(14)

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, 31 MARCH 2023

0915 - 1215 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper

Examination Paper Inserts

Worksheet Q3

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 vessel of 10000 tonne displacement floats in sea water of density 1025 kg/m^3.

The vessel has a wing deep tank 16 m long and 8 m deep which has a constant plan area formed by the transverse end bulkheads and a longitudinal bulkhead, which is parallel to and 4 m from the centreline of the ship.

The equally spaced transverse ordinates defining the plan area are as follows:

4.00, 3.80, 3.50, 3.00 and 2.50 metres.

The base of the tank is 2.0 m above the keel.

With the deep tank full of oil of density 900 kg/m^3, the ship floats upright with a metacentric height of 0.725 m.

Half of the oil in the deep tank is now removed and the KM remains constant at 5.125 m.

Calculate EACH of the following:

(a) the final effective metacentric height; (14)

(b) the final angle of heel. (2)

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2. A vessel of 14000 tonne displacement floats at a draught of 8 m in sea water of density 1025 kg/m^3.

Further hydrostatic data for the above condition are:

centre of buoyancy above the keel (KB) = 4.456 m
transverse metacentre above the keel (KM) = 7.715 m
tonne per centimetre immersion (TPC) = 20

The vessel in the above condition is unstable and heels to an angle of 6°.

To restore positive stability, ballast of 640 tonne is now loaded at a Kg of 0.6 m.

Calculate EACH of the following for the final condition:

(a) the transverse metacentric height; (13)

(b) the righting moment when the vessel is heeled to an angle of 15°. (3)

Note: The vessel may be considered wall-sided between the limits of draught, hence:

$$GZ = \sin\theta\,(GM + \tfrac{1}{2}\,BM\tan^2\theta)$$

3. A ship 120 m long floats at draughts of 6.5 m aft and 4.1 m forward when floating in river water of density 1008 kg/m^3.

Using the hydrostatic curves provided in Worksheet Q3, determine EACH of the following:

(a) the displacement; (8)

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

4. For a box shaped barge 100 m in length, 15 m breadth, floating at an even keel draught of 8 m in sea water of density 1025 kg/m^3, the KG is 5 m.

A full breadth midship compartment 10 m long is divided by a centreline watertight longitudinal bulkhead to form TWO equal compartments.

The permeability of the flooded compartment is 85%.

Calculate the angle of heel for the barge, if one of the compartments is bilged. (16)

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

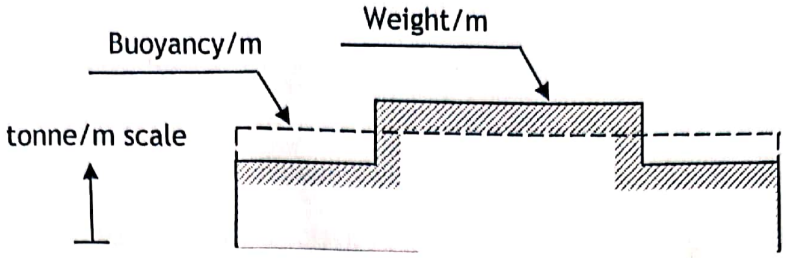

Fig Q5

(a) Explain why the vessel must be of constant cross section on even keel. (2)

(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)

(c) State the manner in which the ship will bend longitudinally. (1)

6. A ship of 8000 tonne displacement has a rudder area of 22 m^2.

The ship has a KM of 6.7 m, KG of 6.1 m and the centre of lateral resistance is 3.8 m above the keel.

The maximum rudder angle is 35 degrees and the centroid of the rudder is 2.3 m above the keel.

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

$$F = 580\ A\ v^2 \sin \alpha$$

Where: A = rudder area
v = ship speed in m/s
α = rudder helm angle

Calculate EACH of the following, when the vessel is travelling at 20 knots:

(a) the angle and direction of heel due to the rudder force only, if it is put hard over to port. (8)

(b) the angle and direction of heel due to the combination of centrifugal force and rudder force when the rudder is hard over to port and the vessel turns in a circle of 800 m diameter (8)

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7. A ship has a length of 130 m and floats in sea water of density 1025 kg/m^3.

A model of this ship has a length of 5 m and a wetted surface area of 6 m^2.

The model has a total resistance of 45 N when towed at 1.85 m/s in fresh water of density 1000 kg/m^3.

(a) Using the data below, calculate EACH of the following:

(i) the ratio of residuary resistance to total resistance for the model; (5)

(ii) the ratio of residuary resistance to total resistance for the ship at the corresponding speed. (8)

(b) State why the TWO ratios should be different. (3)

Note: The frictional coefficient for the model in fresh water is 1.694
The frictional coefficient for the ship in sea water is 1.418
Speed in m/s with the speed index (n) for ship and model 1.825

8. The wetted surface area of a container ship is 5946 m^2.

When travelling at the service speed, the effective power required is 11250 kW, with residuary resistance 26% of the total resistance.

The specific fuel consumption is 0.22 kg/kW hr.

Friction coefficient in sea water is 1.432 when speed is in m/s with index (n) 1.825.

(a) Calculate the service speed of the ship. (10)

(b) To conserve fuel the ship speed is reduced by 10% and the daily fuel consumption is then found to be 83 tonne. The propulsive coefficient based upon shaft power may be assumed constant at 0.6.

Calculate the percentage increase in specific fuel consumption when running at reduced speed. (6)

9. A ship has a displacement of 7650 tonne when the length on the waterline is 126 m.

LCG is 0.8 m aft of midships.

The ship is trimmed by the stern and is dry docked in this condition.

The following data in Table Q9 is available.

Draught (m)	Displacement (tonne)	LCB forward of midships (m)
6.00	9810	3.00
5.75	9270	3.05
5.50	8730	3.10
5.25	8190	3.15
5.00	7650	3.20
4.75	7110	3.25
4.50	6570	3.30
4.25	6030	3.35
4.00	5490	3.40

Table Q9

(a) Plot a curve of moment of buoyancy about the aft end against a base of displacement. **(10)**

(b) Determine the upthrust exerted by the after blocks just before the ship touches the keel blocks all along its length. **(6)**