

1. 導出理想氣體 $ds = \frac{c_v}{T} dT + R \frac{dv}{v}$ 及 $ds = \frac{c_p}{T} dT - R \frac{dP}{P}$ (12%)
2. 導出 $c_p - c_v = -T \left(\frac{\partial v}{\partial T} \right)_P^2 \left(\frac{\partial P}{\partial v} \right)_T$ ，並說明由此式可得到那些物理現象。
(12%)
3. 繪出 Polytropic process $Pv^n = \text{常數}$ 的 P-v 圖和 T-s 圖。並說明當 $n=0, 1, k, \infty$ 各自所代表何種實際變化過程。
(12%)
4. 如果要使一個內裝有理想氣體之汽缸運轉一個循環 (cycle) 後，能夠對外做功，請問應該如何設計？並說明設計之理由。
(12%)
5. 說明 Heat pump (熱泵) and Refrigerator (冷凍機) 之原理，及其性能係數 (performance coefficient) 之表示式。
(12%)
6. 一個剛體容器 (rigid tank) 內裝有氮氣，現欲將其內溫度由 310 K 升高到 390 K，而起始壓力為 200 kPa。
 - (a) 若由一攪拌器給予輸入功，試問此功為多少 kJ/kg？此時之容器為絕熱。
(5%)
 - (b) 若改由一個溫度 450 K 熱庫供給熱量，試問此熱量為何？
(5%)
 - (c) 上述兩種方法之不可逆性 (Irreversibility) 各是多少？
(10%)
 - (d) 由熱力學觀點，說明上述方法何者為佳。
(5%)

(已知外界環境溫度為 298 K，及 $c_{v0}=0.744$ kJ/kg.K,
 $c_{p0}=1.039$ kJ/kg.K, $\bar{R}=8.314$ kJ/kg.mol.K)
7. 一個冷凍液 (Refrigerant-12) 穩定地流進入一個冷凍機之節流閥 (Throttling valve)，壓力為 1 MPa，且為飽和液體狀態；離開時以壓力 250 kPa 射出。試決定進出口之溫度和出口時之乾度 (quality)。假設此時之動能變化及熱傳至外面熱量可略去不計。(參考表一作答)。
(15%)

(背面仍有題目,請繼續作答)

(表一)

TABLE C.2 SATURATED REFRIGERANT-12—PRESSURE TABLE: SI UNITS

| Press., MPa, P | Temp., °C, T | Specific volume, m ³ /kg | | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg·K | | |
|----------------|--------------|-------------------------------------|------------------------|----------------------------|-----------------------------|------------------------|----------------------------|-----------------------------|------------------------|----------------------------|-----------------------------|------------------------|----------------------------|
| | | Sat. liquid, v _f | Evap., v _{fg} | 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 |
| 0.002 | -94.73 | 0.00060086 | 6.1180 | 6.1186 | -46.046 | 178.73 | 132.68 | -46.044 | 190.96 | 144.92 | -0.22791 | 1.07029 | 0.84238 |
| 0.004 | -86.21 | 0.00060905 | 3.1995 | 3.2001 | -39.010 | 174.95 | 135.91 | -39.008 | 187.75 | 148.74 | -0.18851 | 1.00433 | 0.81582 |
| 0.006 | -80.35 | 0.00061486 | 2.1967 | 2.1973 | -34.586 | 172.82 | 138.34 | -34.582 | 186.00 | 151.42 | -0.16254 | 0.96472 | 0.80218 |
| 0.008 | -76.25 | 0.00061901 | 1.6802 | 1.6808 | -31.190 | 171.04 | 139.85 | -31.185 | 184.49 | 153.30 | -0.14480 | 0.93697 | 0.79217 |
| 0.010 | -73.00 | 0.00062236 | 1.3646 | 1.3652 | -28.425 | 169.57 | 141.15 | -28.419 | 183.22 | 154.80 | -0.13093 | 0.91542 | 0.78449 |
| 0.015 | -66.78 | 0.00062893 | 0.93531 | 0.93594 | -23.102 | 166.75 | 143.65 | -23.092 | 180.78 | 157.69 | -0.10492 | 0.87599 | 0.77107 |
| 0.020 | -62.07 | 0.00063405 | 0.71563 | 0.71626 | -19.071 | 164.63 | 145.56 | -19.058 | 178.94 | 159.88 | -0.085679 | 0.84772 | 0.76205 |
| 0.030 | -51.96 | 0.00064199 | 0.49082 | 0.49146 | -12.984 | 161.45 | 148.36 | -12.965 | 176.17 | 163.21 | -0.057357 | 0.80743 | 0.75007 |
| 0.040 | -49.57 | 0.00064822 | 0.37561 | 0.37626 | -8.106 | 159.04 | 150.68 | -8.1147 | 174.05 | 165.73 | -0.036343 | 0.77846 | 0.74212 |
| 0.050 | -45.16 | 0.00065315 | 0.30519 | 0.30585 | -4.5119 | 157.04 | 152.51 | -4.4992 | 172.30 | 167.80 | -0.019474 | 0.75575 | 0.73628 |
| 0.060 | -41.41 | 0.00065801 | 0.25755 | 0.25820 | -1.2734 | 155.34 | 154.07 | -1.2339 | 170.79 | 169.56 | -0.005297 | 0.73702 | 0.73172 |
| 0.070 | -38.13 | 0.00066208 | 0.22309 | 0.22375 | 1.5922 | 153.85 | 155.44 | 1.6385 | 169.46 | 171.10 | 0.006983 | 0.72104 | 0.72803 |
| 0.080 | -35.19 | 0.00066579 | 0.19696 | 0.19763 | 4.1615 | 152.50 | 156.66 | 4.2148 | 168.26 | 172.47 | 0.017849 | 0.70710 | 0.72495 |
| 0.090 | -32.54 | 0.00066921 | 0.17644 | 0.17711 | 6.4987 | 151.28 | 157.77 | 6.5589 | 167.16 | 173.71 | 0.027617 | 0.69470 | 0.72232 |
| 0.100 | -30.10 | 0.00067239 | 0.15989 | 0.16057 | 8.6484 | 150.15 | 158.79 | 8.7156 | 166.13 | 174.85 | 0.036508 | 0.68394 | 0.72005 |
| 0.125 | -24.75 | 0.00067955 | 0.12973 | 0.13041 | 13.397 | 147.64 | 161.04 | 13.482 | 163.85 | 177.34 | 0.05837 | 0.65964 | 0.71547 |
| 0.150 | -20.17 | 0.00068589 | 0.10930 | 0.10998 | 17.489 | 145.46 | 162.95 | 17.592 | 161.86 | 179.45 | 0.072164 | 0.63981 | 0.71198 |
| 0.175 | -16.15 | 0.00069168 | 0.084909 | 0.085200 | 21.110 | 143.53 | 164.64 | 21.231 | 160.07 | 181.30 | 0.086370 | 0.62283 | 0.70920 |
| 0.200 | -12.53 | 0.00069691 | 0.063288 | 0.063485 | 24.375 | 141.77 | 166.15 | 24.514 | 158.43 | 182.94 | 0.098988 | 0.60793 | 0.70692 |
| 0.250 | -6.27 | 0.00070647 | 0.037556 | 0.037862 | 30.116 | 138.65 | 168.77 | 30.273 | 155.49 | 185.78 | 0.12077 | 0.58262 | 0.70338 |
| 0.300 | -0.88 | 0.00071507 | 0.025655 | 0.025720 | 35.095 | 135.91 | 171.01 | 35.309 | 152.88 | 188.19 | 0.13924 | 0.56150 | 0.70074 |
| 0.350 | 3.87 | 0.00072297 | 0.018731 | 0.019151 | 39.524 | 133.44 | 172.97 | 39.777 | 150.50 | 190.28 | 0.15538 | 0.54329 | 0.69867 |
| 0.400 | 8.13 | 0.00073036 | 0.0142791 | 0.014521 | 43.535 | 131.18 | 174.72 | 43.827 | 148.30 | 192.13 | 0.16976 | 0.52723 | 0.69699 |
| 0.500 | 15.58 | 0.00074402 | 0.013447 | 0.013891 | 50.631 | 127.12 | 177.75 | 51.003 | 144.29 | 195.29 | 0.19468 | 0.49973 | 0.69441 |

TABLE C.2 SATURATED REFRIGERANT-12—PRESSURE TABLE: SI UNITS (Continued)

| Press., MPa, P | Temp., °C, T | Specific volume, m ³ /kg | | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg·K | | |
|----------------|--------------|-------------------------------------|------------------------|----------------------------|-----------------------------|------------------------|----------------------------|-----------------------------|------------------------|----------------------------|-----------------------------|------------------------|----------------------------|
| | | Sat. liquid, v _f | Evap., v _{fg} | 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 |
| 0.600 | 22.00 | 0.00075663 | 0.028616 | 0.029373 | 56.824 | 123.49 | 180.31 | 57.278 | 140.65 | 192.93 | 0.21592 | 0.47636 | 0.69247 |
| 0.700 | 27.67 | 0.00076854 | 0.024458 | 0.025227 | 62.365 | 120.17 | 182.53 | 62.903 | 137.29 | 200.19 | 0.23454 | 0.45639 | 0.69092 |
| 0.800 | 32.76 | 0.00077996 | 0.021297 | 0.022077 | 67.407 | 117.08 | 184.49 | 68.031 | 134.12 | 202.15 | 0.25118 | 0.43843 | 0.68961 |
| 0.900 | 37.41 | 0.00079103 | 0.018808 | 0.019599 | 72.055 | 114.18 | 186.24 | 72.767 | 131.11 | 203.88 | 0.26629 | 0.42217 | 0.68846 |
| 1.00 | 41.70 | 0.00080187 | 0.016794 | 0.017595 | 76.382 | 111.42 | 187.81 | 77.184 | 128.22 | 205.40 | 0.28016 | 0.40724 | 0.68740 |
| 1.20 | 49.40 | 0.00082315 | 0.013724 | 0.014547 | 84.277 | 106.24 | 190.51 | 85.265 | 122.70 | 207.97 | 0.30501 | 0.38042 | 0.68543 |
| 1.40 | 56.21 | 0.00084330 | 0.011487 | 0.012331 | 91.393 | 101.36 | 192.75 | 92.575 | 117.44 | 210.02 | 0.32693 | 0.35657 | 0.68350 |
| 1.60 | 62.34 | 0.00086258 | 0.009775 | 0.010641 | 97.923 | 96.69 | 194.62 | 99.308 | 112.33 | 211.64 | 0.34667 | 0.33483 | 0.68150 |
| 1.80 | 67.93 | 0.00088075 | 0.0084168 | 0.0093044 | 104.00 | 92.16 | 196.16 | 105.60 | 107.31 | 212.91 | 0.36474 | 0.31461 | 0.67935 |
| 2.00 | 73.07 | 0.00091029 | 0.0073070 | 0.0082173 | 109.72 | 87.69 | 197.41 | 111.54 | 102.30 | 213.84 | 0.38151 | 0.29549 | 0.67699 |
| 2.25 | 78.98 | 0.00094027 | 0.0064680 | 0.0074082 | 116.48 | 82.12 | 198.60 | 118.60 | 96.00 | 214.59 | 0.40106 | 0.27261 | 0.67367 |
| 2.50 | 84.41 | 0.00097263 | 0.00582260 | 0.0067986 | 122.93 | 76.46 | 199.39 | 125.36 | 89.53 | 214.89 | 0.41944 | 0.25037 | 0.66982 |
| 2.75 | 89.44 | 0.0010082 | 0.0044238 | 0.0054320 | 129.17 | 70.60 | 199.77 | 131.94 | 82.77 | 214.71 | 0.43702 | 0.22827 | 0.66530 |
| 3.00 | 94.12 | 0.0010481 | 0.0037207 | 0.0047688 | 135.30 | 64.41 | 199.70 | 138.44 | 75.57 | 214.01 | 0.45414 | 0.20576 | 0.65990 |
| 3.25 | 98.50 | 0.0010933 | 0.0030849 | 0.0041791 | 141.44 | 57.66 | 199.10 | 145.00 | 67.69 | 212.69 | 0.47116 | 0.18213 | 0.65329 |
| 3.50 | 102.60 | 0.0011499 | 0.0024860 | 0.0036359 | 147.76 | 50.02 | 197.79 | 151.79 | 58.72 | 210.51 | 0.48858 | 0.15628 | 0.64486 |
| 3.75 | 106.46 | 0.0012227 | 0.0018831 | 0.0031058 | 154.57 | 40.73 | 195.30 | 159.16 | 47.79 | 206.93 | 0.50730 | 0.12590 | 0.63321 |
| 4.00 | 110.08 | 0.0013436 | 0.0011565 | 0.0025001 | 162.93 | 26.97 | 189.90 | 168.30 | 31.59 | 199.90 | 0.53044 | 0.08244 | 0.61288 |
| 4.125 | 111.90 | 0.001292 | 0.0 | 0.001792 | 164.75 | 0.0 | 164.75 | 172.14 | 0.0 | 172.14 | 0.54025 | 0.0 | 0.54025 |

Values generated from property formulation given in ASHRAE Thermodynamic Properties of Refrigerants, R.H. Stewart, R.T. Jacobsen and S.G. Democello, ASHRAE, Inc. 1986.