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, 18 DECEMBER 2020

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. Non-programmable calculators may be used.
2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.
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Maritime & Coastguard Agency

SQA

NAVAL ARCHITECTURE

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

Marks will not be awarded unless relevant working is CLEARLY shown

1. A ship 160 m in length has a load displacement of 20500 tonne and floats in water of density 1025 kg/m³. The load waterplane is defined by equally spaced half breadths as shown in Table Q1.

Section	AP	1	2	3	4	5	6	7	FP
Half-breadth (m)	1	6	10	11	12	11	9	5	0

Table Q1

The following particulars are also available:

centre of buoyancy above the keel (KB) = 4.264 m
centre of gravity above the keel (KG) = 7.561 m
centre of lateral resistance above the keel = 4.050 m

A rectangular tank, partially filled with oil of relative density 0.89 has overall dimensions of 10 m by 10 m, but is divided into two equal tanks by an oiltight longitudinal bulkhead.

Calculate EACH of the following:

(a) the effective metacentric height; (12)

(b) the angle to which the ship will heel when turning on a circular course of 400 m diameter at a speed of 16 knots. (4)

2. A vessel floating in sea water of density 1025 kg/m³ with a displacement of 6000 tonne has the following particulars:

mean draught = 6 m
centre of buoyancy above the keel (KB) = 3.305 m
transverse metacentre above the centre of buoyancy (BM) = 3.865 m
transverse metacentric height (GM) = 0.670 m
tonne per centimetre immersion (TPC) = 15

Calculate the mass to be added to the vessel at a Kg of 2 m, to give a final transverse metacentric height of 1.0 m, assuming the vessel to be wall-sided over the affected range of draught. (16)

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3. The following particulars apply to a ship of 125 m length when floating in water of density 1025 kg/m³ at an even keel draught of 6.425 m.

displacement	=	10850 tonne
centre of gravity above the keel (KG)	=	6.69 m
centre of buoyancy above the keel (KB)	=	3.57 m
waterplane area	=	1756 m²
centre of flotation from midships (LCF)	=	2.5 m aft
second moment of area of the waterplane about a transverse axis through midships	=	1.526×10^6 m⁴

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

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

50 tonne added with its lcg 27.5 m forward of midships
230 tonne removed with its lcg 2 m aft of midships
120 tonne moved 46 m aft.

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 188 tonne should be added to restore the ship to an even keel draught. (3)

4. A box shaped vessel 100 m long and 10 m wide floats at an even keel draught of 4 m in sea water of density 1025 kg/m³ with a KG of 5 m.

A full width, empty compartment has its after bulkhead 20 m forward of midships and its forward bulkhead 30 m forward of midships.

Calculate the end draughts of the vessel if this compartment is bilged. (16)

5. A uniformly constructed box shaped vessel of length 80 m and breadth 12 m has an even keel draught of 2 m when floating in the light condition in sea water of density 1025 kg/m³.

The vessel has five holds of equal length and is to be loaded with 7000 tonne of cargo, with equal quantities in each of the centre and end holds, and the balance equally distributed in No.2 and No.4 holds.

The cargo in all holds will be trimmed level.

Calculate EACH of the following:

(a) the maximum amount to be loaded in the centre and end holds in order that a maximum hogging bending moment amidships of 4000 tm will not be exceeded. (10)

(b) the resulting shear force at each of the bulkheads. (6)

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 *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)

7. A ship model of length 5.5 m has a wetted surface area of 4.65 m^2 and is tested in water of density 1000 kg/m^3. The test results give the values of residuary resistance for a range of model speeds as shown in table Q7

Model speed (m/s)	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90
Residuary resistance (N)	4.00	4.20	4.60	5.25	6.35	7.80	9.85	11.80	13.25

Table Q7

(a) (i) Plot a curve of residuary resistance against speed for the model. (2)

(ii) Comment on the shape of this curve. (2)

(b) For a geometrically similar ship of length 132 m operating in sea water of density 1025 kg/m^3 at service speed of 17.0 knots, the following data is applicable:

appendage allowance	=	6%
weather allowance	=	12%
quasi-propulsive coefficient (QPC)	=	0.71
transmission losses	=	3%

Determine the shaft power required for the ship at it's service speed. (12)

Note: frictional coefficient for the ship in sea water is 1.417
speed is in m/s and index (n) for ship and model is 1.825

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8. A model propeller of 0.3 m diameter and 0.25 m pitch is tested in fresh water of density 1000 kg/m^3

At a speed of advance of 1.8 m/s and a rotational speed of 10.0 revs/s, the shaft torque is 12 Nm and the thrust developed is 260 N.

A geometrically similar ship's propeller 5.4 m in diameter, is operating in sea water of density 1025 kg/m^3 at corresponding linear and rotational speeds.

(a) For the ship's propeller, calculate EACH of the following:

(i) revolutions per second; (1)

(ii) speed of advance; (1)

(iii) real slip; (3)

(iv) delivered power; (3)

(v) efficiency. (4)

(b) Calculate the hull efficiency when the propeller is operating on a vessel at a Taylor wake fraction of 0.26 and a thrust deduction fraction of 0.22. (4)

Note: *For geometrically 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 watertight door in a bulkhead is 1.2 m high and 0.75 m wide, with a 0.6 m sill.

The bulkhead is flooded with sea water to a depth of 3 m on one side and 1.5 m on the other side.

(a) Draw the load diagram for the door. (8)

(b) From the load diagram drawn in Q9(a) determine:

(i) the resultant load; (3)

(ii) the position of the centre of pressure on the door. (5)