2506/305
AIRCRAFT MECHANICAL TECHNOLOGY II
June/July 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 shown.
Candidates should answer the questions in English.

This paper consists of 6 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 (60 marks)

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

1. (a) State Joule's law. (2 marks)

(b) With the aid of a labelled T-S diagram, explain the process of an ideal Joule cycle. (4 marks)

(c) In a ramjet engine process m^2, 0.15 g of a gas at 120 kN/m^2 and 20°C is compressed to a final pressure of 1 MN/m^2, according to the law $PV^{1.35}$ = constant. The molar mass of the gas is 30 kg/kmol, and its adiabatic index is 1.5. Determine the:

(i) initial and final volumes of the gas;
(ii) final temperature;
(iii) work transfer;
(iv) heat transfer.

Take universal gas constant.

$R_0 = 8.314$ kJ/kmol K

(14 marks)

2. (a) With the aid of temperature-entropy (T-S) diagrams, explain the effect of incorporating the following in a gas turbine plants:

(i) intercooler;

(ii) reheat combustion chamber.

(6 marks)

(b) In a jet aircraft gas turbine plant, the turbine drives the two compressors and an external load. The pressure ratios of the low and high pressure compressors are 3.5/1 and 4.2/1 respectively. The ambient temperature is 17°C and the intercooler cools the air to 40°C. The maximum temperature of the cycle is 600°C. The specific heat capacities of air and the combustion gases are 1.005 and 1.15 kJ/kgK respectively, while the isentropic efficiencies of the compressors and the turbine are 90% and 85% respectively.

(i) Draw the plant and the T-S diagrams.

(ii) Determine the cycle efficiency.

Take $\gamma_{air} = 1.4$, $\gamma_{gases} = 1.33$

(14 marks)

3. (a) List **three** types of air compressors. (3 marks)

(b) Using a P-V diagram, show that the volumetric efficiency η_{vol} of a reciprocating compressor is given by:

$$\eta_{vol} = 1 - \frac{Vc}{Vs}\left\{\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right\}$$

where Vc = clearance volume
Vs = swept volume
P_1 = suction pressure
P_2 = delivery pressure
n = index of compression and expansion.

(6 marks)

(c) In a two stage, single acting reciprocating air compressor, the suction, interstage and delivery pressures are 0.98 bar, 5 bar and 14 bar respectively. The atmospheric pressure temperature are 1.01 bar and 20°C respectively, and the intercooler cools the air to 40°C. The free air delivery is 4.8 m^3/minute and the temperature inside the low pressure cylinder at the start of compression is 30°C. The index compression and expansion is 1.35 throughout. The clearance volume is 6% of the swept volume in each cylinder. The mechanical efficiency of the compressor and drive is 90%.
Sketch the P-V diagram for the machine and hence determine the following:

(i) indicated power;
(ii) driving motor power;
(iii) rate of cooling at the intercooler.

(11 marks)

4. (a) Explain **three** factors which affect the rate of conduction of heat through a solid slab. (6 marks)

(b) A steam pipe has a bore of 150 mm and a thickness of 20 mm. The pipe is covered with a 30 mm thick layer of lagging material x, which in turn is covered with a 40 mm thick layer of lagging material y. The coefficient of thermal conductivity of the pipe, materials x and y are 50, 0.18 and 0.075 W/m^2K respectively.
Dry saturated steam at 20 bar enters the 20 metre long pipe. The ambient temperature is 18°C. The inside and outside surface heat transfer coefficients are 20 and 40 W/mK respectively. Determine the rate of heat loss through the pipe.

(14 marks)

5. (a) Explain the following:

(i) thermodynamic reversibility;

(ii) principle of the heat engine.

(4 marks)

(b) Sketch the temperature - entropy (T-S) diagram for steam and indicate the wet region, liquid region and superheated steam region. (4 marks)

(c) Steam at 10 bar, 200°C enters a steam turbine and expands to a final pressure of 2 bar following the hyperbolic law PV = C. Determine the following:

(i) final condition of the steam;

(ii) work transfer;

(iii) heat transfer.

(12 marks)

SECTION B: FLUID MECHANICS (40 marks)

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

6. (a) State Buckingham's π - theorem as applied to dimensional analysis. (2 marks)

(b) The resisting force R to the motion of a supersonic jet aircraft depends on the length of the aircraft L, the velocity V, bulk modulus of the air k, dynamic viscosity of the air μ and the mass density ρ. Using dimensional analysis, show that:

$$R = \rho L^2 V^2 \phi\left[\left(\frac{\mu}{\rho VL}\right)\left(\frac{\rho V^2}{k}\right)\right]$$

where ϕ = "function of".

(13 marks)

(c) The ratio of the lengths of a sub-marine and its model is 50:1. The speed of the submarine is 12 m/s. The model is to be tested in a wind tunnel. The kinematic viscosities of sea water and air are 1.2×10^{-6} m^2/s and 1.6×10^{-6} m^2/s respectively. The densities of sea water and air are 1020 k/gm^3 and 1.3 kg/m^3 respectively. Determine the speed of air in the tunnel. (5 marks)

7. (a) Show that the discharge Q of a steady laminar flow between parallel flat plates is given by:

$$Q = \frac{Pbh^3}{12\eta l}$$

where:

P is the pressure difference;
L is the length of the plates;
b is the breadth;
h is the distance between the plates;
η is the coefficient of dynamic viscosity.

(14 marks)

(b) An oil of viscosity 1 Ns/m^2 flows between two parallel fixed plates which are kept at a distance of 40 mm apart. The width of the plates is 180 mm and the pressure drop is 30 kN/m^2 over a length of 1.2 m. Determine the following:

(i) maximum velocity of the oil.

(ii) volume flow rate.

(6 marks)

8. (a) Apart from pipe friction, state **three** types of head losses which occur for a liquid flowing through a pipe. (3 marks)

(b) A fluid flows through a pipe of diameter d and length l. Show that the head loss due to friction.

$$h_f = \frac{4flv^2}{d.2g}$$

where:

f = coefficient of friction;
v = fluid velocity;
d = pipe diameter;
g = acceleration due to gravity.

(11 marks)

(c) Oil of relative density 0.8 flows through a pipe of 320 mm diameter, 1200 m long, at a rate of 600 litres per second.
If the friction factor is 0.2, determine the:

(i) head loss due to friction;

(ii) power required to maintain the flow.

(6 marks)

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