

NATIONAL EXAMINATIONS DECEMBER 2016

07-Mec-A1 Applied Thermodynamics and Heat Transfer

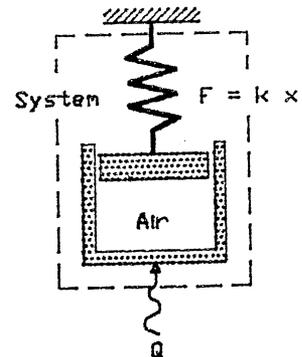
3 Hours Duration

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.

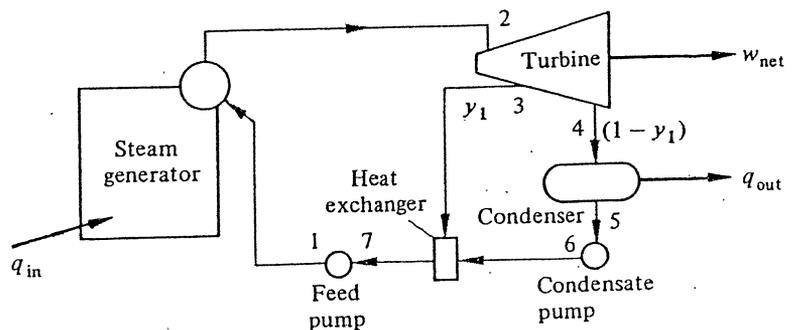
PART A - THERMODYNAMICS

1. (a) Air is contained in a piston cylinder arrangement as depicted with a cross sectional area of 0.04 cm^2 and an initial volume of 20 cm^3 . The air is initially at 1 atmosphere pressure and 20°C . A spring having a spring constant of 100 N/cm which is connected to the piston is initially undeformed. How much heat must be added to the air to increase the pressure to 3 atmospheres? The apparatus is surrounded by air at 1 atmosphere.



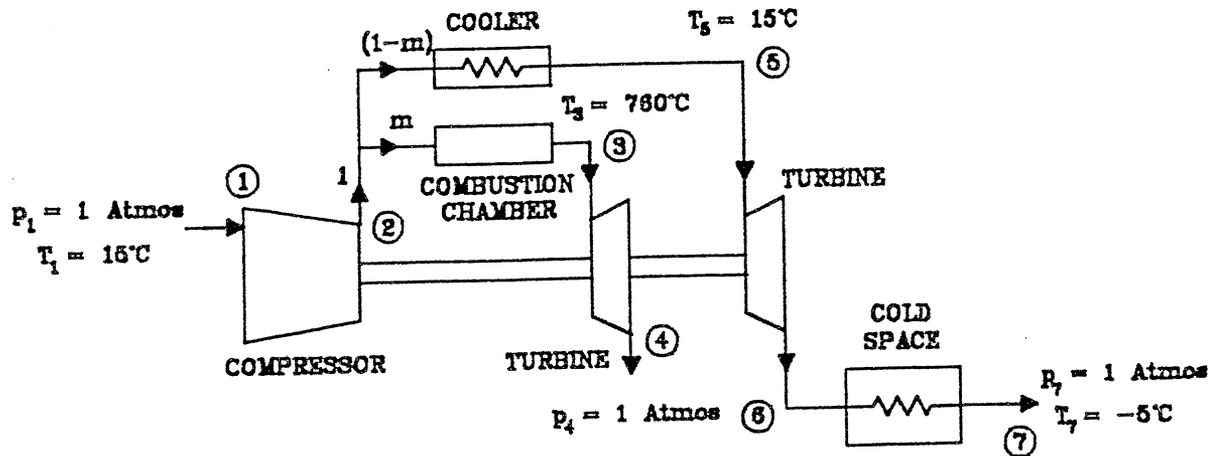
- (b) Water is pumped adiabatically from $T_1 = 40^\circ\text{C}$ and $p_1 = 6.8$ atmospheres to $p_2 = 68.0$ atmospheres at the rate of $\dot{w} = 35 \text{ kg/min}$. Assuming that water is very nearly incompressible, derive the relationship $\dot{w} \approx \dot{m} v_1 (p_2 - p_1)$ for the power required to pump the water and show that $\dot{w} = 3772 \text{ W}$ under these circumstances.
2. A reciprocating compressor receives atmospheric air at 1 atmosphere and 20°C which it discharges at 3 atmospheres. The clearance volume is 5 percent of the piston displacement and the compression and expansion processes are assumed to occur isentropically. Determine
- The piston displacement in cubic meters per minute required to compress 2.85 cubic meters of air / minute at inlet conditions.
 - The volumetric efficiency of the ideal air compressor cycle.
 - The power required to compress the air under these conditions.

3. Determine the efficiency and power output of a steam power plant that has turbine inlet conditions of 6.0 MPa and 500°C , bleeds steam to a feedwater heater at 700 kPa and exhausts to a condenser at 25 kPa . The efficiencies of the turbine and pumps are 90% and the water mass flowrate is 63.0 kg/s . Represent the processes on a Ts diagram.



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4.



The schematic diagram above depicts the arrangement of the components of a system proposed as a refrigeration machine. A fraction of the air mass flowrate is bled off the compressor of a simple gas turbine just before combustion, cooled to 15°C and then expanded through another turbine back to atmospheric pressure. The exhaust from the turbine, which is used to maintain the temperature of a cold space, finally escapes to the atmosphere at -5°C . The compressor and both turbines are connected to a single shaft. The temperature of the air entering the compressor is 15°C and the temperature of the air entering the turbine is 780°C . The pressure ratio of the compressor is 5:1, the compressor efficiency is 80% and the turbine efficiency is 90%. Sketch the processes on a Ts diagram. Determine the ratio of the heat extracted from the cold space to the heat added in the combustion chamber.

PART B - HEAT TRANSFER

5. A hot steam pipe 0.3 m outside diameter was covered with a 0.025 m thick layer of insulation A and a 0.04 m thick layer of insulation B. The temperature of the outer surface of the pipe was found to be 400°C and the temperature of the outer surface of insulation B was found to be 40°C under these conditions. After an additional 0.02 m thick layer of insulation C having thermal conductivity $0.2\text{ W/m}^{\circ}\text{C}$ was added to the outer surface of insulation B, the temperature of the outer surface of the pipe was found to be 500°C , the temperature of the outer surface temperature of insulation B was found to be 180°C and the temperature of the outer surface of insulation C was found to be 30°C . Determine the rate of heat loss per meter length before and after the addition of insulation C.

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6. A 0.3 m square stainless steel hot gas duct 30 m in length with a wall thickness of 2 mm is coated with ceramic 38 mm thick. The heat transfer coefficient at the surface between the gas and the stainless steel is $100 \text{ W/m}^2\text{°C}$ and the heat transfer coefficient at the surface between the ceramic and the surroundings is $10 \text{ W/m}^2\text{°C}$. The temperature of the surroundings is 20°C . The thermal conductivity of the stainless steel and the ceramic are $25 \text{ W/m}^{\circ}\text{C}$ and $0.2 \text{ W/m}^{\circ}\text{C}$ respectively and the specific heat of the gas is $1100 \text{ J/kg}^{\circ}\text{C}$. The gas flows at 1.5 kg/s and enters the duct at 800°C . Determine bulk mean temperature of the gas at the exit.
7. The pipes through which thick liquids such as asphalt or waxes are conveyed are often heated by passing an electric current through them in order to reduce the viscosity of the liquid and the associated pumping costs. Consider such a liquid flowing through a 30 cm diameter pipe situated in calm ambient air at 20°C . The emissivity of outer surface of the pipe is 0.8 and the effective temperature of the surroundings is 25°C . Disregarding the heat transferred to the flowing liquid, determine the power required per unit length of pipe to maintain its temperature constant at 30°C .
8. A crossflow heat exchanger is comprised of 40 thin-walled tubes 1 cm in diameter located in a duct 1 m x 1 m in cross section. Cold water ($C_p = 4180 \text{ J/kg}^{\circ}\text{C}$) enters the tubes at 18°C with an average velocity of 3 m/s while hot air ($C_p = 1010 \text{ J/kg}^{\circ}\text{C}$) enters the channel at 130°C and 105 kPa with an average velocity of 12 m/s. If the overall heat transfer coefficient is $80 \text{ W/m}^2\text{°C}$, determine the temperatures at which the water and the air leave the heat exchanger and the rate of heat transfer.

The End