THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN MECHANICAL ENGINEERING
(PRODUCTION, PLANT AND CONSTRUCTION PLANT OPTION)
DIPLOMA IN AUTOMOTIVE ENGINEERING
DIPLOMA IN WELDING AND FABRICATION

MODULE III

FLUID MECHANICS AND THERMODYNAMICS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Non programmable scientific Calculator;
Drawing instruments;
Tables of "Thermodynamics and Transport properties of fluids' by G.F.C Rogers and Y.R Mayhew.
This paper consists of TWO sections; A and B.
Answer FIVE questions in total taking TWO questions from section A and THREE questions from section B.
All questions carry equal marks.
Maximum marks for each question are 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.

Turnover

SECTION A: FLUID MECHANICS

Answer TWO questions from this section.

1. (a) Show that the average velocity of flow between parallel stationary plates is given by $V = \dfrac{Ph^2}{12\mu L}$, where P is the pressure difference between the ends of the plates, h is the distance between the plates, L is the length of the plates and μ is the fluid viscosity.

(14 marks)

   (b) A horizontal pipe of 5 cm diameter conveys oil of dynamic viscosity 0.8 kg/ms. Measurements indicate a pressure drop of 20 kN/m² per meter of pipe length traversed. Determine the:

   (i) discharge of the oil through the pipe;
   (ii) velocity of the oil 1 cm from the pipe wall;
   (iii) shear stress at the wall of the pipe.

(6 marks)

2. (a) A pipe having a sudden enlargement in diameter from 300 mm to 450 mm is laid horizontally to connect two tanks of water. The smaller section of the pipe is 150 m long and the larger section is 210 m long. Water enters at the smaller end and exits at the larger end. The velocity of flow through the smaller section is 1.2 m/s. Take f = 0.006 for the smaller section and 0.005 for the larger section.

   (i) Determine the loss of head at the

   (I) entrance to the pipe;
   (II) enlargement;
   (III) exit to the second tank.

   (ii) Determine the difference in the levels of the water in the two tanks.

(10 marks)

   (b) A centrifugal pump having an impeller whose outer diameter is two times the inner diameter runs at 1000 rpm. The pump works against a total head of 40 m. The velocity of flow through the impeller is constant and equals to 2.5 m/s. The vanes are set back at an angle of 40° at outlet. If the outer diameter of the impeller is 500 mm and its width at outlet is 50 m, determine the:

   (i) vane angle at inlet;
   (ii) work done by impeller on water per second;
   (iii) manometric efficiency.

(10 marks)

3. (a) The thrust, P of a propeller depends upon the diameter D, speed of advance V, mass density ρ, speed of rotation N, and the coefficient of viscosity μ.

Show that $P = \rho D^2 V^2 \phi \left[\dfrac{\rho V D}{\mu}, \dfrac{ND}{V} \right]$

Where ϕ means 'function of'. (12 marks)

(b) (i) Distinguish between geometric similarity and dynamic similarity.

(ii) The power P required to operate a test tunnel is given by $P = \rho L^2 V^2 \phi \left(\dfrac{\rho V L}{\mu} \right)$

where ρ = density of fluid in which the test is done
V = velocity of fluid
L = length parameter
μ = dynamic viscosity

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 a 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. Determine the sizes of the aerofoils.

(8 marks)

SECTION B: THERMODYNAMICS

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

4. (a) With the aid of a diagram, explain the working the working principle of the Orsat apparatus used in the analysis of combustion gases. (8 marks)

(b) A three stage, single acting reciprocating air compressor has a low pressure cylinder of 450 mm and 300 mm stroke. The clearance volume of the low pressure cylinder is 5% of the swept volume. The intake conditions are 1 bar and 18°C, while the delivery pressure is 15 bar. The intermediate pressure are ideal and the expansion and compression index is 1.3. Calculate the:

(i) intermediate pressures;
(ii) effective swept volume of the low pressure cylinder;
(iii) temperature and volume of air delivered per stroke at 15 bar;
(iv) work done per kg of air.

(12 marks)

5. (a) A nozzle is a device for increasing the velocity of a steadily flowing stream of fluid. At the inlet to a certain nozzle, the enthalpy of the fluid is 3025 kJ/kg and the velocity is 60 m/s. At the exit from the nozzle, the enthalpy is 2790 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it. Determine the:

   (i)   velocity at the nozzle outlet;
   (ii) mass flow rate of the fluid, if the area at inlet is 0.1 m² and the specific volume at inlet is 0.19 m³/kg;
   (iii) exit area of the nozzle, if the specific volume at the nozzle exit is 0.5 m³/kg.

   (6 marks)

   (b) The velocity of steam at inlet to a simple impulse turbine is 1000 m/s and the nozzle angle is 25°. The blade speed is 400 m/s. The blades are symmetrical and frictionless. Determine the:

   (i)   blade angle if the steam enters the blade without shock;
   (ii) tangential force on the blade;
   (iii) power developed for a mass flow rate of 0.75 kg/s.

   (14 marks)

6. (a) A boiler uses coal at the rate of 3300 kg/hr in producing steam with a specific enthalpy of 2850 kJ/kg from feed water with a specific enthalpy of 240 kJ/kg. The combustion of 1 kg of the coal produces 27000 kJ, of which 80% is useful in producing steam. Calculate the rate at which steam is produced. (6 marks)

   (b) A furnace wall consist of 130 mm wide refractory brick and 140 mm wide insulating firebrick separated by an air gap. The outside wall is covered with a 15 mm thickness of plaster. The inner surface of the wall is 1400° C and the room temperature is at 30° C. The heat transfer coefficient from the outside wall surface to the room is 17 W/m²K and the resistance to heat flow of the air gap is 0.18 K/W. The thermal conductivities of the refractory brick, insulating firebrick and plaster are 1.6 W/mK, 0.3 W/mK and 0.14 W/mK. Considering 1 m³ of surface area, determine the:

   (i)   rate of heat transfer;
   (ii) interface temperatures;
   (iii) temperature of the outside surface of the wall.

   (14 marks)

7. (a) (i) State the First law of thermodynamics.

(ii) During a complete cycle of operation, a system is subjected to the following heat transfers; 800 kJ supplied and 350 kJ rejected. At two points, work is done by the system to the extent of 85 kJ and 35 kJ. At a third point, there is a further work transfer. Determine the amount of work done at this third point and state whether it is work done by or on the system.

(5 marks)

(b) In a gas turbine unit, a high pressure (HP) stage turbine drives the compressor and a low pressure (LP) stage turbine drives the alternator. The overall pressure ratio is 7:1 and the maximum temperature is 700° C. The isentropic efficiencies of the compressor, HP turbine and L.P turbine are 0.8, 0.83 and 0.85 respectively. The mechanical efficiency of both shafts is 98%. Calculate the:

(i) intermediate pressure between turbine stages when the intake conditions are 1.01 bar and 25° C;

(ii) thermal efficiency;

(iii) shaft power for a mass flow rate of 60 kg/s.

Take: for air $C_p = 1.005$ kJ/kg K   and $\gamma = 1.4$
         for gases $C_p = 1.15$ kJ/kg K and $\gamma = 1.33$

(15 marks)

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