Ship Stability

Ch. 5 Initial Longitudinal Stability

Spring 2018

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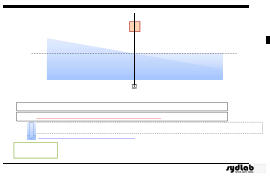
Contents

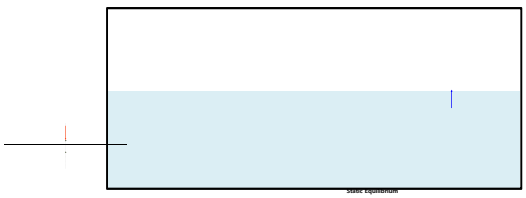
☑ Ch. 1 Introduction to Ship Stability
☑ Ch. 2 Review of Fluid Mechanics
☑ Ch. 3 Transverse Stability Due to Cargo Movement
☑ Ch. 4 Initial Transverse Stability
☑ Ch. 5 Initial Longitudinal Stability
☑ Ch. 6 Free Surface Effect
☑ Ch. 7 Inclining Test
☑ Ch. 8 Curves of Stability and Stability Criteria
☑ Ch. 9 Numerical Integration Method in Naval Architecture
☑ Ch. 10 Hydrostatic Values and Curves
☑ Ch. 11 Static Equilibrium State after Flooding Due to Damage
☑ Ch. 12 Deterministic Damage Stability
☑ Ch. 13 Probabilistic Damage Stability

Ch. 5 Initial Longitudinal Stability

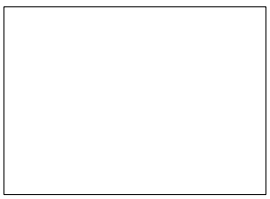
1. Longitudinal Stability
2. Longitudinal Stability in Case of Small Angle of Trim
3. Longitudinal Righting Moment Arm
4. Derivation of Longitudinal Metacentric Radius (BM_L)
5. Moment to Trim One Degree and Moment to Trim One Centimeter (MTC)
6. Example of Longitudinal Stability

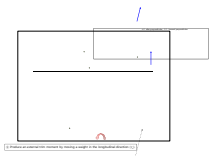
1. Longitudinal Stability



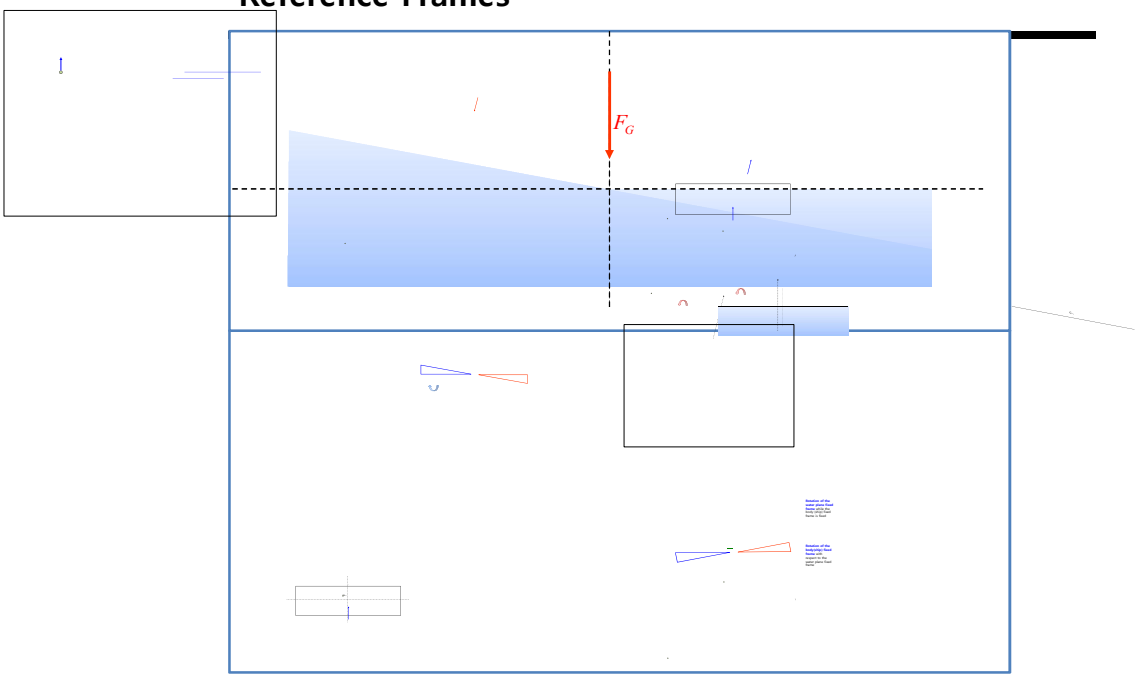


L_1



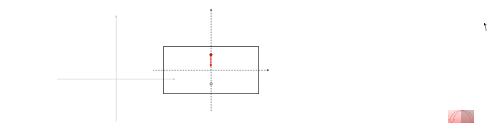


Reference Frames

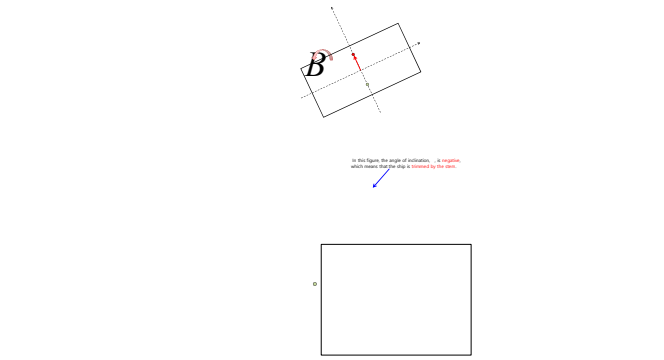


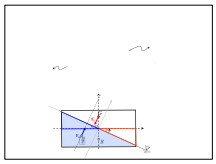
7

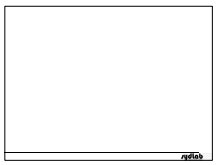
Longitudinal Stability of a Ship
- Stable Condition (1/3)



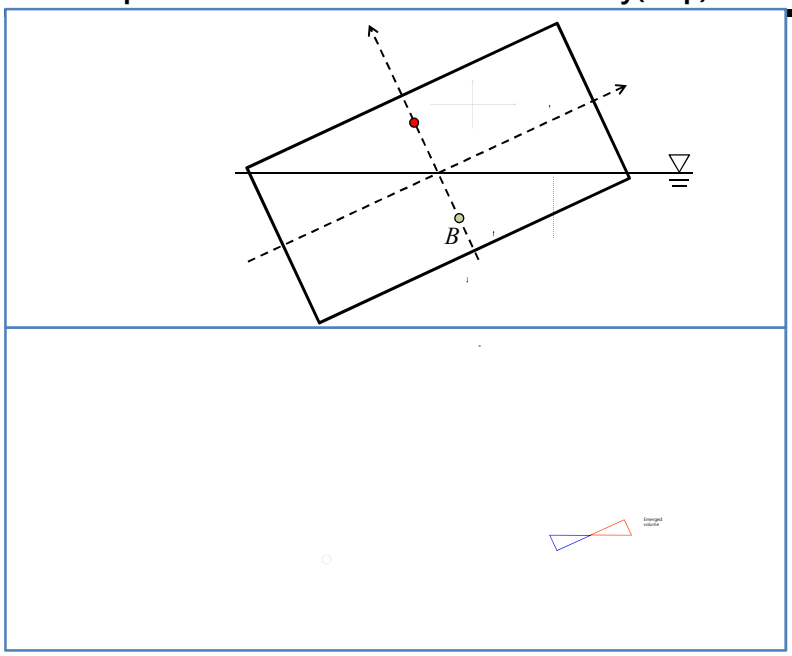
Longitudinal Stability of a Ship - Stable Condition (2/3)







Position and Orientation of a Ship with Respect to the Water Plane Fixed and Body(Ship) Fixed Frame

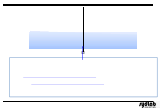


Rotation of the body (ship) fixed frame while the water plane fixed frame is fixed

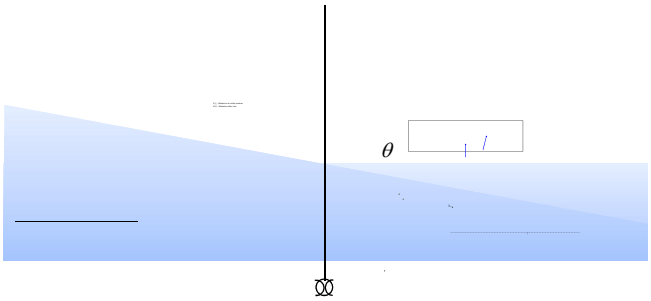
Same in view of the Mechanics!!

Rotation of the water plane fixed frame while the body (ship) fixed frame is fixed

11



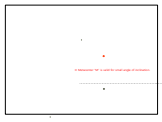
Assumptions for Small Angle of Trim

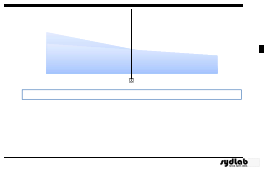


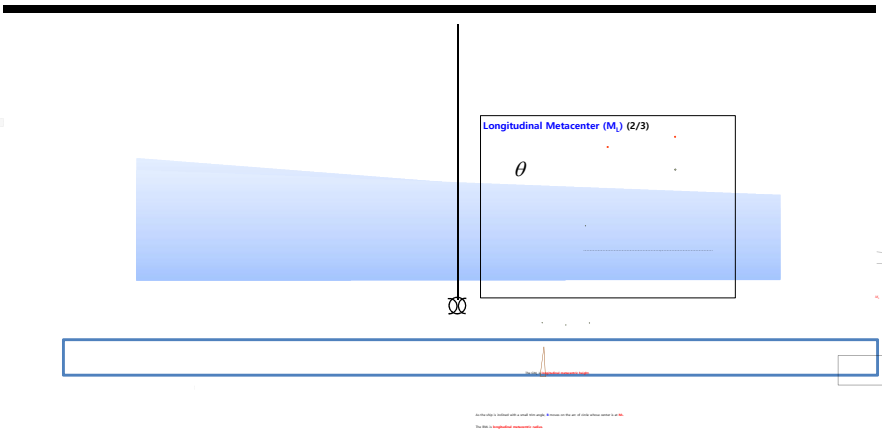
Assumptions

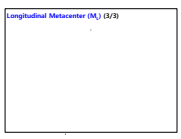
① Small angle of inclination (3~5° for trim)

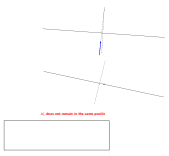
② The submerged volume and the emerged volume are to be the same.

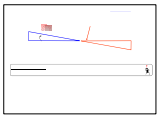


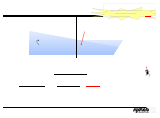



Longitudinal Metacenter (M_L) (2/3)
θ


Longitudinal Metacenter (M_L) (3/3)



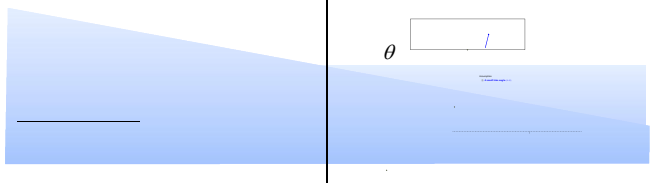




Longitudinal Stability for a Box-Shaped Ship

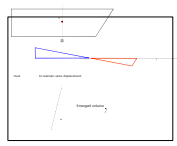
② The **submerged volume** and the **emerged volume** are to be the **same**.

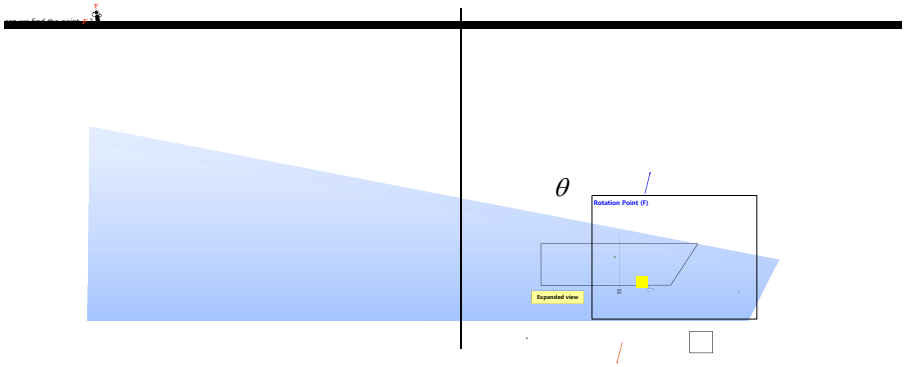
⊠ : Midship



① Apply an external trim moment (τ_e) which results in the ship to incline with a trim angle θ.

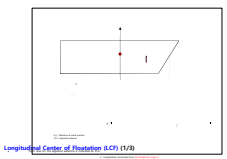
② For the **submerged volume** and the **emerged volume** are to be the **same**, the ship rotates **about the transverse axis through the point O**.

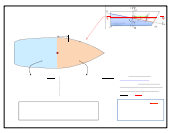




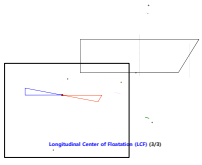
So, **the draft** must **be adjusted** to maintain same displacement.

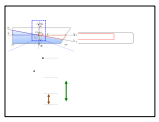
The intersection of the initial waterline (W_1L_1) with the adjusted waterline (W_3L_3) is a point ***F***, on which the submerged volume and the emerged volume are supposed to be the same.



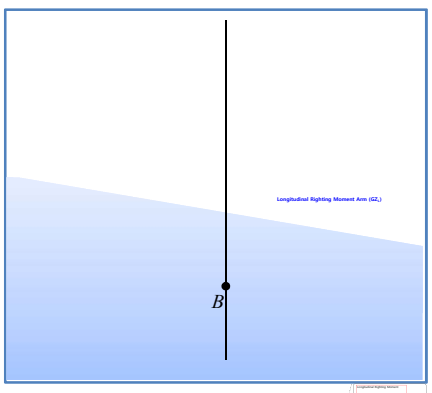


$$= \int_{A.P}^{F} x' \cdot y' \, dx'$$





3. Longitudinal Righting Moment Arm

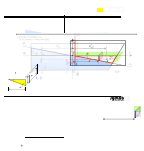


4. Derivation of Longitudinal Metacentric Radius (BM_L)

Derivation of Longitudinal Metacentric Radius (BM_L) (1/8)

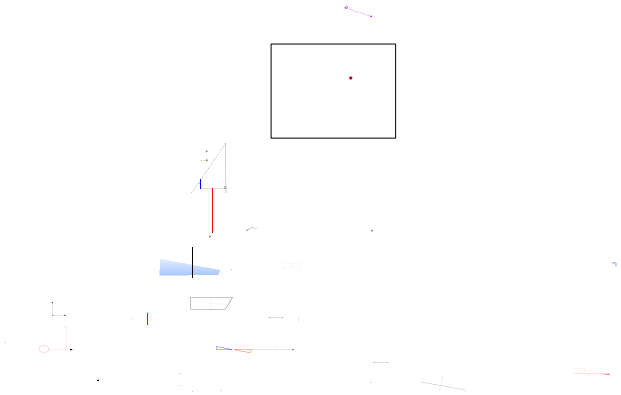
Because the triangle $gg'g_1$ is similar with $BB'B_1$

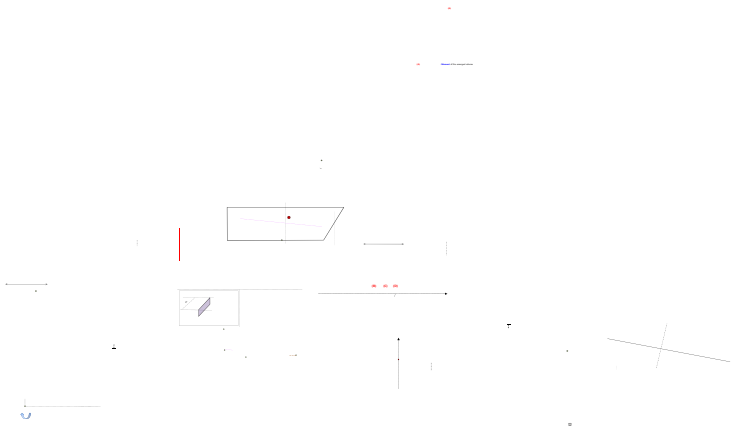
$$\frac{BB_1}{gg_1} = \frac{BB'}{gg'}$$

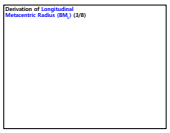


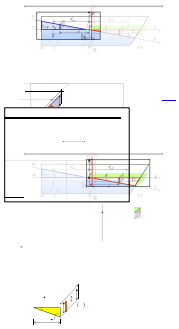
Derivation of Longitudinal Metacentric Radius (BM_L) (2/8)

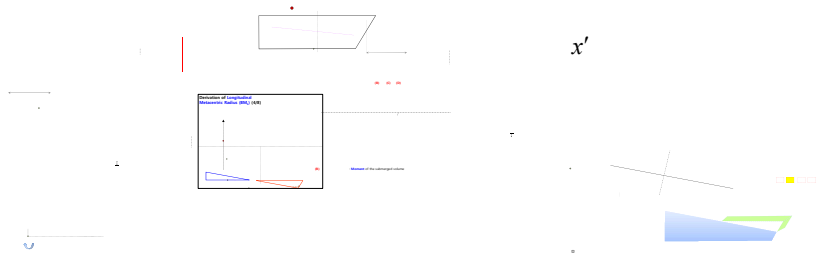
$$BM_L \cdot \tan\theta = BB_2$$

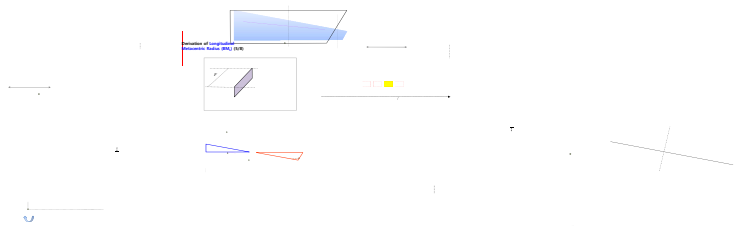


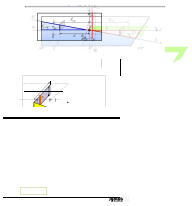






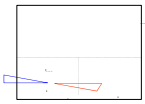


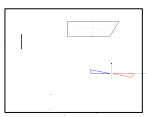


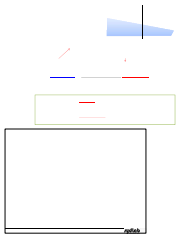


Derivation of Longitudinal Metacentric Radius (BM_L) (6/8)

x'



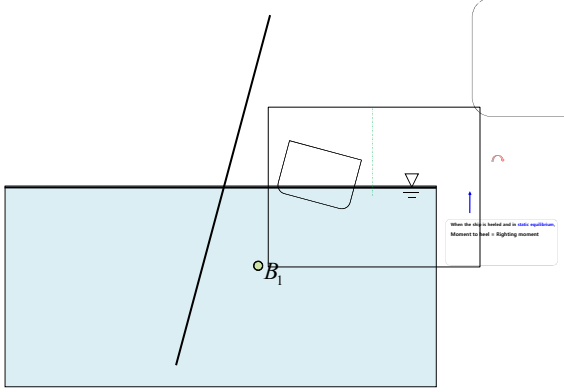


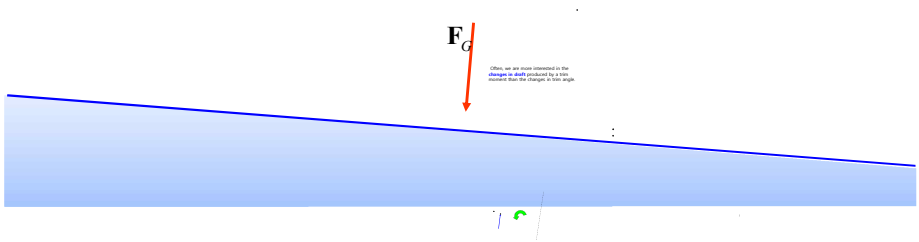


Derivation of Longitudinal Metacentric Radius (BM_L) (8/8)

$$BM_L = \frac{I_L}{\nabla}$$

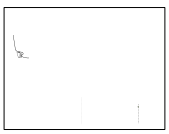
Moment to Heel One Degree

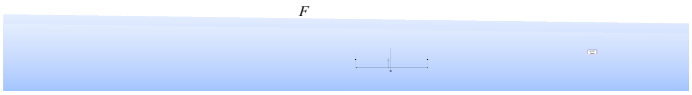



F_G

6. Example of Longitudinal Stability

W_1

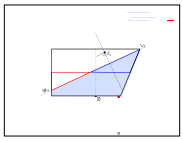




① Calculation of parallel rise (draft change)

- Tones per 1 cm immersion (TPC)


L_3



[Appendix] Derivation of Longitudinal Metacentric Radius (BM_L) by Using the Origin of the Body Fixed Frame

Derivation of BM_L (1/12)

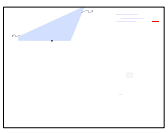
K

Let us derive longitudinal metacentric radius "BM_L".

Assumption

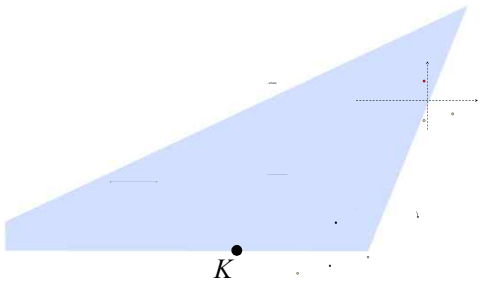
1. **A main deck is not submerged.**
2. **Small angle of inclination** (3~5° for trim)

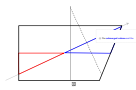
※ The ship is not symmetrical with respect to midship section. Thus to keep the same displaced volume, the axis of inclination does not stand still. In small angle of inclination, the axis of inclination passes through the point "F" (longitudinal center of floatation).



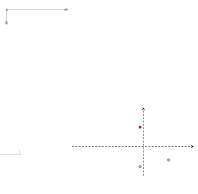
Derivation of BM_L (2/12)

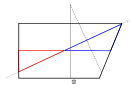
∇: Displacement volume
v: Submerged / Emerged volume
B: The center of buoyancy before inclination
B_1: The center of buoyancy after inclination
g: The center of the emerged volume
g_1: The center of the submerged volume

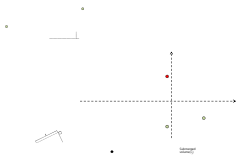


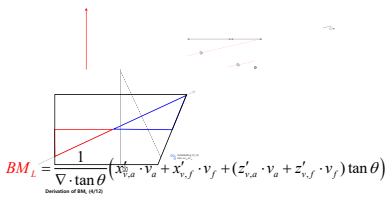


47



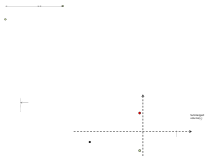


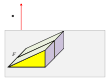


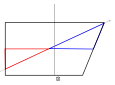


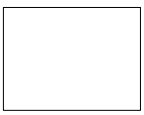
$$BM_t = \frac{1}{\nabla \cdot \tan\theta}\left(x'_{v,a} \cdot v_a + x'_{v,f} \cdot v_f + (z'_{v,a} \cdot v_a + z'_{v,f} \cdot v_f)\tan\theta\right)$$

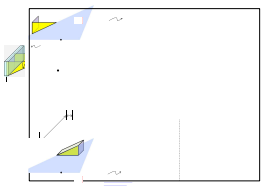
Derivation of BML (4/12)



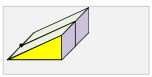


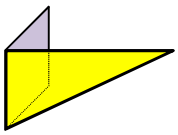




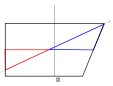


Derivation of BM_L (6/12)

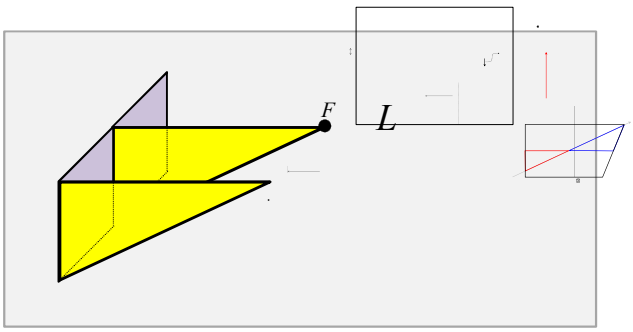




(B) $x'_{v,a} \cdot v_a$: Moment about transverse axis through point O of the emerged volume



51

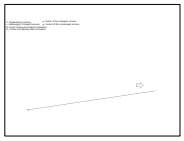


53

Derivation of BM_L (10/12)

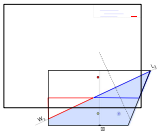
$$BM_L = \frac{1}{\nabla \cdot \tan\theta}\left(x'_{v,f} \cdot v_f + x'_{v,a} \cdot v_a + (z'_{v,f} \cdot v_f + z'_{v,a} \cdot v_a)\tan\theta\right)$$

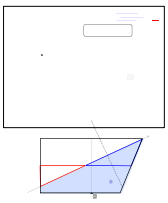
⇩ By substituting (A), (B), (C), and (D) into above equation



Derivation of BM_L (12/12)

$$BM_L = \frac{I_{L,\,t_y}}{\nabla}$$





Derivation of BM_L (1/4)

∇: Displacement volume
v: Submerged / Emerged volume
B: The center of buoyancy before inclination
B_1: The center of buoyancy after inclination
g: The center of the emerged volume
g_1: The center of the submerged volume

The change in moment about the y_t-axis due to the buoyant force caused by a small inclination, θ, consists of two different components:

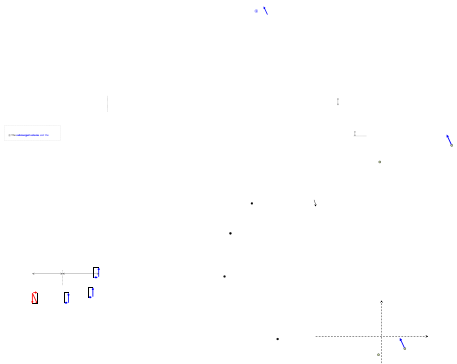
1. The change in moment due to the movement of the previous center of buoyancy B by rotation of the ship : M①

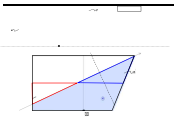
2. The change in the displaced volume

1) The change in moment due to the emerged volume: M②

2) The change in moment due to the (additional) submerged volume: M③

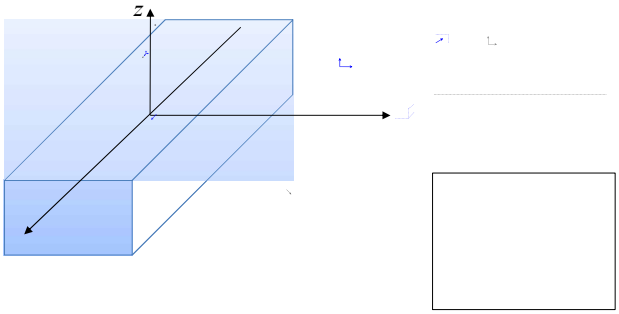
59

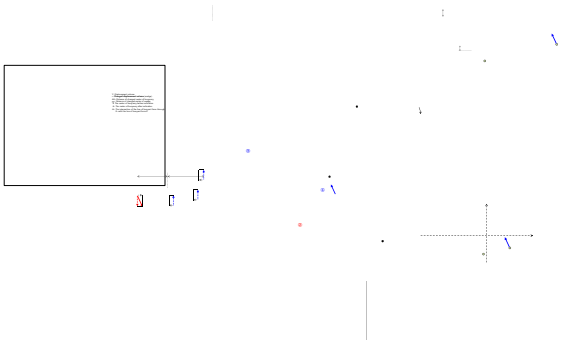


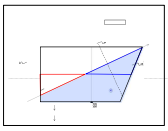


[Reference] Moment about x axis

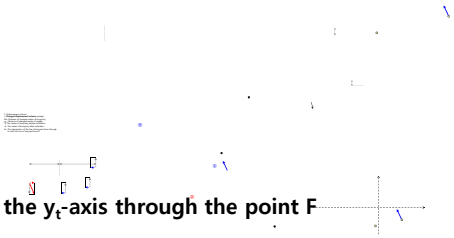
Question)
Force **F** is applied on the point of rectangle object, what is the moment about x axis?







Derivation of BM_L (4/4)



Moment about the y_t-axis through the point F

$$ {}^{t}z_{B_1} \cdot (\rho g \nabla \cdot \cos\theta) = {}^{t}z_{B} \cdot (\rho g \nabla \cdot \sin\theta) + {}^{t}z_{v,a} \cdot (\rho g v_a \cdot \sin\theta) + {}^{t}z_{v,f} (\rho g v_f \cdot \sin\theta) $$