Innovative Ship Design

- 2nd Exam -

Saturday, May 26th, 2012

Part I. Subdivision and Damage Stability, Saturday, May 26th, 2012, 13:00-14:00 (1 hour)
Part II. Computational Ship Stability, Saturday, May 26th, 2012, 14:00-16:00 (2hours)

Name	
SNU ID #	

Note: Budget your time wisely. Some parts of this exam could take you much longer than others. Move on if you are stuck and return to the problem later.

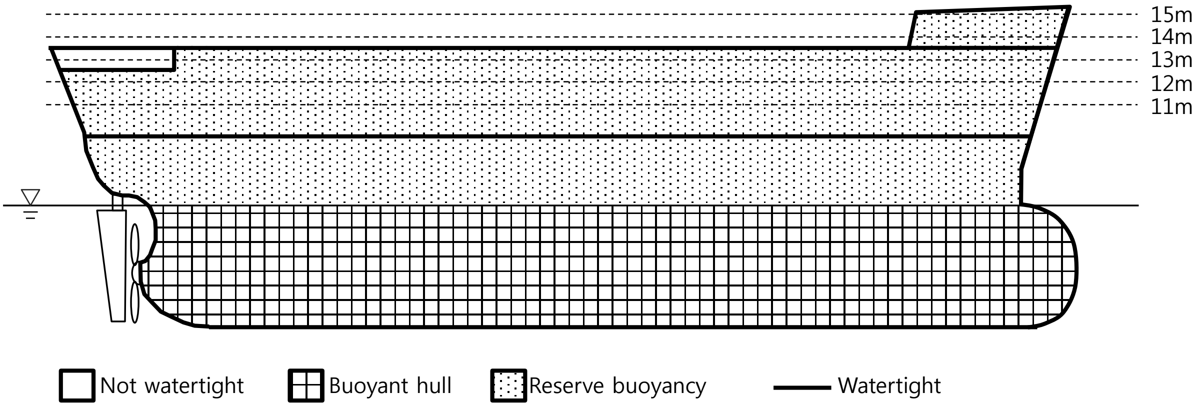
Problem Number		**1**		**2**		**3**		**4**				**5**	**6**	**7**	**8**				**Total**
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**3**	**4**				**1**	**2**	**3**	**4**	
Grader	**Max**	**2**	**3**	**5**	**3**	**5**	**3**	**4**	**5**	**5**	**5**	**4**	**10**	**4**	**7**	**15**	**5**	**15**	**/100**
	Score																		

[PART 1] Subdivision and Damage Stability

1. Figure 1 shows the elevation view of a ship. Answer the following questions about the subdivision length L_s.

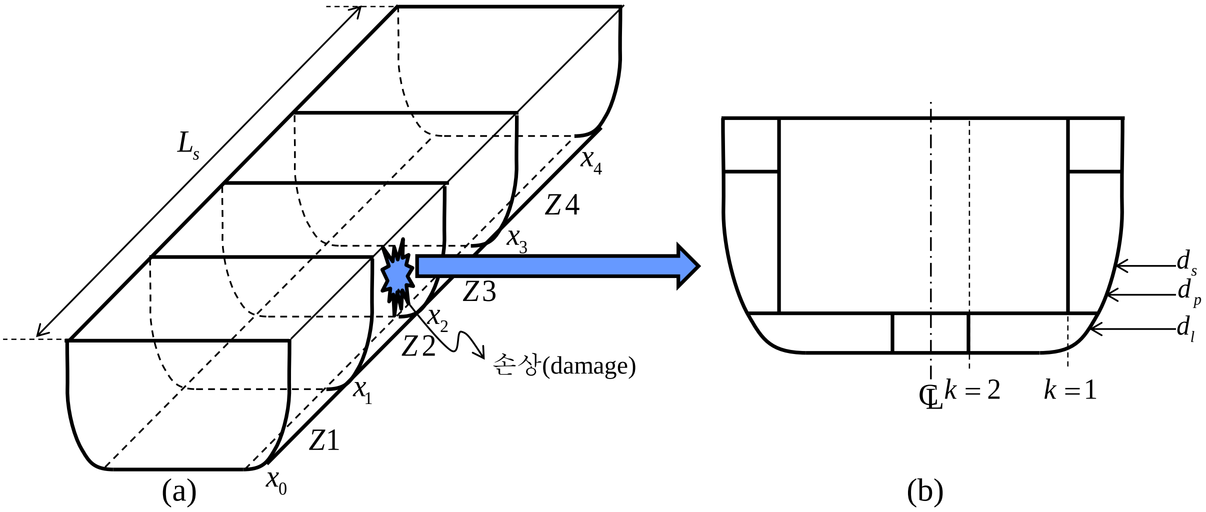
1.1. [2 points] Explain the definition of subdivision length L_s.

1.2. [3 points] Mark the subdivision length L_s in Figure 1.



[Figure 1: Elevation view of a ship]

2. Consider a ship of **subdivision length 100m** and **depth 12m** in Figure 2, assume that the **zone 2 is damaged**, and answer the following questions.



[Figure 2: Damaged ship of subdivision length 100m]

2.1. [5 points] The subdivision attained index A can be determined as follows

$$A = 0.4A_s + 0.4A_p + 0.2A_l$$

, where A_s, A_p, and A_l are calculated at deepest subdivision draft d_s, light service draft d_l, and partial subdivision draft d_p, respectively. The results of trim and stability calculation are provided as follows.

- Trim at deepest subdivision draft: 1.6m
- Trim at light service draft: 0.4m
- Trim at partial subdivision draft: 1.2m

How many times do we have to calculate the attained index A? And how much of meter of trim must be considered for each draft when obtaining the value of each A?

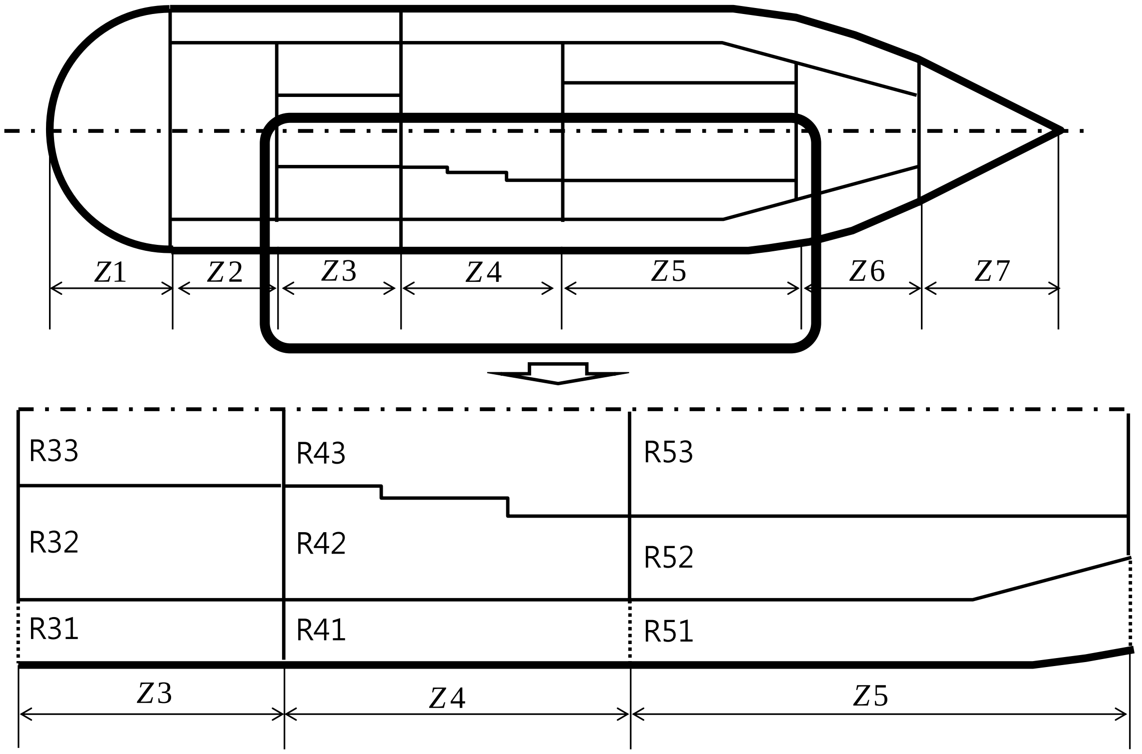
2.2. [3 points] Figure 2 shows the section view of zone 2.

1) For obtaining the value of A_l, which draft must be considered to determine the survivability S_i?

2) For obtaining the value of A_l, which draft must be considered to determine the probability of damage P_i?

3) Mark b_1, which is transverse distance between the shell and the longitudinal bulkhead at k=1, in Figure 2

3. Consider a ship as shown in Figure 3, and assume that the **zone 3, 4, 5 are damaged**.

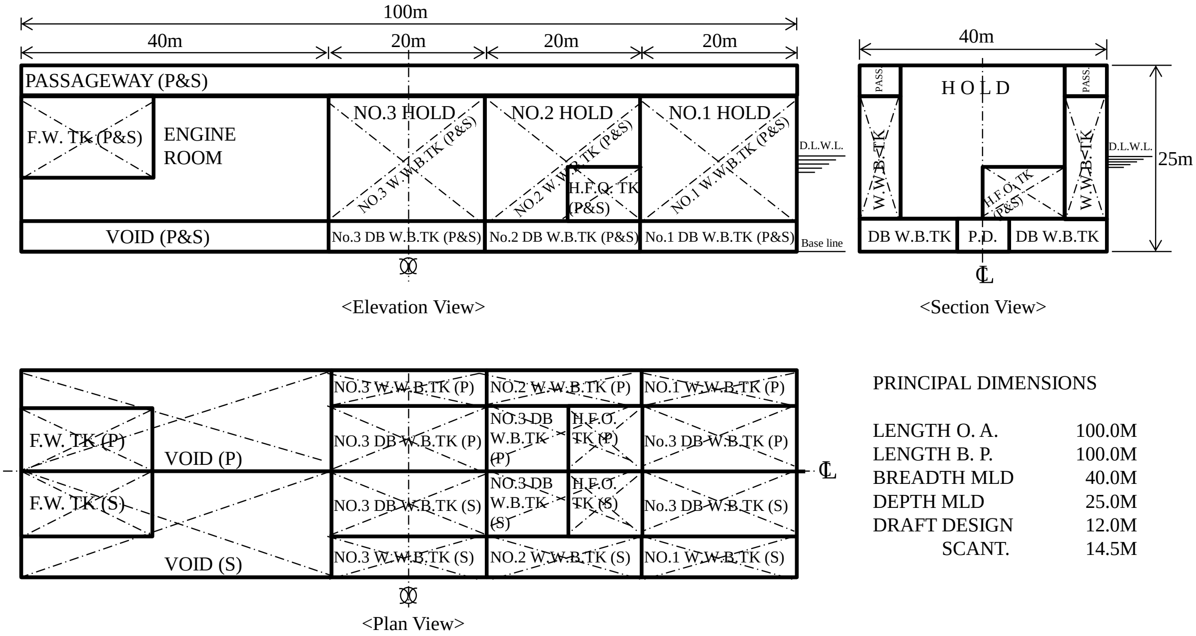


[Figure 3: Longitudinal bulkhead of a Ship]

3.1. [5 points] Determine how many b_i, which is transverse distance between the shell and the longitudinal bulkhead at $k=i$, should be considered for calculating r_i, and explain why.

3.2. [3 points] Determine damaged compartment for each b_i

4. Consider a box-shaped ship as shown in Figure 4, and answer the following questions.



[Figure 4: Compartment Arrangement of a Box-Shaped Ship]

4.1. [4 points] Generate all possible 10 damage cases of zone 3, referring the given examples of 3 damage cases considering lesser extent and higher extent.

1. NO3. W.W.B. TK (S), NO3 DB W.B. TK (S).
2. NO3. W.W.B. TK (S).
3. NO3. W.W.B. TK (S), NO3 DB W.B. TK (S), PASS. (S).
4. ...

…

10. ...

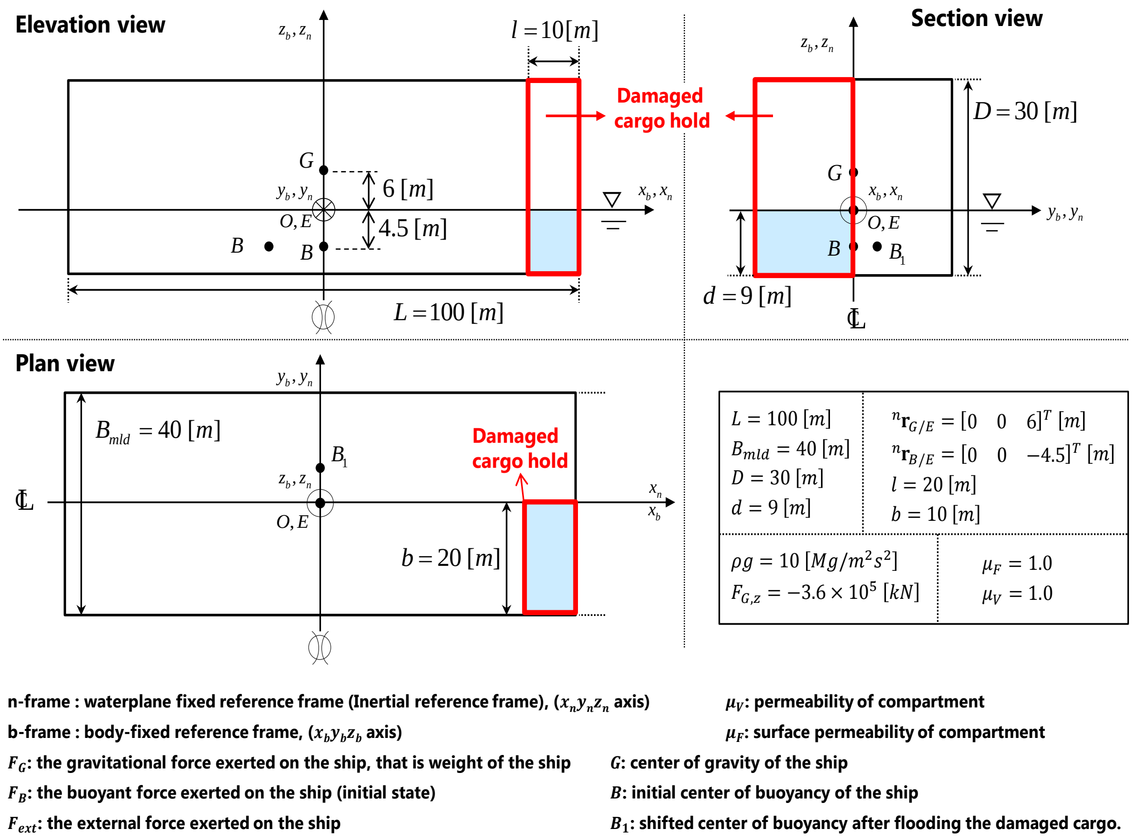
4.2. [5 points] Calculate p_i for damage case 1

4.3. [5 points] Calculate r_i for damage case 1

4.4. [5 points] Calculate v_m for damage case 1

[PART 2] Computational Ship Stability

A box-shaped ship of 100 meter length, 40 meter breadth, 30 meter height and 9 meter draft is floating in fresh water. The ship's initial total weight is $3.6 \times 10^5\ [kN]$. When a compartment is damaged and flooded as shown in Figure 1, the position and orientation of the ship will change.



[Figure 5: A box-shaped ship whose compartment is damaged]

* Eq. (1) is the linearized governing equation for the ship in static equilibrium.

$$
\begin{bmatrix} F_z^* - F_z\left(z_n^{(k)}, \phi^{(k)}, \theta^{(k)}\right) \\ M_T^* - M_T\left(z_n^{(k)}, \phi^{(k)}, \theta^{(k)}\right) \\ M_L^* - M_L\left(z_n^{(k)}, \phi^{(k)}, \theta^{(k)}\right) \end{bmatrix} = \begin{bmatrix} \frac{\partial F_B}{\partial z_n} + \frac{\partial F_G}{\partial z_n} + \frac{\partial F_{ext}}{\partial z_n} & \frac{\partial F_B}{\partial \phi} + \frac{\partial F_G}{\partial \phi} + \frac{\partial F_{ext}}{\partial \phi} & \frac{\partial F_B}{\partial \theta} + \frac{\partial F_G}{\partial \theta} + \frac{\partial F_{ext}}{\partial \theta} \\ \frac{\partial M_{BT}}{\partial z_n} + \frac{\partial M_{GT}}{\partial z_n} + \frac{\partial M_{extT}}{\partial z_n} & \frac{\partial M_{BT}}{\partial \phi} + \frac{\partial M_{GT}}{\partial \phi} + \frac{\partial M_{extT}}{\partial \phi} & \frac{\partial M_{BT}}{\partial \theta} + \frac{\partial M_{GT}}{\partial \theta} + \frac{\partial M_{extT}}{\partial \theta} \\ \frac{\partial M_{BL}}{\partial z_n} + \frac{\partial M_{GL}}{\partial z_n} + \frac{\partial M_{extL}}{\partial z_n} & \frac{\partial M_{BL}}{\partial \phi} + \frac{\partial M_{GL}}{\partial \phi} + \frac{\partial M_{extL}}{\partial \phi} & \frac{\partial M_{BL}}{\partial \theta} + \frac{\partial M_{GL}}{\partial \theta} + \frac{\partial M_{extL}}{\partial \theta} \end{bmatrix}_{\substack{z_n = z_n^{(k)} \\ \phi = \phi^{(k)} \\ \theta = \theta^{(k)}}} \begin{bmatrix} \delta z_n^{(k)} \\ \delta \phi^{(k)} \\ \delta \theta^{(k)} \end{bmatrix} \quad \text{Eq. (1)}
$$

The partial derivatives of the Eq. (1) can be expressed in terms of the area, moment of area, moment of inertia of the waterplane area, volume and moment of volume as follows, and are derived **based on the lost buoyancy method.**

$$\begin{bmatrix} F_z^* - F_z^{(k)} \\ M_T^* - M_T^{(k)} \\ M_L^* - M_L^{(k)} \end{bmatrix} = \left[\begin{array}{c|c|c} \begin{array}{c} -\rho g A_{WP}{}^{(k)} \\ -\left(-\mu_F \cdot \rho g a_{WP}{}^{(k)}\right) \end{array} & \begin{array}{c} -\rho g A_{WP}{}^{(k)} \cdot {}^{n}y_{F^{(k)}/E} \\ -\left(-\mu_F \cdot \rho g a_{WP}{}^{(k)} \cdot {}^{n}y_{f^{(k)}/E}\right) \end{array} & \begin{array}{c} \rho g A_{WP}{}^{(k)} \cdot {}^{n}x_{F^{(k)}/E} \\ -\mu_F \cdot \rho g a_{WP}{}^{(k)} \cdot {}^{n}x_{f^{(k)}/E} \end{array} \\ \hline \begin{array}{c} -\rho g A_{WP}{}^{(k)} \cdot {}^{n}y_{F^{(k)}/E} \\ -\left(-\mu_F \cdot \rho g a_{WP}{}^{(k)} \cdot {}^{n}y_{f/E}\right) \end{array} & \begin{array}{c} -\rho g\left({}^{n}z_{B^{(k)}/E}\nabla^{(k)} + I_T{}^{(k)}\right) - {}^{n}z_{G^{(k)}/E} \cdot F_{G,z} \\ -{}^{n}z_{G_{ext}{}^{(k)}/E} \cdot F_{ext,z}{}^{(k)} - \left(-\mu_F \cdot \rho g i_T{}^{(k)}\right) \end{array} & \begin{array}{c} \rho g I_P{}^{(k)} \\ -\mu_F \cdot \rho g i_P{}^{(k)} \end{array} \\ \hline \begin{array}{c} \rho g A_{WP}{}^{(k)} \cdot {}^{n}x_{F^{(k)}/E} \\ -\mu_F \cdot \rho g a_{WP}{}^{(k)} \cdot {}^{n}x_{f^{(k)}/E} \end{array} & \begin{array}{c} \rho g I_P{}^{(k)} \\ -\mu_F \cdot \rho g i_P{}^{(k)} \end{array} & \begin{array}{c} -\rho g\left({}^{n}z_{B^{(k)}/E}\nabla^{(k)} + I_L{}^{(k)}\right) - {}^{n}z_{G^{(k)}/E} \cdot F_{G,z} \\ -{}^{n}z_{G_{ext}{}^{(k)}/E} \cdot F_{ext,z}{}^{(k)} - \left(-\mu_F \cdot \rho g i_L{}^{(k)}\right) \end{array} \end{array}\right]_{\substack{z_n = z_n^{(k)} \\ \phi = \phi^{(k)} \\ \theta = \theta^{(k)}}} \begin{bmatrix} \delta z^{(k)} \\ \delta\phi^{(k)} \\ \delta\theta^{(k)} \end{bmatrix} \quad \text{Eq. (2)}$$

F_G: gravitational force exerted on a ship

M_T: transverse moment of a ship about x_n axis

M_L: longitudinal moment of a ship about y_n axis

$A_{WP}^{(k)}$: waterplane area of a ship at k^{th} step

$I_T^{(k)}$: transverse moment of inertia of the waterplane area of a ship about x_n axis at k^{th} step

$I_L^{(k)}$: longitudinal moment of inertia of the waterplane area of a ship about y_n axis at k^{th} step

$I_P^{(k)}$: centrifugal moment of the waterplane area of a ship about x_n and y_n axis at k^{th} step

F_B: buoyant force exerted on a ship

F_{ext}: external force exerted on a ship

${}^{n}x_{F^{(k)}/E}$: x_n coordinate of centroid of the waterplane area of a ship

${}^{n}y_{F^{(k)}/E}$: y_n coordinate of centroid of the waterplane area of a ship

${}^{n}z_{B^{(k)}/E}$: z_n coordinate of center of the displaced volume of a ship

${}^{n}z_{G^{(k)}/E}$: z_n coordinate of center of mass of the ship

$\delta z^{(k)}$: change in the draft at k^{th} step

$\delta\phi^{(k)}$: change in the angle of heel at k^{th} step

$\delta\theta^{(k)}$: change in the angle of trim at k^{th} step

μ_V: permeability of a compartment

μ_F: surface permeability of a compartment

$a_{WP}^{(k)}$: waterplane area of a flooded compartment at k^{th} step

$i_T^{(k)}$: transverse moment of inertia of the waterplane area of a flooded compartment about x_n axis at k^{th} step

$i_L^{(k)}$: longitudinal moment of inertia of the waterplane area of a flooded compartment about y_n axis at k^{th} step

$i_P^{(k)}$: centrifugal moment of the waterplane area of a flooded compartment about x_n and y_n axis at k^{th} step

${}^{n}x_{f^{(k)}/E}$: x_n coordinate of centroid of the waterplane area of a flooded compartment at k^{th} step

${}^{n}y_{f^{(k)}/E}$: y_n coordinate of centroid of the waterplane area of a flooded compartment at k^{th} step

${}^{n}z_{G_{ext}^{(k)}/E}$: z_n coordinate of center of the submerged volume of a flooded compartment at k^{th} step

By using the Eq. (2) the position and orientation of the ship in static equilibrium state can be calculated. Answer the following questions for the calculation of the position and orientation of the ship.

5. [4 points] Explain the meaning of the elements of the 3 by 3 matrix in the Eq. (2).

1) $-\rho g A_{WP}$

2) $-\rho g (I_T + z_B V)$

6. [10 points] Derive the following term among the (2,2) element of the 3 by 3 matrix of the Eq. (2).

$$-\rho g\left({}^{n} z_{B^{(k)}/E} \nabla^{(k)} + I_T^{(k)}\right)$$

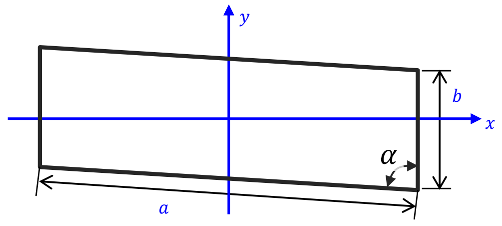
7. [4 points] The following term is in the (2,2) element of the 3 by 3 matrix of the Eq. (2).

$$-\, {}^{n}z_{G^{(k)}/E} \cdot F_G$$

This term means that an additional heeling moment is caused by gravitational force. Explain the reason why this heeling moment is caused by heel.

8. Answer the following question to calculate the static equilibrium position and orientation according to Figure 1 and Equation (2).

Second moment of area of parallelogram



$$I_{xx} = \frac{1}{12} ab \sin\alpha \left(b^2 + a^2 \cos^2\alpha\right)$$

$$I_{yy} = \frac{1}{12} a^3 b \sin^3\alpha$$

$$I_{xy} = 0$$

[Figure 6: Second moment of area of parallelogram]

8.1. [7 points] Carry out the first iteration to obtain the static equilibrium position and orientation of the ship using the lost buoyancy method.

8.2. [15 points] Check for the ship to be in the static equilibrium at the position and orientation of the first iteration.

8.3. [5 points] Explain the reason why we cannot calculate the exact static equilibrium position in the first iteration.

8.4. [15 points] Carry out the second iteration to obtain the static equilibrium position and orientation of the ship using the lost buoyancy method.