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, 15 DECEMBER 2023

0915 - 1215 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. 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 102 m long floats at a draught of 6 m and in this condition the immersed cross sectional areas and waterplane areas are as given in Tables Q1(A) and Q1(B).

The *equivalent base area* (A_b) is required because of the fineness of the bottom shell.

Section	AP	1	2	3	4	5	FP
Immersed cross section area (m^2)	12	29	64	78	70	48	0

Table Q1(A)

Draught (m)	0	0.6	1.2	2.4	3.6	4.8	6.0
Waterplane area (m^2)	A_b	560	720	876	942	996	1028

Table Q1(B)

Calculate EACH of the following:

(a) the equivalent base area value A_b; (8)

(b) the longitudinal position of the centre of buoyancy from midships; (4)

(c) the vertical position of the centre of buoyancy above the base. (4)

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2. A ship of 31500 tonne displacement floating in sea water has 900 tonne of bunker fuel of density 800 kg/m^3 in double bottom tanks which are pressed up full.

In this condition the metacentric height is 0.25 m and the ordinates of the statical stability curve corresponding to this displacement are given in Table Q2:

Angle of heel (degrees)	0	5	10	15	20
GZ (metres)	0	0.017	0.055	0.095	0.137

Table Q2

The oil is transferred to a deep tank 5 m long by 20 m wide, situated on the ship's centreline.

The centre of gravity of the fuel after transfer is 7 m above the original centre of gravity of the oil and there is a free surface.

Determine EACH of the following for the new condition:

(a) the final effective metacentric height; (5)

(b) the angle that the ship heels to; (7)

(c) the dynamical stability at 20° angle of heel. (4)

3. (a) The following particulars apply to a ship of length 140 m when floating in sea water of density 1025 kg/m^3 at an even keel draught of 7.265 m.

displacement	=	15800 tonne
centre of gravity above the keel (KG)	=	7.8 m
centre of buoyancy above the keel (KB)	=	4.05 m
waterplane area	=	2146 m^2
centre of flotation from midships (LCF)	=	3.0 m aft
second moment of area of the waterplane about a transverse axis through midships	=	2.305 × 10^6 m^4

Calculate the moment to change trim by one centimetre (MCT 1 cm). (4)

(b) The ship in the above condition now undergoes the following changes in loading:

352 tonne added at an lcg of 10.5 m forward of midships;
110 tonne removed from an lcg of 2.0 m aft of midships;
150 tonne moved 52.7 m aft of its original position.

Calculate EACH of the following for the new condition:

(i) the new end draughts of the ship; (9)

(ii) the longitudinal position at which a mass of 204 tonne should be added to restore the ship to an even keel draught. (3)

4. A vessel of constant rectangular section 80 m long and 12 m wide has a KG of 4.77 m and floats on an even keel draught of 5.5 m in water of density 1025 kg/m^3.

The vessel is fitted with a transverse watertight bulkhead 10 m from the forward end.

The compartment forward of the transverse bulkhead, which has a permeability of 60%, is now damaged and laid open to the sea.

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

5. A rectangular oil barge of light displacement 300 tonne is 60 m long and 10 m wide.

The barge is divided by FOUR transverse bulkheads into FIVE compartments of equal length.

When compartments 2 and 4 contain equal quantities of oil and the other compartments are empty, the barge floats at a draught of 3 m in fresh water of density 1000 kg/m^3.

(a) Draw EACH of the following curves on a base of barge length:

(i) curve of loads; (4)

(ii) curve of shearing forces; (4)

(iii) curve of bending moments. (5)

(b) State the magnitude and position of the maximum bending moment. (3)

6. (a) Explain how a force normal to the rudder is produced when the rudder is turned to a helm angle. (3)

(b) Define the term *centre of effort* as applied to a rudder. (1)

(c) Describe how the position of the centre of effort changes as helm angle increases. (2)

(d) Explain the term *balanced*, describing the benefits of fitting a balanced rudder. (3)

(e) Describe, with the aid of a sketch, how an angle of heel is produced due to the force on the rudder. (7)

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7. A ship of length 140 m and breadth 18 m floats at a draught of 8 m in sea water of density 1025 kg/m³. In this condition the block coefficient (C_b) is 0.68.

At a speed of 15 knots the following data applies:

Delivered power	=	4720 kW
Quasi-propulsive coefficient (QPC)	=	0.70
Ship correlation factor (SCF)	=	1.18

Calculate the pull required to tow a similar model of length 5 m at the corresponding speed in fresh water density 1000 kg/m³. (16)

Note: The frictional coefficient to be used:

for the model in fresh water of density 1000 kg/m³ is 1.694
for the ship in sea water of density 1025 kg/m³ is 1.415

Speed in m/s with the speed index (n) for ship and model 1.825
Wetted surface area (S) = $2.57\sqrt{\Delta L}$ (m²)

8. A ship 160 m in length and 24 m breadth, displaces 24800 tonne when floating at a draught of 9 m in sea water of density 1025 kg/m³.

The ship's propeller has a diameter of 5.8 m, a pitch ratio of 0.9 and a blade area ratio of 0.45.

With the propeller operating at 1.9 revs/sec, the following results were recorded:

apparent slip ratio	=	0.06
thrust power	=	3800 kW
propeller efficiency	=	64%

Calculate EACH of the following for the above condition:

(a) the ship's speed; (3)

(b) the real slip ratio; (6)

(c) the thrust per unit area of propeller blade surface; (4)

(d) the torque delivered to the propeller. (3)

Note: The Taylor wake fraction w_t is given by: $w_t = 0.5\ C_b - 0.05$

9. An end bulkhead of an upper hopper tank is shown in Fig.Q9.

The hopper tank is tested by filling with fresh water of density 1000 kg/m^3 through a filling pipe to a head of 2.5 m above the upper deck.

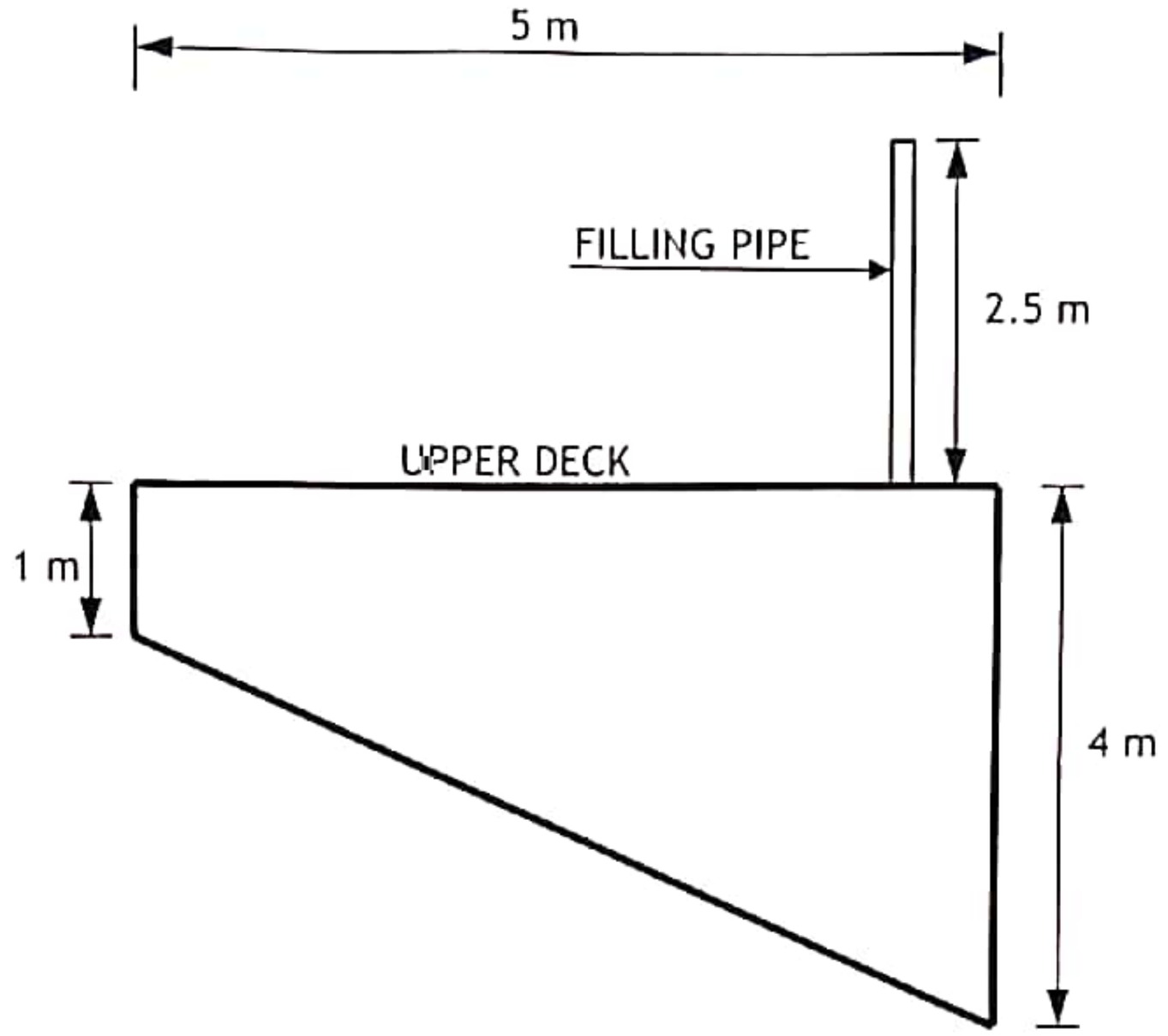

Fig.Q9

Calculate EACH of the following:

(a) The load on the bulkhead; (8)

(b) The distance to the centre of pressure from the upper deck. (8)