2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
June/July 2022
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.

*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 shown.

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: THERMODYNAMICS

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

1. (a) Show that the condition for minimum work in a two stage air compressor with complete intercooling between stages is given by $P_i = \sqrt{P_1 P_2}$.

Where: P_i = the intermediate pressure;
P_1 = the suction pressure;
P_2 = the delivery pressure.

(7 marks)

(b) A two stage air compressor delivers air at a mass flow rate of 0.38 kg/s. The suction, interstage and delivery pressures are 1 bar, 5 bar and 11 bar respectively. Atmospheric air enters the low pressure cylinder (LP) at 18 °C. The air is inter cooled to 20 °C before entering the high pressure cylinder (HP) and is delivered at 65 °C. The clearance volume of the LP and HP cylinders are 6% and 8% of the stroke volume respectively. Assuming the law of compression and expansion to be $PV^n = C$ for both cylinders, determine the:

(i) value of index n;

(ii) swept volume of each cylinder;

(iii) amount of jacket cooling required in each cylinder.

(13 marks)

2. (a) Show that the air standard efficiency of an ideal Otto cycle is given by:

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}} .$$

Where: r = compression ratio;
γ = compression index.

(7 marks)

(b) An engine of 150 mm bore and 250 mm stroke operates on an ideal Otto cycle. The clearance volume is 0.00260 m^3. The intake pressure and temperature are 1 bar and 55 °C respectively. If the maximum pressure is limited to 20 bar and assuming the ideal conditions, determine the:

(i) air standard efficiency of the cycle;

(ii) mean effective pressure for the cycle.

(13 marks)

3. (a) Show that the adiabatic index (γ) for a gas is given by:

$$\gamma = \frac{Cp}{Cv}.$$

Where: Cv = specific heat capacity at constant volume;
Cp = specific heat capacity at constant pressure.

(6 marks)

(b) Air enters the compressor of an open cycle gas turbine plant at a pressure of 1 bar and temperature 15 °C. The pressure of the air after compression is 6 bar. The isentropic efficiencies of compressor and turbine are 78% and 82% respectively. The air-fuel ratio used is 80:1 and the calorific value of the fuel is 41.8 MJ/kg. The flow rate of air is 5 kg/s. Sketch the plant and temperature entropy (T-S) diagrams and hence determine the:

(i) power developed;
(ii) thermal efficiency of the cycle.

Assume Cp = 1.0 kJ/kgK and $\gamma = 1.4$ for both air and combustion gases.

(14 marks)

4. (a) Show that for a counter flow recuperative heat exchanger, the logarithmic mean temperature difference (θ_m) is given by: $\theta_m = \dfrac{\theta_1 - \theta_2}{\ln\left(\dfrac{\theta_1}{\theta_2}\right)}$.

Where θ_1 and θ_2 are the temperature difference at the inlet and exit from the exchanger. (14 marks)

(b) The flow rates of hot and cold water streams running through a parallel flow heat exchanger are 0.4 kg/s and 0.7 kg/s respectively. The inlet temperatures on the hot and cold sides are 65 °C and 15 °C respectively. The exit temperature of hot water is 35 °C. If the individual heat transfer coefficient on both sides are 600 W/m^{2}K, calculate the area of the heat exchange surface.

Take specific heat capacity of water to be 4.187 kJ/kgK. (6 marks)

5. (a) Outline **two** examples for each of the following types of fuels:

(i) solid fuels;
(ii) liquid fuels;
(iii) gaseous fuels.

(6 marks)

(b) Define the following terms as applied to combustion of fuels:

(i) stoichiometric air-fuel ratio;
(ii) mixture strength;
(iii) flash point.

(3 marks)

(c) The volumetric analysis of a sample of flue gases from a coal fired boiler gave 7.4% CO_2, 0.3% CO, 10.8% O_2 and 81.5% N_2. The gravimetric analysis of the coal was 75% C, 9% H_2, 2% O_2 and 14% incombustible material. Determine the:

(i) mass of dry flue gases per kg of fuel;
(ii) mass of excess air per kg of fuel.

(11 marks)

SECTION B: FLUID MECHANICS

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

6. (a) Show that the head loss (H_L) due to sudden contraction in a pipeline is given by:

$$H_L = \frac{(Vc - V_2)^2}{2g}.$$

Where: V_C = Velocity at the constriction;
V_2 = exit velocity;
g = gravitational force.

(9 marks)

(b) Figure 1 shows two reservoirs connected by three pipes arranged in series. If the coefficient of constriction is unity, determine the discharge through the pipes if:

(i) both major and minor losses are considered;
(ii) only the major losses are considered.

(11 marks)

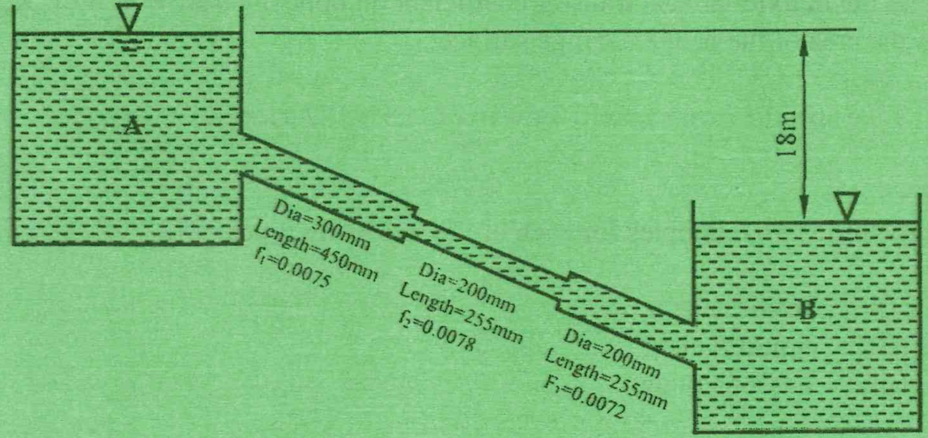

Fig. 1

7. (a) (i) Define the term specific speed as applied to centrifugal pumps.

(ii) Show that the specific speed of a pump is given by:

$$N_s = \frac{NQ^{1/2}}{H^{3/4}}.$$

Where:

N_S = specific speed;
N = speed of pump;
Q = discharge;
H = head developed.

(8 marks)

(b) A centrifugal water pump is required to deliver 45 m^3/min against a manometric head of 16 m. The vane angle at outlet is 60° and the radial velocity is 0.27 times the peripheral velocity at exit. The manometric efficiency is 85% and the width of the impeller at exit is 0.1 times the outside diameter. Determine the:

(i) outside diameter of the impeller;
(ii) speed of rotation of the impeller;
(iii) power developed by the pump.

(12 marks)

8. (a) The shear stress τ for a laminar steady flow of a fluid in a pipe is given by $\tau = -\frac{V}{2}\frac{dp}{dx}$.

Where: r = radial distance from the centre line of the pipe;
dp = change in pressure;
dx = change in distance along the pipe.

Show that the velocity v at any point in the pipe is given by:

$$V = -\frac{1}{4\mu}\cdot\frac{dp}{dx}(R^2 - r^2).$$

Where: R = pipe radius;
μ = dynamic viscosity.

(12 marks)

(b) Oil of dynamic viscosity 0.12 kg/ms and relative density 0.9 flows in a pipe of diameter 30 cm. The velocity of oil along the centre line is 2.6 m/s. If the flow is laminar, determine the:

(i) volumetric flow rate;
(ii) shear stress at the pipe wall;
(iii) shear stress at 45 mm radial distance from the centre line.

(8 marks)

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