3.1 INTRODUCTION

The purpose of this project is to familiarize you with model testing as a method for predicting ship resistance and powering requirements.

Following the methods discussed in class you will use dimensional analysis to determine the speeds at which to test the ship model so that you can scale your data up to the full prototype destroyer. A photo of the test setup is below. Ask the lab assistant to describe the setup and how the data is collected before beginning the laboratory.
3.2 EXPERIMENTAL PROCEDURE

At the MIT Towing Tank (Room 48-015), you will be measuring the resistance of a 100:1 scale *USS Arleigh Burke* class DDG (destroyer, guided missile) model. The primary characteristics of the DDG 51 follow. The model tested will be without a sonar dome.

- \( L_{pp} \): 466.0 ft Length
- \( T \): 20.69 ft Draft
- \( B \): 58.98 ft Beam
- \( C_p \): 0.625
- \( C_X \): 0.830
- \( C_b \): 0.519
- \( C_{wp} \): 0.789
- \( \Delta \): 8240 LT\(_{sw}\) Displacement
- \( S_{ws} \): 29,754 ft\(^2\) Wetted surface area

1) If the full-scale ship operates up to 35 kts, determine the testing speeds for the 100:1 model used in these tests in order to have information about the ship resistance at 5, 10, 15, 20, 25, 30, and 35 kts. (NB: 1 kts = 0.5144 m/s). Froude and Reynolds numbers are both important non-dimensional parameters for ship resistance model testing. Reynolds number \( (R_e = \frac{UL}{\nu}) \), \( U \) is ship speed, \( l \) is ship length, \( \nu \) is kinematic viscosity) dependency is important, however for surface ship is not the only parameter we must consider. Typically we will scale the model tests with Froude Number \( (F_r = \frac{U}{\sqrt{gL}}) \), \( U \) is ship speed, \( g \) is gravity, \( l \) is ship length), ensuring that the flow around the model is in the same flow regime, turbulent or laminar, as the actual full scale ship.

<table>
<thead>
<tr>
<th>Full Scale Ship</th>
<th>Model Ship</th>
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</thead>
<tbody>
<tr>
<td><strong>knots</strong></td>
<td><strong>m/s</strong></td>
</tr>
<tr>
<td>5</td>
<td>2.57</td>
</tr>
<tr>
<td>10</td>
<td>5.14</td>
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<tr>
<td>15</td>
<td>7.72</td>
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<tr>
<td>20</td>
<td>10.29</td>
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<tr>
<td>25</td>
<td>12.86</td>
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<tr>
<td>30</td>
<td>15.43</td>
</tr>
<tr>
<td>35</td>
<td>18.00</td>
</tr>
</tbody>
</table>

2) Conduct an experiment at the tow tank facility to measure model resistance of the DDG 51 hull at equivalent speeds up to the maximum speed allowed by the carriage. Conduct multiple towing runs at each chosen test speed, if possible. The tow carriage speed is set in units of meters per second so calculate the desired tow speeds in these units. The tow speed limit is 1.5 m/s. Resistance data will be recorded on disc for later analysis using MATLAB.
3) For each case observe the wake pattern and the bow wave on the model. How do these appear to change for each run?

4) Consider the effect that ship’s motion might have on the resistance data. Does the model pitch or heave significantly during the runs? If so would this affect the data?

5) Thank the Towtank staff and especially Malima Wolf for setting up such an awesome rig!

3.3 LAB WRITE UP AND DATA ANALYSIS

Treat your project write-up like a “formal” lab report. Type the final report and embed all figures into the text as appropriate.

Provide an introduction, an equipment diagram and a narrative of what you actually did during the laboratory and to process the data afterwards, including the calibration (even though the calibration data was given to us before the lab it is a good idea to ask how it was done!). Ensure you address any questions raised in this assignment. Plots should be well integrated and referenced in your discussion of the data. You may work in groups in gathering the experimental data for this project but your analysis and discussion must be your own.

Specific Tasks to include in the laboratory write up:

1) In the introduction explain the procedure for testing a model ship in the towing tank, discuss theory that was used in your calculations and considerations made during the testing.

2) Discuss the method used to determine the friction and residual resistance on the full scale ship hull based on the data you collected from the model. Cite references where necessary and include these references in a bibliography at the end of your report. A good way to reference a work is as follows: “The equation for force is F=ma (Newton, 1621).” Also include any equations or relations you used to calculate the data.

3) Analyze your results. Specifically, submit plots of:
   - \( R_f \) vs Speed
   - \( R_R \) vs Speed
   - Total Resistance vs. speed
   - Coefficient of resistance vs. Reynolds number
   - Coef. Of resistance vs. Froude number

   Using these required plots, discuss your results. Address significant differences. Identify possible sources of experimental error. Estimate the error based on your multiple measurements and data processing.

4) Estimate the horsepower required to propel the ship at 35 kts based on your resistance estimates.
5) Discuss the effects of ship towing speed on the ship wake and bow waves. Do the bow waves grow, shrink, or stay the same with increased towing speed. What does the wake look like behind the vessel as the speed increases? How do you expect these effects to scale with increased Froude number? Increased Reynolds number?

6) Discuss whether the flow on the model ship was laminar or turbulent. How do you know?

7) Summarize your results in a conclusions section and discuss possible improvements or things you would do differently the next time you test a model ship.