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CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-35 - MATHEMATICS

THURSDAY, 16 DECEMBER 2021

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) THREE mooring lines exert horizontal forces on a bollard, positioned at O, as follows:

18kN at 55°
35kN at 85°
42kN at 140°

78.86 ∠ 103.79

The angles are those that the forces make with the real axis O*x*.

Determine, *using complex numbers*, the magnitude and direction of the resultant force on the bollard. (8)

(b) Given $Z_1 = 2a + j7a$ and $Z_2 = 9b + j5b$, solve the following complex equation for a and b, where a and b are real numbers:

$a = -3, b = 4$

$Z_1 + Z_2 = 30 - j$. (8)

2. (a) Express the following in its simplest possible form:

$$\frac{3}{2x-1} - \frac{2}{x+1} - \frac{x+4}{2x^2+x-1}.$$ $\left(-\frac{1}{x-1}\right)$ (8)

(b) Fully factorise EACH of the following:

(i) $x^6 - 25x^4$; $x^4(x-5)(x+5)$ (2)

(ii) $x^3 - x^2 - x + 1$; $(x-1)(x+1)(x-1)$ (4)

(iii) $18x^2 - 23x - 6$. (2)

3. (a) The general equation of a circle is $x^2 + y^2 + 2gx + 2fy + c = 0$, where g, f, and c are constants.

Given that the points (– 2, 4), (1, 1) and (5, 5) lie on the same circle, determine the values of g, f, and c for this circle. (10)

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

$$a = \frac{T}{\sqrt{ku^2 - lv^2}}$$

$u = \sqrt{\frac{\frac{T^2}{a^2} + lv^2}{k}}$ (6)

4. (a) Solve for x in EACH of the following equations:

(i) $10^{2x^2} = 2^{x+1}$ $0.469, -0.319$ (8)

(ii) $\sqrt{x^3 - 19} = 18$ 7 (4)

(b) Evaluate the following *without using mathematical tables or a calculator*:

$$2\left(\frac{\log 64 - \log 8}{\log 4}\right)$$ 3 (4)

5. (a) Draw the graph of $y = 4\tan 0.8x$, for the range $0 \le x \le 1.4$ in intervals of 0.2. (10)

Note that the angle x is in radian measure.

Suggested scales: *horizontal axis* 2 cm = 0.2
vertical axis 2 cm = 1

(b) Using the same axes and scales, draw the graph of $y = \frac{5}{2}\pi - 4x$, for the range $0 \le x \le 1.4$, on the graph produced in Q 5(a). (3)

(c) Use the graphs plotted in Q5(a) and Q5(b) to solve the equation:

$4(x + \tan 0.8x) = \frac{5}{2}\pi$, for $0 \le x \le 1.4$. 0.98 / 3.98 (3)

6. AB is a link 68 cm long which has a block pivoted to EACH end.

The blocks can slide in grooves as shown in Fig Q6.

The point of intersection of the line of centres is at C.

Initially, BC = 34.8 cm and AC = 40.6 cm.

Calculate EACH of the following:

(a) the angle between the line of centres (i.e. angle BCA); 128·64° (4)

(b) the inclination of AB to AC; 23·56° (3)

(c) the distance A moves if block B moves 20 cm towards C from the given position. 59·33 (9)

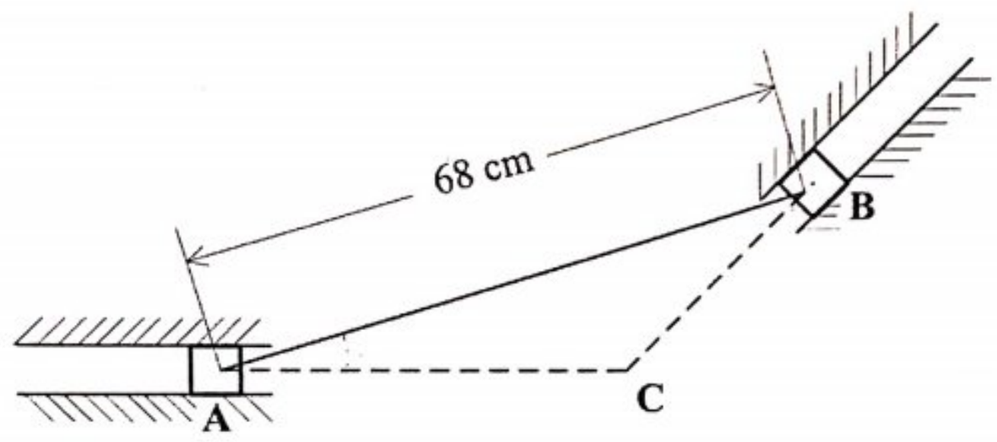

Fig Q6

7. An open rectangular dive training tank, with square ends of side x metres and a volume of 392 m^3, is shown in Fig Q7.

The tank was constructed at a cost £75 per square metre for the base and £50 per square metre for the vertical sides and ends.

Determine EACH of the following for the tank:

(a) the length, L, in terms of x; (2)

(b) the total construction cost in terms of x; (7)

(c) the dimensions, given that the construction cost was minimised. (7)

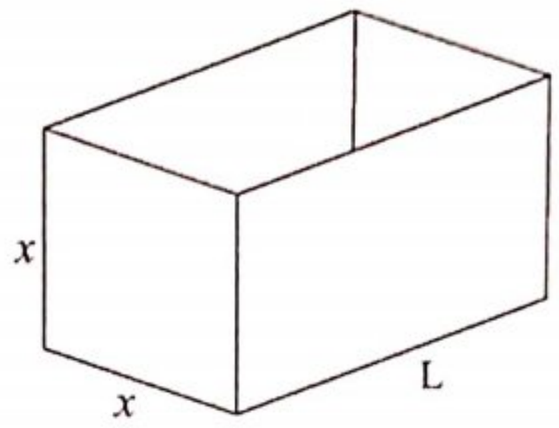

Fig Q7

8. (a) A body starts with an initial velocity, v_0 ms^{-1}, and its acceleration, a ms^{-2}, is given by $a = 2 + 6t$, where t is the time, in seconds, from the start.

Given $a = \frac{dv}{dt}$ and velocity $v = \frac{ds}{dt}$, determine EACH of the following for the body:

(i) v as a function of t, given that $v = 7ms^{-1}$ when $t = 1$ second; $3t^2 + 2t + 2$ (4)

(ii) the initial velocity v_0; $= 2 ms^{-1}$ (1)

(iii) the distance from the start position, s metres, as a function of t; (4)

(iv) the distance travelled in 2 seconds. (1)

(b) Evaluate $\int_1^4 \left(x + \frac{5}{\sqrt{x}} - \frac{2}{x^2} \right) dx$ -16 (6)

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

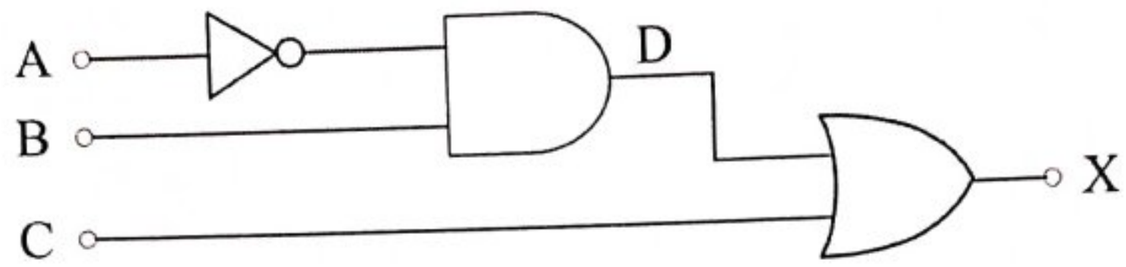

Fig Q9(a)

Produce EACH of the following for this circuit:

(i) an unsimplified Boolean expression for the outputs D and X in terms of the inputs A, B and C; (2)

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

(iii) the equivalent logic circuit using only NAND gates (*crossing out any redundant gates*). (5)

(b) Determine, *without using a calculator conversion function,* the value of

$EA_{16} \div 10010_2$, giving the answer in the three forms: binary, hexadecimal and decimal. (6)