國立臺灣大學 105 學年度碩士班招生考試試題

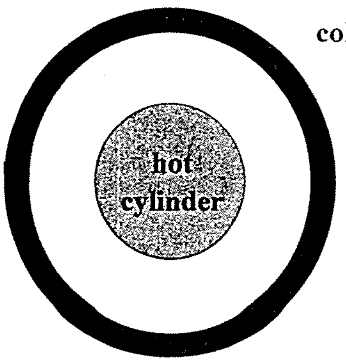
1. (15%) Answer the following questions in brief but clearly.

(i) What is the so-called Boussinesq approximation associated with the natural convection?

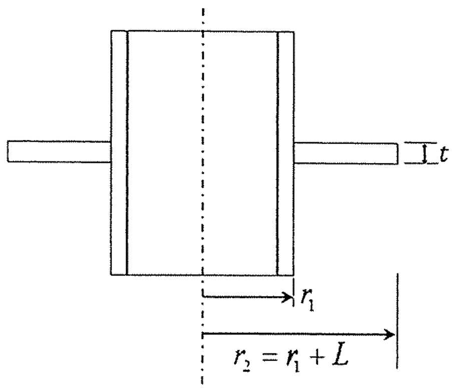
(ii) What is the definition and physical significance of the Prandtl number?

(iii) What is the definition and physical significance of the Eckert number?

2. (10%) A proposed method to reduce heat losses from a horizontal, isothermal cylinder placed within a large room is to encase it within a larger cylinder as shown in the schematic below. Air at atmospheric pressure exists within the annular region. Can the approach work? Explain it.



2.



3.

3. (25%) Consider an annular fin integrally cast with a cylinder made of 2024-T6 aluminum alloy (having a density ρ, a thermal conductivity k, and a specific heat c). The outside diameter of the cylinder is $2r_1$ and the fin is of thickness t and length L as shown above. Under typical operating conditions the outer surface of the cylinder is at a temperature of T_b and is exposed to ambient air at T_∞, with a convection coefficient of h. Assume the fin temperature is axisymmetric and its variation in the thickness direction is negligible. Starting from the first principle (energy conservation), derive the governing equation for the steady fin temperature distribution $T(r)$, where r is the radial coordinate.

4. (10%) The turbocharger of a Diesel engine consists of a turbine/compressor unit. The turbine extracts work from the engine exhaust and transfers it to the compressor, which in turn uses the work to increase the pressure of the air entering the engine. The exhaust gas, which can be considered to be air, enters the turbine at 500°C, 2 MPa, and exits it at 100 kPa. The ambient air enters the compressor at 20°C, 100 kPa. The compressor and turbine can be assumed to be adiabatic and reversible, and the kinetic and potential energy through them can be neglected. Considering that there are no losses in the turbine/compressor coupling, and assuming that their gas mass flow rates are the same, calculate the pressure at the compressor exit (engine intake). Note that constant specific heats are assumed and $k = 1.4$, $C_p = 0.287$ kJ/kg·°C for air.

5. (5%) Mark all of the following conditions which are implied by the equation (i.e. entropy change in terms of temperature and pressure ratios in a process from state 1 to state 2).

$$s_2 - s_1 = C_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$$

(a) Ideal gas
(b) Process is reversible
(c) Closed system
(d) Constant volume
(e) Constant C_p

6. (35%) Steam is supplied to a turbine from a spring-loaded cylinder. Initially, the cylinder pressure is 10 MPa and the volume is 4 m^3. The piston is considered weightless and the backing ambient atmospheric pressure is 100 kPa. The force exerted by the spring on the piston varies linearly with the cylinder volume, with a zero value corresponding to zero cylinder volume. The cylinder temperature is maintained at constant 400°C by exchanging heat with a large reservoir of thermal energy that is at the same temperature. A pressure regulator between the cylinder and the turbine maintains steady pressure and temperature at 1 MPa and 400°C at the turbine inlet. When the pressure in the cylinder drops to 1 MPa, the process stops. The turbine exhaust is to a condenser of pressure 5 kPa. The turbine may be considered reversible and adiabatic. Find

(a) The turbine exhaust temperature (or quality). (5%)

(b) The total work output of the turbine. (20%)

(c) The total heat transfer to the cylinder. (10%)

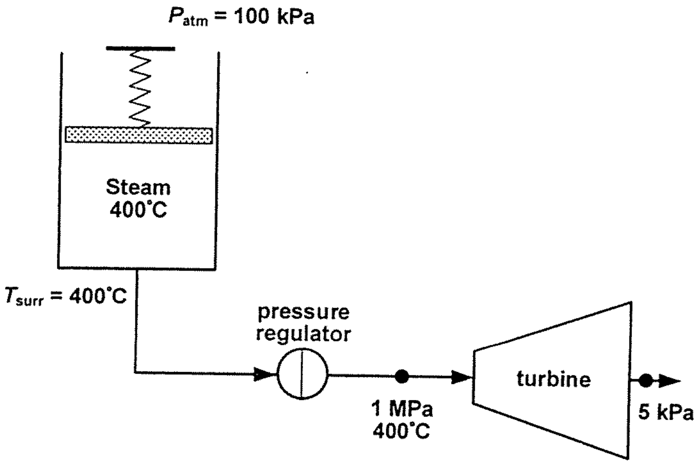


TABLE A-5

Saturated water—Pressure table

		Specific-volume, m³/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
Press., P kPa	Sat. temp., T_{sat} °C	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
1.0	6.97	0.001000	129.19	29.302	2355.2	2384.5	29.303	2484.4	2513.7	0.1059	8.8690	8.9749
1.5	13.02	0.001001	87.964	54.686	2338.1	2392.8	54.688	2470.1	2524.7	0.1956	8.6314	8.8270
2.0	17.50	0.001001	66.990	73.431	2325.5	2398.9	73.433	2459.5	2532.9	0.2606	8.4621	8.7227
2.5	21.08	0.001002	54.242	88.422	2315.4	2403.8	88.424	2451.0	2539.4	0.3118	8.3302	8.6421
3.0	24.08	0.001003	45.654	100.98	2306.9	2407.9	100.98	2443.9	2544.8	0.3543	8.2222	8.5765
4.0	28.96	0.001004	34.791	121.39	2293.1	2414.5	121.39	2432.3	2553.7	0.4224	8.0510	8.4734
5.0	32.87	0.001005	28.185	137.75	2282.1	2419.8	137.75	2423.0	2560.7	0.4762	7.9176	8.3938
7.5	40.29	0.001008	19.233	168.74	2261.1	2429.8	168.75	2405.3	2574.0	0.5763	7.6738	8.2501
10	45.81	0.001010	14.670	191.79	2245.4	2437.2	191.81	2392.1	2583.9	0.6492	7.4996	8.1488
15	53.97	0.001014	10.020	225.93	2222.1	2448.0	225.94	2372.3	2598.3	0.7549	7.2522	8.0071

TABLE A-6

Superheated water (*Concluded*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	P 1.00 MPa (179.88°C)			
Sat.	0.19437	2582.8	2777.1	6.5850
200	0.20602	2622.3	2828.3	6.6956
250	0.23275	2710.4	2943.1	6.9265
300	0.25799	2793.7	3051.6	7.1246
350	0.28250	2875.7	3158.2	7.3029
400	0.30661	2957.9	3264.5	7.4670
500	0.35411	3125.0	3479.1	7.7642
600	0.40111	3297.5	3698.6	8.0311
700	0.44783	3476.3	3924.1	8.2755
800	0.49438	3661.7	4156.1	8.5024
900	0.54083	3853.9	4394.8	8.7150
1000	0.58721	4052.7	4640.0	8.9155
1100	0.63354	4257.9	4891.4	9.1057
1200	0.67983	4469.0	5148.9	9.2866
1300	0.72610	4685.8	5411.9	9.4593

TABLE A-6

Superheated water (*Continued*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	P = 9.0 MPa (303.35°C)				P = 10.0 MPa (311.00°C)			
Sat.	0.020489	2558.5	2742.9	5.6791	0.018028	2545.2	2725.5	5.6159
325	0.023284	2647.6	2857.1	5.8738	0.019877	2611.6	2810.3	5.7596
350	0.025816	2725.0	2957.3	6.0380	0.022440	2699.6	2924.0	5.9460
400	0.029960	2849.2	3118.8	6.2876	0.026436	2833.1	3097.5	6.2141
450	0.033524	2956.3	3258.0	6.4872	0.029782	2944.5	3242.4	6.4219
500	0.036793	3056.3	3387.4	6.6603	0.032811	3047.0	3375.1	6.5995
550	0.039885	3153.0	3512.0	6.8164	0.035655	3145.4	3502.0	6.7585
600	0.042861	3248.4	3634.1	6.9605	0.038378	3242.0	3625.8	6.9045
650	0.045755	3343.4	3755.2	7.0954	0.041018	3338.0	3748.1	7.0408
700	0.048589	3438.8	3876.1	7.2229	0.043597	3434.0	3870.0	7.1693
800	0.054132	3632.0	4119.2	7.4606	0.048629	3628.2	4114.5	7.4085
900	0.059562	3829.6	4365.7	7.6802	0.053547	3826.5	4362.0	7.6290
1000	0.064919	4032.4	4616.7	7.8855	0.058391	4029.9	4613.8	7.8349
1100	0.070224	4240.7	4872.7	8.0791	0.063183	4238.5	4870.3	8.0289
1200	0.075492	4454.2	5133.6	8.2625	0.067938	4452.4	5131.7	8.2126
1300	0.080733	4672.9	5399.5	8.4371	0.072667	4671.3	5398.0	8.3874