EN400

LAB #3 PRELAB

INCLINING EXPERIMENT

Instructions

1. The prelab covers theories that will be examined experimentally in this lab.

2. The prelab is to be completed and handed in to your instructor at the beginning of the lab period.

3. If you can, answer the questions without referring to your notes. Only refer to your notes if you are confused or fail to understand a concept. This will greatly improve your understanding of the concepts this lab is designed to reinforce.

4. By conscientiously completing this prelab, you will have a thorough understanding of what the lab is trying to show. Your lab performance will be maximized.

5. For full credit, all work must be shown. Show generalized equations, substitution of numbers, units, and final answers. Engineering relies on communication. Work that is neat and shows logical progression is much easier to grade.

Student Information

Name(s): _____

Section: _____

Date: _____

Lab Apparatus

A small ship model, (27-B-1 model), will be inclined to port and starboard by shifting 4 x 0.2 lb weights in several combinations between three posts. The resulting moments will incline the ship and the angle of list from each weight shift will be measured with a pendulum assembly.

Before the inclining experiment can begin and the inclining weights and equipment added, the 27-B-1 model will be in its light-ship condition. This is with the model holding the solid floored tank internally with the solid floor down.

Theory

The major goal of the inclining experiment is to find an accurate value for the vertical height of the center of gravity above the keel (KG). This is performed after a ship has been launched and fully equipped, or after any major refit where it is considered that there may have been a significant alteration to KG.

The life-sized experiment is conducted alongside the pier, in calm water, and with the ship free to list. The following major steps are then performed.

Light-ship Condition

The Inclining Experiment is usually performed with the ship in its light-ship condition. The light-ship displacement (Δ_{light}) is defined by *Introduction to Naval Architecture, p131* as:

> *The weight of the ship complete in every respect, including hull, machinery, outfit, equipment, water in the boilers at steaming level, and liquids in machinery and piping, but with all tanks and bunkers empty and no crew, passengers, cargo, stores, or ammunition on board.*

It is necessary to determine Δ_{light}, the displacement of the light-ship. This is achieved inport by observing the forward and aft draft marks and consulting the ship's curves of form. In this step, it is also important to accurately know the density of the water the ship is floating in.

1. Why is water density important? _____

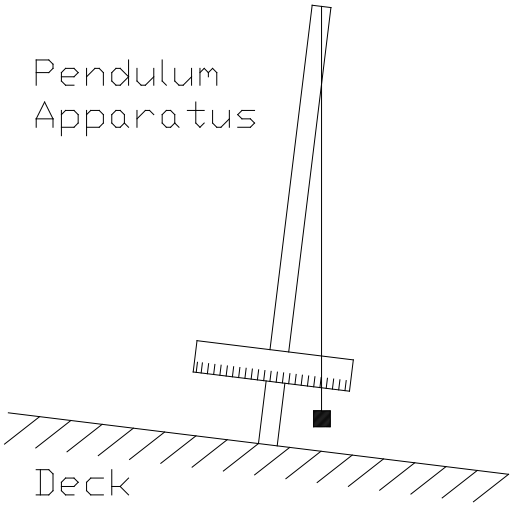
   _____

2. Show the equation that demonstrates the relationship between the <u>displacement</u> of a ship and the water <u>density</u> it is floating in.

Addition of Inclining Weights and Apparatus

The inclining weights and apparatus are brought on board. Typically, the inclining weights are approximately 2% of Δ_{light}. With the inclining weights and apparatus on board, the ship is said to be in an inclined condition. All quantities are then given the inclined suffix. For example Δ_{incl}, KG_{incl}.

The inclining apparatus consists of a pendulum on a mast that is positioned so that the pendulum is free to swing in the transverse direction. Figure 1 below shows the typical pendulum arrangement. It is used to record the tangent of the inclining angle.



3. On Figure 1, <u>show</u> the inclining angle (ϕ) and the adjacent and opposite sides (d_{adj} and d_{opp}) to the triangle that allows the calculation of tan ϕ.

   Based on the geometry, <u>give</u> the equation for tan ϕ in terms of these quantities

Figure 1 Inclining Apparatus

The height of the center of gravity of the inclining apparatus and weights is important to know. On full scale ships, the weight of the pendulum is insignificant, but for our model it does have a significant effect.

These distances are often termed $Kg_{pendulum}$ and $Kg_{weights}$ respectively.

Inclining the Ship

With these stages complete, the inclining can then proceed. The theory behind the experiment is evident when considering the diagram of the inclined ship in Figure 2.

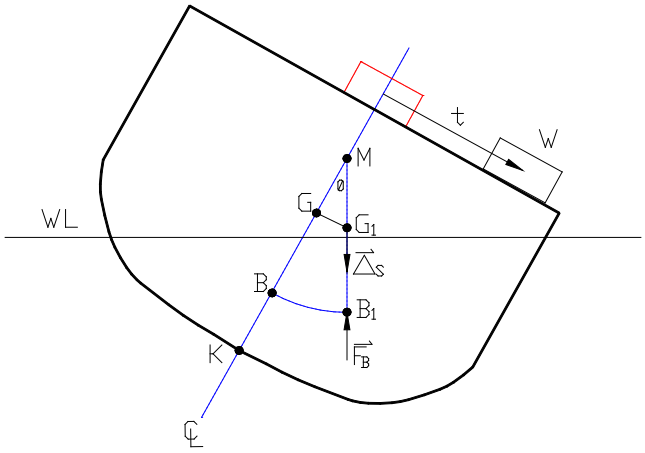


Figure 2 The Inclining Ship

4. Give the geometric relationship between the angle of inclination (ϕ) and the distances GG_1 and GM_{incl}.

The distance GG_1 can also be determined from the weight being shifted (w) and the distance it is moved (t).

$$TCG_{NEW} = \frac{TCG_{OLD}\Delta_{OLD} + w_i tcg_i}{\Delta_{NEW}}$$

Tcg = t. When a ship's TCG_{OLD} = 0ft, then GG_1 = TCG:

$$GG_1 = \frac{wt}{\Delta}$$

5. Combine the geometric triangle and weight shift equations to solve for GM_{incl}.

At each angle of inclination, the tangent of the inclining angle (tan ϕ) is recorded. A plot is then made of inclining moment (wt) against tan ϕ. This data plots as a straight line and a line of best fit can be placed through this data. The slope of this line can then be determined.

6. Write an expression for the slope in terms of the measured quantities.

7. Combine this with the previous expression to find GM_{incl} in terms of the slope of the plot.

Finding KG_{incl}

With a value for GM_{incl} calculated, determining the distance KG_{incl} is fairly straightforward.

8. On Figure 3, insert the locations of the Keel (K), the center of buoyancy (B), the center of gravity (G) and the transverse metacenter (M). Assume all centroids are on the centerline. Also show the distances KM, GM and KG.

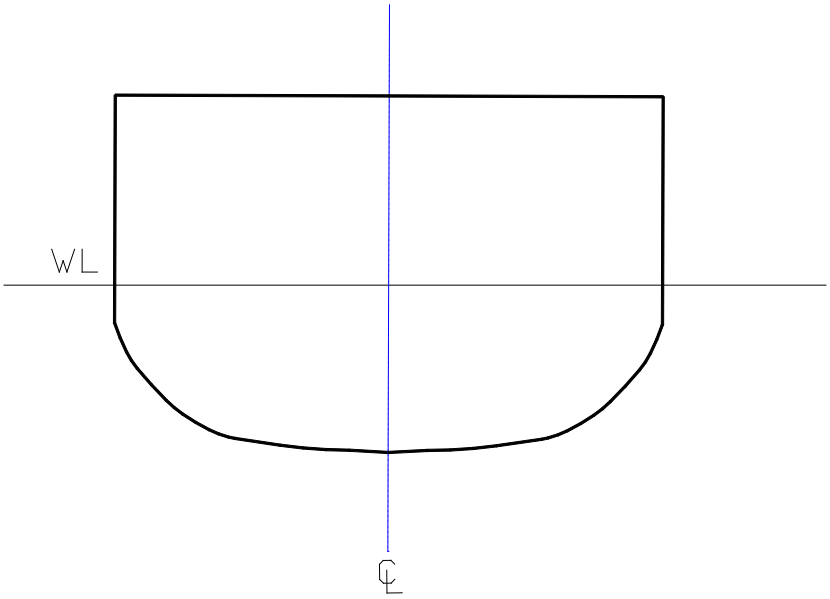


Figure 3 The Upright Ship

9. Use Figure 3 to determine an expression for KG_{incl} in terms of GM_{incl} and KM.

10. Where would you obtain a value for KM? _____

Removing the Inclining Weights and Apparatus and Finding KG_{light}

The final stage in the experiment is to correct the value of KG_{incl} for the removal of the inclining weights and apparatus to obtain KG_{light}.

11. Give the general expression for the new KG of a ship after the removal or addition or shift of a weight.

This equation can be applied to the removal of the inclining equipment given the following:

w_{wt} - The weight of the inclining weights.
Kg_{wt} - The height of the center of gravity of the weights above the keel.
w_{pend} - The weight of the pendulum apparatus.
Kg_{pend} - The height of the center of gravity of the pendulum above the keel.

12. Apply all of the above terms to the general expression to find the mathematical expression for KG_{light}.

The calculation of KG_{light} is the **FINAL GOAL** of the inclining experiment. The height of G above the keel is vitally important in determining the stability characteristics of the ship, which will be explored in future labs.

EN400

LAB #3

THE INCLINING EXPERIMENT

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, the completed prelab, and a calculator to the lab.

4. The lab is to be performed in small groups of 2 or 3. Your instructor will specify whether the 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: _____

Apparatus

1. Before beginning the experiment, ensure the 27-B-1 model number corresponds with the number on the solid floored tank, the pendulum assembly and the tank. Record the data below, as you will need to use the same model in the next three EN400 labs.

27-B-1 model number = _____

Light-ship Condition

The first step is to ensure the model 27-B-1 is in its light-ship condition. This is achieved by the following:

- Ensure all detachable weights are off the model (4 x 0.2 lb weights and pendulum apparatus). **Do not** remove the transverse weights used to adjust list.
- Ensure there is no loose water within the central compartment.
- Ensure the **solid floored tank** with its solid side down is securely installed in the center compartment. (Note: improperly securing the tank may alter your data!)

2. **Important!** You will need to know the height of center of gravity for the inclining weights and pendulum for future calculations. Measure and record their respective kg's before placing the model in the tank.

Carefully place the 27-B-1 model in the water. Make sure it is floating freely and is not being inhibited by the tank sides and appendages.

3. Using the curves of form, determine the light ship weight, $\Delta_{light,}$ for the actual water temperature. (The displacement from the curves of form is for fresh water @ 59 ^{o} F.)

4. In this inclining experiment, the inclining weights consist of 4 x 0.2 lb weights. Use the scale to determine the weight of pendulum apparatus ($w_{pendulum}$). Record this data in the table below and calculate the weight of the inclined model (Δ_{incl}).

Displacement in light-ship condition, Δ_{light} (lb)	
Weight of inclining weights, $w_{weights}$ (lb)	
Weight of pendulum apparatus, $w_{pendulum}$ (lb)	
Displacement in inclined condition, Δ_{incl} (lb)	

The model should be freely floating in the tank with the inclining weights on the centerline post and the pendulum apparatus secure in its stowage. The model is now floating in its **inclined condition**. For best results, the model should be at zero list.

Inclining the Ship

5. With the ship in its inclined condition, the actual inclining part of the experiment can proceed. Record the distances on the pendulum needed to determine tan(ϕ).

6. Carefully move all 4 inclining weights to complete the following table:

Weight Combination	Weight creating the moment w (lb)	Moment Arm t (in) (+ Stbd, - Port)	Inclining Moment w·t (in-lb)	Pendulum deflection (in) (+ Stbd, - Port)	tan(ϕ) (no units)
4 - Port Post 0 - Center Post 0 - Stbd Post					
3 - Port Post 1 - Center Post 0 - Stbd Post					
2 - Port Post 2 - Center Post 0 - Stbd Post					
1 - Port Post 3 - Center Post 0 - Stbd Post					
0 - Port Post 4 - Center Post 0 - Stbd Post					
0 - Port Post 3 - Center Post 1 - Stbd Post					
0 - Port Post 2 - Center Post 2 - Stbd Post					
0 - Port Post 1 - Center Post 3 - Stbd Post					
0 - Port Post 0 - Center Post 4 - Stbd Post					

7. Plot the results of the inclining experiment in Excel. Your plot should be inclining moment (wt) on the y-axis against the tangent of the heel angle (tanϕ) on the x-axis. **Remember to name and label your plot correctly**. Use Excel to determine the line of best fit. Record the Slope and its units below:

Slope = _____

8. What is the advantage of using a 'line of best fit' for multiple data points?

_____

_____

9. Complete the inclined ship diagram in Figure 4. Your diagram should include the initial and final centers of buoyancy (B and B1), the initial and final centers of gravity (G and G1), the metacenter (M_T), the inclining angle (ϕ) and the 2 equal and opposite resultant forces (Δ and F_B).

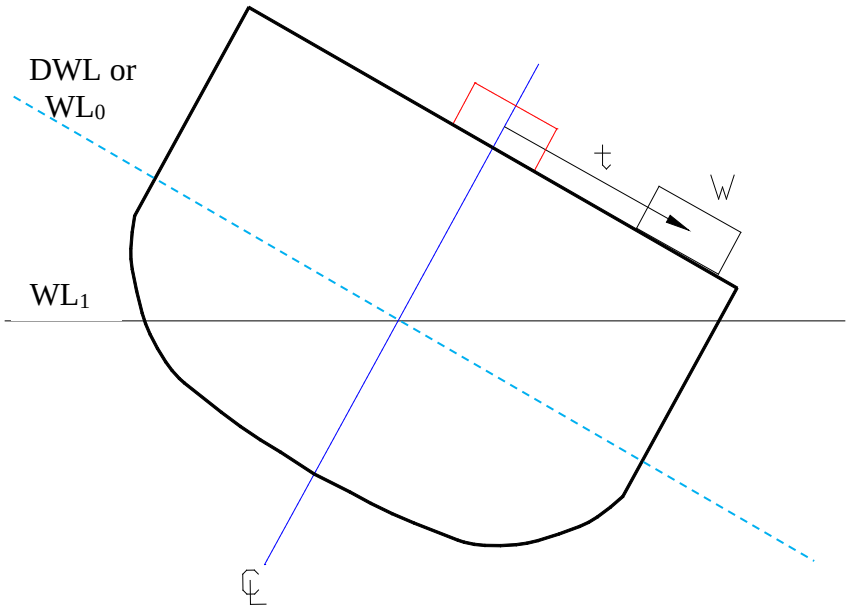


Figure 4: The Inclined Ship

10. Calculate the metacentric height of the 27-B-1 model in its inclined condition (GM_{incl}).

Calculating of KG_{incl} and Correcting for Removal of Inclining Equipment to find KG_{light}

11. Calculate KG_{incl}. Be sure to show any equations used.

12. The last step in the inclining experiment is to correct KG_{incl} for the removal of the inclining weights and apparatus to find KG_{light}.

    Why is this necessary? _____

    _____

13. Write the equation and calculate KG_{light}.

14. Is this value for KG_{light} sensible (refer to the model)? _____

    Why? _____

    _____

15. (For use for Lab 4): 27-B-1 model # _____

    KG_{light} _____