

NATIONAL EXAMINATIONS - May 2003

98-BS-10, Thermodynamics

3 Hours Duration

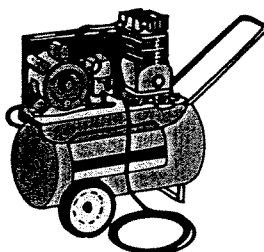
NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.
 2. Any one of the approved Casio or Sharp calculator models is permitted. This is a "Closed-Book" examination with one 8.5×11 inch sheet of notes (both sides) allowed.
 3. Property tables and charts are provided where necessary.
 4. **Five** questions constitutes a complete paper. Unless clearly indicated otherwise by you, only the first five questions you answered will be marked.
 5. The mark associated with each question is specified.
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DO ONLY FIVE OF THE SIX QUESTIONS

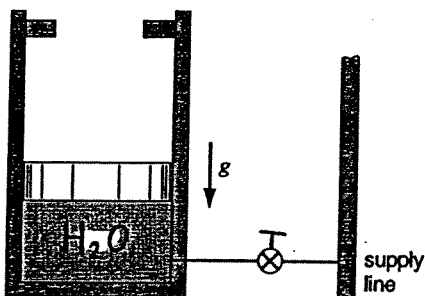
(Each question is worth 20 marks)

1. A refrigerator using R-134a is located in a 20 [°C] room. Consider the cycle to be ideal, except that the compressor is neither reversible nor adiabatic (i.e. non-isentropic). Saturated vapour at -20 [°C] enters the compressor and the R-134a exits the compressor at 50 [°C]. The condenser pressure is 1.0 [MPa]. The mass flow rate of refrigerant through the cycle is 0.2 [kg/s], and the coefficient of performance is measured and found to be 2.3. Sketch the cycle on a T-s diagram. Find the power input to the compressor, the heat transfer to or from the compressor, and the entropy generated in the compression process.
2. You are fortunate enough to have purchased a portable, isentropic air compressor with a tank capacity of 0.040 [m³]. Before you test it, the tank and the surroundings are in thermodynamic equilibrium at 100 [kPa], 17 [°C]. The isentropic compressor is then started and it takes in ambient air and charges the tank until the final pressure is 1 [MPa]. Determine the final temperature of the air in the tank, the final mass of air in the tank and the total work required to charge the tank. The air should be treated as an ideal gas.



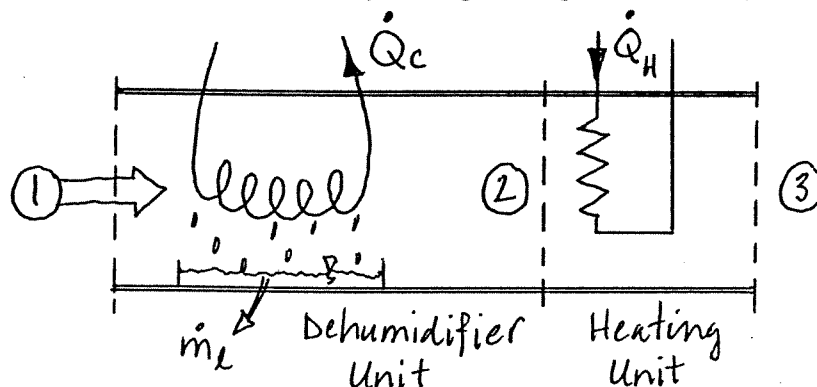
3. A 4.0 [kW] pump operating at steady state draws in liquid water at 100 [kPa], 15 [°C] with a mass flow rate of 4.5 [kg/s]. There are no significant changes in kinetic and potential energy from the pump inlet to outlet and the local acceleration due to gravity is 9.81 [m/s²]. Is it possible for the pump to deliver water at a pressure of 1.0 [MPa]?

4. The piston cylinder device shown below has an initial volume of $0.25 \text{ [m}^3\text{]}$ and a maximum volume of $1 \text{ [m}^3\text{]}$, which is achieved when the moveable piston reaches the stops. The device is initially at a pressure of 300 [kPa] and contains 0.7 [kg] of water, 0.42 [kg] of which is in the vapour state. The cylinder is connected to a supply line that provides steam at 1 [MPa] , $500 \text{ [}^\circ\text{C]}$. The valve from the supply line is opened and steam is allowed to flow into the cylinder until a final state of 500 [kPa] , $400 \text{ [}^\circ\text{C]}$ is achieved. Find the mass of steam that enters the cylinder, and the amount and direction of any heat transfer. Also, show the process on an appropriate diagram.



5. An industrial air conditioner operating at steady state takes in moist air at $30 \text{ [}^\circ\text{C]}$, 100 [kPa] , and 70% relative humidity. The moist air first passes over a cooling coil in the dehumidifier unit and some water vapour is condensed. The rate of heat transfer between the moist air and the cooling coil is 70 [kW] . Saturated moist air and condensate exit the dehumidifier unit at the same temperature. The moist air then passes through a heating unit, exiting at $25 \text{ [}^\circ\text{C]}$, 100 [kPa] , and 40% relative humidity. Use the thermodynamic relations to obtain your solutions; do not use the psychrometric chart. Neglecting kinetic and potential energy effects, determine:

- the temperature of the moist air exiting the dehumidifier unit, in $^\circ\text{C}$.
- the flow rate of the air entering the air conditioner in [kg/s] .
- the rate water is condensed, in [kg/s] .
- the rate of heat transfer to the air passing through the heating unit, in [kW] .



6. A power plant operates on an ideal, regenerative vapour power cycle with one closed feedwater heater as shown in the figure. Steam enters the first turbine stage at 12.5 [MPa], 500 [°C] and expands to 1 [MPa], where some of the steam is extracted and diverted to the closed feedwater heater. Condensate exiting the feedwater heater as saturated liquid at 1 [MPa] passes through a trap into the condenser. The feedwater exits the heater at 12.5 [MPa] with a temperature of 180 [°C]. The condenser pressure is 5 [kPa]. Sketch the cycle on a T-s diagram with respect to saturation lines. Determine for the cycle.

- (a) the rate of heat input to the steam in the steam generator, in [kJ/kg],
 (b) the thermal efficiency, and
 (c) the net power output for a mass flow rate of 10^6 [kg/h] into the first stage turbine.

