CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-35 - MATHEMATICS

THURSDAY, 30 MARCH 2023

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) The characteristic impedance, Z, of a transmission line, may be determined from the complex formula $Z^2 = \frac{R + j\omega L}{G + j\omega C}$.

Determine Z^2 in the polar form, $r\angle\theta$, for a transmission line where

R = 2.1ohms, $\omega = 10^4$ radians/second, $L = 0.2\times10^{-3}$ henrys, $G = 4.2\times10^{-6}$ ohms and $C = 1.2\times10^{-9}$ farads. (8)

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

$$\frac{2Z}{1+j} - \frac{Z}{1-j} = \frac{15}{2+j}$$ (8)

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

$$2x^2 - 3xy + y^2 = 35$$
$$3x - 2y = 12$$ (10)

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

$$d^2 = \frac{16}{\pi f}\left(M + \sqrt{M^2 + T^2}\right)$$ (6)

3. (a) A box-shaped vessel, floating on an even keel, has a water-plane area of 96 m^2.

The beam of the vessel is 15.2 m less than its length.

Calculate the length and beam of the vessel. (8)

(b) Express the following in its simplest form:

$$\frac{3x}{x+1} + \frac{2}{x-3} + \frac{x-11}{x^2-2x-3}$$ (8)

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4. (a) A tyre has a slow puncture causing the tyre pressure to drop.

The pressure in the tyre, P units, t hours after inflation to P_0 units is given by:

$P = P_0 e^{-kt}$, where k is a constant.

Given that the tyre was inflated to a pressure of 40 units and that after 32 hours it had dropped to 15 units, determine the length of time it would have taken for the pressure to have dropped from 40 units to 30 units. (8)

(b) Solve for x in the following equation: (8)

$$e^x - e^{-x} = 3$$

5. For a particular vessel, the fuel consumption, F tonnes per day, at a speed of v knots, are recorded in Table Q5.

(a) Draw a straight line graph to verify that the fuel consumption and the vessel's speed are related by a law of the form $F = av^2 + b$ where a and b are constants. (10)

v	5	10	15	20	25
F	6.5	18.5	38.5	66.5	102.5

Table Q5

Suggested scales: *horizontal axis* 2 cm = 100

vertical axis 2 cm = 10

(b) Use the graph drawn in Q5(a) to estimate the values of a and b. (6)

6. A diesel engine unit has a vertical stroke of 320 mm and a connecting rod AB of length 570 mm as shown in Fig Q6.

Angle CAB is the angle between the vertical and the position of the connecting rod.

Twice during each down stroke of the piston the angle CAB equals 8 degrees.

Calculate the piston travel between these TWO positions. (16)

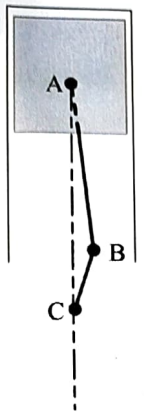

Fig Q6

7. (a) The displacement, s metres, of a body from a fixed point is given by the equation:

$s = 48t + 8t^2 - \frac{4}{3}t^3$, where t is the time in seconds.

Determine EACH of the following for the body:

(i) the time ($t > 0$) when its velocity is zero; (5)

(ii) the time when its acceleration is zero; (2)

(iii) its acceleration after FIVE seconds. (1)

(b) Given $P = 3\cos x - \frac{1}{\sqrt{x}} + ln\, x^3$, determine $\frac{dP}{dx}$ and $\frac{d^2P}{dx^2}$. (8)

8. (a) The shape of an inflatable polyurethane marker buoy may be represented by the rotation of the shaded area in Fig Q8(a), about the x axis, through one complete revolution.

Determine, using integral calculus, the volume of the buoy, given that the unit of length is the metre. (12)

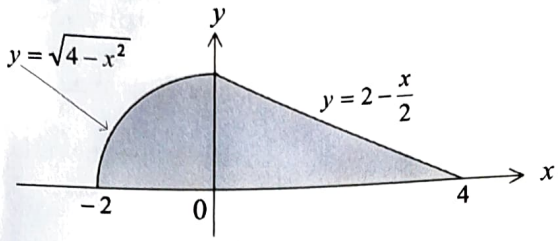

Fig Q8(a)

(b) Evaluate : $\int_0^{\pi} \cos\theta \tan\theta \, d\theta$. (4)

9. (a) The logic circuit shown in Fig Q9(a) has THREE inputs A, B and C, and ONE output X.

Produce EACH of the following for this circuit:

(i) an unsimplified Boolean expression for the outputs D, E and X in terms of the inputs A, B and C; (3)

(ii) the truth table, including columns for A, B, C, D, E, and X; (3)

(iii) the equivalent logic circuit using only NAND gates (*crossing out any redundant gates*). (6)

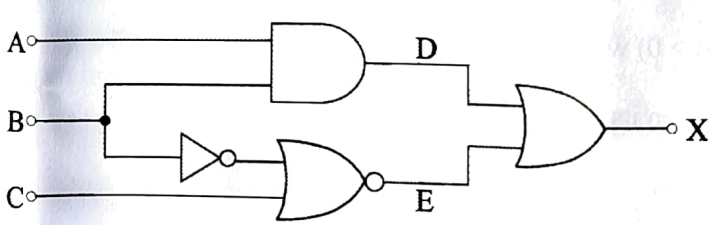

Fig Q9(a)

(b) Simplify, as fully as possible, the following Boolean expression:

$\overline{(A+B).(A.\overline{B})}$ (4)