2506/305
AIRCRAFT MECHANICAL
TECHNOLOGY II
Oct./Nov. 2019
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;*
- *Drawing instruments;*
- *Mathematical tables/Non-programmable scientific calculator;*
- *Thermodynamic and Transport properties of fluid tables by Rogers and 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 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

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

1. (a) Define the following terms as applied to thermodynamics:

(i) system;
(ii) boundary.

(2 marks)

(b) (i) Distinguish between isothermal and adiabatic processes.

(ii) State the first law of thermodyamics.

(4 marks)

(c) (i) Show that for a perfect gas:

$$C_p = \frac{\gamma R}{(\gamma - 1)}$$

where C_p = specific heat capacity at constant pressure;
γ = ratio of specific heat capacity at constant pressure to the specific heat capacity at constant volume;
R = gas constant.

(ii) A quantity of carbon dioxide is compressed from an initial state of 0.092 m^3, 1.2 bar to a final state of 0.043 m^3 and 4.2 bar. The observed temperature rise is 154 K. Determine the:

(I) gas constant;
(II) mass of gas present;
(III) increase in internal energy of the gas.

Assume carbon dioxide to be a perfect gas.

Take: $C_p = 0.82$ kJ/kg K and $C_v = 0.63$ kJ/kg K

(14 marks)

2. (a) With the aid of a P-V diagram, describe the processes of the ideal dual combustion cycle. (8 marks)

(b) Show that for an air standard Otto cycle:

$$\frac{T_2}{T_1} = r_v^{\gamma-1}$$

Where:

T_2 = temperature at the end of compression;
T_1 = temperature at the beginning of compression;
r_v = compression ratio;
γ = adiabatic index.

(6 marks)

(c) In an air standard Otto cycle, the maximum and minimum temperatures are 1,500 °C and 14 °C. The heat supplied per kg of air is 700 kJ. Determine the:

(i) compression ratio;
(ii) thermal efficiency.

Take $\Upsilon = 1.4$; $C_v = 0.718$ kJ/kg K.

(6 marks)

3. (a) Define each of the following as used in combustion of fuels:

(i) stoichiometric mixture;
(ii) ultimate analysis;
(iii) mixture strength;
(iv) calorific value.

(4 marks)

(b) A petrol engine uses ethyl alcohol (C_2H_6O) for combustion. Determine the:

(i) stoichiometric air fuel ratio by mass;
(ii) wet and dry analysis by volume of the exhaust gas in b(i);
(iii) air fuel ratio for a mixture strength of 80%.

(16 marks)

4. (a) With the aid of a T-S diagram, explain the function of an intercooler in a gas turbine plant. (4 marks)

q = P   q =   q = v = Q/A

(b) In an aircraft gas turbine unit, a high pressure stage turbine drives the compressor and a low pressure stage turbine drives the propeller through suitable gearings. The overall pressure ratio is 5/1 and the maximum temperature is 700° C. The isentropic efficiencies of the compressor, high pressure turbine and low pressure turbine are 0.8, 0.82 and 0.86 respectively. The air intake conditions are 1.013 bar and 30° C.

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

(ii) Calculate the:

(I) pressure between turbine stages;
(II) thermal efficiency.

Take: $CP_a = 1.005$ kJ/kg K, $CP_g = 1.15$ kJ/kg K;
$\gamma = 1.4$ for both compression and expansion.

(16 marks)

5. (a) Distinguish between the following types of heat exchangers:

(i) regenerative and evaporative;
(ii) parallel flow and counter flow.

(4 marks)

(b) (i) State the Fourier's law of conduction.

(ii) Show that for a single cylindrical wall of unit length, the logarithmic mean area A_m is given by:

$$A_m = \frac{2\pi (r_2 - r_1)}{\ln\left(\frac{r_2}{r_1}\right)},$$

where: r_1 = internal radius;
r_2 = external radius.

(9 marks)

(c) In a parallel flow tubular heat exchanger, hot gases are cooled from 600° C to 200° C by water initially at 18 °C. The mass flow rate of the gas is 0.4 kg/s and that of water 0.5 kg/s. The specific heat capacities of the gas and water are 1.2 kJ/kg K and 4.2 kJ/kg K respectively. The overall heat transfer coefficient from gases to water is 150 W/m²K.

(i) Sketch the temperature variation along the length of the heat exchanger.

(ii) Calculate the surface area required.

(7 marks)

SECTION B: FLUID MECHANICS

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

6. (a) Assuming that the frictional resistance per unit area of pipe wall q is proportional to the square of the mean velocity of flow, show that the loss of head due to friction h_f in a pipeline is given by the formula:

$$h_f = \frac{4fLV^2}{2dg}.$$

Where: f = resistance coefficient;
L = length of pipe;
V = velocity;
d = diameter of pipe;
g = gravitational acceleration.

(9 marks)

(b) The discharge through a horizontal pipe of varying cross-section is 0.96 m^3/s.
The first part of the pipe is 3 m long and 0.2 m diameter. The second part is 4 m long and 0.5 m diameter. The third part is 5 m long and 0.3 m diameter.
The coefficient of contraction $C_c = 0.6$ and frictional coefficient f = 0.01.

If the change of sections are sharp, determine the total loss of head due to:

(i) sudden enlargement;
(ii) sudden contraction;
(iii) friction.

$h_e = \frac{V^2}{2g}\left[1 - \frac{A_1}{A_2}\right]^2$

(11 marks)

$h_c = \frac{V^2}{2g}\left[\frac{1}{c} - 1\right]^2$

7. (a) Define the following terms as used in fluid mechanics:

(i) coefficient of dynamic viscosity;
(ii) kinematic viscosity.

(3 marks)

(b) Show that the total discharge Q of a viscous incompressible fluid flowing between parallel flat plates is given by:

$$Q = \frac{Pbh^3}{12\mu L},$$

where: P = pressure difference between the ends of the plates;
μ = coefficient of dynamic viscosity;
L = length of plates;
h = distance between the plates;
b = width of the plates.

(13 marks)

(c) A dashpot consists of a cylinder 60 mm diameter in which slides a piston 90 mm long. The radial clearance between the piston and the cylinder is 1.5 mm. The cylinder is filled with an oil of dynamic viscosity 0.1 kg/ms. If the piston is pushed by a force of 200 N, determine the volume of oil leaving the cylinder per second.

(4 marks)

8. (a) Define the following terms as applied to pumps:

(i) specific speed;
(ii) coefficient of discharge.

(2 marks)

(b) (i) State **two** assumptions made while deriving the equation for work done by a centrifugal pump.

(ii) With the aid of a diagram, show that for a centrifugal pump, the work done per unit weight is given by the equation:

$$\text{Work done per unit weight} = \frac{W_2 u_2}{g}$$

Where: w_2 = tangential component of absolute velocity at exit (whirl velocity at exit);
u_2 = tangential velocity of impellor at outlet;
g = gravitational acceleration.

(10 marks)

(c) A centrifugal pump running at 900 rev/min works against a total head of 24 m. The external diameter of the impeller and outlet width are 520 mm and 80 mm respectively. The vanes angle at outlet is 36° and the manometric efficiency is 80%. Determine the:

(i) flow velocity at outlet;
(ii) absolute velocity of the fluid leaving the vane;
(iii) angle of absolute velocity at exit;
(iv) impeller power.

(8 marks)

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