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, 20 OCTOBER 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 SWATH (small waterplane area twin hull) design, has the following hydrostatic particulars when floating in water of density 1025 kg/m^3.

Displacement = 2820 tonne
Centre of buoyancy above the keel (KB) = 2.655 m
Centre of gravity above the keel (KG) = 5.875 m

The distance between the centrelines of each hull is 18 m and the half breadths of each hull, measured at equal intervals along the 66 m length of waterplane, are as shown in Table Q1.

Station	0	1	2	3	4	5	6
½ Breadth (m)	0	0.7	1.0	1.1	1.0	0.7	0

Table Q1

Calculate the transverse metacentric height of the vessel in the above condition. (16)

2. (a) Sketch and label a statical stability curve for a vessel with its centre of gravity on the centreline but having a negative metacentric height when in the upright condition. (3)

(b) The ordinates for part of a statical stability curve for a bulk carrier at a displacement of 128000 tonne are given in Table Q2.

Angle (degrees)	0	10	20	30	45	60
Righting lever GZ (m)	0	0.453	0.996	1.409	1.633	1.486

Table Q2

The ship has a hold 48 m long and 40 m wide which contains bulk grain stowed at a stowage rate of 1.25 m^3/tonne.

During a heavy roll, the grain shifts so that the level surface is lowered by 3 m on one side and raised by 3 m on the other side.

(i) Draw the amended statical stability curve for the ship; (12)

(ii) From the curve, determine the angle of list due to the cargo shift. (1)

3. A ship is loaded to a displacement of 12000 tonne in sea water of density 1025 kg/m³. In this condition the centre of gravity above the keel (KG) is 6.164 m and the longitudinal position of the centre of gravity (LCG) is 0.6 m forward of midships.

A rectangular tank, forward of midships, of length 16 m, breadth 10 m and depth 5 m is partially filled with 656 tonne of sea water ballast to give an effective metacentric height of 1.34 m and a final trim of 0.8 m by the stern.

Using the hydrostatic curves given in Worksheet Q3, determine for the ballast tank EACH of the following:

(a) the height of the base above keel; (8)

(b) the position of the forward bulkhead from midships. (8)

4. A box shaped vessel is 80 m long, 10 m wide and floats at an even keel draught of 4 m in water of density 1025 kg/m³ with a KG of 3.43 m.

A full width empty compartment at the forward end of the vessel is 10 m long and has a watertight flat 2.5 m above the keel.

This end compartment is now bilged above 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. The hull of a box shaped vessel is 80 m long and has a mass of 800 tonne uniformly distributed over its length.

Machinery of mass 200 tonne extends uniformly over the middle quarter length of the vessel.

Two holds extending over the forward and aft quarter lengths of the vessel each have 240 tonne of cargo stowed uniformly over their lengths.

(a) Draw EACH of the following curves for the vessel;

(i) load/metre; (8)

(ii) shearing force. (4

(b) Determine the maximum bending moment. (4

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

Where:

$F_n = 15.5\ A\ v^2\ \alpha$ newtons
A = rudder area (m^2)
v = ship speed (m/s)
α = rudder helm angle (degrees)

A ship travelling at a speed of 20 knots, has a rudder configuration as shown in Fig.Q6.

The centre of effort for areas A_1 and A_2 are 32% of their width from their respective leading edges.

The rudder helm angle is limited to 35° from the ship's centreline.

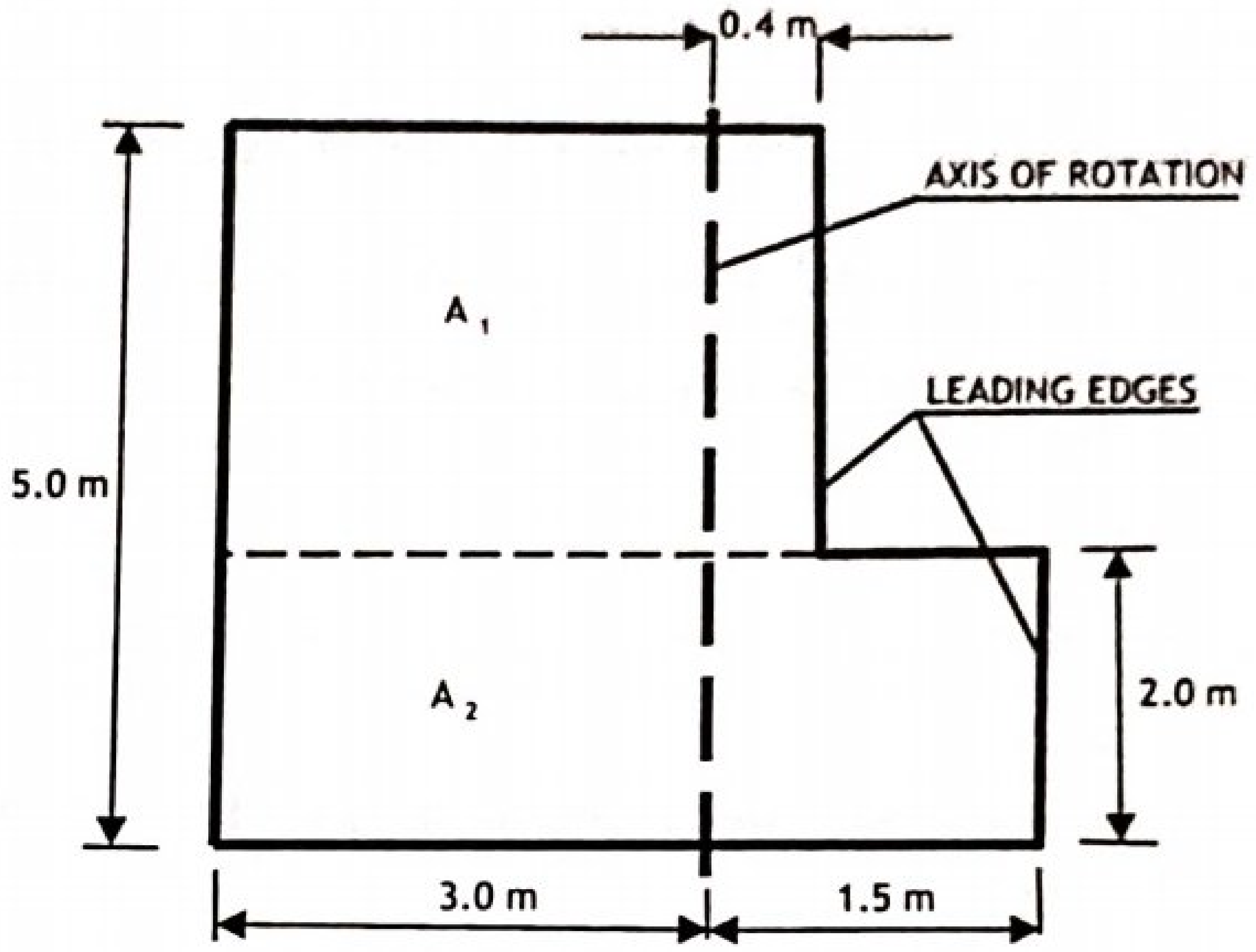

Fig.Q6

Calculate EACH of the following:

(a) the diameter of the rudder stock required for a maximum allowable stress of 77 MN/m^2; (12)

(b) the drag component of the rudder force when the rudder is put hard over at full speed. (4)

7. The following results in Table Q7 were obtained from resistance tests on a ship model 6 m in length having a wetted surface area of 7 m^2 in fresh water of 1000 kg/m^3 at a temperature of 12°C.

Speed (m/s)	1.50	1.75	2.00	2.25
Total resistance (N)	37.5	44.0	55.8	76.3

Table Q7

Ship correlation factor = 1.18
Temperature correction = ±0.43% per °C

Calculate the effective power of a similar ship 140 m long travelling at a speed of 18 knots in sea water of density 1025 kg/m^3 at a temperature of 15°C. (16)

Note: *The frictional coefficient for the model in water of density 1000 kg/m^3 at 15°C is 1.655.*
The frictional coefficient for the ship in water of density 1025 kg/m^3 at 15°C is 1.415.
Speed in m/s with index (n) for ship and model 1.825.

8. A model propeller operating in water of density 1000 kg/m^3 is 0.4 m diameter and has a pitch of 0.4 m.

At a rotational speed of 6.8 revs/sec, the speed of advance is 2 m/s, torque is 40 Nm and the thrust developed is 560 N.

A geometrically similar ship's propeller of 5 m diameter, is operating at corresponding linear and rotational speeds, in water of density 1025 kg/m^3.

(a) Calculate EACH of the following for the ship's propeller:

(i) revolutions per second; (1)

(ii) speed of advance; (1)

(iii) real slip; (3)

(iv) delivered power; (3)

(v) propeller efficiency. (4)

(b) Calculate the hull efficiency when the propeller is operating on a vessel at a Taylor wake fraction of 0.25 and a thrust deduction fraction of 0.2. (4)

Note: *For similar propellers at corresponding speeds, it can be assumed:*

Linear speed is proportional to (diameter)^{½}
Rotational speed is proportional to (diameter)$^{-½}$
Thrust is proportional to (diameter)^3
Torque is proportional to (diameter)^4

9. (a) Show that, the position of the centre of pressure for a rectangular plane, with its edge in surface, is two thirds of the depth of the plane below the surface. (4)

(b) A rectangular bulkhead 8 m wide has sea water of density 1025 kg/m^3 on one side to a depth of 7 m and oil of density 850 kg/m^3 on the other side to a depth of 4 m.

Calculate EACH of the following:

(i) the resultant load on the bulkhead; (8)

(ii) the position of the resultant centre of pressure. (4)