(20)

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 JULY 2022

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's double bottom tank is divided by an oiltight centre girder to form equal port and starboard tanks.

   The tanks are 16 m long and have a constant plan area defined by equidistant ordinates from the centre girder to the sides of the ship of:

   5.5, 5.0, 4.3, 3.5 and 2.5 metres.

   At a displacement of 11164 tonne in sea water of density 1025 kg/m^3, the centre of gravity is 5.733 m above the keel and both tanks are partially full of oil having a density of 900 kg/m^3 to a depth of 0.75 m.

   All of the oil in both tanks is now consumed and the position of the transverse metacentre remains constant.

   Calculate the change in effective metacentric height (16)

2. A ship of 5000 tonne displacement floats at a mean draught of 7 m when in sea water of density 1025 kg/m^3, but is unstable and has an *angle of loll.*

   Hydrostatic particulars for the ship in the upright condition at the above displacement are as follows:

centre of buoyancy above the keel (KB)	=	3.706 m
height of transverse metacentre above the keel (KM)	=	5.926 m
tonne per centimetre immersion (TPC)	=	10.0

   To achieve a satisfactory stable condition with a metacentric height of 400 mm, a load of 500 tonne is added to the ship on the centreline at a Kg of 2.5 m.

   Calculate EACH of the following, for the original unstable condition:

   (a) the height of the original centre of gravity above the keel (KG); (12)

   (b) the angle of loll. (4)

   Note: The vessel may be considered 'wall-sided' between the limits of draught, hence: $GZ = \sin\theta\,(GM + \tfrac{1}{2}BM\tan^2\theta)$

[OVER

3. The following particulars apply to a ship of 160 m length when floating in water of density 1025 kg/m^3 at an even keel draught of 8 m.

displacement	=	16000 tonne
centre of gravity above the keel (KG)	=	8.8 m
centre of buoyancy above the keel (KB)	=	4.5 m
waterplane area	=	2200 m^2
centre of flotation from midships (LCF)	=	4 m aft
second moment of area of the waterplane about a transverse axis through midships	=	2.5×10^6 m^4

(a) Calculate the moment to change trim by 1 cm (MCT 1cm). (6)

(b) The ship now has the following changes of loading:

250 tonne added with its lcg 10 m aft of midships;
100 tonne removed with its lcg at midships;
80 tonne moved 40 m aft.

Calculate the new end draughts of the ship. (10)

4. A ship of displacement 7700 tonne in sea water of density of 1025 kg/m^3 has a breadth of 20 m and a draught of 6.6 m.

The area of waterplane is 1800 m^2, KB is 3.6 m, KG is 4.5 m and the second moment of area of the waterplane about the centreline is 25000 m^4.

A rectangular wing tank of length 10 m and breadth 6 m is situated above a double bottom of depth 1.4 m as shown in Fig Q4.

Calculate the angle of heel that would occur if the wing tank where bilged. (16)

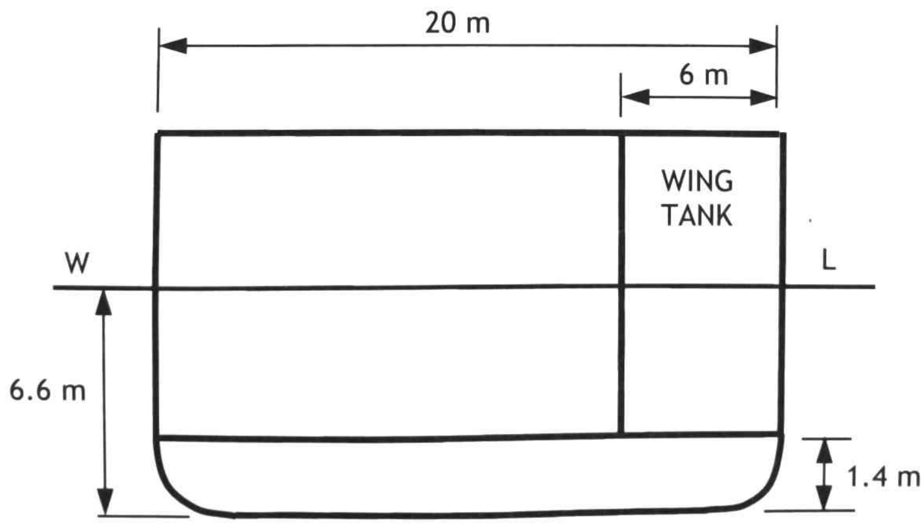

Fig Q4

5. A box barge of length 40 m is of uniform construction and has a displacement of 800 tonne when empty.

The barge is divided by three transverse bulkheads to form four holds of equal length.

Cargo is loaded as shown in Fig Q5, the cargo in each hold being uniformly distributed.

No. 4 hold	No. 3 hold	No. 2 hold	No. 1 hold
600 tonne	200 tonne	800 tonne	400 tonne

AFT FORWARD

Fig Q5

For this condition of loading:

(a) Verify that the barge has an even keel draught. (2)

(b) Using graph paper, draw to scale EACH of the following:

(i) the load diagram; (6)

(ii) the shear force diagram. (4)

(c) Determine the longitudinal position and value of the maximum bending moment, stating whether it is hogging or sagging. (4)

6. With reference to the testing of a ship model in a towing tank:

(a) define the term *corresponding speed;* (2)

(b) state *Froude's Law of Comparison;* (2)

(c) explain how the effective power of a ship can be estimated from a model test. (12)

7. A ship consumes an average of 70 tonne of fuel per day on main engines at a speed of 17 knots. The fuel consumption for auxiliary purposes is 8 tonne per day.

When 800 nautical miles from port it is found that only 140 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)

8. A model propeller of 0.45 m diameter and 0.95 pitch ratio, is tested in fresh water of density 1000 kg/m^3, at a constant speed of advance of 1.4 m/s.

The thrust and torque values for a range of rotational speeds are given in Table Q8.

Revs/s	4.25	4.50	4.75	5.00	5.25
Thrust (N)	34.5	50.6	69.0	89.2	110.0
Torque (Nm)	2.63	3.60	4.62	5.68	6.72

Table Q8

(a) Draw curves of propeller efficiency and delivered power against a base of real slip ratio for the model propeller. (9)

(b) Using the curves drawn in Q8(a), determine EACH of the following:

(i) the model propeller rotational speed for maximum efficiency; (4)

(ii) the delivered power for a geometrically similar ship's propeller of 6 m diameter, operating in sea water of density 1025 kg/m^3 at a real slip ratio of 0.34, given that delivered power is proportional to (diameter)$^{3.5}$. (3)

9. (a) Show that, when a ship is grounded on it's centreline during docking, the transverse stability of the ship reduces by: $\frac{P \times KM}{\Delta}$

Where: Δ is the displacement
KM is the distance from keel to metacentre
P is the upthrust at the point of grounding (8)

(b) A vessel 120 m long and 10000 tonne displacement enters dock with draughts 7.6 m aft and 6.7 m forward.

KM = 8 m
KG = 7.6 m.
MCT 1cm = 110 tm
LCF is at midships.

Calculate the GM at the instant the ship grounds on the blocks. (8)