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CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY MARINE ENGINEER OFFICER

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-32 - APPLIED HEAT

MONDAY, 14 DECEMBER 2020

1315 - 1615 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper Thermodynamic and Transport Properties of Fluids (5th Edition) Arranged by Y.R. Mayhew and C.F.C. Rogers

Examination Paper Inserts

Notes for the guidance of candidates:

1. Examinations administered by the SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer

1. A perfect gas at a temperature of 50°C is compressed according to the law $PV^{1.28}$= constant. The volume compression ratio is 18:1.

   It is then heated at constant volume at the end of which, the specific entropy has changed by 0.4188 kJ/kgK.

   (a) Calculate EACH of the following:

   (i) the overall change in specific internal energy; (3)

   (ii) the net specific heat transfer; (4)

   (iii) the overall change in specific entropy. (4)

   (b) Sketch the processes on a Temperature-specific entropy diagram showing:

   (i) the temperatures; (2)

   (ii) the values of EACH specific entropy change. (3)

   Note: for the gas c_v= 0.718 kJ/kgK, R = 0.287 kJ/kgK

2. In an air standard OTTO cycle. The gas is compressed from a pressure of, 1.013 bar to a pressure of 32.8 bar.

   The minimum cycle temperature is 15.5°C and the change of specific entropy during the heat rejection process is 904 J/kgK.

   (a) Sketch the cycle on Pressure-volume and Temperature-specific entropy diagrams. (2)

   (b) Calculate EACH of the following:

   (i) the temperatures at the cardinal points; (4)

   (ii) the cycle efficiency; (4)

   (iii) the theoretical mean effective pressure. (6)

   Note: for air c_v= 718 J/kgK, γ = 1.4

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3. A pure hydrocarbon fuel is burned in air.

The volumetric analysis of the dry exhaust gives 10.5% CO_2, 1% CO, and 7.4% O_2.

Calculate EACH of the following for 100 kmols of dry exhaust gas:

(a) the complete equation of combustion by volume; (6)

(b) the mass analysis of the fuel; (3)

(c) the air to fuel ratio by mass; (3)

(d) the mass fraction of the total exhaust gas. (4)

Note: atomic mass relationships H = 1, C = 12, N = 14, O = 16
Air contains 21% oxygen by volume.
Molecular mass of air = 28.96 kg/kmol

4. A rigid vessel has a volume of 0.8 m^3 and contains steam at a pressure and temperature of 20 bar and 300°C.

Steam is released until the pressure is 4 bar, the resulting expansion of the steam may be considered to be isentropic.

The vessel is then cooled until the pressure is 2 bar.

(a) Sketch the processes on a Temperature-specific entropy diagram. (2)

(b) Calculate EACH of the following:

(i) the mass of steam released; (5)

(ii) the heat removed; (5)

(iii) the mean temperature of heat rejection. (4)

8. A single acting two stage reciprocating air compressor has an initial pressure and temperature of 1 bar and 15°C respectively.

The pressure and temperature at entry to the second stage are 5 bar and 25°C respectively.

The delivery pressure is 30 bar.

The polytropic index for expansion and compression in both stages is 1.25.

The first stage cylinder has a swept volume of 0.0196 m^3 and the volumetric efficiency is 85% at a speed of 300 Rev/min.

(a) Sketch the cycle on a Pressure-volume diagram indicating the pressures and volumes. (2)

(b) Calculate EACH of the following;

(i) the compressor power; (6)

(ii) the first stage clearance volume; (2)

(iii) the heat rejected during the first stage compression process. (6)

Note: for air R = 287 J/kgK, c_v = 718 J/kgK

7. A cold store has a 150 mm air gap between the inner sheet steel lining and the 8 mm thick outer steel casing.

Some of the air gap is used by coating the steel lining with a layer of insulating foam 75 mm thick, as shown in Fig. Q7.

The minimum temperature of the reduced air gap is to be 15°C.

The lining is at a uniform temperature of -25°C and the ambient air temperature is 35°C. Both of which remain constant.

(a) Calculate EACH of the following for 1 m^2 of surface area;

(i) the rate of heat flow without the foam insulation; (4)

(ii) the required thermal conductivity of the foam insulation; (5)

(iii) the percentage reduction in heat flow when the foam insulation is used. (2)

(b) Sketch the thermal gradient diagram for the insulated wall showing ALL the temperatures. (5)

Note: Thermal conductivity of air = 0.026 W/mK
Thermal conductivity of steel = 52 W/mK
Outer surface heat transfer coefficient = 10 W/m^2K

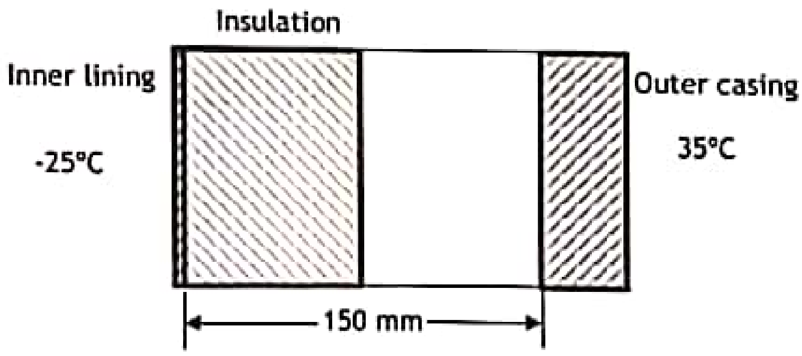

Fig. Q7

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5. The first stage of an impulse turbine is a two row Curtis wheel.

Steam leaves the nozzles at a velocity of 800 m/s and the blade speed is ~~5~~180 m/s.

The first row of moving blades are symmetrical with a blade angle of 30°.

The outlet angles for the fixed blades and the second row of moving blades are 35° and 45° respectively.

The velocity coefficient of friction is 0.85 for all the blades.

The mass flow of steam passing through the stage is 43.2 tonne/hr.

(a) Draw the velocity vector diagram to a scale of 1 mm = 5 m/s (4)

(b) Determine EACH of the following;

(i) the nozzle angle; (1)

(ii) the fixed blade inlet angle; (1)

(iii) the 2nd row moving blade inlet angle; (1)

(iv) the absolute velocity of the steam leaving the stage. (1)

(c) Calculate EACH of the following:

(i) the power output; (3)

(ii) the axial thrust; (2)

(iii) the diagram efficiency. (3)

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6. The vapour compression refrigeration plant shown in Fig. Q6 uses R134a as the working fluid.

The evaporator cools dry air entering a compartment containing electrical equipment, the air leaving the compartment is used to cool the condenser.

At a particular operating condition.

The pressure and temperature at the compressor suction are 2.4335 bar and 5°C respectively.

The compressor discharge pressure and temperature are 6.6525 bar and 45°C respectively. The liquid refrigerant enters the expansion valve at a temperature of 25°C.

Dry air enters the evaporator at a temperature of 15°C and leaves at a temperature of -2.79°C.

The air gains 4 kW of heat energy as it passes through the compartment.

The compressor has a swept volume of 4.6457×10^{-3} m³ and a volumetric efficiency of 0.95 at a speed of 270 rev/min.

(a) Calculate EACH of the following:

(i) the compressor power; (4)

(ii) the volume of air flowing through the system; (4)

(iii) the temperature of the air leaving the condenser coils. (4)

(b) Sketch the cycle on a Pressure-specific enthalpy diagram showing:

(i) the cardinal points and vapour dome; (1)

(ii) irreversible processes as dashed lines; (1)

(iii) the regions of work and heat transfer (2)

Note: *For R134a at 2.4335 bar and 5°C specific volume v = 0.0993 m³/kg*
For air c_p = 1.004 kJ/kgK, ρ = 1.263 kg/m³

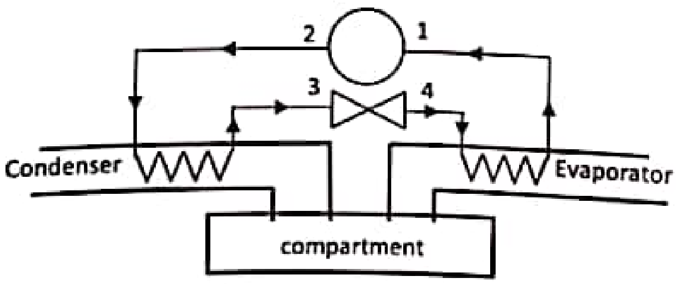
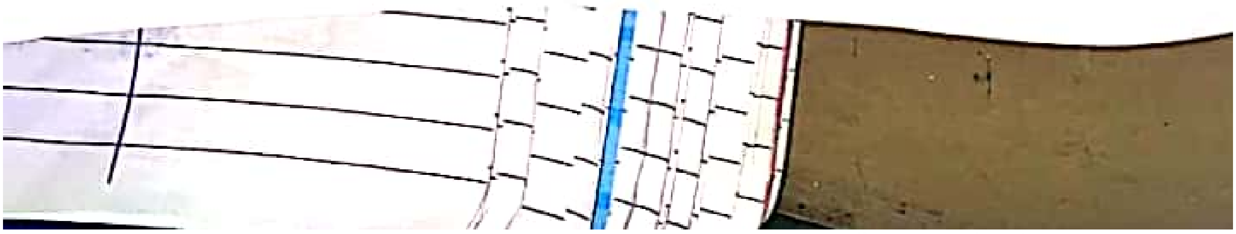


Fig. Q6



9 A bend of constant cross-section is shown in Fig Q9.

It is fitted in a horizontal section of 600 mm diameter seawater system and turns the flow through 70°.

The system pressure at this point is 3.5 bar and the water flow rate is 1530 m^3/hr.

The friction head loss in the bend is 1.5 m of system fluid.

Calculate EACH of the following:

(a) the net force acting on the axis ox; (6)

(b) the net force acting on the axis oy; (4)

(c) the resultant force acting on the bend; (3)

(d) the direction of the resultant force. (3)

Note: for seawater $\rho = 1025\ kg/m^3$

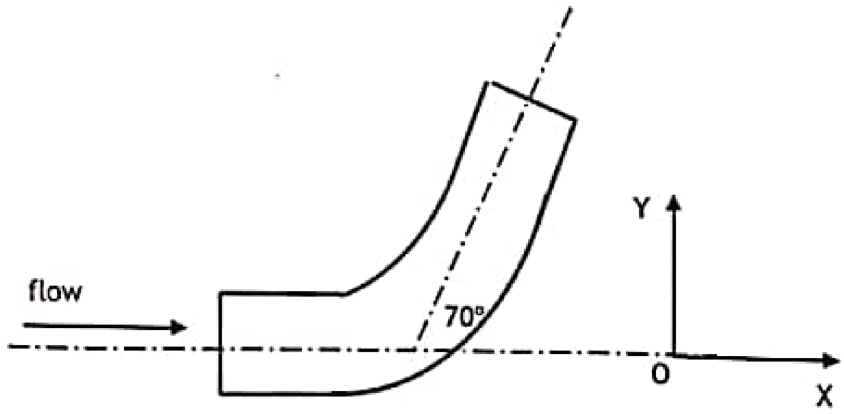


Fig Q9