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 OCTOBER 2022

0915 - 1215 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper

Examination Paper Inserts

Worksheet Q2 Hydrostatic curves

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 floats at a draught of 10 m in sea water of density 1025 kg/m^3.

In this condition the centre of gravity is 8.958 m above the keel and the second moment of area of the waterplane about the centreline is 110000 m^4.

Values of tonne per centimetre immersion (TPC) in sea water are given in Table Q1.

Draught (m)	0	1	2	4	6	8	10
TPC	10	16	19	23	26	28	29

Table Q1

Tanks are partially full with liquid as follows:

ONE rectangular tank 10 m long and 8 m wide, containing fresh water of density 1000 kg/m^3.

ONE rectangular tank, 12 m long and 10 m wide with a centreline oiltight bulkhead, containing fuel oil of density 910 kg/m^3.

A load is to be discharged from the ship's centreline by the ship's own heavy lift crane.

The crane head is 15 m above the original centre of gravity of the load and 10 m from the centreline of the ship when swung out.

During the discharge it is required that the effective metacentric height should not be less than 1.25 m.

Calculate EACH of the following:

(a) the maximum load the crane may lift; (14)

(b) the angle to which the ship will heel when discharging the maximum load. (2)

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2. An inclining test carried out on a passenger vessel at a displacement of 8725 tonne in water of density 1012 kg/m^3 resulted in an angle of heel of 1.5° when an inclining mass of 10 tonne was moved 15 m transversely across the deck.

To obtain the lightship condition for the vessel, corrections for the following masses are required:

40 tonne to be removed at Kg 9.2 m;
65 tonne to be added at Kg 10.15 m.

The following masses in Table Q2 are to be added to give the load condition:

Item	Mass (tonne)	Kg (m)
Passengers & effects	60	10.5
Stores	190	8.1
Oil fuel	1600	3.42
Fresh water	400	1.8

Table Q2

In the above condition, free surfaces of liquid are present in ONE rectangular tank 8 m long and 6 m wide containing fresh water of density 1000 kg/m^3 and in FOUR rectangular tanks EACH 10 m long and 8 m wide containing oil fuel of density 950 kg/m^3.

Using Worksheet Q2 Hydrostatic curves, determine EACH of the following:

(a) the lightship KG; (7)

(b) the final mean draught in sea water; (2)

(c) the final effective metacentric height. (7)

3. A ship of length 130 m is loaded as shown in Table Q3(a).

Item	Mass (tonne)	Lcg from midships (m)
lightship	3850	1.52 aft
cargo	8645	3.40 forward
oil fuel	860	7.25 aft
stores	35	15.20 forward
fresh water	90	26.80 forward
crew & effects	20	midships

Table Q3(a)

Table Q3(b) is an extract from the ship's hydrostatic particulars and linear interpolation may be used to obtain data at intermediate draughts.

Draught (m)	Displacement (tonne)	LCB from midship (m)	MCT 1cm (tm)	LCF from midships (m)
8.0	14600	2.1 forward	179	0.3 aft
7.0	12600	2.5 forward	167	0.5 forward

Table Q3(b)

Determine the end draughts of the ship after loading has been completed. (16)

4. A ship of 7200 tonne displacement floats in sea water of density 1025 kg/m^3 at a draught of 5.2 m.

Area of waterplane is 1600 m^2, centre of buoyancy above the keel (KB) is 2.7 m and metacentric radius (BM) is 4.4 m.

A centrally located rectangular midship compartment 25 m long and 10 m wide is now bilged, causing bodily sinkage to a new draught of 5.8 m.

Calculate EACH of the following using the *lost buoyancy* method:

(a) the permeability of the compartment; (4)

(b) the change in transverse metacentric height due to bilging the compartment. (12)

5. A box barge of 40 m length has a hull mass of 320 tonne evenly distributed over its length.

Bulkheads located 2 m from the barge ends form peak tanks that remain empty.

The remainder of the barge length is divided by TWO transverse bulkheads into THREE holds of equal length.

A total of 960 tonne is loaded, one quarter of which is placed in the middle hold, the remainder being equally distributed over the TWO outer holds.

Using graph paper, draw EACH of the following on a base of barge length:

(a) curves of weight and buoyancy per metre; (4)

(b) curve of loads; (3)

(c) curve of shearing forces; (4)

(d) curve of bending moments. (5)

6. A *spade-type* rudder has an area of 6.33 m^2. At its maximum designed rudder angle of 35°, the centre of effort is 0.12 m aft of the axis of rotation and 1.6 m below the lower edge of the rudder stock bearing.

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

$$F_n = 18.32\, A\, v^2\, \alpha \quad \text{newtons}$$

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 = torque

The maximum stress in the rudder material is to be limited to 77 MN/m^2.

Calculate EACH of the following:

(a) the diameter of the rudder stock required for a ship speed of 16 knots; (10)

(b) the speed to which the ship must be restricted, given that the effective diameter of the stock is reduced by wear and corrosion to 375 mm. (6)

7. Fig Q7 shows the results of progressive speed trials on a ship at a load displacement of 22350 tonne in sea water of density 1025 kg/m^3 with a wetted surface area of 4860 m^2.

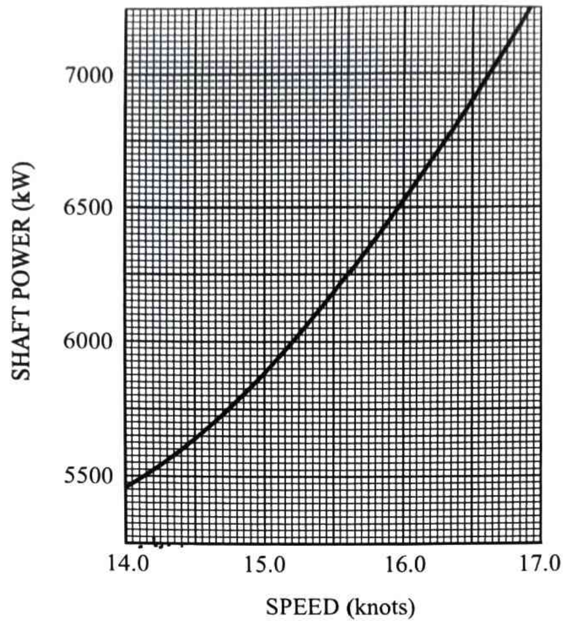

Fig Q7

A geometrically similar ship, having a load displacement of 29245 tonne in sea water, has to achieve a service speed of 17 knots.

Using the data given below, calculate the shaft power required for the similar ship.

Note: *allowance for appendages and weather in trial condition = 8%*
allowance for appendages and weather in service condition = 20%
propulsive coefficient based upon shaft power for trial and service conditions = 0.68
frictional coefficient for the 22350 tonne ship in sea water = 1.410
frictional coefficient for the 29245 tonne ship in sea water = 1.406
speed is in m/s with index (n) = 1.825

8. A vessel of 9250 tonne displacement is fitted with a propeller of 6.0 m diameter and pitch ratio 0.85.

During a fuel consumption trial of 8 hours duration, a steady shaft speed of 1.75 revs/s was maintained and 9.76 tonne of fuel was consumed.

The following results were also recorded:

real slip ratio	=	0.33
Taylor wake fraction	=	0.31
shaft power	=	5950 kW
transmission losses	=	3%
quasi propulsive coefficient (QPC)	=	0.71
propeller thrust	=	645 kN

Calculate EACH of the following:

(a) the speed of the ship; (4)

(b) the apparent slip ratio; (1)

(c) the propeller efficiency; (3)

(d) the thrust deduction fraction; (3)

(e) the fuel coefficient; (3)

(f) the specific fuel consumption. (2)

9. (a) Describe how a ship's propeller produces thrust. (4)

(b) Explain how the action of producing thrust may lead to propeller cavitation. (3)

(c) State the origin of vortex cavitation from the propeller cone. (1)

(d) Explain how a propeller blade may be eroded due to cavitation, describing the progressive nature of the damage. (8)