2501/304 2508/304
2502/304 2509/304
2503/304
FLUID MECHANICS AND THERMODYNAMICS
Oct./Nov. 2022
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

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
- *Answer booklet;*
- *Calculator;*
- *Drawing instruments;*
- *Steam tables by Rogers and 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.

SECTION A: FLUID MECHANICS

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

1. (a) With the aid of a sketch, explain the operation of a reciprocating pump. (8 marks)

(b) A centrifugal pump impeller having an external and internal diameter of 480 mm and 240 mm respectively, is running at 1000 rpm. The rate of flow through the pump is $0.0576\, m^3/s$ and the velocity of flow is constant and equal to 2.4 m/s. The diameters of the suction and delivery heads are 6.2 m and 30.2 m respectively. If the power required to drive the pump is 23.3 kW and the outlet vane angle is 45°, determine the:

(i) inlet vane angle;
(ii) overall efficiency of the pump;
(iii) manometric efficiency of the pump.

(12 marks)

2. (a) Water from a large reservoir is discharged to the atmosphere through a 150 mm diameter pipe, 400 m long. The entry from the reservoir to the pipe is sharp and the outlet is 15 m below the surface level in the reservoir. Taking f = 0.01 in the Darcy formula, calculate the discharge.
(8 marks)

(b) (i) Show by dimensional analysis $F = \rho\vartheta^2 L^2 \phi\left\{\frac{\rho\vartheta L}{\mu}, \frac{Lg}{\vartheta^2}\right\}$ where:

F = drag force
ρ = mass density
ϑ = speed
L = length
μ = dynamic viscosity
g = gravitational acceleration

(ii) An aircraft of wing 10 m is required to fly at an average speed of 1000 km/hr. Its drag force is to be estimated from tests in water on a one third scale model. Determine the drag force on the full size aircraft, if that on the model is 900 N, taking the following:

$\mu_{air} = 1.8 \times 10^{-5}\, kg/ms$, $\mu_{water} = 1.31 \times 10^{-3}\, kg/ms$

$\rho_{air} = 1.225\, kg/m^3$, $\rho_{water} = 1000\, kg/m^3$

(12 marks)

3. (a) Show that discharge Q of a fluid of dynamic viscosity μ, flowing under steady conditions through a horizontal circular pipe of diameter d, length L, with a mean velocity V, when the pressure difference between the ends is P, is given by the expression:

$$Q = \frac{P\pi d^4}{128\,\mu L}$$

Hence show that the difference in pressure P can be expressed as $P = \frac{32\,\mu L\overline{V}}{d^2}$.
Where $\overline{V}$ = mean velocity.

(15 marks)

(b) Oil of viscosity 0.048 kg/ms flows through an 18 mm diameter pipe with a mean velocity of 0.3m/s. Calculate:

(i) the pressure drop which occurs over a length of 45 m;
(ii) the velocity at 3 mm from the wall of the pipe.

(5 marks)

SECTION B: THERMODYNAMICS

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

4. (a) A cylinder contains 0.07 kg of fluid having a pressure of 1 bar, a volume of 0.06 m^3 and a specific internal energy of 200 kJ/kg. After polytropic compression, the pressure and volume of the fluid are 9 bar and 0.0111 m^3 respectively, and the specific internal energy is 270 kJ/kg. Determine the:

(i) amount of work energy required for the compression;
(ii) the quantity and direction of the energy flowing during the compression.

(8 marks)

(b) A two-stage, single-acting reciprocating compressor takes in air at a rate of 6 m^3/min. The intake pressure and temperature are 1.013 bar and 15° C respectively and the air is compressed to 75 bar. The compression index is 1.25 and the compressor runs at 300 rpm. The mechanical efficiency is 80% and the volumetric efficiency is 85%. The ratio of the stroke to bore is 1:1 for both stages. The intermediate pressure is ideal and inter cooling is complete. Determine for the compressor the:

(i) indicated power;
(ii) motor power;
(iii) diameter of the bore in both stages. Assume the stroke is the same in both stages.

(12 marks)

5. (a) In a steam engine, the steam at the beginning of the expansion process is 7 bar, dryness fraction 0.95. The expansion process follows the law $PV^{1.1} = c$, down to a pressure of 0.34 bar. Calculate the:

(i) work done per kg of steam during the expansion;
(ii) heat flow per kg of steam to or from thecylinder walls during the expansion.

(8 marks)

(b) The nozzles of a simple impulse turbine are inclined at an angle of 20° to the direction of the path of the moving blades. The steam leaves the nozzle at 450 m/s and the blade speed is 180 m/s. There is no axial thrust on the blades and the velocity of the steam is reduced by 15% in passing over the blades. Determine the:

(i) blade angles;
(ii) power developed for a steam flow of 3.5 kg/s;
(iii) kinetic energy of the steam finally leaving the wheel.

(12 marks)

6. (a) An ultimate analysis of a fuel gave the following: $C = 70\%$, $H_2 = 5\%$, $O_2 = 12\%$, $N_2 = 2\%$ and $Ash = 10\%$. Determine the:

(i) stoichiometric air fuel ratio;
(ii) air fuel ratio;
(ii) volumetric analysis of the dry products in (a) (ii) above.

Take the atomic masses as $C = 12$, $H = 1$, $O = 16$, $N = 14$. (10 marks)

(b) A 50 mm pipe of 800 mm internal diameter and 950 mm external diameter and a thermal conductivity of 45 W/mK, is insulated with two successive layers. The pipe is in contact with a 35 mm thick layer of asbestos with a thermal conductivity of 0.11W/mK. The asbestos is in turn covered by a 15 mm thick magnesia of thermal conductivity 0.067 W/mk. The inside and outside transfer coefficients are 290 W/m^2k and 7.0 W/m^2k respectively. Determine the rate of heat loss per metre length, if the steam is at a temperature of 350 °C and the ambient temperature is 24 °C.

(10 marks)

7. (a) 1 kg of steam at 20 bar, dryness fraction 0.9, is heated reversibly at constant pressure to a temperature of 300 °C. Determine the:

(i) heat supplied;
(ii) change in entropy;
(iii) show the process on a T.S diagram, indicating the area which represents the heat flow.

(8 marks)

(b) In an open gas turbine plant, the air from the air compressor passes through a heat exchanger where it is heated by the exhaust gases from the low pressure (L.P) turbine. The high pressure (HP) turbine drives the compressor only. The exhaust gases from the H.P turbine passes through the L.P combustion chamber, and then into the L.P turbine, which drives an external load. Given the following data:

Over pressure ratio	=10:1
Isentropic efficiency of the compressor	= 0.85
Isentropic efficiency of the H.P turbine	= 0.86
Isentropic efficiency of the L.P turbine	= 0.88
Heat exchanger effectiveness	= 0.75

Temperature of the gases entering the H.P turbine = 700 °C
Temperature of the gases entering the L.P turbine = 700 °C
Atmospheric pressure and temperature are 1.013 bar and 25 °C respectively

Taking the specific heat capacity at constant pressure for air and gases as 1.005 kJ/kgK and 1.15 kJ/kgK, the index of compression and expansion as 1.4 and 1.33 for air and gas respectively, sketch then plant and T.S diagrams and hence calculate the:

(i) pressure of the gases entering the L.P turbine;
(ii) overall thermal efficiency.

(12 marks)

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