※ 考生請注意：本試題不可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. For a gas obeying the van der Waals equation of state ($p = \frac{\bar{R}T}{\bar{v}-b} - \frac{a}{\bar{v}^2}$),

(a) show that $\left(\frac{\partial c_v}{\partial v}\right)_T = 0$. (5%)

(b) show that $(s_2 - s_1)_T = R \cdot \ln\frac{V_2-b}{V_1-b}$. (5%)

(c) develop expression for $c_p - c_v$. (5%)

2. Determine the Gibbs function of formation of methane at the standard state, 25°C and 1 atm, in kJ/kmol, and compare with the value given in Table A. (15%)

Table A

Thermochemical Properties of Selected Substances at 298K and 1 atm

Substance	Formula	Molar Mass, M (kg/kmol)	Enthalpy of Formation, $\bar{h}_f^\circ$ (kJ/kmol)	Gibbs Function of Formation, $\bar{g}_f^\circ$ (kJ/kmol)	Absolute Entropy, $\bar{s}^\circ$ (kJ/kmol · K)	Heating Values: Higher, HHV (kJ/kg)	Heating Values: Lower, LHV (kJ/kg)
Carbon	$C(s)$	12.01	0	0	5.74	32,770	32,770
Hydrogen	$H_2(g)$	2.016	0	0	130.57	141,780	119,950
Nitrogen	$N_2(g)$	28.01	0	0	191.50	—	—
Oxygen	$O_2(g)$	32.00	0	0	205.03	—	—
Carbon monoxide	$CO(g)$	28.01	−110,530	−137,150	197.54	—	—
Carbon dioxide	$CO_2(g)$	44.01	−393,520	−394,380	213.69	—	—
Water	$H_2O(g)$	18.02	−241,820	−228,590	188.72	—	—
Water	$H_2O(l)$	18.02	−285,830	−237,180	69.95	—	—
Hydrogen peroxide	$H_2O_2(g)$	34.02	−136,310	−105,600	232.63	—	—
Ammonia	$NH_3(g)$	17.03	−46,190	−16,590	192.33	—	—
Oxygen	$O(g)$	16.00	249,170	231,770	160.95	—	—
Hydrogen	$H(g)$	1.008	218,000	203,290	114.61	—	—
Nitrogen	$N(g)$	14.01	472,680	455,510	153.19	—	—
Hydroxyl	$OH(g)$	17.01	39,460	34,280	183.75	—	—
Methane	$CH_4(g)$	16.04	−74,850	−50,790	186.16	55,510	50,020
Acetylene	$C_2H_2(g)$	26.04	226,730	209,170	200.85	49,910	48,220
Ethylene	$C_2H_4(g)$	28.05	52,280	68,120	219.83	50,300	47,160
Ethane	$C_2H_6(g)$	30.07	−84,680	−32,890	229.49	51,870	47,480
Propylene	$C_3H_6(g)$	42.08	20,410	62,720	266.94	48,920	45,780
Propane	$C_3H_8(g)$	44.09	−103,850	−23,490	269.91	50,350	46,360
Butane	$C_4H_{10}(g)$	58.12	−126,150	−15,710	310.03	49,500	45,720
Pentane	$C_5H_{12}(g)$	72.15	−146,440	−8,200	348.40	49,010	45,350
Octane	$C_8H_{18}(g)$	114.22	−208,450	17,320	463.67	48,260	44,790
Octane	$C_8H_{18}(l)$	114.22	−249,910	6,610	360.79	47,900	44,430
Benzene	$C_6H_6(g)$	78.11	82,930	129,660	269.20	42,270	40,580
Methanol	$CH_3OH(g)$	32.04	−200,890	−162,140	239.70	23,850	21,110
Methanol	$CH_3OH(l)$	32.04	−238,810	−166,290	126.80	22,670	19,920
Ethanol	$C_2H_5OH(g)$	46.07	−235,310	−168,570	282.59	30,590	27,720
Ethanol	$C_2H_5OH(l)$	46.07	−277,690	−174,890	160.70	29,670	26,800

3. Please show in both a schematic diagram of the system and a T-s diagram of the cycle for a regenerative gas turbine engine with an intercooling and a reheat. Please explain how the efficiency of the gas turbine engine can be improved by the regenerator, the intercooler and the reheater. (20%)

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4. An insulated rigid tank is divided into two equal parts by a partition. Initially, one part contains n kmol of an ideal gas of nitrogen at a pressure p_1 and a temperature T_1, and the other side is evacuated. The partition is now removed, and the gas fills the entire tank.
   a). Determine the final temperature T_2 and the final pressure p_2. (6 %)
   b). Determine the total entropy change (kJ/K) during this process. (10 %)

5. Show that for an ideal gas undergoing a reversible, adiabatic process in a closed system obeys

$$pv^k = constant,$$

with constant specific heat ratio k. (14 %)

6. Air enters a compressor operating at steady state at a pressure of 1 bar, a temperature of 300 K, and a velocity of 6 m/s through an inlet with an area of 0.1 m^2. At the exit, the pressure is 7 bar, the temperature is 450 K, and the velocity is 2 m/s. Heat transfer from the compressor to its surroundings occurs at a rate of 120 kJ/min. Employing the ideal gas model, with the universal gas constant $\bar{R} = 8.314$ kJ/kmol·K and $c_p = 1$ kJ/kg·K,
   a). determine the mass flow rate $\dot{m}$ at the inlet, and (10 %)
   b). calculate the power input to the compressor, in kW. (10 %)