2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
Oct./Nov. 2018
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 fluid tables by Rogers and Mayhew;
Drawing instruments.

*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*
Answer FIVE questions choosing 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 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 any **THREE** questions from this section.*

1. (a) By use of a P-V diagram, describe the processes of an ideal Otto cycle. (6 marks)

(b) Show that the air standard efficiency of an ideal Otto cycle h_{Otto} is expressed as:

$$\eta_{Otto} = 1 - \frac{1}{(r)^{\gamma-1}}$$

where: r is the compression ratio;
γ is the adiabatic index.

(6 marks)

(c) The minimum pressure and temperature of an engine operating on an Otto cycle are 120 kN/m^2 and 30°C, when the compression ratio is 8:1.

If the amount of heat added to the air per cycle is 1800 kJ/kg, determine each of the following:

(i) maximum temperature and pressure of the cycle;
(ii) work output per cycle for a unit mass;
(iii) the air standard efficiency.

Take: $C_v = 0.72$ kJ/kgK; $\gamma = 1.4$.

(8 marks)

2. (a) Define each of the following thermodynamic reversible processes:

(i) isobaric;
(ii) adiabatic;
(iii) polytropic.

(3 marks)

(b) Show that the work done in a reversible adiabatic process (W), when the corresponding initial and final pressures and volumes are P_1, V_1 and P_2, V_2 respectively is given by:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

where γ is the adiabatic index.

(8 marks)

(c) Air at a pressure of 6 bar and a temperature of 125° C has a volume of 0.55 m^3. A reversible adibatic expansion of the air takes place until the pressure is 1.05 bar. The air is then heated at a constant pressure increasing the enthalpy by 83.6 kJ.

(i) Sketch the P-V diagram for the processes.
(ii) Determine the total work done during the processes.

(9 marks)

3. (a) With the aid of a plant diagram, explain the method of improving the thermal efficiency of a gas turbine by use of a heat exchanger. (3 marks)

(b) Air flowing at 5.8 kg/s enters a gas turbine plant at a pressure and temperature of 1.013 bar and 22°C respectively. The gas turbine consists of a high pressure turbine which drives the compressor only, and a low pressure turbine connected to a power output shaft. Air in the compressor is compressed through a pressure ratio of 8:1 when the isentropic efficiency of the compressor is 85%. The compressed air is then passed into the combustion chamber and heated to 680°C before it enters into the high pressure turbine whose isentropic efficiency of expansion is 88%. Finally the gases are expanded in the low pressure turbine, with an isentropic efficiency of 86%.

(i) Draw the plant and T-S diagrams;
(ii) Determine the temperature and pressure of the gases entering the low pressure turbine;
(iii) Calculate the power output;
(iv) Determine the thermal efficiency of the turbine.

Take:

$Cp_{air} = 1.005$ kJ/kg K $\qquad \gamma_{air} = 1.4$

$Cp_{gas} = 1.15$ kJ/kg K $\qquad \gamma_{gas} = 1.33$

(17 marks)

4. (a) List **two** types of air compressors. (2 marks)

(b) By use of a P-V diagram of a single stage air compressor, show that the work done by a a compressor (W) with a mass flow rate $\dot{m}$ of air, an induction and delivery temperatures T_1 and T_2 respectively is given by:

$$W = \frac{n}{n-1}\dot{m}R(T_2 - T_1);$$

where: n is the compression and expansion index;
R is the characteristic gas constant.

(7 marks)

(c) A single cylinder single acting reciprocating air compressor has a clearance volume of 3% of its swept volume. When the compressor speed is 1050 rev/min, it delivers air at a pressure of 28 bar. The free air delivery at a pressure and temperature of 1.013 bar and 25°C respectively is 0.26 m³/min.

If the stroke is 12 times the cylinder bore, determine each of the following:

(i) diameter of the cylinder;
(ii) length of stroke;
(iii) indicated power.

(11 marks)

5. (a) (i) Define each of the following methods of heat transfer:

I. conduction;
II. convection;
III. radiation.

(ii) State each of the following laws as applied to heat transfer:

I. Fourier's law of conduction;
II. Newton's law of cooling.

(5 marks)

(b) An insulating wall of thickness x and thermal conductivity k, separates two fluids of heat transfer coefficients h_1 and h_2 respectively.
Show that the overall heat transfer coefficient u is given by:

$$u = \frac{1}{\left(\frac{1}{h_1} + \frac{x}{k} + \frac{1}{h_2}\right)}$$

(9 marks)

(c) An exterior wall of a building consists of 0.2 m layer of bricks followed by a 0.05 m of gypsum plaster and a rockwool layer. If the thermal conductivity of the brick, gypsum and rockwool layer are 0.7, 0.04 and 0.068 W/mK respectively. Determine the thickness of the rockwool layer to prevent heat gain into the building by 85%.

(6 marks)

SECTION B: FLUID MECHANICS

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

6. (a) Explain **two** causes of energy losses in pipelines. (2 marks)

(b) Show that the head loss due to sudden enlargement of cross-sectional area of a pipe is given by:

$$h_L = \frac{(V_1 - V_2)^2}{2g}$$

where V_1 and V_2 are inlet and outlet velocities of fluid.

(12 marks)

(c) A pipe carrying water suddenly increases its diameter from 0.56 m to 1.2 m. The pressure head difference between the two sections is 0.45 m of water. Determine each of the following:

(i) head loss due to change of section;

(ii) discharge of the pipe.

(6 marks)

7. (a) Define each of the following terms:

(i) viscous flow;
(ii) coefficient of dynamic viscousity;
(iii) coefficient of kinematic viscousity.

(3 marks)

(b) Show that the discharge Q of a pipe fully filled with a liquid of kinematic viscousity μ, when flowing in a pipe of diameter d and length L, due to pressure difference P is given by:

$$Q = \frac{Pd^4}{128\,\mu L}$$

(11 marks)

(c) A pipe of diameter 155 mm and length 1200 m carries 90 tonnes of oil per hour. The oil is of density 950 kg/m^3. If the coefficient of friction is 0.16, calculate the power required to pump the oil.
(6 marks)

8. (a) Define each of the following terms as applied in reciprocating pumps:

(i) coefficient of discharge;
(ii) percentage slip.
(2 marks)

(b) Using an indicator diagram of a reciprocating pump, derive the expression for the accelerating head at the beginning of suction.
(9 marks)

(c) A single acting reciprocating pump has a piston diameter and stroke of 120 mm and 250 mm respectively. The suction pipe is 85 mm diameter and has a length of 5.6 m. If separation takes place at a pressure head of 1.4 m of water and the atmospheric pressure head is 10.3 m of water, determine each of the following:

(i) maximum speed at which the pump will run without separation, when the water level is 3 m below the pump cylinder head;
(ii) power used by the pump in overcoming friction at this speed.

Take friction factor = 0.01

(9 marks)

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