2501/304 2508/304
2502/304 2509/304
2503/304
FLUID MECHANICS AND THERMODYNAMICS
Oct. / Nov. 2021
Time: 3 hours

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

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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.

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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 $\bar{V} = \frac{Ph^2}{12\mu L}$, 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/m^2 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)

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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 $P = \rho D^2 V^2 \phi\left[\frac{\rho VD}{\mu}, \frac{ND}{V}\right]$

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

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.*

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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 m^2 and the specific volume at inlet is 0.19 m^3/kg;
(iii) exit area of the nozzle, if the specific volume at the nozzle exit is 0.5 m^3/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/m^2K 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 m^3 of surface area, determine the:

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

(14 marks)

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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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