

# 國立中正大學

## 111 學年度碩士班招生考試

### 試題

#### [第 1 節]

科目名稱	熱力學
系所組別	機械工程學系-丙組

#### —作答注意事項—

※作答前請先核對「試題」、「試卷」與「准考證」之系所組別、科目名稱是否相符。

1. 預備鈴響時即可入場，但至考試開始鈴響前，不得翻閱試題，並不得書寫、畫記、作答。
2. 考試開始鈴響時，即可開始作答；考試結束鈴響畢，應即停止作答。
3. 入場後於考試開始 40 分鐘內不得離場。
4. 全部答題均須在試卷（答案卷）作答區內完成。
5. 試卷作答限用藍色或黑色筆（含鉛筆）書寫。
6. 試題須隨試卷繳還。

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(25%)

1. Refrigerant 22 undergoes a constant-pressure process within a piston-cylinder assembly from saturated vapor at 4 bar to a final temperature of 30°C. Neglect both kinetic and potential energy effects. For the refrigerant,

(5%) (a) show the process on a p-v diagram.

(10%) (b) evaluate the work in kJ/kg.

(10%) (c) evaluate the heat transfer in kJ/kg.

(25%)

2. A turbine is operated at a steady state with air entering at 400 kPa, 970 K and exiting at 100 kPa, 670 K. Heat transfer from the turbine occurs at an average surface temperature of 315 K at the rate of 30 kJ per kg of air flowing. Kinetic and potential energy effects are negligible. For air as an ideal gas with a constant  $c_p = 1.1 \text{ kJ/(kg} \cdot \text{K)}$ , determine

(10%) (a) the rate of power developed, in kJ per kg of air flowing

(15%) (b) the rate of entropy production of the turbine, in kJ/K per kg of air flowing

$$\text{(Note: For an ideal gas, } s(T_2, p_2) - s(T_1, p_1) = \int_{T_1}^{T_2} c_p(T) \frac{dT}{T} - R \times \ln\left(\frac{p_2}{p_1}\right))$$

(20%)

3. A compressor operating at steady state takes in 0.5 kg/s of air at 1 bar and 300 K, and compresses it to 10 bar and 500 K. The power input to the compressor is 160 kW, and heat transfer occurs from the compressor to the surroundings at an average surface temperature of 400 K. Let  $T_0 = 300 \text{ K}$ ,  $p_0 = 1 \text{ bar}$ .

(5%) (a) Determine heat transfer rate, in kW.

(5%) (b) Determine exergy transfer out with heat, in kW.

(5%) (c) Determine exergy destroyed, in kW.

(5%) (d) Determine the exergetic efficiency for the compressor.

(20%)

4. Air enters the compressor of an ideal Brayton refrigeration cycle at 100 kPa, 285 K. The compressor pressure ratio is 3, and the temperature at the turbine inlet is 315 K.

(5%) (a) Determine enthalpies of the air at the compressor exit and turbine exit, respectively, in kJ/kg;

(5%) (b) Determine net work input, per unit mass of air flow, in kJ/kg;

(5%) (c) Determine refrigeration capacity, per unit mass of air flow, in kJ/kg;

(5%) (d) Determine coefficient of performance.

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(10%)

5. The state equation of a gas is given by  $v = \frac{RT}{p} - \frac{bp}{T^2}$ , where  $b$  is a constant.

(5%) (a) Test for the exactness of the equation. (choose  $T$  and  $p$  as two independent properties)

(5%) (b) Obtain an expression for the temperatures at the Joule-Thomson inversion states.

$$\text{Joule-Thomson coefficient: } \mu_J = \left( \frac{\partial T}{\partial p} \right)_h = \frac{1}{C_p} \left[ T \left( \frac{\partial v}{\partial T} \right)_p - v \right]$$

● Properties of Saturated Refrigerant 22 – pressure table

Press. bar	Temp. °C	Specific Volume m <sup>3</sup> /kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		Press. bar
		Sat. Liquid $v_f \times 10^3$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
2.25	-22.22	0.7389	0.1005	19.51	218.53	19.67	221.47	241.15	0.0809	0.9636	2.25
2.50	-19.51	0.7436	0.0910	22.54	219.55	22.72	219.57	242.29	0.0930	0.9586	2.50
2.75	-17.00	0.7479	0.0831	25.36	220.48	25.56	217.77	243.33	0.1040	0.9542	2.75
3.00	-14.66	0.7521	0.0765	27.99	221.34	28.22	216.07	244.29	0.1143	0.9502	3.00
3.25	-12.46	0.7561	0.0709	30.47	222.13	30.72	214.46	245.18	0.1238	0.9465	3.25
3.50	-10.39	0.7599	0.0661	32.82	222.88	33.09	212.91	246.00	0.1328	0.9431	3.50
3.75	-8.43	0.7636	0.0618	35.06	223.58	35.34	211.42	246.77	0.1413	0.9399	3.75
4.00	-6.56	0.7672	0.0581	37.18	224.24	37.49	209.99	247.48	0.1493	0.9370	4.00
4.25	-4.78	0.7706	0.0548	39.22	224.86	39.55	208.61	248.16	0.1569	0.9342	4.25
4.50	-3.08	0.7740	0.0519	41.17	225.45	41.52	207.27	248.80	0.1642	0.9316	4.50

● Properties of Superheated Refrigerant 22 Vapor

$T$ °C	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg · K
$p = 3.5 \text{ bar} = 0.35 \text{ MPa}$ ( $T_{\text{sat}} = -10.39^\circ\text{C}$ )					$p = 4.0 \text{ bar} = 0.40 \text{ MPa}$ ( $T_{\text{sat}} = -6.56^\circ\text{C}$ )			
Sat.	0.06605	222.88	246.00	0.9431	0.05812	224.24	247.48	0.9370
-10	0.06619	223.10	246.27	0.9441				
-5	0.06789	225.99	249.75	0.9572	0.05860	225.16	248.60	0.9411
0	0.06956	228.86	253.21	0.9700	0.06011	228.09	252.14	0.9542
5	0.07121	231.74	256.67	0.9825	0.06160	231.02	225.66	0.9670
10	0.07284	234.63	260.12	0.9948	0.06306	233.95	259.18	0.9795
15	0.07444	237.52	263.57	1.0069	0.06450	236.89	262.69	0.9918
20	0.07603	240.42	267.03	1.0188	0.06592	239.83	266.19	1.0039
25	0.07760	243.34	270.50	1.0305	0.06733	242.77	269.71	1.0158
30	0.07916	246.27	273.97	1.0421	0.06872	245.73	273.22	1.0274
35	0.08070	249.22	227.46	1.0535	0.07010	248.71	276.75	1.0390
40	0.08224	252.18	280.97	1.0648	0.07146	251.70	280.28	1.0504
45	0.08376	255.17	284.48	1.0759	0.07282	254.70	283.83	1.0616

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科目名稱：熱力學

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## ● Ideal Gas Properties of Air

$T(K), h \text{ and } u(kJ/kg), s^{\circ} (kJ/kg \cdot K)$											
$T$	$h$	$u$	$s^{\circ}$	when $\Delta s = 0^{\dagger}$		$T$	$h$	$u$	$s^{\circ}$	when $\Delta s = 0$	
				$p_r$	$v_r$					$p_r$	$v_r$
200	199.97	142.56	1.29559	0.3363	1707.	450	451.80	322.62	2.11161	5.775	223.6
210	209.97	149.69	1.34444	0.3987	1512.	460	462.02	329.97	2.13407	6.245	211.4
220	219.97	156.82	1.39105	0.4690	1346.	470	472.24	337.32	2.15604	6.742	200.1
230	230.02	164.00	1.43557	0.5477	1205.	480	482.49	344.70	2.17760	7.268	189.5
240	240.02	171.13	1.47824	0.6355	1084.	490	492.74	352.08	2.19876	7.824	179.7
250	250.05	178.28	1.51917	0.7329	979.	500	503.02	359.49	2.21952	8.411	170.6
260	260.09	185.45	1.55848	0.8405	887.8	510	513.32	366.92	2.23993	9.031	162.1
270	270.11	192.60	1.59634	0.9590	808.0	520	523.63	374.36	2.25997	9.684	154.1
280	280.13	199.75	1.63279	1.0889	738.0	530	533.98	381.84	2.27967	10.37	146.7
285	285.14	203.33	1.65055	1.1584	706.1	540	544.35	389.34	2.29906	11.10	139.7
290	290.16	206.91	1.66802	1.2311	676.1	550	554.74	396.86	2.31809	11.86	133.1
295	295.17	210.49	1.68515	1.3068	647.9	560	565.17	404.42	2.33685	12.66	127.0
300	300.19	214.07	1.70203	1.3860	621.2	570	575.59	411.97	2.35531	13.50	121.2
305	305.22	217.67	1.71865	1.4686	596.0	580	586.04	419.55	2.37348	14.38	115.7
310	310.24	221.25	1.73498	1.5546	572.3	590	596.52	427.15	2.39140	15.31	110.6
315	315.27	224.85	1.75106	1.6442	549.8	600	607.02	434.78	2.40902	16.28	105.8
320	320.29	228.42	1.76690	1.7375	528.6	610	617.53	442.42	2.42644	17.30	101.2
325	325.31	232.02	1.78249	1.8345	508.4	620	628.07	450.09	2.44356	18.36	96.92
330	330.34	235.61	1.79783	1.9352	489.4	630	638.63	457.78	2.46048	19.84	92.84
340	340.42	242.82	1.82790	2.149	454.1	640	649.22	465.50	2.47716	20.64	88.99
350	350.49	250.02	1.85708	2.379	422.2	650	659.84	473.25	2.49364	21.86	85.34
360	360.58	257.24	1.88543	2.626	393.4	660	670.47	481.01	2.50985	23.13	81.89
370	370.67	264.46	1.91313	2.892	367.2	670	681.14	488.81	2.52589	24.46	78.61
380	380.77	271.69	1.94001	3.176	343.4	680	691.82	496.62	2.54175	25.85	75.50
390	390.88	278.93	1.96633	3.481	321.5	690	702.52	504.45	2.55731	27.29	72.56
400	400.98	286.16	1.99194	3.806	301.6	700	713.27	512.33	2.57277	28.80	69.76