1. The cylinder shown in Fig. 1. contains 1 kg of saturated (liquid + vapor) water at 30°C. The piston has a cross-sectional area of 0.065 m², a mass of 40 kg, and is resting on the stops as shown. The volume at this point is 100 L, atmospheric pressure outside is 94 kPa, and the local gravitational acceleration is 9.75 m/s². Heat is now transferred to the system until the cylinder contains saturated vapor.

(a) What is the temperature of the water when the piston first rises from the stops? 8 %

(b) Calculate the work done by the water during the overall process. 8 %

(c) Show the T–v diagram 4 %

(20 %)

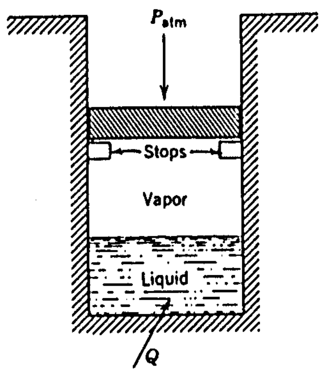

Fig. 1

TABLE A.1.2

Saturated Steam: Pressure Table

Press. kPa P	Temp. °C T	Specific Volume m³/kg Sat. Liquid v_f	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy kJ/kg K Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
0.6113	0.01	0.001 000	206.14	.00	2375.3	2375.3	.01	2501.3	2501.4	.0000	9.1562	9.1562
1.0	6.98	0.001 000	129.21	29.30	2355.7	2385.0	29.30	2484.9	2514.2	.1059	8.8697	8.9756
1.5	13.03	0.001 001	87.98	54.71	2338.6	2393.3	54.71	2470.6	2525.3	.1957	8.6322	8.8279
2.0	17.50	0.001 001	67.00	73.48	2326.0	2399.5	73.48	2460.0	2533.5	.2607	8.4629	8.7237
2.5	21.08	0.001 002	54.25	88.48	2315.9	2404.4	88.49	2451.6	2540.0	.3120	8.3311	8.6432
3.0	24.08	0.001 003	45.67	101.04	2307.5	2408.5	101.05	2444.5	2545.5	.3545	8.2231	8.5776
4.0	28.96	0.001 004	34.80	121.45	2293.7	2415.2	121.46	2432.9	2554.4	.4226	8.0520	8.4746
5.0	32.88	0.001 005	28.19	137.81	2282.7	2420.5	137.82	2423.7	2561.5	.4764	7.9187	8.3951
7.5	40.29	0.001 008	19.24	168.78	2261.7	2430.5	168.79	2406.0	2574.8	.5764	7.6750	8.2515
10	45.81	0.001 010	14.67	191.82	2246.1	2437.9	191.83	2392.8	2584.7	.6493	7.5009	8.1502
15	53.97	0.001 014	10.02	225.92	2222.8	2448.7	225.94	2373.1	2599.1	.7549	7.2536	8.0085
20	60.06	0.001 017	7.649	251.38	2205.4	2456.7	251.40	2358.3	2609.7	.8320	7.0766	7.9085
25	64.97	0.001 020	6.204	271.90	2191.2	2463.1	271.93	2346.3	2618.2	.8931	6.9383	7.8314
30	69.10	0.001 022	5.229	289.20	2179.2	2468.4	289.23	2336.1	2625.3	.9439	6.8247	7.7686
40	75.87	0.001 027	3.993	317.53	2159.5	2477.0	317.58	2319.2	2636.8	1.0259	6.6441	7.6700
50	81.33	0.001 030	3.240	340.44	2143.4	2483.9	340.49	2305.4	2645.9	1.0910	6.5029	7.5939
75	91.78	0.001 037	2.217	384.31	2112.4	2496.7	384.39	2278.6	2663.0	1.2130	6.2434	7.4564
MPa												
0.100	99.63	0.001 043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001 048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001 053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001 057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001 061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271

2.

A cylinder fitted with a piston contains argon gas at 140 kPa, 10°C, at which point the volume is 200 L. The gas is now compressed in a polytropic process to 700 kPa, 180°C. Calculate the heat transfer during the process.

$(C_v)_{Ar} = 0.3122 \ \mathrm{kJ/kg\,K}$ 14%

3.

(a) Why can the relation $\Delta U = mc_v \Delta T$ be used to calculate change in internal energy for an ideal gas in a *constant-pressure* process? 10%

(b) Why are the terms *subcooled liquid* and *compressed liquid* synonymous? (同義) 6%

1. A converging-diverging nozzle is used to accelerate a fluid from subsonic velocity to supersonic velocity. The nozzle is adiabatic , and hydrogen enters the inlet of the nozzle at low velocity with a pressure of 300 kPa and a temperature of 1200 K. At the nozzle exit the pressure and temperature of the hydrogen are 130 kPa and 900 K, respectively.
   (1) Draw P-v and T-s diagram. (5%)
   (2) Write the energy equation for the system. (5%)
   (3) Find the actual exit velocity of the hydrogen. (5%)
   (4) Find the adiabatic-nozzle efficiency. (5%)
   (5) Find the irreversibility per unit mass of hydrogen associated with the process. (10%)

   Assume that T_0=20 °C and that the flow through the nozzle is steady. C_{p0}=14.3 kJ/kg.mol.K, k=1.4.

2. A simple heat engine uses an ideal gas with constant specific heats as the working fluid in a frictionless piston-cylinder assembly. The gas is first heated at constant pressure from state 1 to state 2; then it is cooled at constant volume to state 3, where $T_3=T_1$. The gas is then compressed at constant temperature, thereby returning to state 1.
   (1) Draw P-v and T-s diagram of the three processes. (5%)
   (2) Find the work and the heat transfer for each of the three processes. (5%)
   (3) Find the thermal efficiency of the heat engine. (5%)
   (4) Find the thermal efficiency of a totally reversible heat engine operating between the maximum and minimum temperatures of this cycle. (5%)

   Express all answers in terms of variables from the following list: m, C_v, C_p, R, T_1, T_2, T_3, P_1, P_2, P_3.