07150654C

MECHANICAL PRODUCTION TECHNICIAN LEVEL 6

ENG/OS/MEM/CC/05/6

Apply Thermodynamic Principles

November/December 2025

TVET CURRICULUM DEVELOPMENT, ASSESSMENT AND CERTIFICATION COUNCIL (TVET CDACC)

WRITTEN ASSESSMENT

Time: 3 HOURS

INSTRUCTIONS TO CANDIDATE

1. The paper consists of **TWO** sections: **A** and **B**.
2. Answer ALL questions in section A and any THREE (3) questions in section B.
3. Marks for each question are indicated in the brackets.
4. Candidates are provided with a separate answer booklet.
5. **DO NOT** write on this question paper.

This paper consists of FIVE (5) printed pages

Candidates should check the question paper to ascertain that all pages are printed as indicated and that no questions are missing.

SECTION A (40 MARKS)

Answer ALL Questions in this Section

1. During a factory, a supervisor asks a technician to explain the Carnot cycle. List the THREE thermodynamic processes involved in the cycle that the technician would give (3 Marks)

2. A mechanical tereparing for anindustrial exhibition must choose suitable heat exchangers to demonstrate. Name THREE types of heat exchangers he could have selected based on construction and design. (3 Marks)

3. A hospital plans to install a backup power system. As a mechanical technician, advise the client on FOUR advantages of using reciprocating engines. (4 Marks)

4. In a technical discussion on plant design, a senior engineer asks you to clarify thermodynamic concepts. Distinguish between the terms 'system substance' and 'system properties' with workplace relevance (4 Marks)

5. The gasses in a gas turbine flow through the turbine at 18kg/s. The gases have an inlet and enthalpy of 1200kJ/kg and 360kJ/kg respectively. The inlet and outlet velocities are 70m/s and 120m/s respectively. Calculate: (4 Marks)

   a. Work done if the turbine develops 1400kW
   b. Amount of heat rejected if the flow is assumed to be steady.

6. During system performance analysis in a thermal plant, the engineer emphasizes the importance of equilibrium states. Define the following states of equilibrium as the engld. (3 Marks)

   a. Thermal equilibrium
   b. Mechanical Equilibrium
   c. Chemical Equilibrium

7. As a mechanical intern at a steam turbine plant, you are tasked to train the new recruits. Define the following cycles as used in steam turbine plants to the new recruits. (4 Marks)

   a. Rankine cycle

8. Compressors are mechanical devices commonly used in most engineering firms. List FOUR types of these devices used in industrial plants. (4 Marks)

9. The concept of entropy is important when evaluating the efficiency of a heat engine. State the reasons for this. (2 Marks)

10. Define the term calorific value of fuels and indicate its SI unit. (4 Marks)

11. In a turbine testing facility,a horizontal nozzle has fluid entering at a velocity of the 50m/s. The nozzle area of $0.15m^2$ and the specific volume at the inlet is $0.165m^3Kg^{-1}$. Calculate:

a. The mass flow rate (2 Marks)

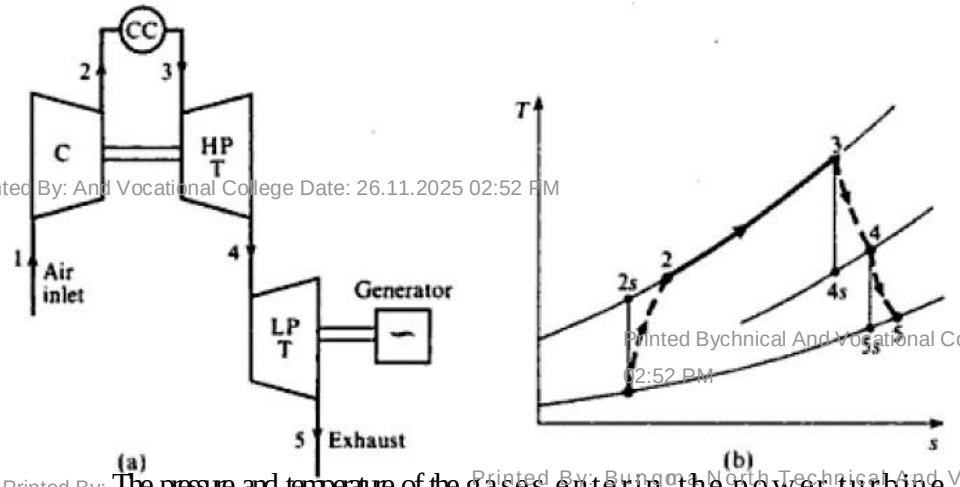
b. The outlet area of the nozzle (3 Marks)

(Take: Specific volume at the nozzle outlet as 0.525m3/Kg)

SECTION B (60 MARKS)

Answer any THREE Questions in this Section

12. In a given industry, a gas turbine unit takes in air at 17°C and 1.01 bar and the pressure ratio is 8/1. The compressor is driven by the High Power (HP) turbine and the Low Power (LP) turbine drives a separate power shaft. The isentropic efficiencies of the compressor and the HP and LP turbines are 0.8, 0.85, and 0.83 respectively. Note that: The maximum cycle temperature is 650°C. For the compression process take $C_P = 1.005kJ/KgK$, and $\gamma = 1.4$;for combustion process, and for the expansion process take $C_P = 1.15kJ/KgK$ and $\gamma = 1.333$. neglect the mass of the fuel. The line diagram of the unit cycle (a) and T-S diagram (b) are as shown below:



. The pressure and temperature of the gases enterin the power turbine, (10 Marks)

i. the net power developed by the unit per kg/s mas flow rate, (6 Marks)

ii. the work ratio and the cycle efficiency of the unit. (4 Marks)

13.

a. During boiler maintenance in a factory, it is often necessary to check the composition of flue gases to assess combustion efficiency. With the aid of a diagram, explain how the apparatus is used to carry out flue gas analysis (8 Marks)

b. Determine the air fuel ratio of a sample of flue gas if it has the following percentage composition by mass; Coal 85%, H_2 12.5%, O_2 2% and the residue 0.5%. The dry fuel has the following by composition by volume; CO_2 9%, CO 7.77% and N_2 82.23%. (8 Marks)

c. A single stage reciprocating compressor takes 1 m^3 of air per minute at 1.013 bar and 15℃ and delivers it at 7bar. Assuming that the law of compression is $pv^{1.35} = constant$, and that clearance is negligible, calculate the indicated power. (4 Marks)

14.

a. An ultimate analysis of a fuel conducted in a power plant gave the following percentage composition: C=70%, H_2= 5%, O_2=12%, N_2=2% and Ash=10%. Determine:

i. Stoichiometric air fuel ratio.

ii. Air fuel ratio.

iii. Volumetric analysis of the dry products in (a)(ii) above. (10 Marks)

Take the atomic masses as C=12, H=1, O=16, N=14

b. The volumetric analysis of the dry products is approximately 0.42% CO_2 and 99.58% N_2. A mild steel tank of wall thickness 12 mm contains water at 95°C. The thermal conductivity of mild steel is 50 W/m°C, and the heat transfer coefficients for the inside and outside the tank are 2850 and 10 W/m^2 °C, respectively. If the atmospheric temperature is 15℃, calculate:

i. The rate of heat loss per m2 of the tank surface area.

ii. The temperature of the outside surface of the tank. (10 Marks)

15. Heat engine cycle is a sequence of processes where a substance undergoes changes in pressure, temperature, and volume, eventually returning to its initial state. You are an industrial mechanical technician designing a heat engine cycle with a hot reservoir at 800 ℃ and a cold reservoir at 15℃, calculate the;

i. Thermal efficiency and

ii. The work ratio of a Carnot cycle using air as working fluid, if the maximum and minimum pressure in the cycle is 210bar and 1bar. (20 Marks)