

071606T4AMT

AUTOMOTIVE MECHATRONIS LEVEL 6

ENG/OS/AMT/CC/05/6/A

APPLY THERMODYNAMICS PRINCIPLES

July /Aug 2023



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

WRI MENT

Time: 3 Hours

Instructions to Candidates:

1. This paper consists of **TWO** Sections; **A** and **B**
2. Attempt all the questions in Section **A** and any **THREE** questions in Section **B**.
3. Marks for each question are indicated in brackets ().
4. You are provided with a separate answer booklet.
5. Do not write on the 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**

Turn over

SECTION A: (40 MARKS)*Attempt ALL questions on this section*

1. State the Charles's law. (2 Marks)
2. Distinguish between Isothermal process and Isobaric process. (2 Marks)
3. List any **three** types of thermodynamic properties. (3 Marks)
4. Show that the difference in specific heat capacities is given by $R = C_p - C_v$. (3 Marks)
5. Outline any **four** factors which determine the rate of heat transfer. (4 Marks)
6. Define the term volumetric efficiency as applied on air compressor. (2 Marks)
7. Differentiate between reversible and irreversible process (3 Marks)
8. List **three** types of air compressors. (3 Marks)
9. Distinguish change of entropy from dryness fraction. (3 Marks)
10. State the function of intercooler in gas turbine (2 Marks)
11. List any **four** common basis used when classifying internal combustion engine. (4 Marks)
12. State why a re-heater is necessary in gas turbine and explain its effects. (3 Marks)
13. Outline any **three** important properties of a good refrigerant. (3 Marks)
14. State any **three** important parameters that are to be measured and controlled of an air conditioning system. (3 Marks)

SECTION B: (60 Marks)*Attempt any THREE questions from this section*

15. (a) A certain perfect gas is compressed reversibly from 1 bar, 20°C to 5.5 bar in a perfectly thermally insulated cylinder. Its final temperature is 85°C. The work done during the process of compression is 45 KJ/Kg. calculate;

- i) The index of compression γ
- ii) The specific heat capacity at constant volume C_v .
- iii) The gas constant R
- iv) The relative molecular mass M , of the gas

Take the universal gas constant $R_0 = 8.3145 \text{ KJ/Kg}$

(12 Marks)

(b) Show from first principles that the volumetric efficiency is given by:

$$\eta_v = 1 - \frac{V_c}{V_s} \left\{ \left(\frac{p_2}{p_1} \right)^{\frac{1}{n}} - 1 \right\}$$

Where:-

η_v = Volumetric Efficiency

V_c = Clearance Volume

V_s = Swept Volume

p_1 = Intake Pressure

p_2 = Delivery Pressure

n = Polytrophic Index

(8 Marks)

16. (a) An ideal dual combustion cycle has a volume ratio for the adiabatic compression as 16:1

The following data related to the cycle:

- Initial pressure = 95 kN/m²
- Initial volume = 0.075 m³
- Initial temperature = 27°C
- Maximum pressure = 6.5 MN/m²

- Maximum temperature = 1500°C

For the cycle, determine the following

- Pressure, volume and temperature at the cycle state point
- Net work done
- Thermal efficiency
- Net heat received

Take: $C_p = 1.005 \text{ KJ/KgK}$, $C_v = 0.717 \text{ KJ/KgK}$

(12 Marks)

(b) A sample of coal contains the following composition by mass: Carbon 89%, hydrogen 3.5%, oxygen 3.0%, sulphur 0.04% and the remainder is ash. Determine

- The stoichiometric air/fuel ratio.
- If the air supplied is 16kg, calculate the percentage of excess air and the masses of the constituent of the wet flue gases per kilogram of fuel burnt.

- Assume air contains 23% Oxyg

- Atomic masses: C=12, H = 1, O

=14

(8 Marks)

17. At the beginning of the induction stroke of an internal combustion engine of compression ratio 8/1, the clearance volume is occupied by residual gas at a temperature of 840°C and pressure 1.034 bar. The volume of mixture induced during the stroke, measured at atmospheric conditions of 1.013 bar and 15°C , is 0.75 of the cylinder swept volume. The mean pressure and temperature in the induction is 0.965 bar and 27°C respectively, and the mean pressure in the cylinder during the induction stroke is 0.828 bar. Calculate the temperature and pressure of the mixture at the end of the induction stroke assuming the process to be adiabatic. For the induced mixture and final mixture take $C_v = 0.718 \text{ KJ/Kg K}$ and $R = 0.287 \text{ KJ/kg K}$; for the residual gas take $C_v = 0.840 \text{ KJ/kg K}$ and $R = 0.296 \text{ KJ/kg K}$. (20 Marks)

18. An open-circuit, continuous combustion, constant pressure, gas turbine takes in air at a pressure, gas turbine takes in air at a pressure of 101 kN/m^2 and at a temperature of 15°C . The air is compressed in a rotary compressor through a pressure ratio of 6:1. The air then passes at constant pressure through a heat exchanger of effectiveness 65%. From the heat exchanger the air passes at constant pressure through a combustion chamber in which its temperature is raised to 870°C . From the combustion chamber the air passes through a gas turbine in which it is expanded to a pressure of 101 kN/m^2 and it then passes through the heat exchanger to exhaust. The isentropic efficiency of the compressor is 85%

while that of the turbine is 80%. Neglect the mass of the fuel and take the air mass flow rate as 4 kg/s. Determine;

- (a) The net power output of the plant.
- (b) The exhaust temperature from the heat exchanger.
- (c) The thermal efficiency of the plant. The thermal efficiency of the plant.
- (d) The thermal efficiency of the plant if there no heat exchanger
- (e) The work ratio.

(20 Marks)

Take $\gamma=1.4$ and $C_p=1.005\text{kJ/kgK}$