CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-34 - NAVAL ARCHITECTURE

FRIDAY, 01 APRIL 2022

0915 - 1215 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper

Examination Paper Inserts

Worksheet Q2

Notes for the guidance of candidates:

1. Examinations administered by SQA on behalf of the Maritime & Coastguard Agency
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

NAVAL ARCHITECTURE

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. A ship of length 160 m displaces 22862 tonnes when floating at a draught of 8.526 m in sea water of density 1025 kg/m^3.

The waterplane area is defined by half breadths as given in Table Q1.

Station	AP	1	2	3	4	5	6	7	8	9	FP
½ Breadth (m)	2	6	9	11	12	12	12	10	7	3	0

Table Q1

The following tanks are partially full of liquid as indicated:

ONE rectangular tank 10.2 m long and 6 m wide, containing fresh water of density 1000 kg/m^3;

ONE rectangular tank 7.4 m long and 5 m wide containing oil fuel of density 890 kg/m^3.

When a mass of 20 tonne is moved a distance of 22 m across the deck, a deflection of 71 mm is recorded on a pendulum of 9.2 m length.

The height of the centre of buoyancy above the keel (KB) may be determined using Morrish's formula as given below:

$$KB = \left(\frac{5}{6} \times d\right) - \left(\frac{\nabla}{3 \times A_W}\right)$$

Calculate the KG of the ship in the above condition.

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2. A coastal tanker has a breadth of 16 m and in the lightship condition, has a displacement of 2600 tonne and a KG of 3.34 m.

The vessel is now loaded as indicated in Table Q2.

Item	mass (tonne)	KG (m)
Crude oil Cargo	5900	4.65
Oil Fuel	330	2.60
Fresh Water	120	1.80
Stores etc.	50	8.90

Table Q2

The following tanks are partially full with liquid as follows:

ONE rectangular slop tank 10 m long and 8 m wide, containing fresh water of density 1000 kg/m^3 with oil of density 900 kg/m^3 floating on top.

FOUR full width rectangular tanks, carrying crude oil of density 952 kg/m^3, EACH 20 m long with centreline oiltight bulkheads.

In this condition, when floating in sea water of density 1025 kg/m^3 the height of the transverse metacentre above the keel (KM) is 5.286 m.

(a) Calculate the effective metacentric height in the loaded condition. (8)

(b) (i) Using Worksheet Q2, draw the curve of statical stability for the loaded condition; (7)

(ii) From the curve drawn in Q2(b)(i), determine the range of stability. (1)

3. The hydrostatic particulars given in Table Q3 are for a ship of length 160 m when floating in water of density 1025 kg/m^3.

Draught (m)	Displacement (tonne)	MCT 1cm (tm)	LCB from midships (m)	LCF from midships (m)
8.5	21800	242.5	0.90 forward	2.34 aft
8.0	20200	240.0	1.08 forward	2.14 aft

Table Q3

The ship floats in water of density 1010 kg/m^3 with draughts of 7.8 m forward and 8.6 m aft.

Calculate EACH of the following:

(a) the displacement; (8)

(b) the longitudinal position of the ship's centre of gravity. (8)

4. A box shaped vessel is 100 m long, 12 m wide and floats at an even keel draught of 5 m in water of density 1025 kg/m^3 with a KG of 3.98 m.

A full width empty compartment at the forward end of the vessel is 10 m long and has a watertight flat 2.8 m above the keel.

This end compartment is now bilged below the flat only.

Calculate the new end draughts of the vessel. (16)

Note: The KB in the bilged condition may be taken as half the new mean draught.

5. A box barge of 88 m length, 12 m breadth and 6 m depth has a hull mass of 600 tonne evenly distributed throughout its length.

Bulkheads located 4 m from the barge ends, form peak tanks which may be used for ballast.

The remainder of the barge length is divided by 4 transverse bulkheads into 5 holds of equal length.

The holds are full of bulk cargo having a stowage rate of 1.6 m^3/tonne.

The peak tanks are empty.

(a) Calculate the midship bending moment during discharge when both end holds are half empty. (8)

(b) The midship bending moment is to be restricted to a maximum of 50 MNm (Sagging) during unloading.

Calculate the minimum depth of sea water ballast of density 1025 kg/m^3, which must be added to the peak tanks to allow complete discharge of the end holds. (8)

6. The force acting normal to the plane of a rudder is given by the expression:

$$F_n = 20.17\, A\, v^2\, \alpha \quad \text{newtons}$$

where:
- A = rudder area (m^2)
- v = ship speed (m/s)
- α = rudder angle (degrees)

A manoeuvrability specification for a ship that requires a constant *transverse* rudder force of 75 kN is generated when the angle of helm is 35° with the ship travelling at a speed of 5 knots.

(a) Determine suitable dimensions for a rectangular rudder having a depth to width ratio of 1.6. (6)

(b) The rudder stock is designed to have a diameter of 320 mm with the allowable shear stress in the material limited to 70 MN/m^2 at its service speed of 15 knots.

At the maximum helm angle of 35° the centre of effort is 34% of the rudder width from the leading edge of the rudder.

Calculate the distance of the axis of rotation from the leading edge of the rudder so that the stock is not overstressed at the service speed. (10)

7. A ship of length 160 m, breadth 28 m and a block coefficient of 0.7, floats at a draught of 12 m in sea water of density 1025 kg/m^3.

A geometrically similar model 8 m in length, when tested at a speed of 1.6 m/s in fresh water of density 1000 kg/m^3 gives a total resistance of 82 N.

appendage allowance = 6%
weather allowance = 14%
quasi-propulsive coefficient (QPC) = 0.71

Calculate the service delivered power for the ship at the corresponding speed to that of the model. (16)

Note: *The frictional coefficient for the model in fresh water is 1.69*
The frictional coefficient for the ship in sea water is 1.42
Speed is in m/s with index (n) = 1.825
Wetted surface area (m^2) = $2.6\sqrt{\Delta L}$

8. A ship of 25120 tonne displacement has a length of 140 m, breadth of 25 m and floats at a draught of 10 m when in sea water of density 1025 kg/m^3.

The ship's propeller has a diameter of 6 m with a pitch ratio of 0.85. When the propeller is operating at 1.85 rev/s, the real slip is 32% and the thrust power is 6200 kW.

The thrust power is reduced to 5000 kW and the real slip is increased to 34%.

Assuming that the thrust power is proportional to (speed of advance)^3, calculate EACH of the following for the reduced power:

(a) ship speed; (11)

(b) the propeller speed of rotation; (3)

(c) the apparent slip. (2)

Note: Wake fraction = $0.5\,C_b - 0.05$

9. (a) Explain how a propeller blade may be eroded due to cavitation, describing the progressive nature of the damage. (8)

(b) Outline the design features that may be considered to minimise cavitation. (8)