

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering



0057

Study Programme : Bachelor of Science Honours in Engineering
Name of the Examination : Final Examination
Course Code and Title : DMX4202 Applied Thermodynamics-I
Academic Year : 2024/25
Date : 7th February 2026
Time : 0930-1230h
Duration : 3 hours

REGISTRATION NO:

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General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of Five (5) questions in Five (5) pages.
3. Answer all questions.
4. All questions carry equal marks.
5. Answer for each question should commence from a new page.
6. This is a Closed Book Test (CBT).
7. If not specified consider for air: $C_p = 1.005 \text{ kJ/kg K}$, $\gamma = 1.4$ and $R = 0.287 \text{ kJ/kgK}$

Question 01

- a. Name two industrial applications of gas turbine. 4 Marks
- b. In a gas turbine plant working on the Brayton cycle, the air at inlet is at 30°C and 1 bar. The overall pressure ratio is 9 and the maximum temperature is 900°C. The turbine efficiency is 85%. The compression is divided into two stages with intercooling. Each compression stage has a pressure ratio of 3 and efficiency of 82%, with perfect intercooling.
- I. Sketch the T-s diagram for the cycle, clearly showing all states and processes. 4 Marks
- II. Calculate the total compressor work. 4 Marks
- III. Calculate the heat added to the cycle. 4 Marks
- IV. Determine the thermal efficiency of the cycle. 4 Marks

Question 02

- a. Derive an expression for the thermal efficiency (η_{Carnot}) of a Carnot cycle operating between two heat reservoirs at temperatures T_1 (high temperature) and T_2 (low temperature). 3 Marks
- I. Sketch the T-s diagram for the above cycle. 2 Marks
- II. Show that the $\eta_{Carnot} = 1 - \frac{T_2}{T_1}$ 3 Marks
- b. In a steam reheat plant, the turbine receives steam at a pressure and temperature of 30 bar and 300°C respectively. The steam expands in the first stage to a pressure of 10 bar with an isentropic efficiency of 0.85. It is then reheated at constant pressure to 300°C. In the second stage, the steam is expanded to a condenser pressure of 0.06 bar with an isentropic efficiency of 0.8. There is no undercooling and feed pump work is negligible. Given that Saturated liquid enthalpy at 0.06 bar, $h_f = 151 \text{ kJ/kg}$.
- I. Sketch the cycle on the h-s diagram provided and attach it to your answer script. 3 Marks
- II. Calculate the cyclic efficiency. 5 Marks
- III. Determine the power output if the steam flow is 3600 ton/h. 4 Marks

Question 03

- a. Derive the Steady Flow Energy Equation starting from the energy balance principle. Show that for a system with one inlet and one outlet, the equation can be written as 6 Marks

$$q - w = h_2 - h_1 + \frac{1}{2} (V_2^2 - V_1^2) + g(Z_2 - Z_1)$$

- b. 50 kg/min of air enters the control volume in a steady flow system at 2 bar and 100°C and at an elevation of 100 m above the datum. The same mass leaves the control volume at 150 m elevation with a pressure of 10 bar and the temperature of 300°C. The entrance velocity is 2400 m/min and the exit velocity is 1200 m/min. During the process, 50000 kJ/hr of heat is transferred to the control volume and the rise in enthalpy is 8 kJ/kg. Calculate the power developed. 7 Marks

- c. The velocity of steam leaving the nozzles of an impulse turbine is 900m/s and the nozzle angle is 20°. The blade velocity is 300m/s, and the blade velocity coefficient is 0.7. For a mass flow of 1kg/s, and symmetrical blading, Calculate the
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|---------------------------------|-----------|
| I. Blade inlet angle. | 1.5 Marks |
| II. Driving force on the wheel. | 1.5 Marks |
| III. Axial thrust. | 1 Mark |
| IV. Diagram power. | 1.5 Marks |
| V. Diagram efficiency. | 1.5 Marks |

Question 04

- a. Write down expressions for the critical pressure ratio and critical temperature ratio of a nozzle. Hence, show that the critical velocity (V_c) of the nozzle. 8 Marks

$$V_c = \sqrt{\gamma R T_c}$$

- b. Exhaust gases from a turbocharged engine enter a nozzle at a pressure of 2.5 bar and at a temperature of 700 K. The gases leave the nozzle at a pressure of 1.0 bar. The mass flow rate of exhaust gases through the nozzle is 0.8 kg/s. The expansion can be isentropic up to the throat, and the isentropic efficiency is 0.90 from throat to exit.

Considering adiabatic index of exhaust gases $\gamma = 1.33$ and $C_p = 1.15$ kJ/kg K, Calculate the

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|---|---------|
| I. The critical pressure on the throat. | 2 Marks |
| II. The critical temperature of the throat. | 2 Marks |
| III. The critical velocity (sonic velocity) at the throat. | 2 Marks |
| IV. The cross-sectional area of the throat. | 2 Marks |
| V. The exit velocity of the gas stream and the exit area of the nozzle. | 4 Marks |

Question 05

- a. Briefly explain the following terms in related to compressors

4 Marks

- I. Free air Delivered (FAD)
- II. Swept Volume
- III. Clearance volume
- IV. Volumetric efficiency

- b. A single-stage, single-acting, reciprocating air compressor has a bore of 180 mm and a stroke of 250 mm. It runs at a speed of 600 rev/min. The clearance volume is 4 % of the swept volume and the polytropic index is 1.35 throughout. Intake pressure and temperature are 100 kPa and 25°C, respectively, and the compression pressure is 650 kPa.

Calculate the following,

- I. The swept volume and clearance volume in m³. 2 Marks
- II. The volume of free air delivered per minute in m³/min (free air conditions 101.325 kPa and 15°C). 3 Marks
- III. The volumetric efficiency referred to free air conditions. 3 Marks
- IV. The air delivery temperature. 2 Marks
- V. The indicated power required to drive the compressor. 3 Marks
- VI. If the mechanical efficiency is 85%, calculate the shaft power required. 1.5 Marks
- VII. The mass flow rate of air in kg/min. 1.5 Marks

You may use following equations. All symbols have standard notations

$$\text{Volumetric Efficiency } \eta_{vol} = 1 - \frac{V_c}{V_s} \left[\left(\frac{P_2}{P_1} \right)^{\frac{1}{n}} - 1 \right]$$

$$\text{Indicated Power } IP = \left(\frac{n}{n-1} \right) P_1 V_{suc} \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

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