EN400

LAB #9

SEAKEEPING

Instructions

1. This lab is conducted in the Hydromechanics Lab on the ground floor of Rickover Hall.

2. Prior to arriving, read through the lab procedure so that you are familiar with the steps necessary to complete the lab.

3. Bring this handout and a calculator to the lab.

4. The lab is to be performed as a whole class. Your instructor will specify whether each small lab group or each individual must submit the completed lab.

5. Follow the stages of the lab in consecutive order. The lab follows a logical thought pattern and jumping ahead without completing the intervening theory questions will limit your understanding of the concepts covered.

6. For full credit, all work must be shown on the lab. Show generalized equations, substitution of numbers, units, and final answers.

7. Keep your workstation (including the floor) clean and dry. Ensure all equipment and the models are returned to their original location when you complete the lab.

Student Information:

Name(s): ______________________________________________________

Section: __________

Date: __________

Note: This lab does not have a pre-lab.
**Part 1: General Questions**

1. In your own words define “simple harmonic motion.”

2. Which of the six ship motions can exhibit simple harmonic motion?

3. What is unique about the motions that can exhibit simple harmonic motions?

4. In your own words, define “natural frequency” of a system.

5. In your own words, define a “forcing function” or “excitation force.”

6. What happens when the frequency of the forcing function is the same as the frequency of the natural frequency of the system?

7. In your own words, define “damping,” as related to simple harmonic motion.

8. On the axes below, sketch motion displacement against time.

   - Under Damped
   - Critically Damped
   - Over Damped
Part 2: Mass/Spring System

Apparatus

The apparatus for this part of the lab consists of a mass/spring system vertically aligned, per Figure 1. The vertical scale allows the motion displacement of the mass to be recorded.

![Figure 1 Mass/Spring System](image)

Theory

The equation that describes the natural period of heave without damping of a simple mass-spring system is:

\[ T = 2\pi \sqrt{\frac{m}{k}} \]

where:
- \( k \) is the spring force constant in lb/ft
- \( m \) is the mass of the system in lb-s\(^2\)/ft
- \( T \) is the period in s

Procedure

9. Calculate the spring constant of the spring. This is required to enable the use of the equation for the natural period.

10. Place different weights on the system and record the corresponding deflection in the table:
    (Note: the unloaded weight is appx 1.5 lb)

<table>
<thead>
<tr>
<th>Weight (lb)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. Plot this data on the grid below. **Ensure you label the axes correctly.**

12. Determine the slope of your plot and use it to calculate the spring constant, $K$.

   **Hint:** Compare the units of the spring constant, $K$, with the units of the plot’s slope

13. For a total weight of 2.5 lb on the mass/spring system, calculate its mass $M$ in lb-s$^2$/ft

14. Use this data and the “Natural Period of Heave” equation provided above to predict the period of oscillation for the mass/spring system.
15. Use the table below to find the period of oscillation of the mass/spring system. For each trial, record the time for at least 5 oscillations.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time for 5 Oscillations (s)</th>
<th>Period (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
<td></td>
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<tr>
<td>#3</td>
<td></td>
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</tbody>
</table>

Average Period =

16. Calculate the percentage error of the experimentally found period of oscillation and that calculated.

Follow-up Questions
17. The mass/spring system that has been analyzed can be used to model one of the ship motions. Which motion is this?

18. When modeled in this way, what ship parameter is equivalent to the mass, M?

19. What ship parameter is equivalent to the spring constant, K? **Hint:** Consider units

20. What damps the motion of the mass/spring system?

21. What damps the ship motions?

22. Which system (spring or ship) is subjected to the greater level of damping?
Part 3: Roll Model

Apparatus

This part of the lab is performed in the 120' towing tank. A ship model is tethered across the tank to prevent it from yawing or swaying down the tank. The model is instrumented to measure the amplitude of roll and heave motions.

Theory

The equation that describes the natural period of roll of a ship is as follows:

\[ T_{\text{roll}} = \frac{CB}{\sqrt{GM_T}} \]

where:  
- \( C \) is the roll constant in \( \text{s/ft}^{0.5} \).
- \( B \) is the beam of the ship at the operating water line in ft.
- \( GM_T \) is the metacentric height in ft.

The value of the roll constant \( C \) is usually found experimentally. If not known, a value of 0.44 \( \text{s/ft}^{0.5} \) is used.

Procedure

23. Determine the roll period of the model and use this to find its metacentric height. This is often referred to as a “Sallying Experiment”. For each trial, record the time for at least 3 oscillations. **Wait for the water disturbance to subside between each trial.**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time for 3 Roll Oscillations (s)</th>
<th>Roll Period (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td></td>
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<tr>
<td>#2</td>
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<td>#3</td>
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</tbody>
</table>

**Average Roll Period =**

24. Using the average roll period found above, calculate the metacentric height of the model.

25. Is the calculated metacentric height reasonable? ________________________________
26. Using the value for the average roll period, calculate the natural frequency of the roll motion \( (\omega_{\text{roll}}) \). Calculate this frequency in rad/sec.

Five wave systems will be created to simulate various encounter frequencies. One encounter frequency will be at your computed value for natural frequency in roll and the rest will be above and below the natural frequency.

27. What frequency will produce the largest roll response from the model?

28. Observe the model response for each frequency and record the data.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Wave Frequency</th>
<th>Roll Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
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<td>#2</td>
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29. How does the data agree with your prediction? _________________________________
________________________________________________________________________

30. Plot the response data in the area provided. Notice the response peak near the calculated natural frequency.