（命題用紙）

國立臺灣科技大學
八十七學年度碩士班招生考試試題

所　別：
學程別：機械工程技術研究所　　組別：熱流組　　科目：熱力學

(每題 25 分. 解題所需之公式與資料, 詳列於 3～6 頁)

1. 有 4 具機器在 300 K 與 600 K 二熱庫(thermal reservoirs)間循環操作. 每具機器之能量傳遞方向如箭頭所示. 例如機具 A 每循環(cycle)中, 由高溫熱庫輸入 2 J 之熱, 產生 0 J 之功, 而向低溫熱庫輸出 2 J 之熱.

a. 圖中四個循環(A, B, C, D), 那些循環違反熱力第一定律 ?

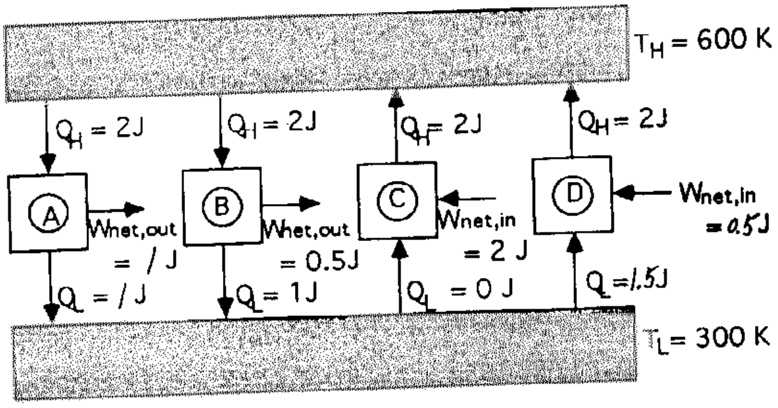
b. 那些循環違反 Kelvin-Planck 或 Clausius 有關熱力第二定律之敘述 ?

c. 那些循環違反 Carnot principles ?

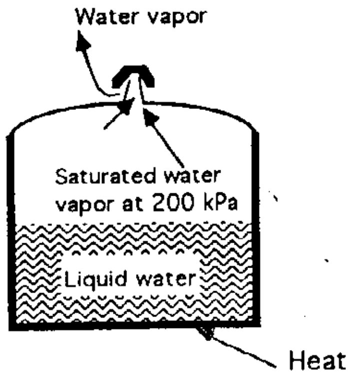
d. 那些循環能實際發生 ?

e. 那些循環爲可逆(reversible)之循環.?

(每小題 5 分. 需說明理由. 答案可能不只一個循環.)



2. 某容量4公升(0.004立方公尺)之壓力鍋(pressure cooker)其操作壓力爲200 kPa. 鍋內起初一半體積爲(液體)水，一半爲水蒸汽. 在穩態加熱狀況下，若淨熱輸入率爲 1 kW，試問鍋內之水是否會在半小時內燒乾 ?



3. 某發明家宣稱已製造出一耗電 5 kW 之空氣壓縮機，可在穩態操作下，將流量 0.02667 kg/s 之空氣，由 17℃, 100 kPa 壓縮至 167℃, 600 kPa. 試判斷此發明之真僞.(環境空氣溫度壓力分別爲 17℃, 100 kPa. 此壓縮過程並非絕熱).

4. 某 100 W 之白熱燈泡 (即普通電燈泡) 內部壓力極低.(例如 : 1 Pa)

a. 此燈泡耗電 100 W 時，燈絲溫度約爲 3000 K. 此時燈泡內部之熱傳，主要靠傳導，對流，或幅射 ?

b. 若此燈泡內之燈絲，爲一直徑 1 公厘之黑色細絲. 試估計燈絲長度.(列出並討論你熱傳分析中，所作之假設)

(a 小題 10 分; b 小題 15 分)

國立臺灣科技大學
八十七學年度碩士班招生考試試題

所　別：
學程別：機械工程技術研究所　　組別：熱流組　　科目：熱力學

TABLE A-5
Saturated water–Pressure table

Press. kPa P	Sat. temp. °C T_{sat}	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	0.00	2375.3	2375.3	0.01	2501.3	2501.4	0.0000	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	0.1059	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	0.1957	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	0.2607	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	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	0.3545	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	0.4226	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	0.4764	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	0.5764	7.6750	8.2515
10	45.81	0.001 010	14.67	191.82	2246.1	2437.9	191.83	2392.8	2584.7	0.6493	7.5009	8.1502
15	53.97	0.001 014	10.02	225.92	2222.8	2448.7	225.94	2373.1	2599.1	0.7549	7.2536	8.0085
20	60.06	0.001 017	7.649	251.38	2205.4	2456.7	251.40	2358.3	2609.7	0.8320	7.0766	7.9085
25	64.97	0.001 020	6.204	271.90	2191.2	2463.1	271.93	2346.3	2618.2	0.8931	6.9383	7.8314
30	69.10	0.001 022	5.229	289.20	2179.2	2468.4	289.23	2336.1	2625.3	0.9439	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
Press. 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
0.225	124.00	0.001 064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001 067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001 070	0.6573	548.59	1991.9	2540.5	548.89	2172.4	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001 073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001 076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001 079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001 081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001 084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001 088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001 093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001 097	0.3427	655.32	1909.2	2564.5	655.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001 101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001 104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001 108	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001 112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001 115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001 118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001 121	0.2150	741.83	1838.6	2580.5	742.83	2031.1	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001 124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001 127	0.194 44	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001 133	0.177 53	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001 139	0.163 33	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001 144	0.151 25	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953

國立臺灣科技大學
八十七學年度碩士班招生考試試題

所別：
學程別：機械工程技術研究所　組別：熱流組　科目：熱力學

TABLE A-17
Ideal-gas properties of air

T K	h kJ/kg	P_r	u kJ/kg	v_r	$s°$ kJ/(kg · K)
200	199.97	0.3363	142.56	1707.0	1.295 59
210	209.97	0.3987	149.69	1512.0	1.344 44
220	219.97	0.4690	156.82	1346.0	1.391 05
230	230.02	0.5477	164.00	1205.0	1.435 57
240	240.02	0.6355	171.13	1084.0	1.478 24
250	250.05	0.7329	178.28	979.0	1.519 17
260	260.09	0.8405	185.45	887.8	1.558 48
270	270.11	0.9590	192.60	808.0	1.596 34
280	280.13	1.0889	199.75	738.0	1.632 79
285	285.14	1.1584	203.33	706.1	1.650 55
290	290.16	1.2311	206.91	676.1	1.668 02
295	295.17	1.3068	210.49	647.9	1.685 15
300	300.19	1.3860	214.07	621.2	1.702 03
305	305.22	1.4686	217.67	596.0	1.718 65
310	310.24	1.5546	221.25	572.3	1.734 98
315	315.27	1.6442	224.85	549.8	1.751 06
320	320.29	1.7375	228.42	528.6	1.766 90
325	325.31	1.8345	232.02	508.4	1.782 49
330	330.34	1.9352	235.61	489.4	1.797 83
340	340.42	2.149	242.82	454.1	1.827 90
350	350.49	2.379	250.02	422.2	1.857 08
360	360.58	2.626	257.24	393.4	1.885 43
370	370.67	2.892	264.46	367.2	1.913 13
380	380.77	3.176	271.69	343.4	1.940 01
390	390.88	3.481	278.93	321.5	1.966 33
400	400.98	3.806	286.16	301.6	1.991 94
410	411.12	4.153	293.43	283.3	2.016 99
420	421.26	4.522	300.69	266.6	2.041 42
430	431.43	4.915	307.99	251.1	2.065 33
440	441.61	5.332	315.30	236.8	2.088 70
450	451.80	5.775	322.62	223.6	2.111 61
460	462.02	6.245	329.97	211.4	2.134 07
470	472.24	6.742	337.32	200.1	2.156 04
480	482.49	7.268	344.70	189.5	2.177 60
490	492.74	7.824	352.08	179.7	2.198 76
500	503.02	8.411	359.49	170.6	2.219 52
510	513.32	9.031	366.92	162.1	2.239 93
520	523.63	9.684	374.36	154.1	2.259 97
530	533.98	10.37	381.84	146.7	2.279 67
540	544.35	11.10	389.34	139.7	2.299 06
550	554.74	11.86	396.86	133.1	2.318 09
560	565.17	12.66	404.42	127.0	2.336 85
570	575.59	13.50	411.97	121.2	2.355 31
580	586.04	14.38	419.55	115.7	2.373 48
590	596.52	15.31	427.15	110.6	2.391 40
600	607.02	16.28	434.78	105.8	2.409 02
610	617.53	17.30	442.42	101.2	2.426 44
620	628.07	18.36	450.09	96.92	2.443 56
630	638.63	19.84	457.78	92.84	2.460 48
640	649.22	20.64	465.50	88.99	2.477 16
650	659.84	21.86	473.25	85.34	2.493 64
660	670.47	23.13	481.01	81.89	2.509 85
670	681.14	24.46	488.81	78.61	2.525 89
680	691.82	25.85	496.62	75.50	2.541 75
690	702.52	27.29	504.45	72.56	2.557 31
700	713.27	28.80	512.33	69.76	2.572 77
710	724.04	30.38	520.23	67.07	2.588 10
720	734.82	32.02	528.14	64.53	2.603 19
730	745.62	33.72	536.07	62.13	2.618 03
740	756.44	35.50	544.02	59.82	2.632 80
750	767.29	37.35	551.99	57.63	2.647 37
760	778.18	39.27	560.01	55.54	2.661 76
780	800.03	43.35	576.12	51.64	2.690 13
800	821.95	47.75	592.30	48.08	2.717 87
820	843.98	52.59	608.59	44.84	2.745 04
840	866.08	57.60	624.95	41.85	2.771 70
860	888.27	63.09	641.40	39.12	2.797 83
880	910.56	68.98	657.95	36.61	2.823 44
900	932.93	75.29	674.58	34.31	2.848 56
920	955.38	82.05	691.28	32.18	2.873 24
940	977.92	89.28	708.08	30.22	2.897 48
960	1000.55	97.00	725.02	28.40	2.921 28
980	1023.25	105.2	741.98	26.73	2.944 68
1000	1046.04	114.0	758.94	25.17	2.967 70
1020	1068.89	123.4	776.10	23.72	2.990 34
1040	1091.85	133.3	793.36	22.39	3.012 60
1060	1114.86	143.9	810.62	21.14	3.034 49
1080	1137.89	155.2	827.88	19.98	3.056 08
1100	1161.07	167.1	845.33	18.896	3.077 32
1120	1184.28	179.7	862.79	17.886	3.098 25
1140	1207.57	193.1	880.35	16.946	3.118 83
1160	1230.92	207.2	897.91	16.064	3.139 16
1180	1254.34	222.2	915.57	15.241	3.159 16
1200	1277.79	238.0	933.33	14.470	3.178 88
1220	1301.31	254.7	951.09	13.747	3.198 34
1240	1324.93	272.3	968.95	13.069	3.217 51

3 ***Ideal gases:***

a Constant specific heats (approximate treatment):

$R = 0.287$ kJ/kg-K for air

Any process:

$$s_2 - s_1 = C_{v,\text{av}} \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1} \quad [\text{kJ/(kg} \cdot \text{K)}]$$

and

$$s_2 - s_1 = C_{p,\text{av}} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1} \quad [\text{kJ/(kg} \cdot \text{K)}]$$

b Variable specific heats (exact treatment):

Any process:

$$s_2 - s_1 = s_2^\circ - s_1^\circ - R \ln \frac{P_2}{P_1} \quad [\text{kJ/(kg} \cdot \text{K)}]$$

or

$$\bar{s}_2 - \bar{s}_1 = \bar{s}_2^\circ - \bar{s}_1^\circ - R_u \ln \frac{P_2}{P_1} \quad [\text{kJ/(kmol} \cdot \text{K)}]$$

國立臺灣科技大學
八十七學年度碩士班招生考試試題

所　別：
學程別：機械工程技術研究所　　組別：熱流組　　科目：熱力學

steady-flow processes are expressed as

$$\sum \dot{m}_i = \sum \dot{m}_e \qquad \text{(kg/s)} \qquad \text{(4-14)}$$

$$\dot{Q} - \dot{W} = \underbrace{\sum \dot{m}_e\left(h_e + \frac{\mathbf{V}_e^2}{2} + gz_e\right)}_{\text{for each exit}} - \underbrace{\sum \dot{m}_i\left(h_i + \frac{\mathbf{V}_i^2}{2} + gz_i\right)}_{\text{for each inlet}} \quad \text{(kW)} \qquad \text{(4-19)}$$

where the subscript i stands for *inlet* and e for *exit*. These are the most general forms of the equations for steady-flow processes. For single-stream (one-inlet, one-exit) systems such as nozzles, diffusers, turbines, compressors, and pumps, they simplify to

$$\dot{m}_1 = \dot{m}_2 \qquad \text{(kg/s)} \qquad \text{(4-15)}$$

or

$$\frac{1}{v_1}\mathbf{V}_1 A_1 = \frac{1}{v_2}\mathbf{V}_2 A_2 \qquad \text{(4-17)}$$

and

$$\dot{Q} - \dot{W} = \dot{m}\left[h_2 - h_1 + \frac{\mathbf{V}_2^2 - \mathbf{V}_1^2}{2} + g(z_2 - z_1)\right] \qquad \text{(kW)} \quad \text{(4-20)}$$

$$q - w = h_2 - h_1 + \frac{\mathbf{V}_2^2 - \mathbf{V}_1^2}{2} + g(z_2 - z_1) \qquad \text{(kJ/kg)} \qquad \text{(4-22)}$$

or

$$q - w = \Delta h + \Delta \text{ke} + \Delta \text{pe} \qquad \text{(kJ/kg)} \qquad \text{(4-23)}$$

where

$$q = \frac{\dot{Q}}{\dot{m}} \qquad \text{(heat transfer per unit mass, kJ/kg)} \qquad \text{(4-24)}$$

and

$$w = \frac{\dot{W}}{\dot{m}} \qquad \text{(work done per unit mass, kJ/kg)} \qquad \text{(4-25)}$$

In the above relations, subscripts 1 and 2 denote the inlet and exit states, respectively.

The steady-flow process is the model process for flow through nozzles, diffusers, turbines, compressors, fans, pumps, pipes, throttling valves, mixing chambers, and heat exchangers.

For *unsteady-flow processes*, the conservation of mass and energy equations are

$$\sum m_i - \sum m_e = (m_2 - m_1)_{\text{CV}} \qquad \text{(kg)} \qquad \text{(4-29)}$$

$$Q - W = \sum \int_{m_e} \left(h_e + \frac{\mathbf{V}_e^2}{2} + gz_e\right) \delta m_e - \sum \int_{m_i} \left(h_i + \frac{\mathbf{V}_i^2}{2} + gz_i\right) \delta m_i + \Delta E_{\text{CV}} \qquad \text{(4-35)}$$

The various subscripts appearing in the above equations are i = inlet, e = exit, 1 = initial state, and 2 = final state of the control volume.

Often one or more terms in Eq. 4-29 are zero. For example, $m_i = 0$ if no mass enters the CV during the process, $m_e = 0$ if no mass leaves the CV during the process, and $m_1 = 0$ if the CV is initially evacuated.

The unsteady-flow processes are, in general, difficult to analyze because the integrations in Eq. 4-35 are difficult to perform. Some unsteady-flow processes, however, can be represented by another simplified model called the *uniform-flow process*. During a uniform-flow process, the state of the control volume may change with time, but it may do so uniformly. Also the fluid properties at the inlets and the exits are assumed to remain constant during the entire process. The conservation of energy equation for a uniform-flow process reduces to

$$Q - W = \sum m_e\left(h_e + \frac{\mathbf{V}_e^2}{2} + gz_e\right) - \sum m_i\left(h_i + \frac{\mathbf{V}_i^2}{2} + gz_i\right) + (m_2 e_2 - m_1 e_1)_{\text{CV}} \qquad \text{(4-37)}$$

When the kinetic and potential energy changes associated with the control volume and the fluid streams are negligible, Eq. 4-37 simplifies to

$$Q - W = \sum m_e h_e - \sum m_i h_i + (m_2 u_2 - m_1 u_1)_{\text{CV}} \qquad \text{(kJ)} \qquad \text{(4-38)}$$

國立臺灣科技大學
八十七學年度碩士班招生考試試題

所　別：
學程別：機械工程技術研究所　　組別：熱流組　　科目：熱力學

heat engine is defined as

$$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H} \qquad (5\text{-}7, 5\text{-}8)$$

where $W_{net,out}$ is the net work output of the heat engine, Q_H is the amount of heat supplied to the engine, and Q_L is the amount of heat rejected by the engine.

Refrigerators and heat pumps are devices that absorb heat from low-temperature media and reject it to higher temperature ones. The performance of a refrigerator or a heat pump is expressed in terms of the *coefficient of performance*, which is defined as

$$\mathrm{COP}_R = \frac{Q_L}{W_{net,in}} = \frac{1}{Q_H/Q_L - 1} \qquad (5\text{-}9, 5\text{-}11)$$

$$\mathrm{COP}_{HP} = \frac{Q_H}{W_{net,in}} = \frac{1}{1 - Q_L/Q_H} \qquad (5\text{-}12, 5\text{-}13)$$

The *Kelvin-Planck statement* of the second law of thermodynamics states that no heat engine can produce a net amount of work while exchanging heat with a single reservoir only. The *Clausius statement* of the second law states that no device can transfer heat from a cooler body to a warmer one without leaving an effect on the surroundings.

Any device that violates the first or the second law of thermodynamics is called a *perpetual-motion machine.*

A process is said to be *reversible* if both the system and the surroundings can be restored to their original conditions. Any other process is *irreversible.* The effects such as friction, not-quasi-equilibrium expansion or compression, and heat transfer through a finite temperature difference render a process irreversible and are called *irreversibilities.*

The *Carnot cycle* is a reversible cycle that is composed of four reversible processes, two isothermal and two adiabatic. The *Carnot principles* state that the thermal efficiencies of all reversible heat engines operating between the same two reservoirs are the same, and that no heat engine is more efficient that a reversible one operating between the same two reservoirs. These statements form the basis for establishing a *thermodynamic temperature scale,* also called the *Kelvin scale,* related to the heat transfers between a reversible device and the high- and low-temperature reservoirs by

$$\left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L} \qquad (5\text{-}18)$$

Therefore the Q_H/Q_L ratio can be replaced by T_H/T_L for reversible devices, where T_H and T_L are the absolute temperatures of the high- and low-temperature reservoirs, respectively.

A heat engine that operates on the reversible Carnot cycle is called the *Carnot heat engine.* The thermal efficiency of a Carnot heat engine, as

Heat Transfer Modes :

(1) Conduction :

Fourier's law of conduction : q"(heat flux) = - k dT/dx

You may assume k(thermal conductivity) = 1×10^{-6} W/m.K for air at 1500 K, 1 Pa.

(2) Convection :

Newton' law of cooling : $q'' = h(T_{solid} - T_{fluid})$

You may assume h(convection coefficient) = 1×10^{-5} W/m^2.K for natural convection in air at 1500 K. 1 Pa.

(3) Radiation :

The Stefan-Boltzmann law : $q'' = \sigma T^4$ for black-body emission

$\sigma = 5.67 \times 10^{-8}$ W/m^2.K^4