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, 28 AUGUST 2020

0915 - 1215 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper

Examination Paper Inserts

Worksheet Q3 - 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

Marks will not be awarded unless relevant working is CLEARLY shown

1. A ship of length 180 m floats at its load draught with a displacement of 50000 tonne in sea water of density 1025 kg/m^3.

The longitudinal centre of buoyancy (LCB) is 1.80 m aft of midships.

In this condition, the forward of the ship displaces 23000 tonne and has a centre of displaced volume (lcb) 33.00 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)	370	354	330	272	172	95	0

Table Q1

For the new condition, calculate EACH of the following:

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

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

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

(b) A box shaped vessel is 40 m long, 10 m wide and floats at a draught of 4 m in sea water of density 1025 kg/m^3 with a KG of 3.883 m.

A beam wind acts on the exposed area of the vessel causing it to heel to an angle of 12°.

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

Heeling moment $= 850\,v^2\cos^2\theta$ Nm

where: 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 140 m long floats at draughts of 6.8 m aft and 4.4 m forward when floating in river water of density 1012 kg/m^3.

Using the hydrostatic curves provided in Worksheet Q3, determine EACH of the following:

(a) the displacement; (8)

(b) the longitudinal position of the centre of gravity. (8)

4. A vessel of constant rectangular section 80 m long and 12 m wide has a KG of 3.93 m and floats on an even keel draught of 5 m in water of density 1025 kg/m^3. The vessel is fitted with a transverse watertight bulkhead 10 m from the forward end.

The compartment forward of the transverse bulkhead, which has a permeability of 75%, is now damaged and laid open to the sea.

Calculate the new end draughts of the vessel. (16)

5. 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 the model test. (12)

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

$$F_n = 15.5\ A\ v^2\ \alpha \text{ newtons}$$

Where:

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

A ship travelling at a speed of 20 knots, has a rudder configuration as shown in Fig Q6.

The centre of effort for areas A_1 and A_2 are 32% of the width from their respective leading edges.

The rudder angle is limited to 35° from the ship's centreline.

Calculate EACH of the following:

(a) the diameter of the rudder stock required for a maximum allowable stress of 77 MN/m^2; (12)

(b) the drag component of the rudder force when the rudder is put hard over at full speed. (4)

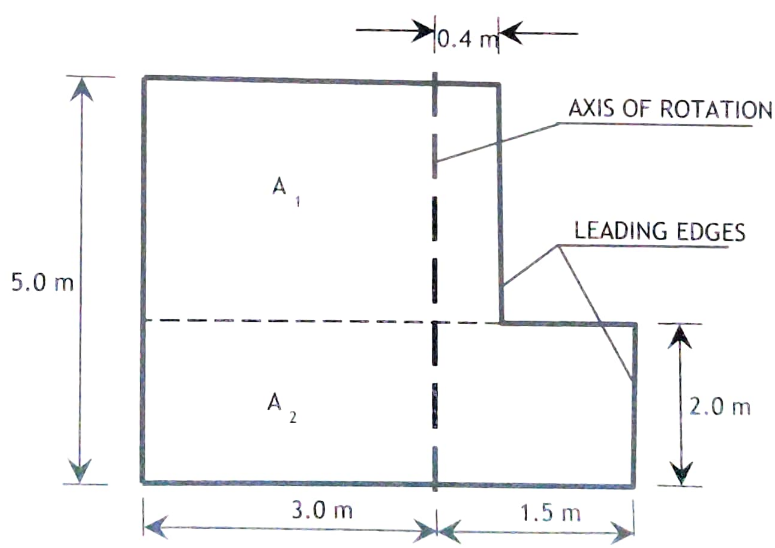

Fig Q6

7. The speed of a ship is reduced by 20% when 600 nautical miles from port, thereby reducing the daily fuel consumption by 42 tonne. The ship arrives in port with 60 tonne of fuel on board. The fuel consumption in tonne per hour is given by the expression:

$C = 0.14 + 0.001V^3$

where V is the ship speed in knots.

Calculate EACH of the following:

(a) the reduced daily fuel consumption; (6)

(b) the amount of fuel on board when the speed was reduced; (4)

(c) the percentage decrease in fuel consumption for the reduced speed part of the voyage; (4)

(d) the percentage increase in time for this latter part of the voyage. (2)

8. A ship 156 m in length, 22 m breadth, displaces 19700 tonne when floating at a draught of 8 m in sea water of density 1025 kg/m^3.

The ship's propeller has a diameter of 5.5 m, a pitch ratio of 0.9 and a blade area ratio of 0.45.

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

apparent slip ratio	=	0.05
thrust power	=	3250 kW
propeller efficiency	=	66%

Calculate EACH of the following for the above condition:

(a) the ship's speed; (3)

(b) the real slip ratio; (6)

(c) the thrust per unit area of blade surface; (4)

(d) the torque delivered to the propeller. (3)

Note: The Taylor wake fraction w_t is given by: $w_t = 0.5\,C_b - 0.05$

9. (a) Show that when a ship is grounded on its centreline during docking, the metacentric height 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 140 m long and 15000 tonne displacement enters dock with draughts 7.7 m aft and 6.8 m forward.

KM = 8.3 m
KG = 7.9 m
MCT 1 cm = 120 tm
LCF = 1.5 m forward of midships.

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