2501/304 2508/304
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2503/304
FLUID MECHANICS AND THERMODYNAMICS
June/July 2022
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN MECHANICAL ENGINEERING (PRODUCTION, PLANT AND CONSTRUCTION PLANT OPTIONS)
DIPLOMA IN AUTOMOTIVE ENGINEERING
DIPLOMA IN WELDING AND FABRICATION

MODULE III

FLUID MECHANICS AND THERMODYNAMICS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Non programmable scientific calculator;
Drawing instruments;
Tables of "Thermodynamic and Transport properties of fluids" by G.F.C Rogers and Y.R Mayhew;
This paper consists of ***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 indicated.
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: FLUID MECHANICS

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

1. (a) Show that the discharge, Q through a pipe of length L and diameter d, carrying oil of viscosity μ is given by

$Q = \frac{P\pi d^4}{128\mu L}$, where P is the pressure difference between the ends of the pipe.

(11 marks)

(b) A horizontal pipe of diameter 400 mm is suddenly contracted to a diameter of 200 mm. The pipe is carrying water at a pressure of 147.15 kN/m^2 in the larger section and 127.53 kN/m^2 in the smaller section. The coefficient of contraction is 0.62. Determine the:

(i) loss of head due to pipe contraction;
(ii) discharge through the pipe.

(9 marks)

2. (a) (i) Define each of the following terms as applied to pumps:

(I) slip;
(II) manometric efficiency.

(ii) With the aid of a diagram, explain the operation of a centrifugal pump.

(10 marks)

(b) The diameter of a cylinder of a single acting reciprocating pump is 150 mm. The pump stroke is 300 m long and its speed is 50 rpm. The pump lifts water through a total height of 25 m. The delivery pipe is 22 mm long and its diameter is 100 mm. The pump discharges water at 0.0042 m^3/s. Density of water is 1000 kg/m^3. Determine the:

(i) percentage slip of the pump;
(ii) acceleration head at the beginning, middle and end of the delivery stroke.

(10 marks)

3. (a) State:

(i) the principle of dimensional homogeneity;
(ii) Buckingham π-theorem;
(iii) two applications of dimensional analysis.

(6 marks)

(b) Show that the equation $P + \frac{1}{2}\rho V^2 + \rho g h$ = constant is dimensionally homogeneous, where P = pressure, ρ = density, V = velocity, g = gravitational acceleration and h = height. (6 marks)

(c) A spherical ball of diameter d, moves down in a liquid of mass density ρ and dynamic viscosity μ at a uniform velocity V. Show by dimensional analysis that the viscous resistance of flow, F on the ball is given by

$$F = \rho V^2 d^2 \phi\left[\frac{\mu}{\rho V d}\right];$$ where ϕ is 'function of'. (8 marks)

SECTION B: THERMODYNAMICS

Answer THREE questions from this section.

4. (a) A single stage double acting air compressor has a FAD of 15 m^3/min measured at 1.0132 bar and 25 °C. The induction pressure and temperature are 0.94 bar and 30 °C. If the compression and expansion index is 1.33 and the delivery pressure 8.5 bar. Calculate the:

(i) volumetric efficiency given that the clearance volume is 5% of the swept volume;

(ii) indicated power.

(8 marks)

(b) At the beginning of compression of an ideal diesel cycle, the gas has a temperature and pressure of 40 °C and 90 kN/m^2 respectively. The volume ratio of compression is 16:1. the maximum cycle temperature is 1400 °C. Taking γ = 1.4 and Cp = 1.004 kJ/kgK, calculate the:

(i) pressure and temperature at each of the cycle state points;
(ii) thermal efficiency;
(iii) work ratio;
(iv) mean effective pressure;
(v) Carnot efficiency within the cycle temperature limits.

(12 marks)

5. (a) 1 kg of a fluid at 30 bar, 300 °C expands reversibly and isothermally to a pressure of 0.75 bar. Calculate the heat flow and the work done when the fluid is:

(i) air;
(ii) steam.

Sketch the process on P-V and T-S diagram. (9 marks)

(b) A quantity of a fuel has the following analysis : 82%C, 5%H, 6%O_2 and 7%N. The dry fine gas analysis showed 14% CO_2 and some oxygen. Determine the:

(i) oxygen content of the dry gas;
(ii) air fuel ratio;
(iii) percentage of excess air supplied.

Take the atomic masses as C - 12, O - 16, H - 1, N - 14). (11 marks)

6. (a) Define the following terms as applied in thermodynamics:

(i) system;
(ii) boundary;
(iii) surroundings.

(3 marks)

(b) 0.05 m^3 of a gas at 6.9 bar expand reversibly in a cylinder behind a piston according to the law $PV^{1.2}$ = constant until the volume is 0.08 m^3. Calculate the work done. (3 marks)

(c) A gas turbine has two stages of compression with an intercooler between stages. The high pressure turbine drives the high pressure compressor and the law pressure turbine drives the low pressure compressor and a generator. Exhaust gases from the low pressure turbine passes through a heat exchanger which heats the air leaving the high pressure compressor.
There is a reheat combustion chamber which raises the gas temperature between the turbine stages to 600 °C, which is also the temperature at entry to the high pressure turbine. The overall pressure ratio is 10:1, with the compressors having the same pressure ratio.
The air temperature at the entry to the turbine unit is 20 °C. the heat exchanger thermal ratio is 0.7, and with complete inter-cooling between compressor stages. The isentropic efficiency of both compressor stages and turbine stages are 0.8 and 0.85 respectively. 2% of each turbine work is used in overcoming friction. Neglecting losses of pressure and velocity:

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

(ii) Determine the:

(I) overall thermal efficiency;

(II) power output for a mass flow rate of 115 kg/s.

Take for:

Compression $\gamma = 1.4$, $Cp = 1.005$ kJ/kgK

Expansion $\gamma = 1.25$, $Cp = 1.15$ kJ/kgK

(14 marks)

7. (a) A steel pipe 150 mm external diameter conveys steam at a temperature of 260 °C and it is covered by two layers of lagging, each 50 mm thick. The thermal conductivities of the inside layer of the lagging is 0.086 W/mK and that of the outside layer is 0.055 W/mK. The outside surface temperature of the steel pipe can be taken as being the same as the temperature of the steam; the temperature of the outside layer of the lagging is 27 °C. Determine the:

(i) heat lost per hour for a pipe length of 30 m;

(ii) the interface temperature between the two layers of lagging.

(10 marks)

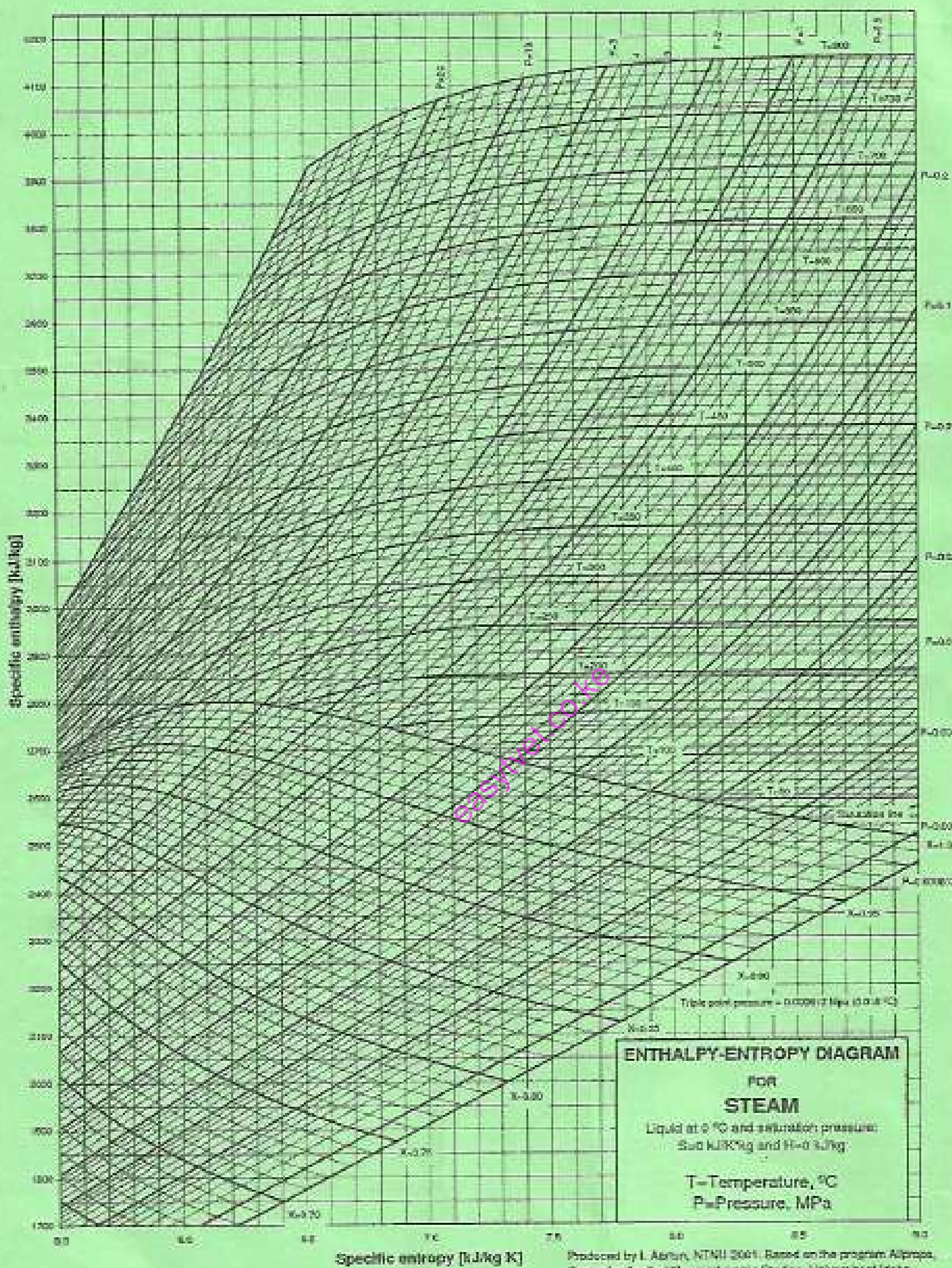
(b) Steam at a pressure of 20 bar and temperature 250 °C is expanded to a pressure of 3.5 bar according to the law $PV^{1.25}$ = constant. Determine for this expansion the:

(i) final condition of the steam;

(ii) specific heat transfer;

(iii) change of entropy.

Sketch the process on a T-S diagram. (10 marks)



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