National Exams May 2016

98-Nav-B3, Small Commercial Ships

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK EXAM. Any non-communicating calculator is permitted.
3. FIVE (5) questions constitute a complete exam paper. The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

98-Nav-B3, Small Commercial Ships
Marking Scheme (this is part of the exam)

Marking Scheme

1. a) 5 marks
   b) 15 marks

2. a) 8 marks
   b) 8 marks
   c) 4 marks

3. a) 6 marks
   b) 7 marks
   c) 7 marks

4. a) 10 marks
   b) 10 marks

5. a) 5 marks
   b) 5 marks
   c) 5 marks
   d) 5 marks

6. a) 6 marks
   b) 7 marks
   c) 7 marks

7. 20 marks

Question 1
Propulsion

a) Draw the velocity vectors for flow approaching a section of a marine propeller, at 0.7 radius, and show how the pitch angle of the propeller blade is related to the resultant velocity.

b) A propeller design with the performance given below is available from a manufacturer.

Open water data for peak efficiency of propeller;

Propeller diameter	3.5 m
Pitch ratio	0.60

P/D	J	Kt	Kq
0.6	0.475	0.075	0.012

The ship's design data is given below.

Engine power	3750 kW
Propeller rate of rotation	4.5 rps
Ship design speed	10 m/s
Resistance at design speed	200 kN
Thrust deduction factor	0.20
Wake fraction	0.25

Assume ship is in salt water, with density 1025 kg/m^3.

Determine if the ship will make its design speed.

Useful Formulae
Propulsion

$J=V/ND$

$Kt=T/\rho N^2D^4$

$Kq=Q/\rho N^2D^5$

Question 2
Stability

A ship arrives in port in the condition given below.

Displacement	12000 tonnes salt water
Vertical centre of buoyancy (KB), above keel	3m
Metacentre (KM), above keel	10m

a) Estimate the value of the metacentric height (GM) and the distance from the keel to the centre of gravity for the ship based on the results of the inclining test given below.

Heeling weight	50 tonnes
Distance moved	20m
Heel angle	6.35 degrees

While unloading cargo at the port, it is planned to move a weight of 3000 tonnes from the bottom of the hold, to the main deck, a vertical change in centre of gravity of the weight of 14m. Will the ship remain upright in this condition? State any assumptions you make in your assessment.

b) Given the additional information below, for the ship in its original loading condition (when it arrived in port), estimate the heel angle that the ship will take after the cargo has been moved.

Heel angle, degrees	Righting arm, GZ, m
5	0.08
10	0.25
20	0.34
30	0.36
40	0.32

c) What is the maximum amount of weight that could be moved without producing an unstable ship?

Question 3
Design Alternatives

The president of your company has a hunch that there is a significant market for a high speed ferry service (top speed over 30 knots) across Lake Ontario. The region is characterized by waves with a significant height less than 1.0 metres, with occasional occurrences of up to 3.0m.

You have been asked to review possible combinations of hull shape and propulsion system prior to selecting the most promising option for detailed development.

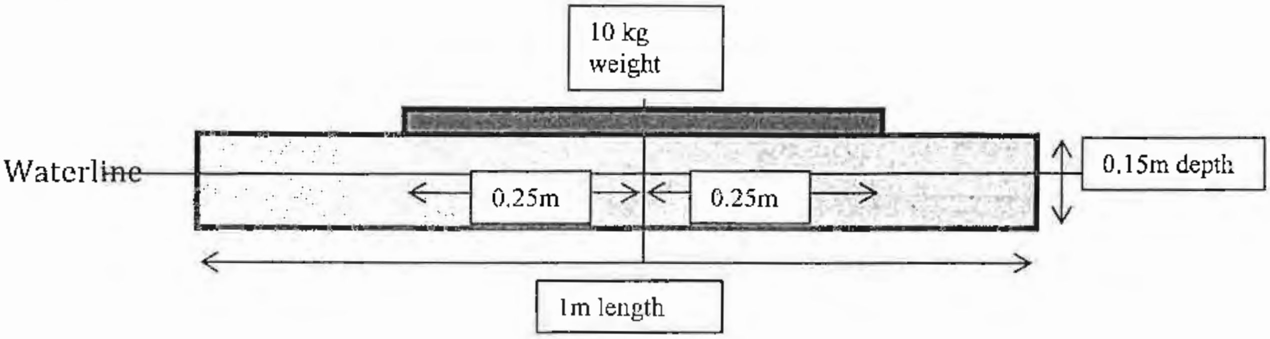
Some possible options for each are shown in the matrix below;

Hull/ propulsion	Semi-planing monohull	Planing monohull	Catamaran	Small Waterplane Area Twin Hull (SWATH) ship
Conventional propellers				
Water jets				
Azimuthing (steerable) podded propellers				
Super-cavitating propellers				

a) In your opinion, which are the four most promising combinations from a technical perspective? Explain your reasoning. Are there other possible options not considered in the matrix above?
b) Which elements of each combination do you think present the largest technical challenges?
c) What additional factors do you need to consider before you can determine the most feasible solution?

Question 4
Strength of Ships Structure

A rectangular block of wood, of uniform density, has a length of 1 metre, a breadth of 0.30m and a depth of 0.15m. Its mass is 20 kg. A weight of 10kg is added at the centre of the block. The weight is evenly distributed over 0.25m either side of the midpoint. The combined block and weight are floating in fresh water with a density of 1000 kg/m^3, as shown in the sketch below.



a) Calculate the shear force distribution along the long axis of the block of wood.
b) Calculate the bending moment distribution along the long axis of the block of wood.

Sketch the resulting curves, and identify all key points on the diagram with numerical values.

Question 5
Expected structural loads and materials used for construction

Small commercial ships are subjected to a variety of loads due to the environment within which they operate.

a) Identify the different types of environmental load that a small commercial ship can reasonably expect to encounter in operation.
b) Explain how the ship can be constructed to withstand each of these loads.

Small commercial ships can be made from a variety of materials, such as composites, steel or aluminum.

c) What are the primary advantages and disadvantages of each material discussed above?
d) Which of the three materials discussed above do you consider to be the most 'production friendly' and why?

Question 6
Ship Types and Regulations

a) Small commercial fishing boats have some unique operating features compared to other ships. Please describe them.
b) Stability of small commercial fishing boats has been a challenging issue for Naval Architects. Please explain why?
c) You have been asked to comment on a new proposal for fishing vessel stability regulations which requires that a maximum heel angle (e.g. 10 degrees) should result from a constant applied heeling moment (e.g. 5 tonne-m) combined with a minimum freeboard (e.g. 1.5m). Does this approach have merit?

You may use sketches and formulae to present your arguments for any part of this question.

Question 7
Design trade-offs for major ship systems

Describe all the factors that you would consider when selecting the main engines for a tug, which has the following requirements;

Length overall; 24 metres
Beam overall; 8 metres
Propellers; 2
Required Bollard pull: 60 tonnes

Explain why each feature you discuss is important, and what influence it may have on other aspects of the design. Use practical examples to illustrate your answer where you can.