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, 22 MARCH 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 ship of length 160 m, floats at its load draught with a displacement of 35000 tonne in sea water of density 1025 kg/m^3.

   The longitudinal centre of buoyancy (LCB) is 1.60 m aft of midships.

   In this condition, the forward half of the ship displaces 16000 tonne and has a centre of displaced volume (lcb) 30 m forward of midships.

   This part of the ship is to be replaced with a new forward half of similar length, but having new immersed cross section areas, to the same load draught, as given in Table Q1.

Section	Midships	6	7	8	9	9½	FP
Section area (m^2)	295	280	260	215	136	75	0

Table Q1

   Calculate EACH of the following for the new condition:

   (a) the displacement of the ship; (6)

   (b) the longitudinal position of the ship's centre of buoyancy. (10)

2. The '*wall sided formula*' gives an expression for righting lever (GZ) as follows:

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

(a) Derive an expression for the '*angle of loll*' of a ship which is initially unstable in still water, using the wall sided formula. (5)

(b) A box shaped vessel is 80 m long, 12 m wide and floats at a draught of 5 m in sea water of density 1025 kg/m^3 with a KG of 4.815 m.

A beam wind acts on the exposed area of the vessel causing it to heel to an angle of 15°.

The heeling moment caused by the wind is given by the expression:

Heeling moment = $0.85\,A\,b\,v^2\cos^2\theta$ Nm

where: A = exposed area = 627 m^2
b = lever = 6.5 m
v = wind speed in m/s
θ = angle of heel in degrees.

Calculate the wind speed using the wall sided formula for GZ. (11)

3. A ship of length 150 m has the following hydrostatic particulars when floating at an even keel draught in sea water of density 1025 kg/m^3.

waterplane area	=	2000 m^2
displacement	=	13500 tonne
longitudinal metacentric height (GM_L)	=	165 m
centre of flotation from midships (LCF)	=	2.4 m aft

The ship in the above condition grounds on a rock which may be assumed to be at a point 60 m forward of midships and settles such that the end draughts are 6.35 m aft and 5.65 m forward.

Calculate the original draught of the ship. (16)

4. (a) Describe, with the aid of sketches, the influence on a statical stability curve of EACH of the following:

(i) an increase in the breadth of the ship, with the draught, freeboard and KG remaining constant; (4)

(ii) an increase in the freeboard of the ship, with the draught, breadth and KG remaining constant. (4)

(b) With reference to the statical stability curve, state the minimum standards. (8)

5. A box barge of 64 m length, 8 m breadth and 4.5 m depth has a hull mass of 322 tonne evenly distributed throughout its length.

Bulkheads located 2 m from the barge ends, form fore and aft peak tanks which may be used for ballast. The remainder of the barge length is divided by 4 transverse bulkheads into 5 holds of equal length.

The holds are full of bulk cargo having a specific volume of 1.543 m^3/t.

The peak tanks are empty.

(a) Calculate the midship bending moment during discharge when both end holds are half empty. (8)

(b) Calculate the minimum depth of sea water ballast of density 1025 kg/m^3, which must be added to the peak tanks to allow complete discharge of the end holds, if the midship sagging bending moment is to be restricted to a maximum of 19.8 MNm. (8)

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

F_n = 20.2 A v^2 α newtons

where: A = rudder area (m^2)

v = ship speed (m/s)

α = rudder angle (degrees)

A manoeuvrability specification for a ship that requires a transverse rudder force of 92 kN is generated when the angle of helm is 35° with the ship travelling at 5 knots.

(a) Determine suitable dimensions for a rectangular rudder having an aspect ratio (depth to width ratio) of 1.5. (6)

(b) The rudder stock is designed to have a diameter of 360 mm with the allowable shear stress in the material limited to 70 MN/m^2 at its service speed of 16 knots.

At the maximum helm angle of 35°, the centre of effort is 35% of the rudder width from the leading edge of the rudder.

Calculate the maximum distance of the axis of rotation from the leading edge of the rudder so that the stock is not overstressed at the service speed. (10)

7. A ship model of length 5 m has a wetted surface area of 4.2 m^2 and is tested in fresh 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)	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
Residuary resistance (N)	3.00	3.35	3.85	4.60	5.80	7.40	9.15	10.50	11.40

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 125 m operating in sea water of density 1025 kg/m^3 at service speed of 16.0 knots, the following data is applicable:

appendage allowance = 7%
weather allowance = 14%
quasi-propulsive coefficient (QPC) = 0.7
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 1.42*
speed in m/s and index (n) for ship and model is 1.825

8. A ship 160 m long and 28 m breadth, displaces 32600 tonne when floating at a draught of 10 m in sea water of density 1025 kg/m^3.

The propeller has a diameter of 6.0 m and a pitch ratio of 0.9.

With the propeller operating at 1.8 revs/sec, the following results were recorded:

propeller thrust	=	1500 kN
real slip	=	36%
propeller efficiency	=	65%
transmission losses	=	3%
fuel consumption per day	=	68 tonne

Calculate EACH of the following:

(a) the ship speed; (6)

(b) the apparent slip; (2)

(c) the specific fuel consumption; (4)

(d) the mass of fuel required to travel 4000 nautical miles at a constant speed of 18 knots including a reserve of 10%. (4)

Note: Wake fraction = $0.5\ C_b - 0.05$

9. (a) Describe how cavitation occurs on a ship's propeller, explaining how it is more likely to occur as draught reduces and sea water temperature increases. (8)

(b) Describe FOUR types of propeller cavitation. (4)

(c) State FOUR detrimental effects of propeller cavitation. (4)