CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-35 - MATHEMATICS

THURSDAY, 03 APRIL 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) Given $Z = \dfrac{(1-j)(5+j3)}{3-j5}$, determine EACH of the following :

   (i) Z in the form a + *j* b, where a and b are real numbers; (5)

   (ii) the value of Z^3 in its simplest form. (3)

   (b) The impedance, *Z*, of an electronic circuit is given by $Z = 4 - j7$ ohms and the current, *i*, is given by $i = 8 + j3$ amps.

   Determine, in polar form, the voltage, *V*, across the impedance, given $V = iZ$. (8)

2. (a) The force produced on a ship's rudder, *F* kN, varies directly as the area of the rudder, *A* m^2, the square of the ship's speed, *V* knots, and the sine ratio of the rudder angle, $\theta°$.

   For a ship travelling at 15 knots, with a rudder area 22 m^2 operating at an angle of 20°, the rudder force is 280 kN.

   Calculate the force on a similar rudder of area 25 m^2 operating at an angle of 28° when the ship's speed is 20 knots: (8)

   (b) Fully factorise EACH of the following:

   (i) $12x^2 - 28x + 15$; (2)

   (ii) $36x^3 - 4xy^2$; (3)

   (iii) $3x^3 + 2x^2 - 15x - 10$. (3)

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3. (a) A particular white metal bearing for marine use is composed of, by mass, 89% tin, 7.5% antimony and the remainder is copper.

Determine the masses of antimony and copper required to combine with 200 kg of tin to make this white metal. (6)

(b) The bending moment in Newton metres at a point in a beam is given by:

$$M = \frac{5x(15-x)}{4}$$

where x metres is the distance from the point of support.

Evaluate x, correct to two decimal places, when the bending moment is 50 Nm. (6)

(c) Solve the following equation for x:

$$\frac{x+3}{4} - \frac{5x}{6} + \frac{2-x}{8} = \frac{7}{24}$$ (4)

4. (a) The amount, A_t micrograms, of a certain radioactive substance remaining after t years decreases according to the formula:

$$A_t = A_0 e^{-1.2\times10^{-4}t}$$

where A_0 is the amount present initially.

(i) Determine the amount of this substance present initially if 400 micrograms remain after 1000 years. (3)

(ii) The half-life of a substance is the time taken for the amount to decrease to half its original amount.

Determine the half-life of this substance. (5)

(b) Transpose the following formula to make t the subject:

$$i = Ie^{-\frac{t}{CR}}$$ (4)

(c) Simplify the following as fully as possible:

$$\frac{\left(8a^9b^3c^6\right)^{\frac{2}{3}}}{4\left(a^3b^2c\right)^2}$$ (4)

5. During a particular tidal period the depth of water, d metres, in a harbour t hours after midnight, can be modelled approximately by the function $d = 4 + \cos 30t°$.

(a) Plot the graph of $d = 4 + \cos 30t°$, $0 \leq t \leq 10$, in intervals of 1 hour.

Suggested scales with landscape orientation: horizontal axis 2 cm = 1
vertical axis 2 cm = 1 (10)

(b) Use the graph drawn in (a) to determine EACH of the following during this period:

(i) the minimum ground clearance of a vessel in the harbour of draught 2.5m; (2)

(ii) the length of time a vessel of draught 3.8 m may be expected to be aground; (3)

(iii) the expected depth of water in the harbour at 0730 hours. (1)

6. (a) A vertical aerial, AB, is 18 m high, standing on ground which is inclined 10° to the horizontal.

A stay connects the top of the aerial A to a point C on the ground 12 m downhill from B, the foot of the aerial.

Calculate EACH of the following:

(i) the length of the stay AC; (5)

(ii) the angle the stay AC makes with the ground; (3)

(iii) the length of a second stay which connects to a point D, 6m from the top of the aerial to point C. (2)

(b) A current, i amps, is given by $i = 5\cos(100\pi t + 0.25)$, where t is the time in seconds.

Calculate the earliest time, $t > 0$, for which the current $i = 2$ amps. (6)

7. (a) A vessel sailing at v knots has a running cost, of £$\left(v^2 + \frac{13\,500}{v}\right)$ per hour.

Determine EACH of the following for this vessel when it makes a passage of 300 nautical miles :

(i) the speed which minimises the cost of the passage; (10)

(ii) the minimum cost of the passage. (2)

(b) Given $u = \frac{t(2+3t)}{\sqrt{t}}$ determine $\frac{du}{dt}$. (4)

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8. (a) Calculate the total shaded area shown in Fig Q8(a). (10)

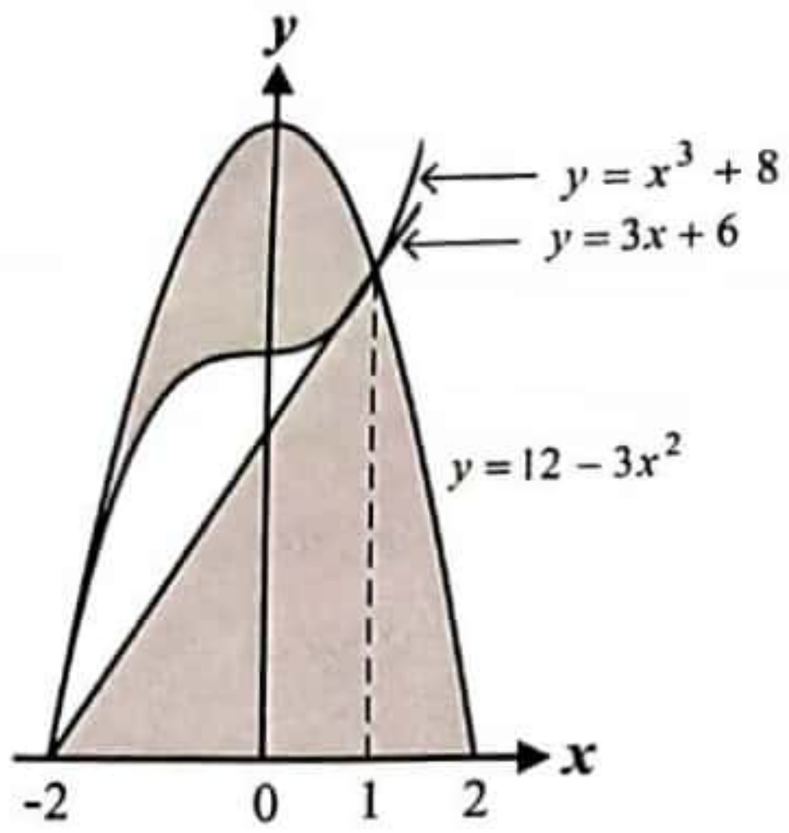

Fig Q8(a)

(b) Evaluate $\int_{\frac{\pi}{4}}^{\frac{\pi}{3}} (2\cos\theta - \sin\theta)\,d\theta$ correct to 3 decimal places. (6)

9. (a) A logic circuit behaves according to the Boolean expression:

$$X = A.\overline{B}.\overline{C} + A.B.\overline{C} + \overline{A}.B.C + A.B.C$$

Produce EACH of the following for the logic system:

(i) the Boolean expression in its simplest form; (4)

(ii) the logic circuit, *using only* AND, OR and NOT gates; (3)

(iii) the equivalent circuit diagram to that obtained in (ii), *using only* NAND gates (*crossing out any redundant gates*). (3)

(b) Determine, *without using a calculator conversion function*, the value of $152_{16} \div 1A_{16}$, giving the answer in EACH of the three forms:

- binary;
- hexadecimal;
- decimal. (6)