National Exams December 2019

16-Nav-A3, Hydrodynamics of Ships (II): Ship Motion

3 hours duration

NOTES:

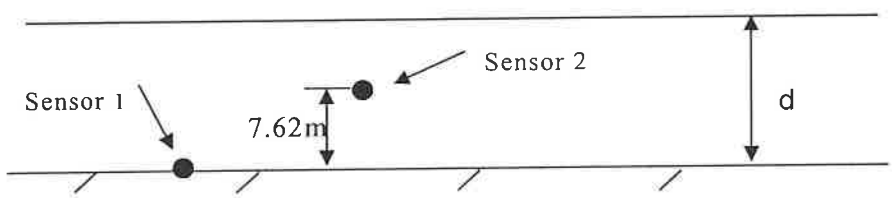
1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK EXAM. Only one formula sheet (8.5"x11" and two sided) is allowed. Approved Casio or Sharp calculator is permitted.
3. Six (6) questions constitute a complete exam paper. The first six questions as they appear in the answer book will be marked.
4. The value of each question is noted in square brackets. The total value of the questions is 100.
5. Clarity and organization of the answer are important.

1.(25 marks) Explain the following terms

(a) [5] Please list and illustrate four kinds of motion stabilities in ship maneuvering
(b) [5] Froude-Krylov force
(c) [5] Wave slope
(d) [5] Added mass
(e) [5] Hydroelasticity of the ship. List two of the hydroelastic analysis methods of ships and ocean structures.

2. (10 marks)

Two pressure sensors are located as shown in the sketch below. For an 8-second progressive wave, the dynamic pressure amplitudes at sensors 1 and 2 are 20,700 N/m^2 and 25,600 N/m^2, respectively. What are the water depth, wave height, and wave length? Note that the second-order term associated with the velocities can be neglected in the calculation of the dynamic pressure.



3.(25 marks)

A ship is heading at an angle of 150^0 relative to the wave direction at a speed of 20 knots.
a).[20] Plot the magnification factors for rolling against the tuning factors for wave frequencies ω_w ranging from 0.1 to 0.4 at an interval of 0.1. The relevant dimensions of the ship are as follows:

$L_{WL} = 450 ft;$ $k_x = 30.8 ft,$ $\overline{GM}_T = 5.79 ft,$ $\Delta = 12500 tonnes.$

The added moment inertia in roll is 20% of the moment inertia of the ship, and the damping moment is $32000(d\phi / dt) ft - tonnes$.
b). [5] Find the amplitude of the **maximum** rolling motion the ship will experience if the wave height is taken to be 60 ft.

4. (20 marks)

A ship of length =100 m carrying a 40,000 kg container travels at 10 knots in an irregular head seas. The significant wave height for the irregular seaway is 8m. The seaway is described by the ITTC spectrum, $S(\omega) = \frac{A}{\omega^5} e^{-B/\omega^4}$ $(cm^2 - \sec)$ where A= $8.1 \times 10^{-3} g^2$, $B = 3.11 \times 10^4 / H_{1/3}^2$, $H_{1/3}$ is in cm, g is the acceleration of gravity in cm/sec^2, and ω is the wave frequency in rad/s.

RAO's of the ship (at CG) in terms of wave frequency are given as below:

$\omega\,(rad/s)$	0.3	0.4	0.5	0.6	0.7	0.8
Heave (m/m)	0.90	0.90	0.92	0.95	0.98	0.75

(a) [5] Find the wave energy for the given sea state.
(b) [10] Calculate the significant heave amplitude for the given sea state.
(c) [5] Find the significant vertical acceleration right on the C.G.

5. (10 marks)

For a box-shaped barge of $L \times B \times T$ with a depth D in a wave $\eta(x,t) = \eta_a \sin(kx - \omega t)$, where $k = 2\pi/\lambda$, λ =wave length.

Show that (1). Wave exciting force of heave :

$$F_1/\rho g \eta_a = -\frac{BL}{\pi}\frac{\lambda}{L}\sin(\frac{\pi L}{\lambda});\sim F_2/\rho g \eta_a = 0$$

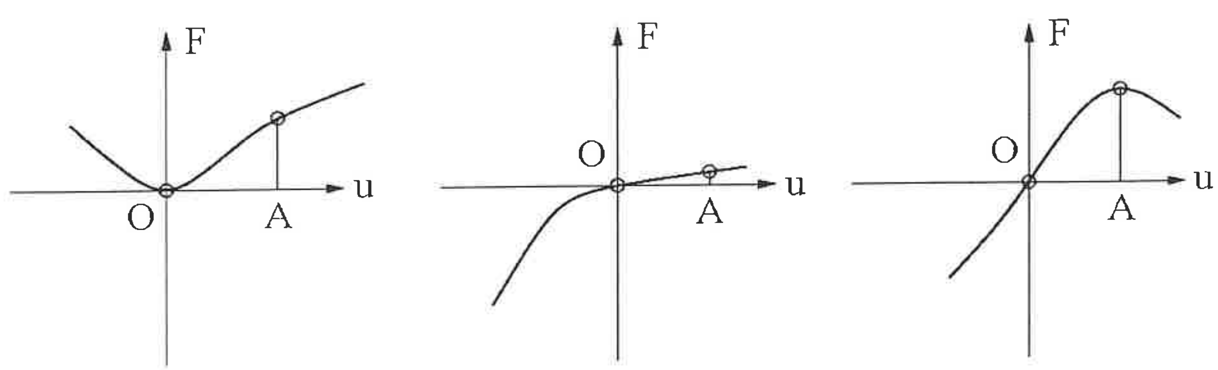
(2). Wave exciting moment of pitch:

$$M_1/\rho g \eta_a = 0; \qquad M_2/\rho g \eta_a = \frac{BL^2}{2}(\frac{\lambda}{\pi L})^2[\sin(\frac{\pi L}{\lambda}) - \frac{\pi L}{\lambda}\cos(\frac{\pi L}{\lambda})];$$

6. (10 marks) Please try any one of the following two questions.

(a).[10]

The figures below shows some characteristic fluid force curves versus forward velocity. Given the linear hydrodynamic derivatives at two different operating conditions, (origin O and A), please state the hydrodynamic derivatives are (a) zero; (b) small; (c) finite positive or (d) finite negative?



(b).[10]

An 8000 ton ship, length L=160m and draft T= 6m, has the hydrodynamic derivatives as follows:

$Y_v^{'} = -0.31, \quad Y_r^{'} = 0.0822, \quad N_v^{'} = -0.1073, \quad N_r^{'} = -0.0871, \quad Y_\delta^{'} = 0.0777, N_\delta^{'} = -0.03$

Calculate the steady turning radius at 35 degree rudder angle. Note that the CG of the ship is located at the origin.