CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY –
MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

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

040-35 – MATHEMATICS

THURSDAY, 30 MARCH 2017

1315 - 1615 hrs

Examination paper inserts:

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.
2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidate's examination workbook
Graph Paper

MATHEMATICS

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. (a) Given $Z = \frac{3+j}{1-j}$, determine $Z + Z^{-1}$ as a complex number in Cartesian form. (8)

(b) Two impedances $Z_1 = 8 + j5$ and $Z_2 = 4 - j10$ are connected in series to a supply voltage v of 250 volts.

Calculate the current i amperes as a complex number in polar form, given that $i = \frac{v}{Z}$ where $Z = Z_1 + Z_2$. (8)

2. (a) The minimum diameter d of a shaft subjected to a bending moment M and torque T is given by the formula:

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

Calculate the value of M when $f = 3200$, $T = 12000$ and $d = 5$. (8)

(b) The amount of energy stored in flywheels of similar shapes is directly proportional to the squares of their speeds and to the fifth power of their diameters.

One wheel has a diameter 1.48 times that of the other and runs at 0.84 of the speed.

The smaller wheel stores 6.75kJ.

Calculate the energy stored in the larger wheel. (8)

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

$2x^2 + y = 5$

$x + 4y = 13$ (10)

(b) The voltage drop, V, across an electronic component can be calculated using the equation $V = 4.5e^{-0.15t} \sin 0.2t$, where V is the voltage drop in millivolts and t is the time in seconds after the actuating switch is closed.

Determine the voltage drop 40 seconds after closure of the actuating switch. (6)

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4. (a) The time, t hours, to charge a certain mobile phone to a level C (expressed as a decimal fraction of the battery's full charge) is given by:

$t = -2.5ln(1 - C)$

Determine EACH of the following for this mobile phone:

(i) the percentage of the full charge achieved after charging for $4\frac{1}{2}$ hours. (6)

(ii) the time taken, to the nearest $\frac{1}{4}$ hour, to achieve 90% of full charge. (4)

(b) Express the following in its simplest form:

$$\left(\frac{x^{\frac{3}{4}}}{y^{-\frac{2}{3}}}\right)^3 \times \sqrt{\frac{y^6}{x^{-\frac{3}{2}}}} \qquad (6)$$

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

(a) Draw 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. (10)

P	120	100	80	60	40	20
V	2.034	2.302	2.704	3.315	4.430	7.153

Table Q5

Suggested scales: *horizontal axis* 2 cm = 0.1
vertical axis 2 cm = 0.1

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

6. (a) Given:

$\frac{ds}{dt} = 3t^2 - 2t + 5$ and $s = 9$ when $t = 2$:

(i) express s as a function of t; (6)

(ii) determine s when $t = 3$. (2)

(b) Evaluate EACH of the following:

(i) $\int_1^4 3\sqrt{x}\,dx$ (4)

(ii) $\int_0^{\frac{\pi}{4}} (\cos\theta + \sin\theta)\,d\theta$ (4)

7. An open rectangular test tank, with square ends of side x metres and a volume of 3136 m^3, is shown in Fig Q7.

The tank was constructed at a cost £60 per square metre for the base and £40 per square metre for the vertical sides and ends.

Determine EACH of the following for the tank:

(a) the length 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)

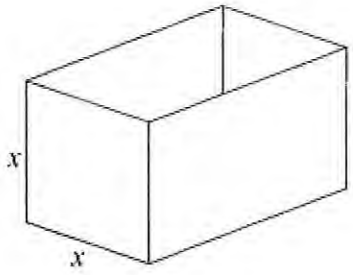

Fig Q7

8. (a) An idler gear 16 cm in diameter has to be fitted between a 50 cm diameter driving gear and a 70 cm diameter driven gear as shown in Fig Q8(a).

AC is 65 cm.

Calculate the size of angle ACB. (8)

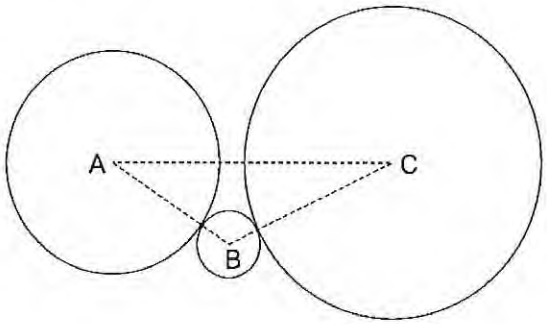

Fig Q8(a)

(b) The depth of water, h metres, over a rock on a particular day, is given by:

$$h = 4 + 3cos\frac{\pi t}{6}$$

where t is the number of hours after local high-water.

Determine EACH of the following for that day:

(i) the minimum depth of water over the rock; (2)

(ii) the time when the minimum depth occurs; (3)

(iii) the clearance a yacht of draught 2 metres has when it passes over the rock four hours after local high water. (3)

9. (a) Determine, *without the use of a calculator*, EACH of the following binary operations:

(i) 100101 + 1011001 (1)

(ii) 10111010 – 1110101 (1)

(iii) 10111 x 1001 (1)

(iv) 110111 ÷ 101 (1)

(b) Determine, *without the use of a calculator*, EACH of the following hexadecimal operations:

(i) EF4C + B39A (2)

(ii) F29C – 7AD8 (2)

(c) A nuclear power station operates a pressurised water reactor which has a safety system based on three inputs to a logic circuit.

An alarm sounds when certain conditions occur in the reactor.

The output, X, of the logic circuit which drives the alarm must have a value of 1 when any of the following occur:

either the reactor pressure > 15 MPa **and** the reactor temperature ≤ 340°C
or the cooling water flow rate is ≤ 17 kg/s **and** the temperature is > 340°C

The inputs to the system are shown below in Table Q9(c).

Input	Binary value	Reactor status
T	0	Temperature ≤ 340°C
	1	Temperature > 340°C
P	0	Pressure ≤ 15 MPa
	1	Pressure > 15 MPa
C	0	Cooling water flow rate ≤ 17 kg/s
	1	Cooling water flow rate > 17 kg/s

Table Q9(c)

Produce EACH of the following for the safety system:

(i) the truth table; (2)

(ii) the Boolean expression in its simplest form; (3)

(iii) the logic circuit, with as few gates as possible. (3)