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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, 21 JULY 2023

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 *spade type* rudder, supported only at the rudder head, has a depth of 4.8 m, with the following widths at equal intervals commencing from the top of the rudder:

   2.80, 2.75, 2.40, 1.95 and 1.50 metres.

   The top of the rudder is 0.4 m from the bearing at the rudder head.

   The centre of effort of the rudder can be taken to act at the vertical centroid of the rudder and at a distance of 0.2 m from the axis of rotation.

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

   $$F_n = 18\,A\,v^2\,\alpha \quad \text{newtons}$$

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

   The equivalent twisting moment (T_E) is given by:

   $$T_E = M + \sqrt{M^2 + T^2}$$

   where:
   M = bending moment
   T = twisting moment

   Calculate the required diameter of the rudder stock, assuming a maximum allowable stress of 75 MN/m^2, for a ship speed of 20 knots and rudder angle 35°. (16)

2. A ship of breadth 18 m has a displacement of 11500 tonne and a metacentric height of 1.45 m when floating upright in sea water of density 1025 kg/m^3.

A rectangular oil fuel bunker 3 m long, 18 m wide and 12 m deep is divided on the centreline by a longitudinal oiltight bulkhead to form TWO equal tanks which are both full of fuel oil of density 899 kg/m^3.

An adjoining rectangular cargo hold of length 16.5 m and breadth 18 m is empty.

The transverse bulkhead separating the starboard oil fuel bunker and the hold ruptures at the bottom so that liquid flows freely between the bunker and hold.

Calculate the angle to which the ship will heel. (16)

3. A ship 160 m in length displaces 15000 tonne and floats at draughts of 6.4 m forward and 6.9 m aft.

The longitudinal metacentric height is 170 m, the centre of flotation is 1.9 m aft of midships and the TPC is 24.

The vessel is required to enter dock with a draught aft of 6.6 m and a trim of 0.8 m by the stern.

Calculate EACH of the following:

(a) the mass of ballast to be discharged; (6)

(b) the distance of its centre of gravity from midships. (10)

4. (a) Sketch transverse cross sections of a ship, showing the forces acting when the ship is lying at a LARGE angle of heel due to EACH of the following, indicating the positions of the initial and final centres of buoyancy and gravity and the initial position of the transverse metacentre:

(i) an external force (wind or wave); (2)

(ii) a transverse shift of cargo; (2)

(iii) initial instability. (2)

(b) Sketch and label typical statical stability curves for EACH of the following ship loading conditions:

(i) with the ship's centre of gravity on the centreline and the ship having a positive metacentric height; (4)

(ii) with the ships centre of gravity off the centreline and the ship having a positive metacentric height; (3)

(iii) with the ship's centre of gravity on the centreline and the ship having a negative metacentric height. (3)

5. A uniformly constructed box shaped vessel of length 60 m and breadth 10 m has an even keel draught of 2 m when floating in the light condition in sea water of density 1025 kg/m^3.

The vessel has FIVE holds of equal length and is to be loaded with 4000 tonne of cargo, with equal quantities in EACH of the centre and end holds.

The balance is 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 3000 tm will not be exceeded; (12)

(b) the resulting shear force at EACH of the bulkheads. (4)

6. A ship consumes an average of 60 tonne of fuel per day on main engines at a speed of 16 knots.

The fuel consumption for auxiliary purposes is 8 tonne per day.

When 1000 nautical miles from port it is found that only 160 tonne of fuel remains on board and this will be insufficient to reach port at the normal speed.

Using a graphical solution, determine the speed at which the ship should travel to complete the voyage with 20 tonne of fuel remaining. (16)

7. The following data in Table Q7 were obtained during progressive speed trials on a ship of 11400 tonne displacement.

Ship speed (knots)	12	13	14	15	16
Shaft power (kW)	1960	2455	3040	3720	4505

Table Q7

Under normal service conditions, the ship operates within this range and has an Admiralty Coefficient of 458, based upon shaft power.

(a) Determine the normal service speed of the ship. (6)

(b) In a fouled hull condition, with the service shaft power being maintained, the ships speed is found to have decreased by 6% from normal.

Assuming that the specific fuel consumption remains constant at 190 g/kW hr, determine the increase in fuel consumed over a distance of 2500 nautical miles. (5)

(c) A geometrically similar ship is to be built having a displacement of 13500 tonne.

Determine the shaft power required for this ship at a speed of 15.5 knots. (5)

8. A ship 160 m long and 26 m beam displaces 24000 tonne when floating at a draught of 8 m in sea water of density 1025 kg/m^3.

The following data are given for the service speed of 18 knots.

effective power (naked)	=	5500 kW
appendage and weather allowance	=	18%
quasi-propulsive coefficient	=	0.72
thrust deduction fraction	=	0.2
transmission losses	=	3.5%
specific fuel consumption	=	0.210 kg/kW hr

The Taylor wake fraction (w_T) is obtained from:

$w_T = 0.5\, C_b - 0.05$

(a) Calculate EACH of the following at the service speed:

(i) the delivered power; (2)

(ii) the thrust power; (7)

(iii) the fuel consumption per day. (3)

(b) Calculate the maximum speed at which the ship must travel to complete a voyage of 4000 nautical miles, with only 300 tonne of fuel on board. (4)

9. A watertight door is 1.8 m high and 0.8 m wide, with a 0.5 m sill.

The bulkhead is flooded with sea water to a depth of 3.9 m on one side and 2.0 m on the other side.

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

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

(i) the resultant load; (3)

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