

**CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY –
MARINE ENGINEER OFFICER**

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 95 CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-32 – APPLIED HEAT

MONDAY, 15 JULY 2013

1315 - 1615 hrs

Examination paper inserts:

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Notes for the guidance of candidates:

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| <ol style="list-style-type: none">1. Non-programmable calculators may be used.2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer. |
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Materials to be supplied by examination centres:

Candidates examination workbook Graph paper 'Thermodynamic and Transport Properties of Fluids' by Mayhew & Rogers (5 th edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. A mass of 0.1 kg of helium is compressed reversibly in a cylinder, according to the law $pV^n = \text{constant}$, from a pressure of 0.98 bar and a temperature of 12°C to a pressure of 8.2 bar. The final temperature is 551.4°C .
- (a) Calculate EACH of the following:
- (i) the index of compression; (3)
 - (ii) the magnitude and direction of the work transfer; (2)
 - (iii) the magnitude and direction of the heat transfer; (4)
 - (iv) the change in entropy. (3)
- (b) Sketch the process on p-V and T-s diagrams. (4)

Note: For helium, $\gamma = 1.667$ and $R = 2.077 \text{ kJ/kg K}$.

2. An air standard dual combustion cycle operates with a minimum temperature and pressure of 30°C and 0.98 bar respectively. The volume compression ratio is 23/1. The maximum pressure is 90 bar and the maximum temperature is 1430°C .
- (a) Sketch the cycle on p-V and T-s diagrams. (6)
- (b) Calculate the thermal efficiency of the cycle. (10)

Note: For air, $\gamma = 1.4$ and $R = 0.287 \text{ kJ/kg K}$.

3. A fuel has mass analysis 80% carbon, 16% hydrogen, 2% moisture, 0.5% sulphur, remainder ash.
- (a) Calculate the theoretical air/fuel ratio by mass. (8)
- (b) Calculate the volumetric analysis of the dry combustion products (ie excluding H_2O and soluble SO_2) when the fuel is completely burned in 15% excess air. (8)

*Note: relative atomic masses: $H = 1$; $C = 12$; $N = 14$; $O = 16$; $S = 32$
Air contains 21% oxygen by volume.*

4. In a regenerative steam power plant, the steam enters the turbine at a pressure of 50 bar and a temperature of 400°C , and leaves at a pressure of 0.08 bar with a dryness fraction of 0.9. Dry saturated steam is bled from the turbine at a pressure of 2 bar, and supplied to a direct mixing feed heater. The feed water leaves the heater at the saturation temperature of the bled steam. The mass of bled steam is 14.7% of the boiler supply.
- (a) Sketch the T-s diagram for the cycle. (4)
- (b) Determine EACH of the following:
- (i) the isentropic efficiency of the turbine; (4)
- (ii) the enthalpy of the condensate leaving the condenser; (4)
- (iii) the thermal efficiency of the cycle. (4)

Note: Work input to feed pumps may be disregarded.

5. The specific enthalpy drop in the nozzles of a simple impulse turbine is 495 kJ/kg. The moving blades are symmetrical, and the blade velocity coefficient is 0.9. Steam leaves the blades in an axial direction. The diagram efficiency is 0.82.
- (a) Sketch the combined velocity diagram, clearly labelling velocities and angles. (5)
- (b) Determine EACH of the following:
- (i) the blade velocity; (5)
- (ii) the change in whirl velocity; (2)
- (iii) the nozzle angle; (2)
- (iv) the blade angle. (2)

6. In a vapour compression refrigeration cycle the evaporating temperature is -10°C and the condensing temperature is 40°C . The refrigerant enters the compressor as dry saturated vapour, and leaves the condenser as saturated liquid. Compression is isentropic.
- (a) Sketch the cycle on p-h and T-s diagrams. (5)
- (b) Given that the refrigerant is Tetrafluoroethane (R 134a), determine EACH of the following:
- (i) the maximum cycle pressure; (1)
- (ii) the maximum cycle temperature; (3)
- (iii) the coefficient of performance of the cycle. (3)
- (c) The refrigerant is replaced with Ammonia (R 717). Determine EACH of the following:
- (i) the maximum cycle pressure; (1)
- (ii) the maximum cycle temperature. (3)

7. An aluminium hot air duct has outer diameter 0.9 m and negligible wall thickness. The air in the duct is at a temperature of 50°C and the surrounding air temperature is 22°C . The inner surface heat transfer coefficient is $20\text{ W/m}^2\text{K}$ and the outer surface heat transfer coefficient is $15\text{ W/m}^2\text{K}$.

It is proposed to lag the duct with rock wool to a thickness of 200 mm. The rock wool is provided in flat sheets 100 mm thick, each square metre having a quoted thermal resistance of 2.25 K/W. When the lagging is applied to the duct, the outer surface heat transfer coefficient may be assumed to be unchanged.

Calculate EACH of the following:

- (a) the rate of heat loss per metre run without lagging; (6)
- (b) the rate of heat loss per metre run after the lagging is applied. (10)

8. At the beginning of compression in a single stage, single acting reciprocating air compressor, the air is at a pressure of 1.02 bar and a temperature of 30°C. When the delivery valve opens, the pressure is 6.5 bar. The index of compression and expansion is 1.27. The bore diameter and stroke length are respectively 0.30 m and 0.35 m. The clearance volume is 6% of the swept volume and the compressor runs at 560 rev/min.

(a) Sketch the p-V diagram. (2)

(b) Calculate EACH of the following:

(i) the volumetric efficiency; (3)

(ii) the indicated power; (8)

(iii) the free air capacity in m³/min, given that the free air conditions are 1.00 bar and 26°C. (3)

Note: For air, $R = 0.287 \text{ kJ/kg K}$.

9. (a) Explain the term “choked flow” in a nozzle. (4)

(b) Steam expands isentropically in a convergent-divergent nozzle. The pressure of the steam at nozzle inlet is 10 bar and its temperature is 400°C. The outlet pressure is 2 bar. The expansion follows the law $pv^{1.3} = \text{constant}$. The mass flow rate of steam is 5 kg/s. The overall enthalpy drop is calculated as 410 kJ/kg.

Calculate EACH of the following:

(i) the throat area; (7)

(ii) the exit area. (5)

Note:
$$p_C = p_O \times \left(\frac{2}{n+1} \right)^{\left(\frac{n}{n-1} \right)} ; \quad a = \sqrt{npv} .$$