2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
Oct./Nov. 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 terms as applied to steam:

I. dryness fraction;
II. degree of superheat.

(ii) Draw a temperature-entropy (T - S) diagram showing the states of water when heated at constant pressure to superheat.

(5 marks)

(b) The nozzles of a single-wheel impulse turbine discharge steam with a velocity of 540 m/s at 22° to the plane of the wheel. The blade wheel rotates at 3000 rev/min. The blade mean radius is 480 mm. The axial velocity of the steam at exit is 180 m/s and the blades are symmetrical.

Determine the:

(i) angle of the blade at exit;

(ii) diagram power for a unit mass flow of steam;

(iii) diagram efficiency;

(iv) blade velocity coefficient.

(15 marks)

2. (a) (i) Define the following terms as applied to fuels:

I. flash point;

II. calorific value.

(ii) With the aid of a diagram, describe the procedure for analyzing a sample of flue gas using the Orsat apparatus.

(10 marks)

(b) A steel pipe of 90 mm bore and 10 mm wall thickness carries wet steam at 250 °C. The pipe is insulated with 36 mm of moulded high temperature diatomaceous earth covering which in turn is insulated with 50 mm of asbestos felt. The atmospheric temperature is 17 °C. Heat transfer coefficients for the inside and outside surfaces are 550 W/m^{2}K and 15 W/m^{2}K respectively. The thermal conductivities of steel, diatomaceous earth and asbestos felt are 50, 0.09 and 0.07 W/mK respectively.

Determine the:

(i) rate of heat loss by steam per unit length of pipe;

(ii) temperature of the outside surface.

(10 marks)

3. (a) Show that the ideal intermediate pressure, Pi for a two-stage air compressor is given by:

$$P_i = \sqrt{P_1 P_2}\,.$$

Where P_1 and P_2 are the suction and delivery pressures respectively. (8 marks)

(b) Air enters a two-stage single acting reciprocating air compressor at the rate of 5.2 kg per minute. It is then compressed from 1.013 bar and 18 °C through a pressure ratio of 12:1. Both stages have the same pressure ratio, and the law of compression and expansion in both stages is $PV^{1.3}$ = constant. The compressor runs at 320 rev/min and intercooling between the stages is perfect. The clearance volumes for both stages are 5% of their respective swept volumes. Specific gas constant, R = 0.287 kJ/kgK .

Determine the:

(i) indicated power;

(ii) swept volume per cycle for each cylinder.

(12 marks)

4. (a) Distinguish between:

(i) thermodynamic phase and thermodynamic state;

(ii) forward heat engine and reverse heat engine.

(4 marks)

(b) A two stage gas turbine plant unit draws in air at 18 °C and 1.01 bar. The pressure ratio for the unit is 9:1. The high pressure (HP) turbine drives the compressor and the low pressure (LP) turbine drives a separate power shaft. The isentropic efficiencies of the compressor, the HP turbine and the LP turbine are 0.78, 0.80 and 0.90 respectively. The maximum cycle temperature is 630 °C. The specific heat capacities at constant pressure for air and for the exhaust gases are 1.005 kJ/kgK and 1.15 kJ/kgK respectively. The isentropic index for the compression process is 1.4 and for the expansion process is 1.33. Neglecting the mass of fuel used:

(i) draw the plant and temperature-entropy (T - S) diagrams for the cycle, hence;

(ii) determine the:

I. temperature and pressure of the gases at entry to the power turbine;

II. net work done by the plant;

III. thermal efficiency.

(16 marks)

5. (a) (i) State the:

I. Boyle's law of perfect gases;

II. first law of thermodynamics.

(ii) 0.12 m^3 of a perfect gas contained in a cylinder behind a piston at 1.01 bar and 18 °C, is compressed isothermally and reversibly until the pressure is 3.8 bar.

Given that R = 0.287 kJ/kgK, determine the:

I. change in entropy;

II. work done.

(7 marks)

(b) (i) State the:

I. **two** types of heat exchangers;

II. Fourier's law of thermal conduction.

(ii) An exhaust pipe of 80 mm outside diameter is cooled by surrounding it by an annular space containing water. The exhaust gas enters from the exhaust pipe at 300 °C and the water enters from the mains at 10 °C. The two fluids flow in opposite directions. The heat transfer co-efficient for the gases is 0.3 kW/m^{2}K and that of water is 1. 5 kW/m^{2}K. The pipe thickness is negligible. The gases are required to be cooled to 80 °C. The flow rates for the gases and for the water are 180 kg/h and 1200 kg/h respectively. The mean specific heat capacity for water is 4.19 kJ/kgK and for the gases is 1.13 kJ/kgK.

Determine the length of pipe required. (13 marks)

SECTION B: FLUID MECHANICS

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

6. (a) (i) Distinguish between dynamic viscosity and kinematic viscosity.

(ii) A horizontal pipe of inside diameter 60 mm conveys oil of dynamic viscosity 0.8 kg/ms. Measurements indicate a pressure drop of 24 kN/m^2 per metre of pipe length.

Determine the:

I. discharge of the oil through the pipe;

II. velocity of oil 10 mm from the pipe wall;

III. shear stress at the wall of the pipe.

(10 marks)

(b) From first principles, show that the loss of heat due to a sudden enlargement of a horizontal circular pipe is given by:

$$h_e = \left(\frac{V_1 - V_2}{2g}\right)^2.$$

Where: h_e = loss of head due to sudden enlargement in pipe section;
g = gravitational acceleration;
V_1 and V_2 are velocities of fluid in smaller and larger sections of the pipe.

Assume the pressure at the annular section of the pipe is equal to the pressure in the smaller pipe. (7 marks)

(c) A horizontal pipe of diameter 470 mm is suddenly contracted to a diameter of 210 mm. Water flows through the larger section of the pipe at a velocity of 1. 37 m/s. The pressure intensities in the larger and smaller pipes are 137 kN/m^2 and 117 kN/m^2 respectively. The co-efficient of contraction, $C_c = 0.62$.

Determine the head loss due to the sudden contraction. (3 marks)

7. (a) Define the following terms as applied to pumps:

(i) slip;

(ii) manometric efficiency;

(iii) net positive suction head.

(3 marks)

(b) The impeller of a centrifugal pump has internal and external diameters of 185 mm and 420 mm respectively. The pump runs at 800 rev/min. The vane angles of the impeller at inlet and outlet are 22° and 32° respectively. Water enters the impeller radially and velocity of flow is constant. Gravitational acceleration is 9.81 m/s^2.
Determine the work done by the impeller per unit weight of water. (8 marks)

(c) A single acting reciprocating pump has a piston of diameter 220 mm and a stroke length of 285 mm. The centre of the pump is 3 m above the water surface in the sump. The suction pipe has a diameter of 115 mm and a length of 8 m. The pump speed is 30 rev/min. The atmospheric pressure head is 10. 3 m of water. Acceleration due to gravity is 9.81 m/s^2.

Determine the pressure head on the piston at the beginning, middle and end of the suction stroke. (9 marks)

8. (a) Distinguish between geometrical similarity and dynamic similarity. (4 marks)

(b) A partially submerged object is towed under water against a resistive force R. Show by dimensional analysis that this force is given by:

$$R = \rho L^2 V^2 \phi\left\{\frac{\mu}{\rho VL}, \frac{Lg}{V^2}\right\}.$$

Where:
ρ = density of the object;
μ = dynamic viscosity of water;
L = length of the object;
V = velocity of the object;
g = acceleration due to gravity;
ϕ = 'function of'.

(9 marks)

(c) The ratio of lengths of a submarine and its model is 40:1. The speed of the submarine is 14 m/s. The model is to be tested in a wind tunnel. The kinematic viscosities for sea water and air are 0.014 stokes and 0.016 stokes respectively. The densities of sea water and of air are 1030 kg/m^3 and 1.62 kg/m^3 respectively.

Determine the:

(i) air speed in the wind tunnel;

(ii) ratio of the drag between the model and the prototype.

(7 marks)

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