2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
June/July 2023
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 7 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 as applied to thermodynamics:

I working substance;
II thermodynamic cycle.

(ii) Distinguish between closed thermodynamic system and open thermodynamic system.

(4 marks)

(b) In a gas turbine unit, gases flow through the turbine at 20 kg/s and the power developed by the turbine is 1600 kW. The specific enthalpies of the gas at inlet and outlet are 1200 kJ/kg and 360 kJ/kg respectively. The velocities of the gases at at inlet and outlet are 72 m/s and 180 m/s respectively.

Determine the:

(i) rate at which heat is rejected from the turbine;

(ii) area of the inlet pipe given that the specific volume of the gases at inlet is 0.42 m^3/kg.

(6 marks)

(c) The velocity of steam leaving the nozzles of an impulse steam turbine is 1200 m/s and the nozzle angle is 22°. The blade velocity is 300 m/s and the blade velocity coefficient is 0.7. The gases are flowing at 1 kg/s and the blades are symmetrical.

Determine the:

(i) blade inlet angle;

(ii) axial thrust;

(iii) diagram efficiency.

(10 marks)

2. (a) (i) Using a pressure-volume (P - V) diagram, describe the processes of an ideal Otto cycle.

(ii) A petrol engine operating on the ideal Otto cycle has a cylinder bore of 60 mm and a stroke of 80 mm. The clearance volume is 20 cm^3. If the isentropic index is 1.4, determine the air standard cycle efficiency.

(7 marks)

(b) A gas turbine plant receives air at a pressure and temperature of 1 bar and 17 °C respectively. The air is compressed to a pressure of 4. 5 bar then heated to a temperature of 507 °C before expanding through the turbine. The compressor and turbine efficiencies are 0.82 and 0.86 respectively. The pressure drop in the plant is negligible. The isentropic index for the compression and expansion processes is 1.4. The specific heat capacity for air and the hot gases is 1 kJ/kgK. A heat exchanger of effectiveness 0.7 is incorporated.

(i) Draw a temperature-entropy (T - S) diagram for the cycle.

(ii) Determine the overall efficiency of the plant.

(13 marks)

3. (a) (i) Using diagrams, distinguish between a parallel flow recuperator and a counter-flow recuperator.

(ii) A pipe carrying oil at a flow rate of 185 kg/h is held centrally inside a larger pipe. The two pipes create an annular space through which cooling water flows in counter-flow to the oil at the rate of 1600 kg/h. The oil enters the pipe at 400 °C and leaves at 60 °C. The temperature of water at entry is 15 °C. The specific heat capacities of oil and water are 5.2 kJ/kgK and 4.2 kJ/kgK respectively. The overall heat transfer coefficients for oil and water are 0.7 kW/m^2K and 1. 5 kW/m^2K respectively.

Determine the:

I. logarithmic mean temperature difference;

II. heat transferred to the cooling water;

III. heat exchange surface area.

(11 marks)

(b) The Orsat analysis of dry exhaust gas from an oil engine gave the following composition by volume: 9.2% CO_2, 1.2% CO, 5.2% O_2 and the remainder was Nitrogen. The fuel oil had a percentage composition by mass of 86% carbon, 12% Hydrogen and 2% Oxygen. The atomic masses of Carbon, Oxygen and Nitrogen are 12, 16 and 14 respectively. Air contains 23% Oxygen by mass. Determine the mass of air supplied per kg of fuel oil burnt.

(9 marks)

4. (a) With the aid of a diagram, explain the operation of a single-acting, single cylinder reciprocating air compressor. (6 marks)

(b) A two stage reciprocating air compressor delivers 3.6 m^3 of free air per minute. The pressure and temperature at entry to the compressor are 1 bar and 20 °C respectively. The delivery pressure is 60 bar. The clearance volumes of the low pressure (LP) and high pressure (HP) cylinders are each 5% of the stroke volumes. Intercooling between the stages is perfect and the strokes of both cylinders are equal. The compression and re-expansion of air in the cylinders follow the law $PV^{1.3}$ = constant.
The compressor runs at 210 rev/min. The specific gas constant, R = 0.287 kJ/kgK.
Sketch the pressure-volume (P - V) diagram for the compressor, hence determine the:

(i) minimum power required to run the compressor;

(ii) diameter of the LP and the HP cylinders.

(14 marks)

5. (a) (i) State Newton's law of cooling.

(ii) A tank made of mild steel sheet of 14 mm thickness contains water at 105 °C. Thermal conductivity of steel is 60 W/mK. The heat transfer coefficients for the inside and outside of the tank are 2750 W/m^2K and 14 W/m^2K respectively. The temperature of the air outside the tank is 24 °C.

Determine the:

I. rate of heat loss per unit area of tank surface;

II. temperature of the outside surface of the tank.

(8 marks)

(b) 0.85 kg of a fluid at 10 bar and 400 °C expands to a final pressure of 2 bar following the hyberbolic law PV = C.
Determine the work and heat transferred if the fluid is:

(i) steam;
(ii) a gas of molar mass 30 kg/kmol and adiabatic index $\gamma = 1.52$.

(12 marks)

SECTION B: FLUID MECHANICS

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

6. (a) State the:

(i) principle of dimensional homogeneity;

(ii) Buckingham Π - theorem;

(iii) two uses of dimensional analysis.

(6 marks)

(b) Show that the equation $P + \frac{1}{2}\rho V^2 + \rho g h = C$, is dimensionally homogenous.

Where:
P = Pressure;
ρ = density;
C = constant;
V = velocity;
g = gravitational acceleration;
h = height.

(5 marks)

(c) The power P, required to operate a test tunnel is given by:

$$P = \rho L^2 V^3 \phi\left(\frac{\rho V L}{\mu}\right).$$

Where
ρ = density of fluid in which the test is done;
V = velocity of fluid;
L = length parameter;
μ = coefficient of dynamic viscosity;
ϕ = 'function of'.

Tests are carried out on aerofoils in a laboratory to estimate the drag force on a 10 m long wing of an aircraft with a frontal projected area of 0.2 m by 10 m, which is subjected to wind blowing at 20 m/s. One aerofoil is subjected to an airstream flowing at 40 m/s in a wind tunnel. The other aerofoil is subjected to a water stream flowing at 10 m/s. The densities of water and air are 1000 kg/m^3 and 1.225 kg/m^3 respectively, while their dynamic viscosities are 10 kg/ms and 1.7×10^{-5} kg/ms respectively.

Determine the sizes of the aerofoils. (9 marks)

7. (a) From first principles, show that the maximum velocity U_{max}, for viscous flow of fluid between two stationary parallel plates is given by:

$$U_{max} = \frac{Ph^2}{8\mu L}.$$

Where: P = pressure difference between the two ends of the plates;
h = distance between the plates;
μ = coefficient of dynamic viscosity;
L = length of the plates.

(9 marks)

(b) A wall 80 mm thick has a horizontal crack through it measuring 30 mm in width and 2.2 mm in depth. Water leaks through the crack. The pressure difference between the two ends of the crack is 300 N/m^2. The viscosity of water is 0.0001kg/ms. Determine the rate of leakage of water through the crack. (4 marks)

(c) A horizontal pipe of diameter 480 mm is suddenly contracted to a diameter of 240 mm. The pipe carries water at a pressure of 148 kN/m^2 in the larger section and 120 kN/m^2 in the smaller section. The coefficient of contraction is 0.62.

Determine the:

(i) loss of head due to pipe contraction;

(ii) discharge through the pipe.

(7 marks)

8. (a) For each of the following, outline **two:**

(i) conditions under which negative slip occurs in a pump;

(ii) advantages of centrifugal pumps over reciprocating pumps. (4 marks)

(b) The diameter of the cylinder of a single acting reciprocating pump is 135 mm. The pump stroke is 325 mm and its speed is 60 rev/min. The pump is used to lift water through a total height of 25 m. The delivery pipe is 18 m long and its diameter is 100 mm. The pump discharges 4.2 litres of water per second. The density of water is 1000 kg/m^3.

Determine the:

(i) percentage slip of the pump;

(ii) acceleration head at the beginning, middle and end of the delivery stroke.

(8 marks)

(c) A centrifugal pump having an impeller whose outer diameter is two times the inner diameter runs at 900 rev/min. The pump works against a total head of 36 m. The velocity of flow though the impeller is constant and is equal to 2.0 m/s. The vanes are set back at an angle of 40^o at outlet. If the outer diameter of the impeller is 500 mm and its width at outlet is 50 mm, determine the:

(i) vane angle at inlet;

(ii) work done by impeller on water per second;

(iii) manometric efficiency.

(8 marks)

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