Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_ Period \_\_\_\_\_

CTE Science Laboratory Investigation

INVESTIGATING HYDRODYNAMICS

**Introduction**

The way that fluids behave is of vital importance to your very existence. As an example, if there was too much turbulence in your bloodstream, the rate of diffusion of oxygen would be reduced, greatly lowering the overall efficiency of your cardiovascular system. Further, if the viscosity of your cerebrospinal fluid were to change, the cilia that cause it to circulate would have to work harder, causing you to expend more energy or putting your nervous system at risk.

On a broader level, many of the products that you use or wear everyday were not produced in this country. They were made elsewhere and shipped here on a…ship. Ship hulls have been precisely designed to provide either maximum buoyancy or to cut through the water to deliver maximum speed. Either way, without such an understanding, shipping would remain costly and slow, and prices of everyday goods would rise. Even the water that comes out of your taps wouldn’t flow so freely if the system of pipes that delivers it wasn’t designed by engineers who understand how water flows best.

So it behooves us to investigate how fluids (in this case, water), flow, because it is a vital part of how the world works. An exciting and representative way to study the movement of fluids is by moving something, such as a boat, through them. In order for a boat to be efficient, it must meet two main criteria:

1. It must counteract the force of gravity on itself, with a vertical buoyant force, and
2. It must be able to move easily through the water.

It would seem that this couldn’t possibly be more straightforward. However, this is not the case. When you consider that most ships are made out of things with a density that is greater than that of water, it’s a wonder they don’t sink! Many large ships are made out of metal or even concrete. They don’t sink, though, due to their shape. There was a famous mathematician named Archimedes of Syracuse (no really, he was from a city in Italy called Syracuse!) who came up with an idea (now known as Archimedes’ Principle) about buoyancy:

“An object immersed in a fluid experiences a buoyant force equal to the weight of fluid that it displaces.”

We can see from his statement that if an object (like a ship) displaces more water, then it will experience a greater upward, buoyant force.

The ideal shape for a boat to hold the most mass, then, would be a ship that can displace a lot of water. That’s why large oil tankers or container ships are so wide and deep: the fact that they move a lot of water out of the way allows them to float because it provides more lift. Common sense will tell you that this is not the most efficient design for moving through the water, though. It would make more sense to have a hull shaped to “cut” through the water, presenting as little surface at the front as possible.

It will be your job to research the various types of hulls out there, and design the one that you think will be the most efficient. That is, one that can hold a specific amount of mass but still move through the water with a reasonable speed. Engineers frequently face this kind of dilemma when designing many types of products.

**Purpose**

The purpose of this investigation is to acquaint you with the basic principles surrounding the flow of fluids and buoyancy. You’ll also get to apply scale drawing and modeling techniques. You’ll finally be able to see if you can design a boat that will be able to create the perfect balance between buoyancy and efficient travel.

**Materials**

Papier-mâché Cardboard

Scissors Waterproofing Agent

Test Trough Photogates

LabQuest Pulley

Masses String

PENCIL

**Procedure**

PART I – RESEARCH BOAT HULLS

In this section, you’ll research the relative benefits or detriments of several different types of boat hulls. Use the internet wisely to pick six types of hulls to examine.

A. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Cross-sectional drawing:

Benefits:

Detriments:

Purpose:

B. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Cross-sectional drawing:

Benefits:

Detriments:

Purpose:

C. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Cross-sectional drawing:

Benefits:

Detriments:

Purpose:

D. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Cross-sectional drawing:

Benefits:

Detriments:

Purpose:

E. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Cross-sectional drawing:

Benefits:

Detriments:

Purpose:

F. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Cross-sectional drawing:

Benefits:

Detriments:

Purpose:

PART II – SELECT AND DESIGN A HULL

In this section, you’ll select one of the boat hulls from part I, and design a mold that you’ll use to make your hull. Keep in mind that you don’t have to simply pick one and make it! You may choose to combine two or more of the designs to try and make your boat as efficient as possible. Here are the requirements that you must meet:

1. The boat must fit in the test trough.

2. A flag must be able to be attached to the boat to work with the photogates.

3. The boat must support at least 75 g of mass, distributed however you choose.

4. The boat must be able to be towed by the towing system.

Apart from these requirements, you are free to take any design liberties in terms of construction, materials, decorations or other modifications that you think might help you win. The winner is the person whose boat has the fastest speed in three, consecutive trials.

1. After selecting your hull, craft the keel of the boat using cardboard.

2. Then, use more cardboard to create perpendicular ribs in the shape desired. Remember, you’ll be coating the entire thing with papier-mâché to create a solid hull, so space the ribs appropriately.

3. Place a piece (or several pieces) of plastic wrap over the mold to make removing the papier-mâché easier.

4. Coat your mold with several layers of papier-mâché.

5. If you wish, you may paint or otherwise decorate your boat at your discretion.

6. Your teacher will spray the boat with an appropriate waterproofing agent when it has dried.

PART III – TEST YOUR HULL

In this section, you will have time in class to practice with the test trough and experiment with the distribution of mass throughout your hull. You’ll also be able to make adjustments if need be and as time permits.

1. Attach a small loop of tape to the prow of your hull so that the towing mechanism can be attached to it.

2. Attach a flag to your hull if it is not tall enough to set off the photogates.

3. Test your hull, each time experimenting with the amount or distribution of mass throughout it. Remember, you boat must hold at least 75 g of mass, but you may add more if you determine that it is needed. You must keep a record of your experimentation in the space below:

|  |  |
| --- | --- |
| **Configuration** | **Notes** |
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Table 1. Hull configurations and results.

4. When you have completed testing your hull to your satisfaction, your teacher will assist you in running three consecutive timed trials. The boat that has the fastest average time over these three trials is the winner.

**Analysis**

QUESTION 1: What is the force that counteracts the force of gravity upon a floating object?

QUESTION 2: Archimedes of Syracuse is said to have used the principle of buoyancy to determine if the crown of King Heiro II was actually made of gold. He determined that the crown was not real gold. How do you think he went about testing the crown?

QUESTION 3: Submarines are curious because they can both float and sink, depending on what they need to do at any particular instant. Describe how you think submarines accomplish this task.

QUESTION 4: Would you have to change the design of your hull at all if we tested them in oil instead of water? Why or why not?

QUESTION 5: Some boat hulls are designed specifically to rise out of the water at high speeds in a process known as hydroplaning. Why is this beneficial to the boat?

QUESTION 6: Our boats were not self-propelled; rather, they had an external force applied to them in order to move them. What differences or problems might arise if the boats we created were self-propelled?

QUESTION 7: Referring again to Archimedes’s Principle stated in the background information, propose a reason that a very heavy ship must have a shape that allows it to displace a lot of water.

QUESTION 8: What are two things that you would change about this lab if you could?