

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.

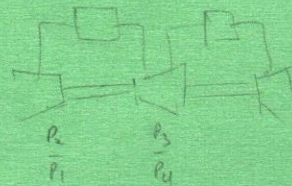
1. (a) State Joule's law. (2 marks)
- (b) With the aid of a labelled T-S diagram, explain the process of an ideal Joule cycle. (4 marks)
- (c) In a ramjet engine process  $m^2$ , 0.15 g of a gas at 120 kN/m<sup>2</sup> and 20°C is compressed to a final pressure of 1 MN/m<sup>2</sup>, according to the law  $PV^{1.35} = \text{constant}$ . 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.

$$R_0 = 8.314 \text{ kJ/kmol K}$$

(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.
- (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  $\gamma_{\text{air}} = 1.4$ ,  $\gamma_{\text{gases}} = 1.33$



(14 marks)

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

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

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

where  $V_c$  = clearance volume

$V_s$  = 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<sup>3</sup>/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<sup>2</sup>K 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  $\pi$  - 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  $\mu$  and the mass density  $\rho$ . Using dimensional analysis, show that:
- $$R = \rho L^2 V^2 \phi \left[ \left( \frac{\mu}{\rho V L} \right) \left( \frac{\rho V^2}{k} \right) \right]$$
- where  $\phi =$  "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  $1.2 \times 10^{-6} \text{ m}^2/\text{s}$  and  $1.6 \times 10^{-6} \text{ m}^2/\text{s}$  respectively. The densities of sea water and air are  $1020 \text{ kg/m}^3$  and  $1.3 \text{ kg/m}^3$  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;
- $\eta$  is the coefficient of dynamic viscosity.

(14 marks)

- (b) An oil of viscosity  $1 \text{ Ns/m}^2$  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  $30 \text{ kN/m}^2$  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.

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

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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