CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-35 - MATHEMATICS

THURSDAY, 12 DECEMBER 2024

1315 - 1615 hrs

Materials to be supplied by examination centres

Candidate's examination workbook
Graph paper

Examination paper inserts:

Notes for the guidance of candidates:

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

Maritime & Coastguard Agency

SQA

MATHEMATICS

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. (a) Solve the following complex equation for r and θ:

$$r\angle\theta^\circ = (5\angle 20^\circ \times 2\angle 40^\circ) + \frac{8\angle 85^\circ}{2\angle 55^\circ} - 5\angle 10^\circ \qquad (8)$$

(b) Two impedances, $Z_1 = 5\angle 60^\circ$ and $Z_2 = 2\angle -30^\circ$ are connected in series to a supply voltage, v, of 100 volts.

Calculate the current, i amperes, as a complex number in Cartesian form, given that:

$$i = \frac{v}{Z}, \text{ where } Z = Z_1 + Z_2 . \qquad (8)$$

2. (a) A hydrofoil on a ferry run takes 6 minutes to overtake a vessel on a parallel course 3 nautical miles ahead.

On the return journey the hydrofoil takes 4 minutes to pass the same vessel which is still on the same course and speed, again from a distance of 3 nautical miles.

Calculate the speed of the hydrofoil and the vessel. (8)

(b) Make p the subject of the following formula:

$$t = r\left(\sqrt{\frac{f+r}{f-p}} - 1\right) \qquad (8)$$

3. (a) Solve the following system of equations for x and y:

$$3x^2 - 2y^2 = -5$$
$$3x - 2y = 1 \qquad (8)$$

(b) Solve the following equation for $x > 0$, correct to 3 decimal places:

$$\frac{1}{x+2} - \frac{2x}{x-1} = 2 \qquad (8)$$

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4. (a) The temperature, T °C, of a cooling liquid after t minutes is given by:

$$T = 150e^{-0.05t}$$

Calculate the time taken, to the nearest minute, for the temperature of the liquid to fall to 75°C. (6)

(b) Solve EACH of the following equations for x:

(i) $\log(x^2 + 8) - \log(x + 2) = \log 4$; (6)

(ii) $8^{3x+2} = 32^{2x-1}$. (4)

5. (a) During a gas engine test, of a given mass of gas contained in a cylinder, the values of pressure P (kPa) and the volume V (m^3) were recorded as shown in Table Q5.

Plot a straight line graph to verify that the relationship between P and V is the gas law $PV^n = C$, where n and C are constants.

P	50	40	30	20	10
V	1.74	2.06	2.60	3.55	5.97

Table Q5

Suggested scales: *horizontal axis* 2 cm = 0.1
vertical axis 2 cm = 0.1 (10)

(b) Use the graph plotted in Q5(a) to estimate the value of n and C. (6)

6. (a) Fig Q6(a) shows a rectangle EFGH, 55mm × 48mm, enclosed within rectangle ABCD such that angle BGF = 55°.

Calculate the length of DC. (8)

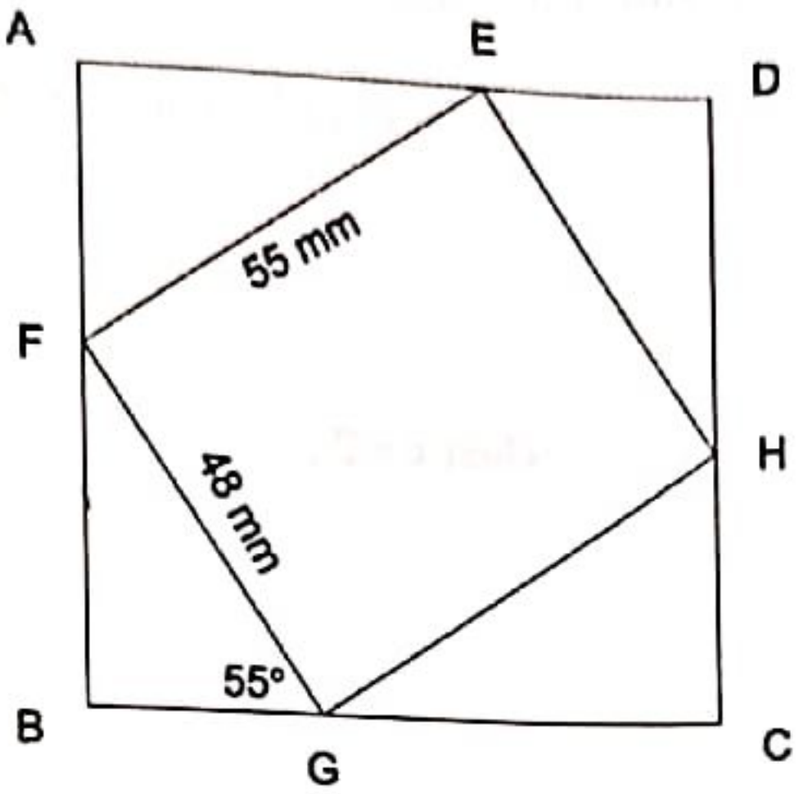

Fig 6(a)

(b) Two ships, A and B, leave the same port, P, at the same time.

Ship A makes a steady speed of 20 knots on a bearing of 310° and ship B makes a steady speed of 16 knots on a bearing of 025°.

Calculate EACH of the following:

(i) the distance between A and B after 3 hours; (5)

(ii) the bearing of B from A after 3 hours. (3)

7. (a) A company specialises in producing water pump control panels.

The cost of producing x control panels per day is £$(x^2 + 50x + 15)$.

The selling price of each control panel is £$(300 - 4x)$.

Use differential calculus to determine EACH of the following:

(i) the daily output for maximum profit; (8)

(ii) the maximum daily profit; (2)

(iii) the production cost of each panel when operating at maximum profit. (2)

(b) Given $T = 5 + 3\cos\theta - 2\sin\theta$, calculate correct to 2 decimal places, the value of $\frac{dT}{d\theta}$ when $\theta = \frac{2\pi}{3}$ radians. (4)

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8. (a) A gas expands in a cylinder according to the relationship $PV^{1.25} = 1294$.

The initial volume of the gas is 0.05 m^3 and the final volume of the gas is 0.105 m^3.

Calculate the work done by the gas during the expansion.

Note: the work done by the gas as it expands from V_1 to V_2 units of volume is

W Joules, where $W = \int_{V_1}^{V_2} PdV$. (8)

(b) Given $\frac{dy}{dx} = 3x^2 + 4x + 1 - \frac{3}{x^2}$ and $y = 19$ when $x = 2$,

determine the value of y when $x = -1$. (8)

9. (a) Many new cars have systems to switch on windscreen wipers, either automatically when moisture is detected, or when they are switched on manually by the driver. The system only operates if the ignition switch is on. A typical logic system for this operates as follows:

- Ignition switch **A** outputs a logic 1 when it is switched on.
- Moisture sensor **B** outputs a logic 1 when rain is detected.
- Wiper switch **C** outputs a logic 1 when it is switched on by the driver.
- The windscreen wiper motor operates when output **X** is at logic 1.

Produce EACH of the following for this logic system with inputs **A, B, C** and output X:

(i) the truth table, including columns for **A, B, C** and **X**; (3)

(ii) a Boolean expression for output **X** in its simplest form; (5)

(iii) the logic circuit for the Boolean expression obtained in (ii). (2)

(b) Determine EACH of the following, *without using a calculator conversion function*:

(i) the hexadecimal operation CF9F + EDAF; (2)

(ii) the binary operation 10110 × 1110; (2)

(iii) the conversion of $DBCA_{16}$ to decimal. (2)