CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-35 - MATHEMATICS

THURSDAY, 17 JULY 2025

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) Impedances, $Z_1 = 3 + j4$ ohms and $Z_2 = 5 - j6$ ohms are connected in series to a supply voltage, v, of 110 volts.

Calculate the current, i amperes, as a complex number in polar form, given

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

(b) Given $Z = x + jy$, where x and y are real, solve the following equation for x and y:

$$\frac{Z}{j} - \frac{Z}{1+j} = \frac{10}{2+j}$$ (8)

2. (a) Solve the system of equations:

$$2x - y + 3z = 20$$
$$5x + 2y + z = 4$$
$$7x - 3y - 2z = 6$$ (8)

(b) The current I amperes in an a.c. circuit is given by the formula:

$$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$$

(i) Determine I when $V = 50$ volts, $R = 10$ ohms and $X_L - X_C = 20$ ohms. (2)

(ii) Transpose the formula to make X_L the subject. (6)

3. (a) For a certain ship at deadweight displacement, the power of the main engines, P kilowatts, and the speed of the ship, V knots, are related by the formula:

$P = V(a + bV^2)$ where a and b are constants.

When P = 29 300 kW, V = 20 knots and when P = 6 828 kW, V = 12 knots.

Calculate the power of the main engines when the speed of the ship is 24 knots. (8)

(b) Factorise EACH of the following as fully as possible:

(i) $2ab - 8ad + 3bc - 12cd$; (3)

(ii) $9x^2 + 12xy + 4y^2$; (3)

(iii) $a^2 + b^2 - 2ab - 4$. (2)

4. (a) A tractor tyre is inflated to a pressure of 32 units.

Twenty four hours later the pressure has dropped to 12 units.

The pressure in this tyre P_t units, t hours after being inflated to P_0 units, is given by the formula: $P_t = P_0e^{-kt}$, where k is a constant.

(i) Determine the value of k. (5)

(ii) Determine the expected tyre pressure, to the nearest unit, after the farmer inflates the tyre to 32 units and then drives the tractor for 6 hours. (3)

(b) Solve the following equation for x, correct to 2 decimal places:

$$4^{x^2-2} = 8^{x+2}$$ (8)

5. (a) Draw the graphs of $y_1 = 2 \sin A$ and $y_2 = 3 \cos A$ on the same set of axes, from $A = 0°$ to $A = 180°$, in intervals of 20°. (9)

Suggested scales: *horizontal axis* 1 cm = 20°
vertical axis 2 cm = 1

(b) Making use of the ordinates obtained in Q5(a) plot the graph of $y_R = 2 \sin A + 3 \cos A$ on the same set of axes. (3)

(c) Use the graphs in Q5(a) and (b) to determine EACH of the following:

(i) the maximum value of $y_R = 2 \sin A + 3\cos A$; (2)

(ii) the solution of the system of equations:

$y = 2 \sin A$

$y = 3 \cos A$ (2)

6. (a) An idler gear, 10 cm in diameter, has to be fitted between a 30 cm diameter driving gear and a 50 cm diameter driven gear such that the distance between the centres of the driving and driven gears is 45 cm.

Given that the centres of the driving gear, the driven gear and the idler gear are A, B and C respectively, calculate the size of angles ABC, BCA and CAB. (12)

(b) Determine the value of θ in the range $0° < \theta < 90°$ which satisfies the equation:

$\cos^2 \theta + 5\sin^2 \theta = 3$. *Note*: $\sin^2\theta + \cos^2\theta = 1$ (4)

7. (a) Use differential calculus to determine the coordinates and nature of the stationary points for the function:

$y = -3x^4 + 24x^2 - 48$. (12)

(b) Given $S = \left(t + \frac{1}{t}\right)^2$ determine $\frac{dS}{dt}$ and $\frac{d^2S}{dt^2}$. (4)

8. Given $\frac{ds}{dt} = 3t^2 - 12t + 5$ and $s = 84$ when $t = 7$, determine EACH of the following:

(a) s as a function of t; (8)

(b) the value of s when $t = 6$; (2)

(c) the values of t when $s = 0$. (6)

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9. (a) The logic circuit in Fig Q9(a) has three inputs A, B and C, and one final output X.

For this circuit, produce an unsimplified Boolean expression for the intermediate outputs D and E and the final output X in terms of the inputs A, B and C. (4)

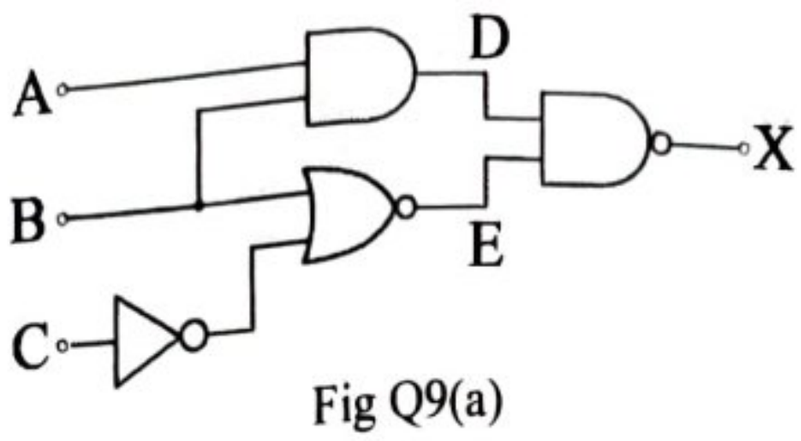

Fig Q9(a)

(b) The final output R, of a logic circuit with THREE inputs A, B and C, is given by the Boolean equation:

$$R = \overline{\left(\overline{A.\overline{B}}\right) + \left(\overline{A + C}\right)}$$

(i) Use De Morgan's theorem and Boolean algebra to simplify this equation as fully as possible. (5)

(ii) State which input which has no relevance to the output of this circuit. (1)

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

(i) 105_{10} to binary; (2)

(ii) 1110110110011_2 to hexadecimal; (2)

(iii) $BEAD_{16}$ to decimal. (2)