NATIONAL EXAMINATIONS MAY 2007

Phys-B6. **Applied Thermodynamics and Heat Transfer**

3 Hours Duration

Notes :

1. If doubt exists concerning the interpretation of any question, the candidate is urged to make assumptions and clearly explain what has been assumed along with the answer to the question.

2. The examination is open book. As a consequence, candidates are permitted to make use of any textbooks, references or notes.

3. Any non-communicating calculator is permitted. However, candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the inside of the cover of the first examination book.

4. It is expected that each candidate will have copies of both a thermodynamics text and a heat transfer text in order to make use of the information presented in the tables and graphs contained.

5. The answers to five questions, either three questions from Part A and two questions from Part B or two questions from Part A and three questions from Part B, comprise a complete examination.

6. Candidates must indicate the answers that they wish to have graded on the cover of the first examination book. Otherwise the answers will be graded in the order in which they appear in the examination book(s) up to a maximum of three answers per section .

7. The answer to any question carries the same value in the grading .

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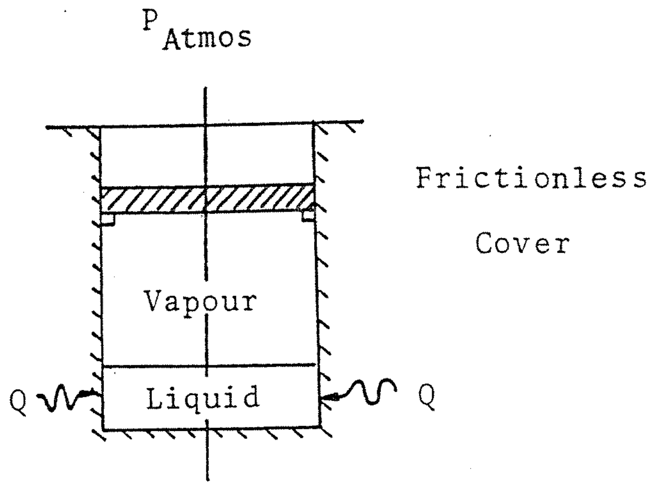
PART A - THERMODYNAMICS

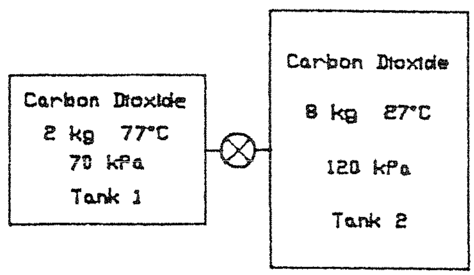
1(a) The vertical cylinder shown in the illustration is fitted with a frictionless cover resting on stops and contains 130 gm of water (liquid and vapour) at 40°C. The cover has a mass of 100 kg and a face area of $3.575*10^{-2}$ m^2 and the volume enclosed is $2.70*10^{-2}$ m^3. The gravitational acceleration is 9.69 m/s^2 and the atmospheric pressure is 93,700 Pa. Heat is transferred slowly at the base of the cylinder raising the temperature of the water. Find



(i) The temperature of the water when the cover begins to lift off.

(ii) The amount of heat absorbed by the water during the process.

1(b) Two tanks containing different amounts of carbon dioxide gas at different initial states are connected by a valve as shown in the illustration. The valve is opened and the gases are allowed to mix while a certain amount of energy is transferred. The final equilibrium temperature is 42°C. Determine the final pressure and the amount of heat transferred during the process.



2. A two stage turbine receives steam at 4.50 MPa and 350°C. The high pressure stage exhausts at 150 kPa and 10,900 kg/hr are removed at this point for process purposes. The remaining steam is reheated at 150 kPa to 300°C and then expanded through a low pressure stage to a condenser at 7.5 kPa. The turbine output is 3730 kW. The isentropic efficiencies of the high pressure and low pressure stages of the turbine are 84% and 81% respectively. Draw the process on a T-s diagram. What is the boiler capacity in kg/s ?

3. A double-acting reciprocating air compressor having a piston 200 mm in diameter with a 150 mm stroke receives atmospheric air at 100 kPa and 20°C which it discharges at 700 kPa. The clearance volume is 5% of the piston displacement and the compression and expansion processes are assumed to occur polytropically (n = 1.3).

(a) Determine the capacity of the compressor at inlet conditions while operating at 300 revolutions/minute.

(b) Find the volumetric efficiency of the air compressor and the power required to drive it.

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4. A gas turbine power plant in which the air enters the compressor at 100 kPa and 25°C operates with a pressure ratio of 5 and a turbine inlet temperature of 980°C. Kinetic energy changes can be assumed to be negligible. Considering all processes to be ideal

(a) Calculate the thermal efficiency of the cycle assuming the working fluid to be air having constant specific heat.

(b) Calculate the thermal efficiency of a cycle in which the compressor and turbine are each 80% efficient.

(c) Determine by how much the cycle performance could be improved by installing a regenerator which has an effectiveness of 75%.

PART B - HEAT TRANSFER

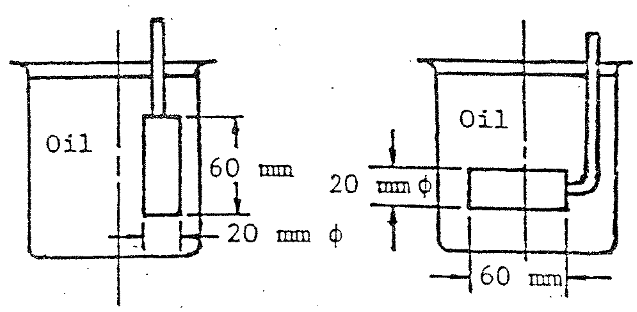
5. A horizontal steam pipe 168.4 mm outside diameter by 154.2 mm inside diameter is covered by 50 mm of insulation. The thermal conductivity of the pipe is 46.7 W/m°C and the thermal conductivity of the insulation is 0.069 W/m°C. The temperature of the inside surface of the pipe is 93°C and the ambient air temperature is 21°C. Heat is transferred to the surrounding air by natural convection. Use the simplified relationship below which predicts the natural convection heat transfer coefficient h_c at the exposed surface in W/m²°C when the temperature difference ($T_s - T_\infty$) is substituted in °C and the diameter d is substituted in metres.

$$h_c = 1.31 \left\{ \frac{T_s - T_\infty}{d} \right\}^{1/4}$$

(a) Calculate the temperature of the surface of the insulation.

(b) Determine the heat loss per metre run of the insulated pipe.

6. Engine oil at 30°C is to be heated by a cartridge heater as indicated at the right. The dimensions of the cartridge heater are 20 mm diameter by 60 mm long. Up to 20 W may be dissipated by the cartridge heater provided that the surface temperature does not exceed 90°C because above this temperature, the oil will decompose. Do you recommend the vertical or horizontal configuration to heat the oil ? Show your reasoning.



Configuration (a) Configuration (b)

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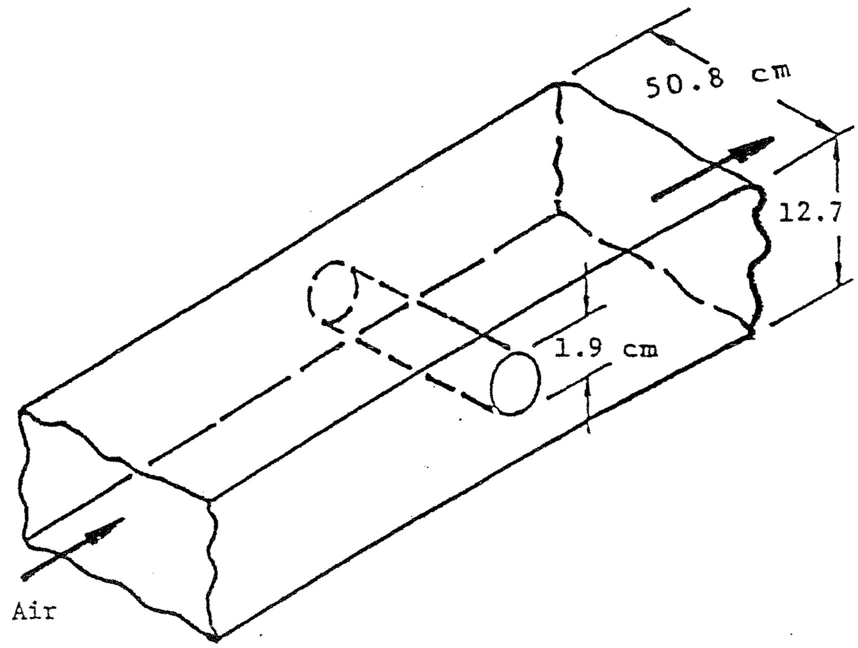
7. An air heater consists of a cylinder 50.8 cm long by 1.9 cm diameter closely wound with thin resistance wire installed across a rectangular duct 50.8 cm wide by 12.7 cm high as shown in the diagram. Air flowing at 7.15 m/s enters the duct at 15.6°C. The heater surface temperature is maintained at 550°C and its emissivity is 0.85 . The walls of the duct are maintained at 15.6°C and may be assumed to be black to incident radiant energy. The convective heat transfer coefficient at the surface of the heater can be predicted by the use of the relationship below.



$$\frac{\bar{h}_c D}{k} = 0.26 \left[\frac{\rho V D}{\mu}\right]^{0.6} \left[\frac{\mu C_p}{k}\right]^{0.3}$$

(a) Determine the rate at which heat has to be dissipated to maintain these conditions.

(b) Find the temperature of the air leaving the duct under the conditions described above.

8. A counterflow tube in shell heat exchanger uses hot air that enters at 0.8 kg/s and 250°C and leaves at 100°C to heat engine oil that enters at 35°C and leaves at 110°C. The overall heat transfer coefficient is 85 W/m²°C. Determine

(a) The heat exchanger area required to effect the exchange of heat.

(b) The temperature of the oil exiting the heat exchanger if the area were 36% larger.

End