Exam OE4630D1 Offshore Hydromechanics Module 1
Wednesday October 27th 2010
09:00-12:00u

Instructions

1. Be sure to put your name and student number on each submitted page. The questions are stated in English. Answers may be given using either Dutch or English.
2. This quiz includes 4 groups of questions, each associated with one of the chapters 2 through 5. An extensive formula sheet is included at the end of the exam.
3. No book or notes allowed during the exam. You are required to include in your answers full calculations and motivations.
4. Finish all questions to complete the exam. A maximum of 38 points can be earned.

1 Hydrostatics and stability (10 points)

1.1 A rectangular barge loaded with *150* basalt blocks enters a lock (situation 1 in the figure below). After closing the doors of the lock the water level in the lock equals $h = 4.5\ m$, resulting in situation 2 in the figure below.

The dimensions of the barge are:

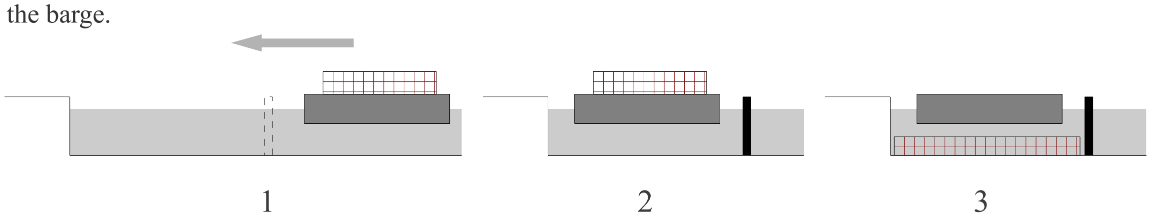
Length	L	*60.00*	*m*
Beam	B	*8.00*	*m*
Displacement	∇	*900*	m^3 (including basalt blocks)
Height center of gravity	KG	*2.10*	*m* (including basalt blocks)
Number of blocks	n	*150*	-
Dimensions per block	$dxdxd$	*1.0x1.0x1.0*	*m*
Density basalt	ρ_b	*3011*	kg/m^3
Location center of gravity basalt		*2.50*	*m* (above baseline, *K*)

The dimensions of the lock:

Length	L_{lock}	*100.00*	*m*
Width	B_{lock}	*10.00*	*m*
Density water in lock	ρ	*1000*	kg/m^3

a Determine (1) the *GM* and (2) the *clearance* between the bottom of the loaded barge and the bottom of the lock. *(2 points)*

Now, while the doors of the lock remain closed, the 150 basalt blocks are dumped into the water of the lock in such way that they are all fully submerged (situation 3 in the figure below). There is no contact between the blocks and the barge.



b Determine (1) the *GM* and (2) the *clearance* between the bottom of the <u>unloaded</u> barge and the bottom of the lock. *(3 points)*

1.2 On an internet forum the following question is posted (I slightly edited an actual question asked by "DanishStudent2" on http://www.physicsforums.com/archive/index.php/t-21821.html). Could you help out DanishStudent2?

> **Calculating the tilt (=heeling angle) of a floating box?**
> Does anyone know how to calculate the angle at which the box will tilt, if the center of mass is above the center of buoyancy?
>
> Suppose we have a box with the dimensions:
>
> | | | | |
> |---|---|---|---|
> | Width | *W* | *15.4* | *cm* |
> | Length | *L* | *27.4* | *cm* |
> | Heigth | *H* | *27.0* | *cm* |
> | Mass | *m* | *4796.5* | *grams* |
>
> The center of mass lies *8 cm* above the underside of the box.
>
> I cannot figure out how to calculate the angle at which the box will tilt. Any ideas? :confused:

a Use the techniques of the class to formulate an answer to his question. Assume suitable values for parameters when necessary. *(3 points)*

b Is the answer you formulated in **a** exact? Motivate with a short calculation. *(2 points)*

2 *Potential Flow (12 points)*

2.1 The following potential function is given in cylindrical coordinates r and θ:

$$\Phi = A(r + B/r)\cos\theta$$

a Show that the this potential function represents the flow (of an ideal fluid) around a long cylinder. *(2 points)*

b Evaluate the constants A and B if the cylinder has $R = 40\ mm$ as radius and the velocity of the main flow is $u_\infty = 3\ m/s$. *(2 points)*

c Derive expressions for (1) the tangential and (2) radial velocities and (3) for the stream function ψ. *(3 points)*

d Evaluate the location and magnitude of the largest velocity on the cylinder wall. *(2 points)*

e Derive an expression for the pressure distribution along the cylinder wall. Compute the location and magnitude of the highest and lowest pressures along the cylinder wall, the latter expressed in terms of the pressure coefficient:

$$C_p = \frac{p - p_0}{1/2\,\rho u_\infty^2}$$ *(3 points)*

3 *Real Flows (8 points)*

3.1 We again consider the cylinder from the previous question.

a Sketch the pressure coefficient along the cylinder wall (1) in a potential flow (corresponding to question 2.1 d) and (2) in a real (viscous) flow (x-axis coordinate along the cylinder wall, y-axis pressure coefficient). *(2 points)*

b Indicate in words the difference between both pressure distributions and the mechanism behind this difference. Explain how resistance plays a role in this mechanism. *(2 points)*

3.2 Froude number and Reynolds number:

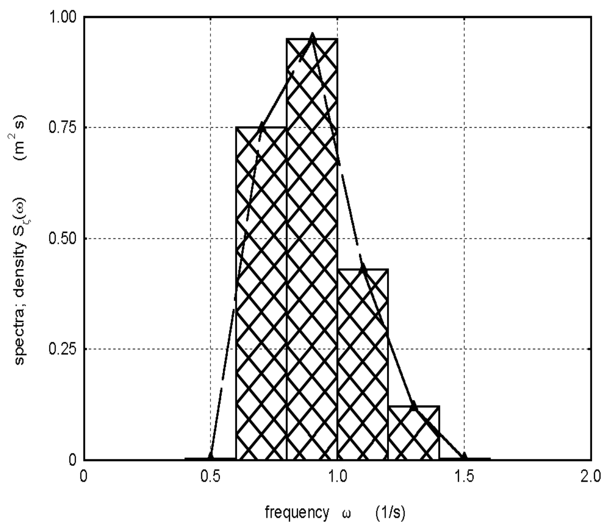
a What is the physical meaning of keeping the Froude number identical at model scale and full scale. *(1 point)*

b What is the physical meaning of keeping the Reynolds number identical at model scale and full scale. *(1 point)*

c Explain why it is practically impossible to keep both constant for model scale and full scale. *(2 points)*

4 *Waves (8 points)*

4.1 A simplified wave energy spectrum of a storm in the North Atlantic Ocean, measured by a wave buoy, is given by:



ω	*rad/s*	0.50	0.70	0.90	1.10	1.30	1.50
$S_\zeta(\omega)$	m^2s	0.00	0.75	0.95	0.43	0.12	0.00

Sketch and data for a wave spectrum

a Calculate the significant wave height, $H_{1/3}$, and the mean wave periods T_1 and T_2. *(2 points)*

b Determine the probability P of exceeding a wave height of 3.50 meters in this storm, by using the Rayleigh probability density function. *(1 point)*

c Compute the maximum expected wave height during 1 hour. *(1 point)*

d Determine also the number of times per hour that this wave height will be exceeded. *(2 points)*

e What is the probability that the significant wave height $H_{1/3}$ will be exceeded? *(2 points)*