Unified Engineering Spring 2008
Thermodynamics & Propulsion Z. S. Spakovszky

(Add a short summary of the concepts you are using to solve the problem)

Problem T4

Steam at 20 bar, 360ºC is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler.

a) Sketch this power cycle and draw all the processes in a *T*-*s* diagram.

b) Assuming ideal processes, find the net work and the cycle efficiency per kg of steam.

c) If the turbine and the pump each have 80% efficiency, find the percentage reduction in the net work and cycle efficiency.

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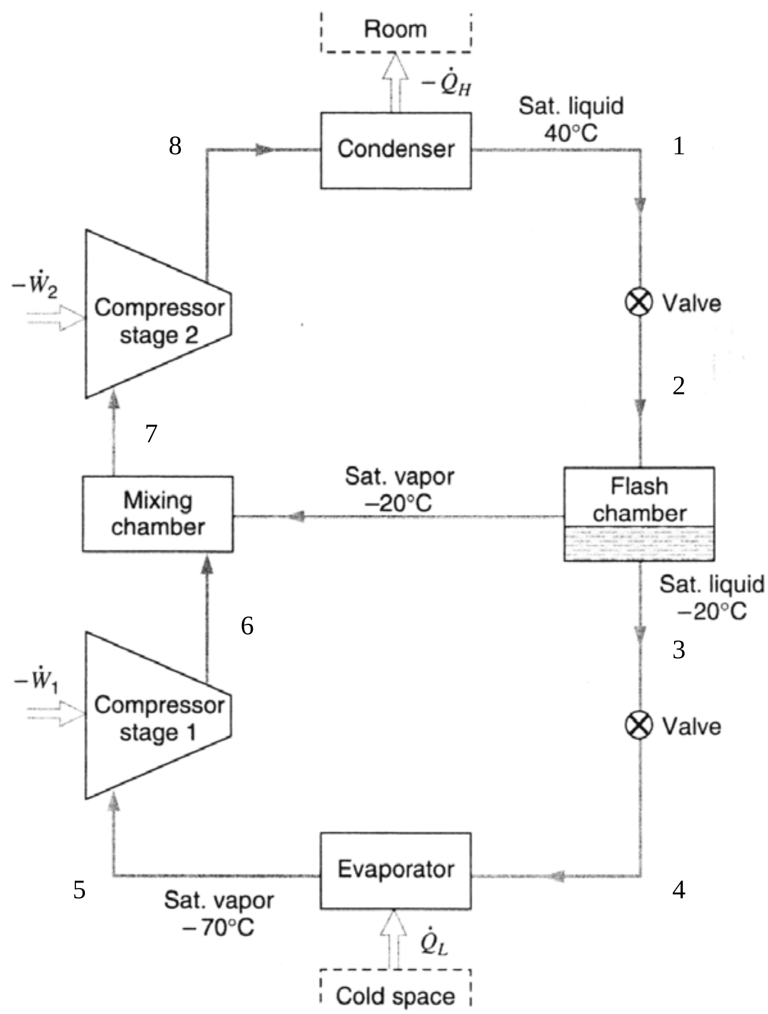
Problem T5

One means of improving the performance of a refrigerator system that operates over a wide temperature range is to use a two-stage compressor. Consider an ideal refrigeration system of this type that uses R-12 as the working fluid, as shown below. Saturated liquid leaves the condenser at 40ºC and is throttled to -20ºC. The liquid and vapor at this temperature are separated, and the liquid is throttled to the evaporator temperature, -70ºC. Vapor leaving the evaporator is compressed to the saturation pressure corresponding to -20ºC, after which it is mixed with the vapor leaving the flash chamber. It may be assumed that both the flash chamber and the mixing chamber are well insulated to prevent heat transfer from the ambient. Vapor leaving the mixing chamber is compressed in the second stage of the compressor to the saturation pressure corresponding to the condenser temperature, 40ºC.



b) Sketch the process in a *T-s* diagram and label all states.

c) Determine the heat absorbed from the cold space.

d) Determine the work needed to drive the 1st stage compressor.

e) Determine the work needed to drive the 2nd stage compressor.

f) Find the coefficient of performance of the system.

R-12 Properties

Temp.	Press.	Enthalpy, kJ/kg			Entropy, kJ/kg K		
C T	kPa P	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
-90	2.8	-43.28	189.75	146.46	-0.2086	1.0359	0.8273
-80	6.2	-34.72	185.74	151.02	-0.1631	0.9616	0.7984
-70	12.3	-26.13	181.76	155.64	-0.1198	0.8947	0.7749
-60	22.6	-17.49	177.77	160.29	-0.0783	0.8340	0.7557
-50	39.1	-8.78	173.73	164.95	-0.0384	0.7785	0.7401
-45	50.4	-4.40	171.68	167.28	-0.0190	0.7524	0.7334
-40	64.2	0	169.59	169.59	0	0.7274	0.7274
-35	80.7	4.42	167.48	171.90	0.0187	0.7032	0.7219
-30	100.4	8.86	165.34	174.20	0.0371	0.6799	0.7170
-29.8	101.3	9.05	165.24	174.29	0.0379	0.6790	0.7168
-25	123.7	13.33	163.15	176.48	0.0552	0.6574	0.7126
-20	150.9	17.82	160.92	178.74	0.0731	0.6356	0.7087
-15	182.6	22.33	158.64	180.97	0.0906	0.6145	0.7051
-10	219.1	26.87	156.31	183.19	0.1080	0.5940	0.7019
30	744.9	64.59	135.03	199.62	0.2399	0.4454	0.6853
35	847.7	69.55	131.90	201.45	0.2559	0.4280	0.6839
40	960.7	74.59	128.61	203.20	0.2718	0.4107	0.6825
45	1084.3	79.71	125.16	204.87	0.2877	0.3934	0.6811

v m³/kg	h kJ/kg	s kJ/kg K	v m³/kg	h kJ/kg	s kJ/kg K
750 kPa (30.26)			1000 kPa (41.64)		
0.02335	199.72	0.6852	0.01744	203.76	0.6820
—	—	—	—	—	—
0.02467	206.91	0.7086	—	—	—
0.02595	214.18	0.7314	0.01837	210.32	0.7026
0.02718	221.37	0.7533	0.01941	217.97	0.7259
0.02837	228.52	0.7745	0.02040	225.49	0.7481
0.02952	235.65	0.7949	0.02134	232.91	0.7695
0.03064	242.76	0.8148	0.02225	240.28	0.7900
0.03174	249.89	0.8342	0.02313	247.61	0.8100
0.03282	257.03	0.8530	0.02399	254.93	0.8293

100 kPa (-30.10)			200 kPa (-12.53)		
0.15999	174.15	0.7171	0.08354	182.07	0.7035
0.16006	174.21	0.7174	0.08861	189.80	0.7325
0.16770	179.99	0.7406	0.09255	196.02	0.7548
0.17522	185.84	0.7633	0.09642	202.28	0.7766
0.18265	191.77	0.7854	0.10023	208.60	0.7978
0.18999	197.77	0.8070	0.10399	214.97	0.8184
0.19728	203.85	0.8281	0.10771	221.41	0.8387
0.20451	210.02	0.8488	0.11140	227.90	0.8585
0.21169	216.26	0.8691	0.11506	234.46	0.8779
0.21884	222.58	0.8889	0.11869	241.09	0.8969

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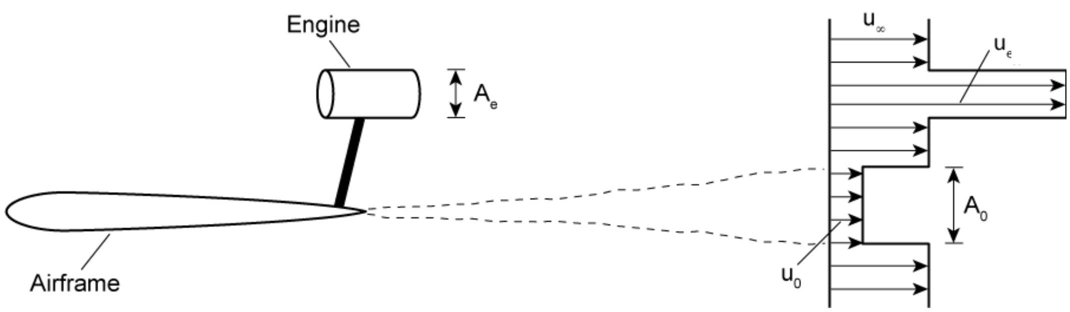
Problem T6

Consider the airframe-engine combination shown below. The engine ingests air at the free stream velocity. The fluid can be considered incompressible throughout, with density ρ. The engine is of constant area, i.e., the flow area is constant from the front of the inlet to the exit, and equal to A_e. The flow exits the engine with velocity u_e. For simplicity consider the turbomachinery in the engine to be represented only by a lossless fan that is driven by some power source. The free stream relative to the airframe has a velocity $u = u_\infty$, and the airframe has a wake with velocity u_0 and wake area A_0. At the downstream location the static pressure is uniform and the velocity profile is as indicated at the right of the figure. The aircraft is in steady level flight and the drag of the pylon and the engine nacelle is negligible.



In terms of some or all of the parameters $u_\infty, u_0, \rho, A_0, u_e$:

a) What is the drag of the airframe?

b) What is the thrust of the engine?

c) What is the ratio of the engine exit area to the wake area A_e / A_0?

d) What is the stagnation pressure rise across the fan?

e) What is the power input to the fan?

f) What is the power required to propel the airframe?