Faculteit der Werktuigbouwkunde & Maritieme Techniek
Sectie Scheepshydromechanica

Sample Exam questions
Module 2 Offshore Hydromechanics OE 4620

READ THIS FIRST:

- **No books / personal notes allowed**
- **Write clearly**
- **Always give dimensions of calculated results !!**

- **Useful formulae:**
  - $\cos(a+b) = \cos(a) \cdot \cos(b) - \sin(a) \cdot \sin(b)$
  - Mass moment of inertia roll:

    $I_{xx} = k_{xx}{}^{2} \cdot \Delta$

    where :

    I_{xx} = mass moment of inertia [kg m^2]

    k_{xx} = roll radius of gyration [m]

    Δ = displacement mass [kg]

Linear Potential Theory

1 Give a definition of "velocity potential". (1 pt)

2 The velocity potential can be split into three parts. Which three are these? (1 pt)

3 Give the boundary condition at the body surface for all three parts. (1 pt)

The six degrees of freedom motion equation for an arbitrary floating body (not necessarily symmetric) is given below:

$$\begin{bmatrix} M+a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & M+a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & M+a_{33} & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & I_{xx}+a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & I_{yy}+a_{55} & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & I_{zz}+a_{66} \end{bmatrix} \cdot \begin{pmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \\ \ddot{\varphi} \\ \ddot{\theta} \\ \ddot{\psi} \end{pmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} & b_{16} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} & b_{26} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} & b_{36} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} & b_{46} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & b_{56} \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & b_{66} \end{bmatrix} \cdot \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \\ \dot{\varphi} \\ \dot{\theta} \\ \dot{\psi} \end{pmatrix} + \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} \\ c_{21} & c_{22} & c_{23} & c_{24} & c_{25} & c_{26} \\ c_{31} & c_{32} & c_{33} & c_{34} & c_{35} & c_{36} \\ c_{41} & c_{42} & c_{43} & c_{44} & c_{45} & c_{46} \\ c_{51} & c_{52} & c_{53} & c_{54} & c_{55} & c_{56} \\ c_{61} & c_{62} & c_{63} & c_{64} & c_{65} & c_{66} \end{bmatrix} \cdot \begin{pmatrix} x \\ y \\ z \\ \varphi \\ \theta \\ \psi \end{pmatrix} = \begin{pmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{pmatrix}$$

Suppose you know the radiation potential for heave $\phi_3(x,y,z,t)$ (This is the potential due to the oscillatory heave motion.) Which coefficients in the motion equation above can you calculate with this and how can you calculate them? (1 pt)

4 Suppose you want to determine the added mass and damping of a floating structure experimentally over a frequency range. Describe the kind of experiment you'd have to carry out and how the desired coefficients can be determined from the measurement results. (1 pt)

Hydrodynamics

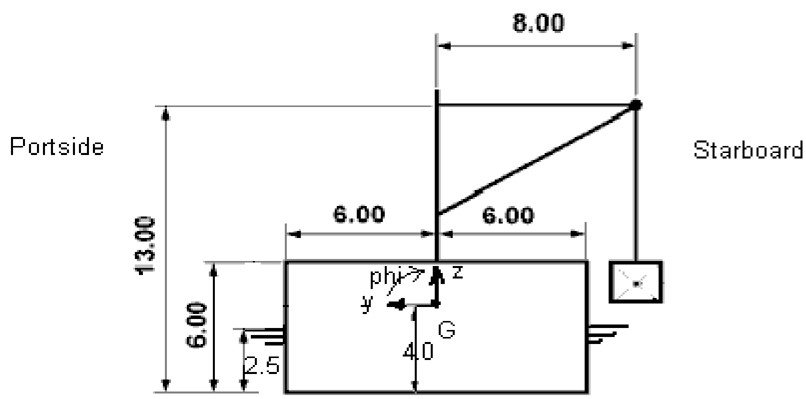


Figure 1

Consider the pontoon of Figure 1.
Imagine the pontoon is floating in beam waves in open sea.
Motion analysis of the pontoon in regular beam waves (coming from Portside) having a frequency of 0.75 rad/s resulted in the following Response Amplitude Operators (RAO) and phase angles for Heave and Roll:

Heave:

$\frac{z_a}{\zeta_a} = 1.1$, $\varepsilon_{z,\zeta} = 11^\circ$

Roll:

$\frac{\varphi_a}{\zeta_a} = 4.0$ deg/m , $\varepsilon_{\varphi,\zeta} = 185^\circ$

(the phase angles are given with respect to the incident wave at G.)

To assess the loads in the crane tip, the local accelerations at the crane tip are to be calculated.

5 Using the given RAO's and phase angles at the given frequency, determine amplitude and phase angle of the <u>vertical</u> (z-direction) motion and acceleration at the crane tip in regular beam waves from PS. (3 pt)

Answer:

$$\frac{z_{a,P}}{\zeta_a} = 1.65, \varepsilon_{z_P,\zeta} = 8.98$$

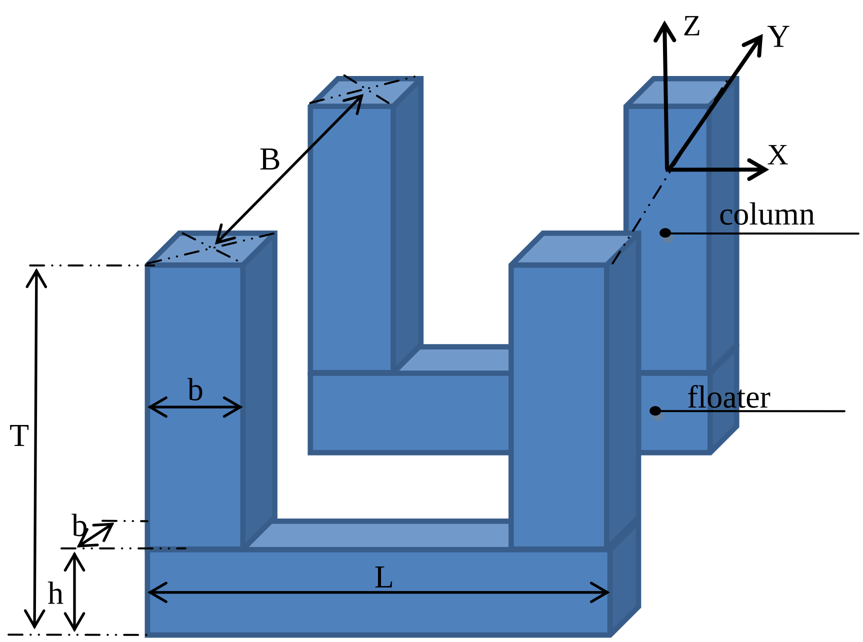
$$\frac{z_{a,P}}{\zeta_a} = 0.93, \varepsilon_{z_P,\zeta} = 188.98$$

6 **Would the vertical accelerations at the crane tip be different if the waves came from starboard ? (If yes, explain why, if no, explain why not.) (1 pt)**

In addition to the calculations that gave the motion transfer functions, model experiments were carried out. A difficulty that is often encountered with model experiments for sea keeping behavior is the tuning of the mass moments of inertia.

7 **If the k_{xx} value of the used model is not accurately matching the desired value, at what frequency (range) would you expect errors in the measured transfer function for the roll motion? (1 pt)**

Wave exciting roll moment on semi-sub



See above a sketch of the submerged part of a semi-submersible with 4 identical columns with square cross sections of size b x b. The height of the floaters is h. The total draft is T and length is L.
The transverse distance between the column centres is B.

The axis system connected to the structure has its origin exactly half way between the portside and starboard columns and at the bow of the semi-sub.
Let's consider the roll moment due to undisturbed incoming waves traveling in Y-direction, the so-called Froude-Krilov roll moment. Assume waves with amplitude ζ_a, frequency ω and wave number k.

8 Which parts of the structure contribute to the roll moment due to the undisturbed incoming waves? (choose from: floater sides, floater tops, floater bottoms, column sides) Explain your answer. (0.5 pt)

If we assume the wave length is very long compared to b, the calculation of the roll exciting moment simplifies drastically: instead of integrating pressures over surfaces, one can just multiply pressures with surface areas in order to obtain forces and besides, some of the contributions mentioned in the previous question will vanish.

9 Assuming the above mentioned simplification, calculate the expression for the Froude Krilov roll moment. (0.5 pt)

10 Prove that (still assuming above mentioned simplification) the Froude Krilov roll moment is zero under the following condition: $\frac{2b}{L} = 1 - e^{-kh}$ (where h is the floater height, k is the wave number) (0.5 pt)

11 Is there another condition for which the Froude Krilov roll moment can be zero? If yes, give this condition in terms of the mentioned wave characteristics and semi-sub dimensions. (0.5 pt)

As mentioned, the origin of the axis system is located at the bow and not at the Centre of Gravity which is quite unusual. As a result there will be strong heave pitch coupling.

12 Determine the pitch-heave coupling restoring coefficient c_{53} (0.5 pt)