2-1 A small boat weighing 40 \( LT \) has a submerged volume of 875 \( ft^3 \) when traveling at 20 \( kts \) in seawater. \( (\rho = 1.99 \frac{lb \cdot ft^2}{s^2}; 1 \, LT = 2240 \, lb) \)

(a) Calculate the magnitude of the hydrostatic support being experienced by boat.

\[
F_{Buoyancy} = \rho g V_{sub} = 1.99 \frac{lb \cdot s^2}{ft^4} \cdot 32.2 \frac{ft}{s^2} \cdot 875 \, ft^3 = 56,068 \, lb \cdot \frac{1 \, LT}{2240 \, lb} = 25 \, LT
\]

(b) What other type of support is the boat experiencing?

In addition to hydrostatic support, this boat is experiencing hydrodynamic support/lift.

(c) Calculate the magnitude of this other type of support.

\[
F_{Hydrodynamic} = W_{boat} - F_{Buoyancy} = 40 \, LT - 25 \, LT = 15 \, LT
\]

(d) What will happen to the submerged volume of the boat if it slows to 5 knots? Explain your answer.

Hydrodynamic lift is proportional to \( V_{boat}^2 \). As the boat slows, the reduction in hydrodynamic support will cause the boat weight to exceed the total lift so the boat will sink down (draft, \( T \), will increase). As \( T \) increases, \( V_{sub} \) increases so \( F_{buoyancy} \) increases until a new equilibrium is reached at a new, deeper, draft.
2. Both hovercraft and surface effect ships are supported by air cushions while moving across the water.

**ACV**: - ride on top of water, allowing amphibious capability
  - high speed vessel
  - expensive to operate
  - small payloads
  - poor directional stability

**SES**: - ride on air cushion, however, rigid sides extending into water allow greater directional stability and require less energy expended to maintain air cushion,
  - higher payload than ACV
  - no amphibious capability
  - expensive to operate

3. a. **SWATH** - Small Waterplane Area Twin Hull

  b. Supported by hydrostatic forces while underway

  c. Advantages of SWATH:

    - very stable platform ➔ good sea keeping
    - large deck area
    - fuel efficient
2-4 Sketch a profile of a ship and show the following:

(a) Forward Perpendicular
(b) After Perpendicular
(c) Sections, assuming the ship has stations numbered 0 through 10.
(d) Length Between Perpendiculars
(e) Length Overall
(f) Design Waterline
(g) Amidships

2-5 Sketch a section of a ship and show the following:

(a) Keel
(b) Depth
(c) Draft
(d) Beam
(e) Freeboard
For this question, use a full sheet of graph paper for each drawing. Choose a scale that gives the best representation of the ship’s lines. Use the FFG-7 Table of Offsets given on the following page for your drawings.

(a) For stations 0-10 draw a Body Plan for the ship up to the main deck. Omit stations 2.5 and 7.5.

(b) Draw a half-breadth plan showing the 4 ft, 12 ft, 24 ft waterlines, and the deck edge.

(c) Draw the sheer profile of the ship.
Prob 8

Box-shaped barge has \( L = 100 \text{ ft} \), \( B = 40 \text{ ft} \), depth = 25 \text{ ft}.
Current draft \( T = 10 \text{ ft} \).

a, b. Draw waterplane, profile, and end view of barge.
Indicate \( G \), \( WL \), \( \delta \), \( B \), and \( F \). Also show \( KB \), \( LCF \), \( LCB \).

\begin{center}
\begin{tikzpicture}
\draw (0,0) rectangle (4,4);
\draw (2,2) circle (0.5);\node at (2,2) {\( \delta \)};
\draw (0,2) -- (4,2) node[midway, above] {\( KB \)};
\draw (2,0) -- (2,4) node[midway, right] {\( LCB \)};
\draw (0,0) -- (4,0) node[midway, below] {\( F \)};
\draw (2,0) -- (2,4) node[midway, right] {\( LCF \)};
\end{tikzpicture}
\end{center}

c. Determine the following dimensions:
\[ KB = \frac{T}{2} = \frac{10 \text{ ft}}{2} = 5 \text{ ft} \]
\[ LCF \text{ from } \delta: \quad LCF = 0 \text{ ft from } \delta \]
\[ LCB \text{ from } FP: \quad LCB = 50 \text{ ft aft } FP \]
Height of \( F \) above the keel = 10 ft
Use Simpson's Rule to calculate the following:

a) Right triangle with base of \( a \) and height \( b \)

\[
A = \frac{\Delta x}{3} \left[ 1 \frac{y_0}{2} + 4 \frac{y_1}{2} + 1 \frac{y_2}{2} \right] \\
\Delta x = \frac{a}{l} \quad y_0 = b \quad y_1 = \frac{b}{2} \quad y_2 = 0.
\]

\[
A = \left( \frac{1}{3} \right) \left( \frac{a}{l} \right) \left[ 1 \left( b \right) + 4 \left( \frac{b}{2} \right) + 1 \left( 0 \right) \right] \\
= \frac{a}{l} \left[ b + 2b \right] \\
= \left( \frac{a}{l} \right) \left( 3b \right) \\
A = \frac{3ab}{l} = \frac{ab}{\frac{a}{l}}
\]

Note: For any right triangle, \( y(x=\frac{a}{l}) = \frac{b}{2} \)

Consider triangle \( \Delta \left( \frac{a}{l}, a, y_1 \right) \)

\[
\tan \theta = \frac{\text{opp}}{\text{adj}} = \frac{y_1}{\frac{a}{l}} \\
y_1 = \frac{a}{l} \tan \theta \\
\text{but, } \tan \theta = \frac{b}{a} \\
y_1 = \left( \frac{a}{l} \right) \left( \frac{b}{a} \right) \\
\therefore y_1 = \frac{b}{l}
b) Semi-circle of radius \( r \)

\[ A = \int_{-r}^{r} y(x) \, dx \]

\[ A = \frac{\Delta x}{3} \left[ 1 \cdot y_0 + 4 \cdot y_1 + 1 \cdot y_2 \right] \]

\[ \Delta x = r \]

\[ y_0 = 0, \quad y_1 = r, \quad y_2 = 0 \]

\[ A = \frac{4r^2}{3} \quad \text{actual is: } \frac{\pi r^2}{2} \]

c) Equilateral triangle with each side having length \( a \):

For equilateral \( \Delta, \ \theta = 60^\circ \)

\[ \tan \theta = \frac{y_1}{a \cdot \frac{\sqrt{3}}{2}} \]

\[ y_1 = \frac{a}{2} \cdot \tan \theta = \frac{a}{2} \cdot \tan 60^\circ = \frac{a \sqrt{3}}{2} \]

\[ y_1 = \frac{a}{2} \left( \frac{\sqrt{3}}{2} \right) = \frac{a \sqrt{3}}{4} \]

\[ A = \frac{\Delta x}{3} \left[ 1 \cdot y_0 + 4 \cdot y_1 + 1 \cdot y_2 \right] \]

\[ \Delta x = \frac{a}{2}, \quad y_1 = 0, \quad y_1 = \frac{a \sqrt{3}}{2}, \quad y_2 = 0 \]

\[ A = \left( \frac{1}{3} \right) \left( \frac{a}{2} \right) \left[ 0 + 4 \left( \frac{a \sqrt{3}}{2} \right) + 0 \right] \]

\[ = \frac{a}{6} \left( 2a \sqrt{3} \right) \]

\[ A = \frac{a^2 \sqrt{3}}{3} \]

Note: If 5 divisions are used, get
calculate $A_{wp}$ at DWL and compare to actual result.

Use stations $0, 2.5, 5, 7.5, 10$

$$\int_{F_0}^{P_0} y(x) \, dx$$

$$A_{wp} = 2 \int_{F_0}^{P_0} y(x) \, dx$$

$$= 2 \left( \frac{\Delta x}{3} \right) \left[ \frac{1}{2} v_0 + 4 \frac{y_{2.5}}{2} + 2 \frac{y_5}{2} + 4 \frac{y_{7.5}}{2} + y_{10} \right]$$

$$\Delta x = \frac{L_{PP}}{n-1} = \frac{400 \text{ ft}}{5-1} = 102 \text{ ft}$$

$$A_{wp} = (\frac{1}{3})(102 \text{ ft}) \left[ \frac{1}{2} (1.33 \text{ ft}) + 4 (15.52 \text{ ft}) + 2 (22.61 \text{ ft}) + 4 (20.82 \text{ ft}) + 1 \right]$$

$$A_{wp} = (\frac{1}{3})(102 \text{ ft}) (203.37 \text{ ft})$$

$$A_{wp} = 13827.2 \text{ ft}^2$$

Using 5 stations produces $A_{wp}$ being slightly greater than actual. Increasing number of stations improves accuracy.

Error $\approx 0.02\%$
Using FF6-7 table of offsets, calculate area of Station 3 up to DWL.

\[
A = 2 \int_{z}^{\infty} \gamma(z) \, dz
\]

\[
= 2 \left( \frac{\Delta z}{3} \right) \left[ 0 \gamma_0 + 4 \gamma_4 + 2 \gamma_8 + 4 \gamma_{12} + \gamma_{12} \right]
\]

\[
\Delta z = 4 \text{ ft}
\]

\[
A = 2 \left( \frac{4 \text{ ft}}{3} \right) \left[ 0.68 \text{ ft} + 4 (10.77 \text{ ft}) + 2 (14.48 \text{ ft}) + 4 (16.31 \text{ ft}) + 17.75 \text{ ft} \right]
\]

\[
A = \left( \frac{8 \text{ ft}}{3} \right) (155.61 \text{ ft})
\]

\[
A = 414.96 \text{ ft}^2
\]
Calculate the area of Station 6 up to the 24 ft we.

\[ A_6 = \frac{1}{2} \int_0^{24} y(x) \, dx = \frac{2}{3} \int_0^8 y(x) \, dx + \frac{2}{3} \int_8^{24} y(x) \, dx \]

\[ = 2 \left( \frac{\Delta z_1}{3} \right) \left[ 1 \gamma_0 + A \gamma_A + 1 \gamma_b \right] + 2 \left( \frac{\Delta z_2}{3} \right) \left[ 1 \gamma_b + 4 \gamma_d + 1 \gamma_d \right] \]

\[ \Delta z_1 = 4 \text{ ft} \quad \Delta z_2 = 8 \text{ ft} \]

\[ = 2 \left( \frac{4 \text{ ft}}{3} \right) \left[ 1.68 \text{ ft} + 4(12.84 \text{ ft}) + (17.21 \text{ ft}) \right] \]

\[ + 2 \left( \frac{8 \text{ ft}}{3} \right) \left[ 1.19 \text{ ft} + 4(23.24 \text{ ft}) + 23.33 \text{ ft} \right] \]

\[ = \left( \frac{8 \text{ ft}}{3} \right) (17.33 \text{ ft}) + \left( \frac{4 \text{ ft}}{3} \right) (133.5 \text{ ft}) \]

\[ A_6 = 190.21 \text{ ft}^2 + 712 \text{ ft}^2 \]

\[ A_6 = 902.2 \text{ ft}^2 \]
Using sectional areas for stations 0, 2.5, 5, 7.5, 10, calculate the submerged volume and displacement to the DWT.

\[ V = \int_{FP}^{AP} A(x) \, dx \]

\[ V = \frac{\Delta x}{3} \left[ A_o + 4A_{2.5} + 2A_5 + 4A_{7.5} + A_{10} \right] \]

\[ \Delta x = \frac{\text{PP}}{n-1} = \frac{400 \text{ ft}}{5-1} = 102 \text{ ft} \]

\[ V = (102 \text{ ft}) \left[ 0.88 \text{ ft}^2 + 4(357.5 \text{ ft}^2) + 2(556.9 \text{ ft}^2) + 4(334.1 \text{ ft}^2) + 33.21 \text{ ft} \right] \]

\[ V = (102 \text{ ft}) \left( 3914.7 \text{ ft}^3 \right) \]

\[ V = 133079.8 \text{ ft}^3 \]

Displacement in salt water

\[ \Delta_{sw} = \rho_{sw} g \, V \]

\[ = (1.97 \frac{18 \text{ k}}{\text{ft}^3})(32.17 \frac{\text{ ft}^3}{\text{ k}})(133079.8 \text{ ft}^3) \left( \frac{\text{ k}}{2240 \text{ lb}} \right) \]

\[ \Delta_{sw} = 3804 \text{ LT} \]

Displacement in fresh water

\[ \Delta_{fw} = \rho_{fw} g \, V \]

\[ = (1.94 \frac{62 \text{ k}}{\text{ft}^3})(32.17 \frac{\text{ ft}^3}{\text{ k}})(133079.8 \text{ ft}^3) \left( \frac{\text{ k}}{2240 \text{ lb}} \right) \]

\[ \Delta_{fw} = 3708 \text{ LT} \]
Determine LCF at DWL referenced to \( \theta \).

\[
\text{Find LCF from FP:}
\]

\[
\text{LCF}_{FP} = \frac{\text{2} \int_{FP}^{AP} x \cdot y(x) \, dx}{A_{FP}}
\]

\[
= \frac{2}{3} \frac{dx}{A_{FP}} \left[ 1 \times 0 \cdot y_0 + 4 \times 2.5 \cdot y_{2.5} + 2 \times 5 \cdot y_5 + 4 \times 7.5 \cdot y_{7.5} + 1 \times 10 \cdot y_{10} \right]
\]

\[
\Delta X = \frac{L_{PP}}{n-1} = \frac{408 \text{ ft}}{5-1} = 102 \text{ ft}
\]

\[
A_{FP} = 13826.0 \text{ ft}^2
\]

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Step} & x (\text{ft}) & y (\text{ft}) & (x)(y) \ (\text{ft}^2) \\
\hline
0 & 0.33 & 0 & 0 \\
2.5 & 15.52 & 102 & 4 \times 6332.16 \\
5 & 22.61 & 204 & 2 \times 7224.88 \\
7.5 & 20.82 & 306 & 4 \times 25483.7 \\
10 & 12.42 & 408 & 1 \times 5083.36 \\
\hline
\end{array}
\]

\[
\Sigma = 46124.4 \text{ ft}^2
\]

\[
\text{LCF}_{FP} = \frac{2}{3} \frac{(46124.4 \text{ ft}^2)}{(13826.0 \text{ ft}^2)}
\]

\[
\text{LCF}_{FP} = 226.9 \text{ ft at FP}
\]

Reference from \( \alpha \):

\[
\text{LCF}_{\alpha} = \frac{L_{PP}}{2} - \text{LCF}_{FP}
\]

\[
= \frac{408 \text{ ft}}{2} - 226.9 \text{ ft}
\]
15) What are the assumptions made when computing a ship's hydrostatic parameters in the curves of form?

- ship floating on an even keel
  (zero list, zero trim)
- salt water at 39°F

16) FF6-7 floating on an even keel at draft of 14 ft. We want to find the following:

Parameter = (General Scale)(Scale Factor)

a. Displacement: \( \Delta = (108)(30 \text{ LT}) = 3240 \text{ LT} \)

b. LCF: LCF = 22 ft aft & (top scale)

c. KB: \( KB = (44)(.2 \text{ ft}) = 8.8 \text{ ft} \)

d. TP\( F \): TP\( F \) = (158)(.2 \%\text{in}) = 31.6 \%\text{in} \)

e. MT\( F \): MT\( F \) = (125)(5.78 \%\text{ft} \%\text{in}) = 722.5 \%\text{ft} \%\text{in} \)

f. \( \nabla \): \( \nabla = \frac{\Delta}{\rho g} \)

\[ \nabla = \frac{3240 \text{ LT}}{1.99 \frac{\text{lb}}{\text{ft}^3}} \times \frac{1240 \text{ lb}}{32.17 \%\text{in}} \times \text{LT} \]

\[ \nabla = 113367.6 \text{ ft}^3\]
17) FF6-7 floating with forward draft = 14.9 ft and aft draft = 15 ft. Use curves of form to find:

\[ T_m = \frac{T_f + T_a}{2} = \frac{14.9 \text{ ft} + 15.5 \text{ ft}}{2} = 15.2 \text{ ft} \]

a) \[ \Delta: \quad \Delta = (123)(30 \text{ ft}) = 3690 \text{ ft} \]

b) LCF: \quad LCF = 24 \text{ ft all \&}

c) MTI: \quad MTI = (131)(5.78 \text{ ft} \times \%) = 757.2 \text{ ft} \times \%

18) FF6 in problem 15 changes draft to 15.5 ft.

What is new TPI? \[ TPI_{15} = (162)(.2 \text{ ft} \times \%) = 32.4 \text{ ft} \times \% \]

Why does TPI change?

TPI is a function of waterplane area. As draft changes, waterplane changes. Therefore TPI changes.
DDG-51 floating on even keel at draft of 21.5 ft. 150 ft piece of machinery is added.

a. Where must 150 ft be added so that trim doesn't change?

At Center of Flotation

b. What is change in draft due to weight addition?

\[ \delta T = \frac{W}{TPI} \]

\[ TPI = (173)(0.3 \text{ LF} / \text{in}) = 51.9 \text{ LF} / \text{in} \]

\[ \delta T = \frac{150 \text{ LF}}{51.9 \text{ LF/in}} \]

\[ \delta T = 2.87 \text{ in} \]

c. What is new draft?

\[ T_{new} = T_{old} + \delta T = 21.5 \text{ ft} + \frac{2.87 \text{ in}}{12 \text{ in/ft}} = 21.74 \text{ ft} \]

DDG-51 floating on even keel at draft of 21.5 ft. 50 LF is moved from center of flotation to a point 150 LF forward of F.

Calculate the change in trim.

\[ \delta \text{Trim} = \frac{W}{MTS} \]

\[ MTS^* = (143)(9.24 \text{ LF} / \text{in}) = 1306.12 \text{ LF} / \text{in} \]

\[ \delta \text{Trim} = \frac{(50 \text{ LF})(150 \text{ ft})}{1306.12 \text{ LF} / \text{in}} = 4.98 \text{ in} = 0.42 \text{ ft} \]