國立臺灣大學 103 學年度碩士班招生考試試題

1. (25%) Consider thermodynamic relations involving enthalpy h, internal energy u and entropy s. The definitions of specific heats at constant pressure and that at constant volume are given by

$$C_p=\left(\frac{\partial h}{\partial T}\right)_P,\quad C_v=\left(\frac{\partial u}{\partial T}\right)_v$$

where T is the temperature, P the pressure, and v the specific volume.

(a) (6%) Assume $h=h(T,P)$ and derive the equation for dh in terms of C_p, dT, and dP and other thermodynamic variables.

(b) (6%) Assume $u=u(T,v)$ and derive the equation for du in terms of C_v, dT, and dv and other thermodynamic variables.

(c) (7%) Assume that the equation of state of a certain substance over a certain small range of pressures and temperatures can be accurately given by

$$\frac{Pv}{RT}=1-C'\frac{P}{T^3}\quad \text{or}\quad v=\frac{RT}{P}-\frac{C}{T^2}$$

where C' and C are constants. Derive an expression for the change of enthalpy of this substance in an isothermal process from state 1 to state 2.

(d) (6%) Derive an expression for the change of entropy of this substance in an isothermal process from state 1 to state 2.

2. (25%) Consider the ideal vapor-compression refrigeration cycle shown schematically in Fig. P2 together with the T-s diagram. A refrigerator uses refrigerant-134a as the working fluid and operates on an ideal vapor-compression refrigeration cycle between 132.82 kPa and 770.64 kPa. The mass flow rate of the refrigeration is 0.05kg/s.

(a) (7%) Describe the four processes consisted in such a cycle (i.e., 1-2, 2-3, 3-4 and 4-1).

(b) (6%) Determine the rate of heat removal from the refrigerated space and the power into the compressor.

(c) (6%) What is the rate of heat rejection to the environment?

(d) (6%) What is the coefficient of performance (COP) of the refrigerator?

[Hint: State 1: $h_1=h_{g@132.82kPa}=238.41$ kJ/kg, $s_1=s_{g@132.82kPa}=0.9456$ kJ/(kg·K); State 2: $P_2=770.64$ kPa, $s_2=s_1$, $h_2=273.5$ kJ/kg; State 3: $h_3=h_{f@770.642kPa}=93.58$ kJ/kg.]

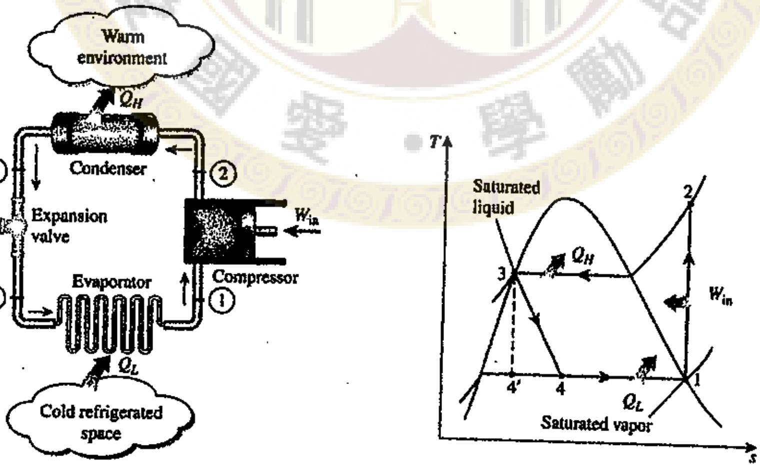

Fig. P2

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3. (20%) Answer the following short questions with key descriptions, sketch, or calculations. (2% each)
   (1) Write down the first law of thermodynamics involving total energy, kinetic energy, potential energy, and internal energy.
   (2) Find the volume occupied by 3 mol of an idea gas at 200 kPa and 350 K with the universal gas constant $R = 8.314$ J/(mol·K).
   (3) Derive an expression for the work required to expand a film of soap solution from a radius of R_1 to radius R_2.
   (4) What is a heat engine? What is a heat pump?
   (5) Two reservoirs are respectively maintained at 300K and 600K. Find the maximum work can be obtained from 1000J of heat extracted from the hot reservoir.
   (6) Clausius inequalitiy
   (7) "Availability + Irreversibility = Total energy." Is this statement correct? Give your comment.
   (8) Give a method and instrument(s) to measure the change of entropy at a point in a flow system.
   (9) Draw a P-v diagram of an Otto cycle with short explanations.
   (10) Draw a T-s diagram of the Stirling cycle.

4. (15%) The initial conditions of an ideal gas in a frictionless cylinder are: $V_1 = 0.3\text{m}^3$, $P_1 = 0.3$MPa, $T_1 = 25°$C, with $C_p = 27$ J/(mol·K), and $C_v = 18$ J/(mol·K). (3% each)
   (a) Find the work done if the gas expands in isentropic process to $V_2 = 0.5\text{m}^3$.
   (b) Find the work done if the gas expands isothermally to $P_2 = 0.15$MPa.
   (c) Find the gas temperature if the gas expands adiabatically to $V_2 = 0.5\text{m}^3$.
   (d) Find the total enthalpy increased if the cylinder is heated in constant pressure process to 50°C.
   (e) Find the work required to compress adiabatically to $V_2 = 0.15\text{m}^3$.

5. (15%) A diesel engine is operated with the volume ratios of compression and expansion 15 and 7.5, respectively. The pressure and temperature at the beginning of the compression are $P_1 = 1$ bar and $T_1 = 25°$C. For air: $C_p = 1.005$ kJ/(kg·K) and $C_v = 0.718$ kJ/(kg·K). (5%each)
   (a) Find the temperature and pressure at the end of compression.
   (b) Find the temperature at the end of heat added to the engine at constant pressure process.
   (c) Find the temperature at the end of adiabatic expansion.

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