بسم الله الرحمن الرحيم .

Mansoura University
Faculty of Engineering
1st Year Mechanical Power Engineering

Thermodynamics I
Allowed Time: 3 hrs.
Fall Semester, January 2010

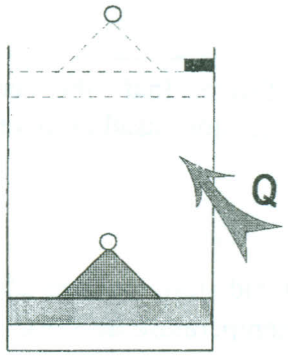
Steam Tables and Charts are allowed to be used.
Illustrate your answer with neat sketches, whenever it is possible.

1.

a) Prove that, the first law of thermodynamics for closed system process 1-2, is given by:

$$Q_{12} - W_{12} = U_2 - U_1$$

b) A cylinder-piston device is filled with 1 kg of liquid water at 1 bar and 30°C. Heat is added to the cylinder till the volume becomes ten times its original volume. At this instant the piston is prevented to move and heat is, continuously, supplied till the pressure inside the cylinder is doubled. Represent the two processes on *p-v* and *T*-s diagrams and determine:



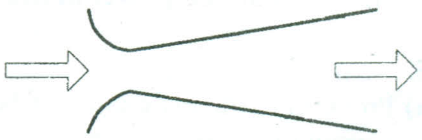
- **i)** The temperature at the end of constant pressure heating.
- **ii)** The work done and heat added through constant pressure heating.
- **iii)** The temperature and pressure at the end of constant volume heating.
- **iv)** The work done and heat added through constant volume heating process.

2.

a) Prove that, the internal energy (u) and enthalpy (h) of perfect gas, are given by:

$$u = c_v \cdot T \qquad \text{and} \qquad h = c_p \cdot T$$

b) Air leaves a convergent divergent nozzle at 120°C and 1 bar with velocity of 500 m/s. If the flow through the nozzle is assumed to be irreversible adiabatic process with adiabatic efficiency of 95%, represent the process on *p-v* and *T*-s diagrams and determine:



- **i)** The inlet temperature and pressure, if the velocity of approach (inlet velocity) is neglected.
- **ii)** The exit cross-sectional area per kg flow rate.

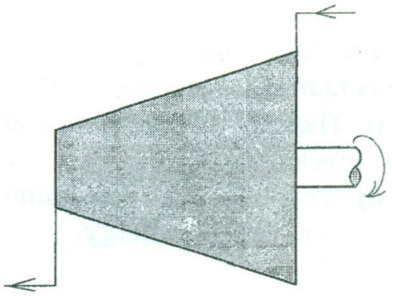
(Take for air R = 0.287 kJ/kg-K, c_v = 0.718 kJ/kg-K)

3.

a) Prove, for reversible steady flow process 1–2, that the steady flow energy equation (SFEE) can be written as:

$$\int_2^1 v \cdot dp = w_{1-2} + \tfrac{1}{2}(c_2^{\,2} - c_1^{\,2}) + g(z_2 - z_1)$$

And hence prove, for rotary compressor, that the required work can be determined through the following equation:



$$w_{comp} = -\int_1^2 v \cdot dp = -\frac{n}{n-1}(p_2 v_2 - p_1 v_1) = -\frac{nR}{n-1}(T_2 - T_1)$$

Where n is the polytropic index ($pv^n = Const.$)

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Continuation of Prob. 3

b) Air rotary compressor receives air at 1 bar and 300 K. The air is delivered at 5bar. If the compression process is considered reversible polytropic process of the law $pv^{1.2} = C$, represent this process on *p-v* and *T*-s diagrams and determine:

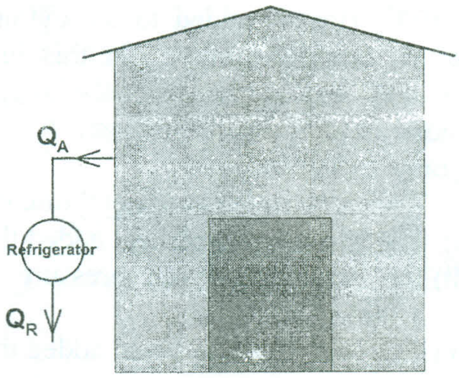
i) The air exit temperature and the required work/kg.
ii) The amount of heat transferred through this process and its direction.
iii) The change of entropy through this process.

(Take for air R = 0.287 kJ/kg-K, c_v = 0.718 kJ/kg-K)

4.

a) Prove that the coefficient of performance of refrigerator based on reversed Carnot cycle is given by:

$$COP_{refrigerator} = \frac{T_{min}}{T_{max} - T_{min}}$$



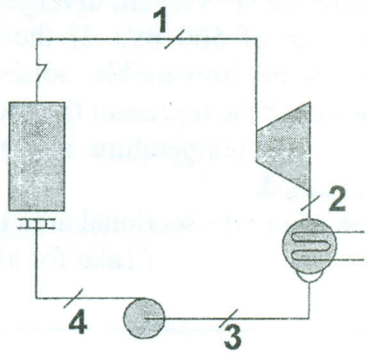
b) Cold store requires 25 kW as cooling load to maintain its temperature at – 5°C. The average temperature of the environment outside the store is estimated by 30°C. If the second law efficiency of the required refrigerating unit is taken as 30%, determine:

i) The COP of reversed Carnot cycle operates between the same temperature limits.
ii) The COP of the used refrigerating unit.
iii) The required power of the used unit.

5.

a) Prove that, the efficiency of heat engine operates based on Carnot cycle, is given by:

$$\eta_{Carnot} = \frac{T_{max} - T_{min}}{T_{max}}$$



b) Simple steam power cycle, the pressure of condenser is 0.2 bar and the boiler pressure is 50 bar. The steam enters the turbine at temperature of 400°C. Sketch the cycle on *T*-s diagram and determine for one kg:

i) The turbine work, **ii)** Heat added, **iii)** Heat rejected,
iv) The pump work and **v)** The thermal efficiency of the cycle.

c) For the same temperature limits of the foregoing cycle, considering its minimum temperature and pressure as the condition of dead state, determine:

i) Thermal efficiency of Carnot cycle, and hence second law efficiency of the foregoing cycle.
ii) For one kg, determine the available work, work potential, irreversibility and unavailable energy.

(GOOD LUCK **Prof. Dr. M. G. WASEL)**