系所組別： 機械工程學系甲組
考試科目： 熱力學
考試日期：0222，節次：2

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

1. A liquid water pump on the ground, taking water in at 20°C, 1 atm, at a flow rate of 2 kg/s, brings the pressure up so that the water can be delivered to a receiver tank maintaining a gauge pressure of 400 kPa at the top floor 10 m above ground level. Assume the process is adiabatic and the water stays at 20°C, v = 0.001 m^3/kg. Also neglect any difference in kinetic energy. Find the required pump work. (15%)

2. An industrial turbine process requires a steady 0.5 kg/s of air at 200 kPa. This air is to be the exhaust from a specially designed turbine with inlet state 400 kPa, 400 K. The heat transfer could be obtained from a source at 500 K if necessary. This process may be assumed to be reversible and the changes in kinetic and potential energy are negligible. Air is an ideal gas, with constant specific heat, C_p = 1.004 kJ/kg-K and R = 0.287 kJ/kg-K.

   (a) Which of the following processes: (i) polytropic with n = 1.3; (ii) isothermal; (iii) adiabatic, will produce the maximum work output? Demonstrate your answer by evaluating the work of air flowing for each case. Also, sketch the processes on the same P-v and T-s diagrams. (25%)

   (b) Could the process with maximum work output be possible to take place? Demonstrate your answer in accordance with the principle of the increase of entropy. (10%)

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3. A Stirling cycle operates with air; the thermal efficiency is 45 %. At the beginning of the isothermal expansion the pressure is 5 bars and the temperature is $257^\circ C$, and at the end of isothermal compression the volume is two-thirds the maximum volume. Use a cold air-standard basis and ignore kinetic and potential energy effects. Determine the mean effective pressure of the cycle. (20 %)

4. (a) The Joule-Thomson coefficient is defined as $\mu_J = \left(\frac{\partial T}{\partial p}\right)_h$. Show that

$$c_p = \frac{1}{\mu_J}\left(\frac{\partial h}{\partial p}\right)_T .$$ (10 %)

(b) In general, the specific entropy can be regarded as a function of the form $s = s(T, v)$ and the specific internal energy can be regarded as a function of the form $u = u(T, v)$. The equation of state of a van der Waals gas is $P = \frac{RT}{v-b} - \frac{a}{v^2}$ in which R, a and b are three constants. If the specific heat c_v is also a constant, show that

$$u = u_0 + c_v(T - T_0) + a\left(\frac{1}{v_0} - \frac{1}{v}\right)$$

with u_0 denoting $u = u(T_0, v_0)$. (20 %)