B.1.3 at 500 kPa and 200°C:

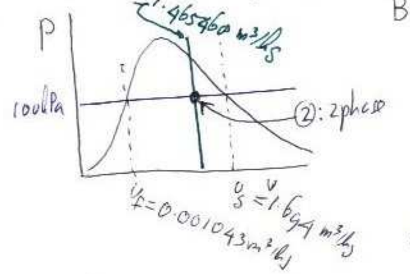
$v_1 = 0.42492 \frac{m^3}{kg}$

$u_1 = 2642.91$ kJ/kg

$V_1 = mv_1 = 2\,kg\ 0.42492 \frac{m^3}{kg}$
$= 0.84984\ m^3$

$P_2V_2^{1.3} = P_1V_1^{1.3} \rightarrow V_2 = V_1 \left(\frac{P_1}{P_2}\right)^{\frac{1}{1.3}} = 2.930936\ m^3$

$v_2 = V_2/m = 2.930936\ m^3/2\,kg = 1.465468 \frac{m^3}{kg}$



B.1.2 @ 100 kPa applies:

$v_2 = v_{f_2} + x_2(v_{g_2} - v_{f_2})$ $1.465468 \frac{m^3}{kg} = [0.001043 + x\ (1.694 - 0.001043)] \frac{m^3}{kg}$

$\rightarrow x_2 = 0.86501$

$u_2 = u_{f_2} + x_2 u_{fg_2} = (417.33 + 0.86501\ 2088.72)$ kJ/kg

$= 2224.0943$ kJ/kg

$_1W_2 = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{100\,kPa\ 2.930936\,m^3 - 500\,kPa\ 0.84984\,m^3}{1-1.3}$

$= \underline{\underline{439.42\ kJ}}$

1st law $U_2 - U_1 = m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

$_1Q_2 = 2\,kg\,(2224.0943 - 2642.91) \frac{kJ}{kg} + 439.42\,kJ = \underline{\underline{-398.21\ kJ}}$