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, 19 JULY 2024

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 RO-RO ferry of length 100 m has a displacement of 6000 tonne in sea water of density 1025 kg/m^3 with BM = 3.8 m.

   The breadth of the ship at the waterline, between sections 3 and 7 is constant at 16 m.

   To increase stability, *sponsons* 2.4 m deep and of constant plan area, are to be fitted as shown in Fig.Q1.

   For the new condition there is no change in draught and the load waterline is at mid-depth of the sponson.

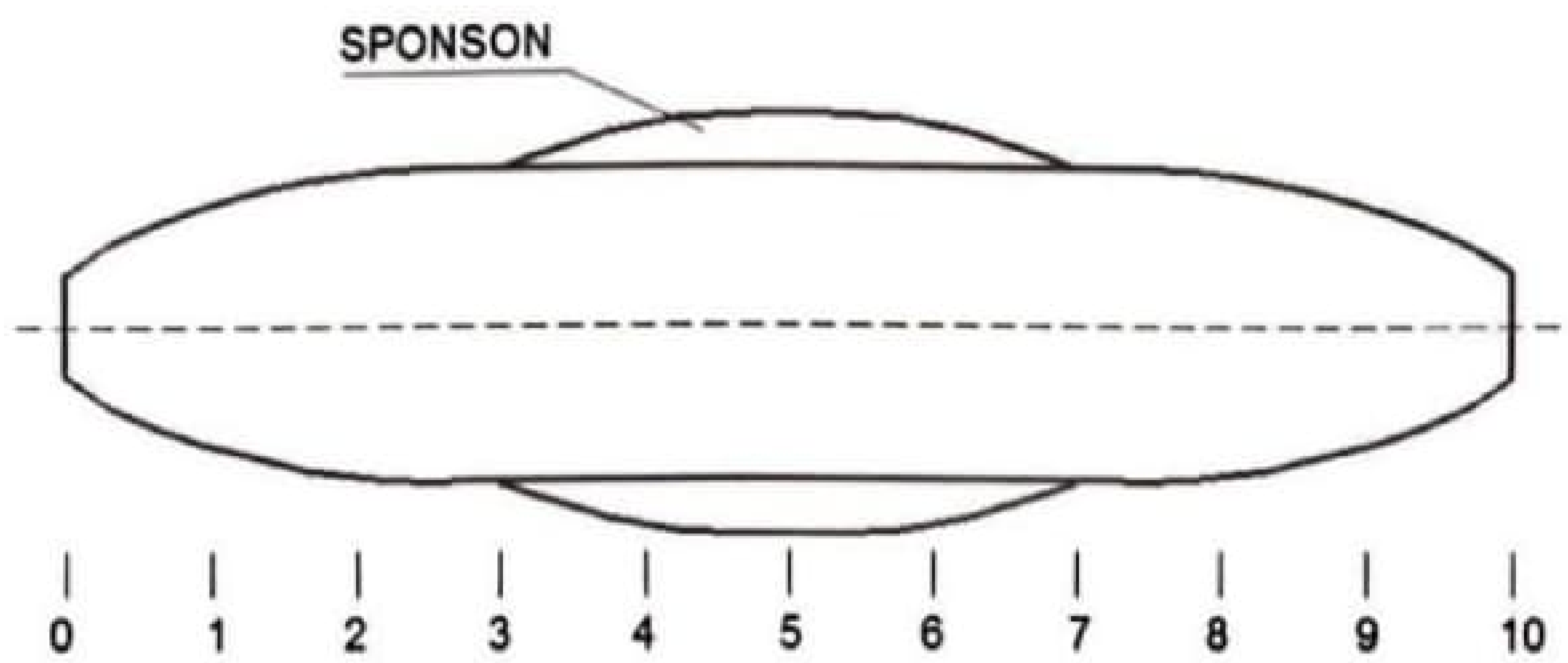

Fig.Q1

The sponsons extend over the midship length between sections 3 and 7, with sponson widths as shown in Table Q1.

Section	3	4	5	6	7
Sponson width (m)	0	1.5	2.2	1.5	0

Table Q1

Calculate the increase in BM due to the sponsons. (16)

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2. A ship of length 120 m and breadth 16 m floats upright at a draught of 6.5 m in sea water of density 1025 kg/m^3 and the height of the centre of gravity above the keel (KG) is 4.735 m.

Further hydrostatic data for this condition are as follows:

centre of buoyancy above the keel (KB)	=	3.2 m
height of metacentre above the keel (KM)	=	6.6 m
waterplane area coefficient (C_w)	=	0.8
block coefficient (C_b)	=	0.7

In the above condition there is an empty rectangular wing tank 12 m long, 4 m wide and 6 m deep, adjacent to the hull and directly above a double bottom tank 1.2 m deep.

Calculate the angle to which the ship will heel when the tank is completely filled with fresh water of density 1000 kg/m^3, assuming the ship to be wall sided over the change of draught. (16)

3. A ship of length 240 m has draught marks 6.0 m aft of the forward perpendicular and 10.0 m forward of the after perpendicular.

The draughts at the marks are 8.8 m aft and 7.6 m forward.

For this condition, the following hydrostatic data are available:

LCF	=	2.4 m aft of midships
Displacement	=	65000 tonne
GM_L	=	120 m
LCB	=	1.4 m aft of midships

Calculate EACH of the following:

(a) the true mean draught; (4)

(b) the draughts at the perpendiculars; (4)

(c) the longitudinal position of the centre of gravity. (8)

4. A ship of displacement 6000 tonne in sea water of density of 1025 kg/m^3 has a breadth of 20 m and a draught of 5.5 m.

The area of waterplane is 1500 m^2, KB is 3.2 m, KG is 4.2 m and the second moment of area of the waterplane about the centreline is 22000 m^4.

A rectangular wing tank of length 10 m and breadth 6 m is situated above a double bottom of depth 1.1 m as shown in Fig.Q4.

Calculate the angle of heel that would occur if the wing tank where bilged. (16)

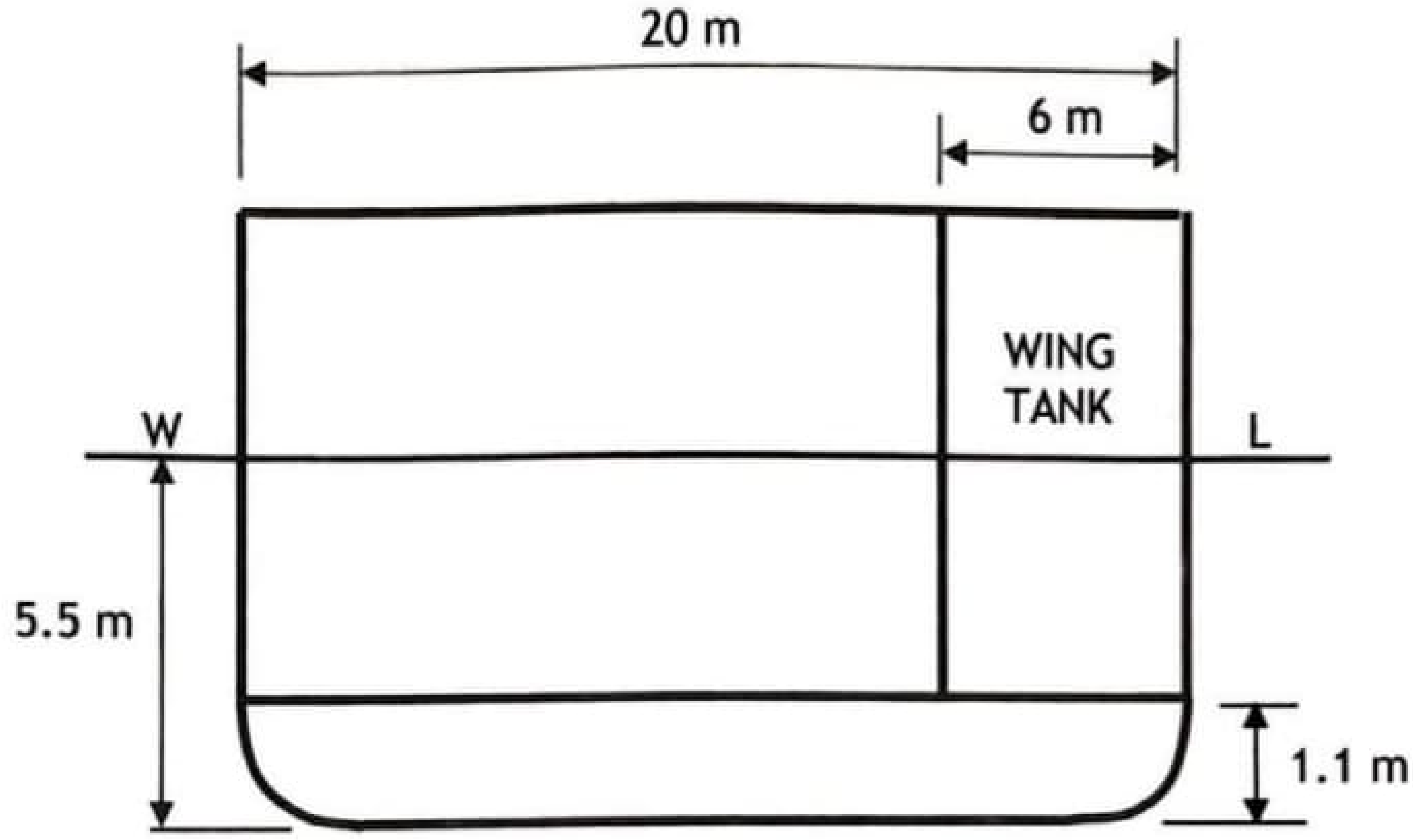

Fig.Q4

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5. Fig.Q5 shows the distribution of weight per metre and buoyancy per metre for a freely floating vessel.

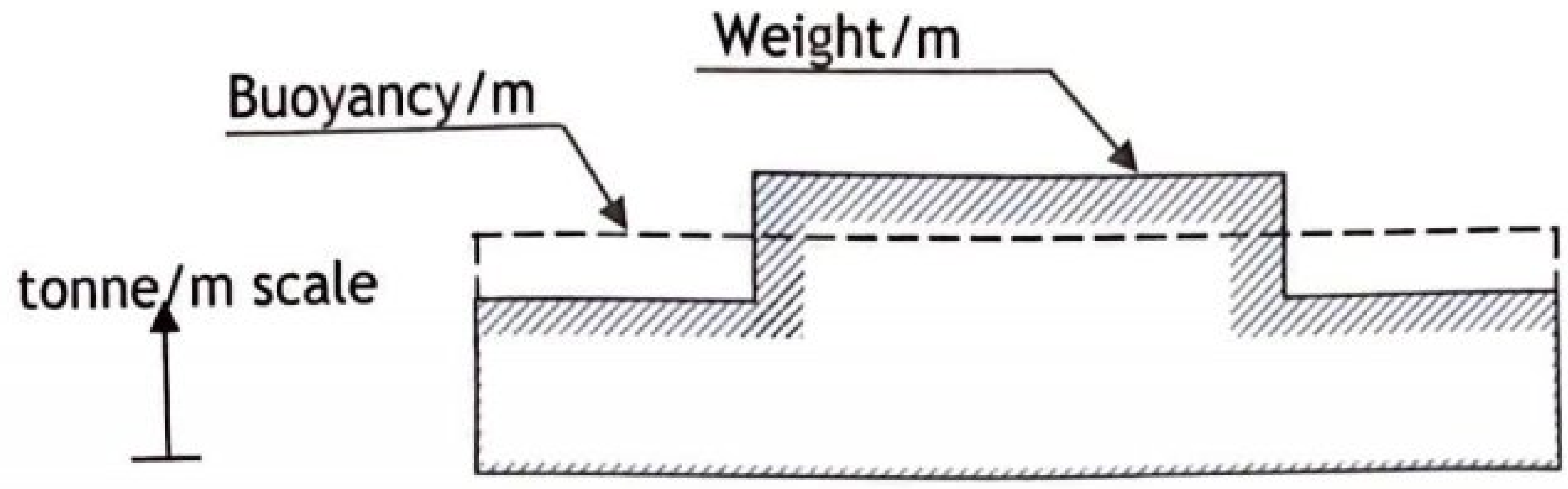

Fig.Q5

(a) Explain why the vessel must be:

(i) of constant cross section; (1)

(ii) on even keel; (1)

(iii) sagging. (1)

(b) Sketch the expected shapes of EACH of the following diagrams explaining the reasons for the form they take:

(i) Load diagram; (4)

(ii) Shear force diagram; (4)

(iii) Bending moment diagram. (5)

6. A single screw ship with a service speed of 15 knots is fitted with a rectangular rudder, 5.5 m deep and 3.5 m wide, with its axis of rotation 0.4 m from the leading edge.

At a rudder helm angle of 35 degrees, the centre of effort is 32% of the rudder width from the leading edge.

The force on the rudder normal to the plane of the rudder is given by the expression:

$$F = 577\ A\ v^2 \sin \alpha \quad \text{(newtons)}$$

Where: A = area of the rudder (m^2)
v = ship speed (m/s)
α = rudder angle (degrees)

The maximum stress on the rudder stock is to be limited to 70 MN/m^2.

Calculate EACH of the following, for a rudder angle of 35 degrees:

(a) the minimum diameter of the rudder stock for ahead running; (9)

(b) the speed of the ship, when running astern, at which the maximum stress level would be reached. (7)

7. A ship 150 m long has a load displacement of 27500 tonne in sea water of density 1025 kg/m^3.

To maintain a speed of 16 knots in the above condition during trials, a shaft power of 7860 kW is required.

A geometrically similar ship of 22360 tonne load displacement is to operate in the service condition at the corresponding speed.

SCF for trial condition	=	1.08
SCF for service condition	=	1.23
Quasi-propulsive coefficient (QPC)	=	0.70
Transmission losses	=	3%
Wetted surface area (m^2)	=	$2.57\sqrt{\Delta L}$

Calculate the shaft power required for this ship. (16)

Note: The frictional coefficient for the 27500 tonne ship in sea water is 1.413
The frictional coefficient for the 22360 tonne ship in sea water is 1.415
The frictional coefficients are to be used with speed in m/s
Speed index (n) is 1.825

8. The ship data in Table Q8 have been derived from the results of model experiments:

Ship speed (knots)	14	15	16
Effective power (kW)	2620	3380	4580
Thrust deduction fraction	0.196	0.192	0.186
Taylor wake fraction	0.305	0.300	0.297
Propeller efficiency	0.685	0.695	0.690

Table Q8

Determine EACH of the following using the data in Table Q8:

(a) the ship speed when the propeller is absorbing 5050 kW delivered power; (10)

(b) the propeller speed (rev/s) given that the propeller has a diameter of 6 m with a pitch ratio of 0.85 and is operating at a real slip of 34%. (6)

9. (a) Show that when a ship is grounded on its centreline during docking, the transverse stability of the ship reduces by:

$$\frac{P \times KM}{\Delta}$$

Where: Δ is the displacement
KM is the distance from keel to metacentre
P is the upthrust at the point of grounding (8)

(b) A vessel 150 m long and 15000 tonne displacement enters dock with draughts of 8.6 m aft and 7.7 m forward.

KM = 8.5 m
KG = 8.1 m
MCT 1cm = 130 tm
LCF = 2 m forward of midships

Calculate the GM at the instant the ship grounds on the blocks. (8)