2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
March/April 2024
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN AERONAUTICAL ENGINEERING (AIRFRAMES AND ENGINES OPTION)

MODULE III

AIRCRAFT MECHANICAL TECHNOLOGY II

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;
Mathematical tables/Non-programmable scientific calculator;
Thermodynamic and transport properties of fluids tables, by G.F.C. Rogers and Y.R. Mayhew;
Drawing instruments.

*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*
*Answer **THREE** questions from section **A** and **TWO** questions from section **B**.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.

This paper consists of 5 printed pages.

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

SECTION A: THERMODYNAMICS

*Answer any **THREE** questions from this section.*

1. (a) (i) Define the following terms:

I thermodynamic cycle;
II thermodynamic properties.

(ii) Explain the following thermodynamic processes:

I non-flow process;
II steady flow process.

(6 marks)

(b) 1 kg of C_8H_{18} fuel is supplied to an engine with 14 kg of air. Determine the percentage by volume of CO_2 in the dry exhaust gas considering exhaust gas to consist of CO_2, CO and N_2. (14 marks)

2. (a) Show that the diagram efficiency η_d of a steam turbine with symmetrical blades and a unit blade velocity coefficient is given by:

$$\eta_d = \frac{4C_b}{C_{ai}}\left[\cos\alpha_i - \frac{C_b}{C_{ai}}\right].$$

Where: C_b = blade speed;
Cai = he inlet velocity of the steam;
α_i = nozzle angle.

(8 marks)

(b) (i) Define the following terms as applied to steam:

I. specific volume;
II. dryness fraction.

(ii) Steam 0.95 dry at a pressure of 0.8 MN/m^2 is supplied to a heater through a pipe 30 mm internal diameter, the velocity in the pipe is 10 m/s. Water enters the heater at 17 °C, the steam is blown into it and the mixture of water and condensate leaves the heater at 85 °C.

Determine the:

I. mass of steam entering the heater in kg/h;
II. mass of water entering the heater in kg/h.

(12 marks)

3. (a) Derive the expression for the air standard efficiency Otto cycle in terms of compression ration (r) and adiabatic index (γ). (9 marks)

(b) (i) Define the term volumetric efficiency as applied to air compressor.

(ii) A single stage double acting reciprocating air compressor, runs at 300 rev/min with a mechanical efficiency of 90%. Air flows in the compressor at the rate of 6.77 m^3/min measured at atmospheric conditions of 1.03 bar, 15 °C. The compressed air is delivered at a pressure of 8 bar and the clearance volume is 5% of the stroke volume. The air intake pressure and temperature are 0.98 bar and 25 °C respectively. The compression follows a polytropic process with index of 1. 3 and the stroke bore ratio is 1. 5.

Determine the:

I. power required to drive the compressor;
II. volumetric efficiency;
III. cylinder diameter.

(11 marks)

4. (a) With the aid of a plant diagram, state the reason for incorporating a heat exchanger to a basic cycle gas turbine plant. (4 marks)

(b) A gas turbine plant has air supplied at 1 bar, 25 °C to be compressed through pressure ratio of 9:1. Compression of air is achieved in two stages with perfect intercooling in between at optimum pressure. The maximum temperature in the cycle is 950 K and compressed air at this temperature is expanded in two stages. The first stage expansion occurs up to 3 bar and is subsequently reheated up to 900 K before entering the second stage turbine. Fuel used for heating in the combustion chamber has a calorific value of 42,000 kJ/kg. The isentropic efficiency for the compressor and turbines are 80 % and 85 % respectively. Considering C_P = 1.0032 kJ/kgK and γ = 1.4 throughout the cycle, determine the:

(i) net output of the plant;
(ii) thermal efficiency;
(iii) air fuel ratio.

(16 marks)

5. (a) (i) State the Fourier's law of thermal conduction.

(ii) Show that the heat transfer 'Q' for a parallel flow heat exchanger is given by

$$Q=\frac{\mu A(\theta_1-\theta_2)}{\frac{\theta_1}{\theta_2}}.$$

Where: μ = overall heat transfer coefficient;
A = mean surface area of the heat exchange surface;
θ_1 and θ_2 = temperature differences at entry and exit of the heat exchanger respectively.

(14 marks)

(b) Hot air at a temperature of 60 °C flows through a steel pipe of 115 mm diameter. The pipe is covered with two layers of insulating materials. The inner and outer insulating layers are of thickness 500 mm and 30 mm respectively and their corresponding thermal conductivities are 0.24 and 0.4 W/m °C respectively. The atmosphere is at 15 °C. Neglecting the pipe thickness, determine the rate of heat loss from the 40 m length of pipe.

(6 marks)

SECTION B: FLUID MECHANICS

*Answer any **TWO** questions from this section.*

6. (a) Define the following terms with reference to centrifugal pumps:

(i) manometric head;

(ii) manometric effeciency;

(iii) overall efficiency.

(3 marks)

(b) With the aid of a diagram, describe the operation of a reciprocating pump. (7 marks)

(c) A single acting reciprocating pump has a cylinder of diameter 200 mm and a stroke length of 300 mm. The pump draws water from a sump and delivers to a tank. The water level in the sump is 4. 5 m below the pump axis and in the tank, the water level is 14 m above the pump axis. The diameter and length of the suction pipe are 50 mm and 6 m respectively, while for delivery pipe, the diameter and length are 50 mm and 15 m respectively.
Taking atmospheric pressure head as 10. 3 m of water, determine the maximum speed of the pump to avoid separation which occurs at 2.8 m of water.

(10 marks)

7. (a) (i) State the Buckingham's Π theorem.

(ii) Define the following terms:

I. geometric similarity;
II. dynamic similarity.

(4 marks)

(b) The pressure difference ΔP in a pipe of diameter D and length L due to turbulent flow depends on the velocity v, dynamic viscosity μ, density ρ and roughness K. Using dimensional analysis, show that:

$$\Delta P = \rho V^2 \ \phi\left(\frac{L}{D}, \frac{\mu}{DV\rho}, \frac{K}{D}\right).$$

(16 marks)

8. (a) (i) State **two** minor energy losses in pipelines due to fluid flow.

(ii) Derive the expression for loss of head due to sudden contraction in a pipeline.

(10 marks)

(b) Two water tanks at different elevations are connected by a horizontal pipe of diameter 350 mm and length 450 m. The rate of flow of water through the pipe is 250 litres/s. Considering all losses and taking the value of coefficient of friction 'f' = 0.007, determine the elevation difference of the water surfaces.

(10 marks)

THIS IS THE LAST PRINTED PAGE.