2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
Oct./Nov. 2021
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;
Drawing instruments;
Mathematical tables/Non-programmable scientific calculator;
Thermodynamics and transport properties of fluids tables by Rogers and Mayhew.
*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*
*Answer **FIVE** questions choosing **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 indicated.
All dimensions are in millimetres.
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.

Turn over

SECTION A: THERMODYNAMICS

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

1. (a) A single acting air compressor has a suction temperature T_1 and pressure P_1. When the delivery pressure is P_2, the mass flow rate of the air is $\dot{m}$ and the compression index is n. Using a pressure-volume (P-V) diagram, show that the indicated power (IP) of the compressor is given by:

$$I.P = \frac{n}{n-1}\dot{m}RT_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

Where R = specific gas constant for air. (9 marks)

(b) A single cylinder single acting reciprocating air compressor has a suction pressure and temperature of 90 kN/m² and 15 ^0C respectively. It delivers air at 500 kN/m² when running at 600 rev/min. The compressor has a cylinder bore of 150 mm, a stroke of 250 mm and a clearance volume 3% of the swept volume. The polytropic index is 1.4 throughout. If the free air delivery conditions are 101.325 kN/m² and 15 ^0C determine the:

(i) volumetric efficiency referred to the free air conditions;
(ii) indicated power;
(iii) isothermal efficiency, neglecting clearance volume. (11 marks)

2. An open cycle gas turbine plant takes in air and compresses it through two series compressors having equal pressure ratios and perfect intercooling between them. The compressed air is then passed through a heat exchanger where it is heated by the exhaust gases from the low pressure turbine before entering the combustion chamber. The gases then flow into a high pressure turbine, which drives the compressors only. The exhaust gases leaving the high pressure turbine passes through a re-heater and then to the low pressure turbine which drives the alternator. The following data refers to the plant:

Overall pressure ratio = 9/1
Air at entry to low pressure compressor = 20 ^0C
Heat exchanger thermal ratio = 0.72
Temperature of gas entering the high pressure turbine = 720 ^0C
Temperature of gases entering the low pressure turbine = 650 ^0C
Isentropic efficiency of each compressor = 0.82
Isentropic efficiency of the high pressure turbine = 0.8
Isentropic efficiency of the low pressure turbine = 0.78
Mechanical efficiency of the drive to the compressors = 0.9

For gases, γ = 1.333 and C_p = 1.13 kJ/kgK
air, γ = 1.4 and C_p = 1.005 kJ/kgK

(a) Sketch the plant layout and its temperature - entropy (T-S) diagrams. (3 marks)

(b) Determine the:

(i) thermal efficiency of the plant ;
(ii) work ratio. (17 marks)

3. (a) (i) Define the term diagram, efficiency as applied to steam turbines.

(ii) Show that for an impulse steam turbine with symmetrical blading and without shock, the diagram efficiency.

η_{diag} is given by:

$$\eta_{diag} = 4\frac{C_b}{C_{ai}}\left[\cos \alpha_i - \left(\frac{C_b}{C_{ai}}\right)^2\right]$$

Where:

C_b = blade velocity
C_{ai} = nozzle velocity at inlet
α_i = nozzle inlet angle (10 marks)

(b) The analysis of a fuel by weight is: C 87% and H 13%. Volumetric analysis of the dry exhaust gas from combustion of the fuel is CO_2 7%, O_2 10.5% and N_2 82.5%.

Determine the:

(i) air/fuel ratio;
(ii) mixture strength. (10 marks)

4. (a) Distinguish between adiabatic and polytropic processes. (2 marks)

(b) Show that the work done in a polytropic expansion process is given by:

$$W = \frac{P_1V_1 - P_2V_2}{n-1}$$

Where:

P_1 and P_2 = Initial and final pressures respectively

V_1 and V_2 = Initial and final volume respectively.
n = index of expansion. (7 marks)

(c) Dry saturated steam at 20 bar expands to a final pressure of 4 bar following the hyperbolic law PV = C. Determine the:

(i) final temperature of steam;
(ii) work transfer;
(iii) heat transfer. (11 marks)

5. (a) Show that the logarithmic mean area (A_m) of a cylinder of unit length, internal radius r_1 and external r_2 is given by:

$$A_M = \frac{2\bar{x}(r_2 - r_1)}{\ln\left(\frac{r_2}{r_1}\right)}$$

(10 marks)

(b) A refrigerated room has a wall 5 m long and 3 m high. The wall is built of 120 mm thick brick insulated on the inside with an 80 mm layer of cork. The coefficient of thermal conductivity of the brick is 0.7 W/mK and that of the cork is 0.043 W/mK. The exterior brick surface temperature of the wall is $21\,^0C$ and that of the interior cork surface is $-4\,^0C$. Determine the:

(i) heat leakage through the wall in 24 hours;
(ii) temperature of the interface between the cork and the brick. (10 marks)

SECTION B: FLUID MECHANICS

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

6. (a) A pipeline of diameter d and length L has a discharge Q. Assuming that the frictional resistance per unit area of the pipe wall is proportional to the square of the mean velocity of fluid flow, show that the head loss due to friction hf is given by:

$$hf = \frac{fLQ^2}{3d^5}$$

Where f = friction coefficient. (15 marks)

(b) A reservoir is 5.5 km away from a town having 3500 inhabitants. Each inhabitant consumer 150 litres of water per day and half of the daily supply is pumped within 12 hours. If the frictional head loss is 16 m, and the coefficient of friction in the pipeline is 0.007, determine the supply pipe diameter required. (5 marks)

7. (a) Show that the discharge Q of a steady laminar flow between two stationary parallel flat plates is given by:

$$Q = \frac{PBh^3}{12\mu L}$$

Where:

P = the pressure
L = the length of the plates
b = breadth
h = distance between the plates
μ = the coefficient of dynamic viscosity. (14 marks)

(b) A dashpot has a cylinder bore of 55 mm with a radial clearance of 3 mm. It is filled with oil of dynamic viscosity 0.2 Ns/m², which is acted upon by a piston 300 mm long , moving with a velocity of 0.15 m/s.

Determine the:

(i) mean velocity of oil;
(ii) load on the piston. (6 marks)

8. The power P required to run a centrifugal pump is found to depend on the following;
diameter of the impeller D
density of the fluid ρ
dynamic viscosity of the fluid μ.
bulk modulus of water k
roughness of internal passage of the pump and pipe ε
the gravitational acceleration g
delivery head H
rotational speed N
the discharge Q.

By the method of dimensional analysis, show that the power P required to drive the pump can be expressed as:

$$P = N^3 D^5 \rho \phi \left[\frac{Q}{ND^3}, \frac{gH}{N^2 D^2}, \frac{U}{ND^2 \rho}, \frac{\varepsilon}{D}, \frac{K}{N^2 D^2 \rho} \right]$$

Where 'ϕ' denotes function of. (20 marks)

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