系所組別： 機械工程學系甲組
考試科目： 熱力學

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1. (35%)

A frictionless piston/cylinder is loaded with a linear spring, and if the piston sits at the bottom, the spring force balances the other loads on the piston. The cylinder initial volume of 30 L contains air at 210 kPa, and ambient temperature, 20℃. The cylinder has a set of stops that prevents its volume from exceeding 50 L. A valve connects to a line flowing air at 500 kPa, 40℃. The valve is now opened, allowing air to flow in until the cylinder pressure reaches 500 kPa, at which point the temperature inside the cylinder is 60℃. The valve is then closed and the process ends. Assume air is an ideal gas, with constant specific heat, C_p = 1.004 kJ/kg-K, C_v = 0.717 kJ/kg-K, and R = 0.287 kJ/kg-K.

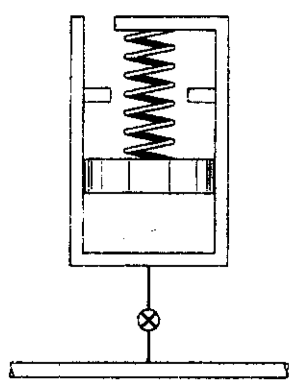
(a) What is the pressure while the piston first hit the stops (P_{stop})?

(b) Find the air mass that enters.

(c) Taking the inside of the cylinder as a control volume, calculate the work and heat transfer during the process.

(d) Is this process possible to happen? Why?

(e) Plot the process in a P-V diagram and clearly mark each state.



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2. (15%)

A closed, rigid tank having a volume of 2 m^3 initially contains air at 100℃, 500 kPa, and 50% relative humidity. If the tank contents are cooled to 85℃, check whether the condensation happens or not and determine the heat transfer, in kJ. Please use the following tables for calculation. Assume the gas mixture act as an ideal gas, with Air: R = 0.287 kJ/kg-K; H_2O: R = 0.4615 kJ/kg-K.

Saturated Water

		Specific Volume, m³/kg			Internal Energy, kJ/kg		
Temp. (°C)	Press. (kPa)	Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g
50	12.350	0.001012	12.0308	12.0318	209.30	2234.17	2443.47
55	15.758	0.001015	9.56734	9.56835	230.19	2219.89	2450.08
60	19.941	0.001017	7.66969	7.67071	251.09	2205.54	2456.63
65	25.03	0.001020	6.19554	6.19656	272.00	2191.12	2463.12
70	31.19	0.001023	5.04114	5.04217	292.93	2176.62	2469.55
75	38.58	0.001026	4.13021	4.13123	313.87	2162.03	2475.91
80	47.39	0.001029	3.40612	3.40715	334.84	2147.36	2482.19
85	57.83	0.001032	2.82654	2.82757	355.82	2132.58	2488.40
90	70.14	0.001036	2.35953	2.36056	376.82	2117.70	2494.52
95	84.55	0.001040	1.98082	1.98186	397.86	2102.70	2500.56
100	101.3	0.001044	1.67185	1.67290	418.91	2087.58	2506.50

Ideal Gas Properties of Air

T (K), h and u (kJ/kg), s^o (kJ/kg · K)

T	h	p_r	u	v_r	s^o
315	315.27	1.6442	224.85	549.8	1.75106
320	320.29	1.7375	228.42	528.6	1.76690
325	325.31	1.8345	232.02	508.4	1.78249
330	330.34	1.9352	235.61	489.4	1.79783
340	340.42	2.149	242.82	454.1	1.82790
350	350.49	2.379	250.02	422.2	1.85708
360	360.58	2.626	257.24	393.4	1.88543
370	370.67	2.892	264.46	367.2	1.91313
380	380.77	3.176	271.69	343.4	1.94001
390	390.88	3.481	278.93	321.5	1.96633
400	400.98	3.806	286.16	301.6	1.99194
410	411.12	4.153	293.43	283.3	2.01699
420	421.26	4.522	300.69	266.6	2.04142
430	431.43	4.915	307.99	251.1	2.06533
440	441.61	5.332	315.30	236.8	2.08870

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3. A well-insulated rigid tank of volume $7\,ft^3$ initially contains helium at $160\,^{\circ}F$ and $30\,lbf/in^2$. A valve connected to the tank is opened, and helium is withdrawn slowly until the pressure within the tank drops to p. An electrical resistor inside the tank maintains the temperature at $160\,^{\circ}F$. Determine the mass of helium withdrawn, in lb, and the energy input to the resistor, in *Btu*, when $p = 20\,lbf/in^2$. (20 %)

4. Air at $600\,kPa$, $330K$ enters a well-insulated, horizontal pipe having a diameter of $1.2\,cm$ and exits at $120\,kPa$, $300K$. The ideal gas model with $c_p = 1.0067\,kJ/kg\cdot K$ can be assumed for air. Determine at steady state the inlet and exit velocity, each in *m/s*, and the mass flow rate, in *kg/s*. (15 %)

5. In many texts of thermodynamics it was point out that the internal energy of gas at low pressures could be approximated by a relation of the type $du = c_v dT$. This approximation was based on Joule's law, which stated that $(\partial u/\partial v)_T$ at low pressure was experimentally determined to be zero. Besides, we have found that $ds = (c_v/T)dT + (\partial P/\partial T)_v dv$. Demonstrate that Joule's law holds exactly for ideal gases. (15 %)