

Ship Stability

Ch. 4 Initial Transverse Stability

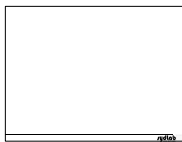
Spring 2018

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Contents

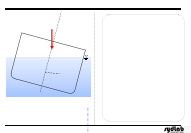
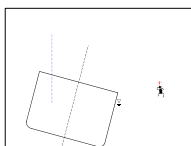
- ☑ Ch. 1 Introduction to Ship Stability
- ☑ Ch. 2 Review of Fluid Mechanics
- ☑ Ch. 3 Transverse Stability Due to Cargo Movement
- ☑ Ch. 4 Initial Transverse Stability
- ☑ **Ch. 5 Initial Longitudinal Stability**
- ☑ Ch. 6 Free Surface Effect
- ☑ Ch. 7 Inclining Test
- ☑ Ch. 8 Curves of Stability and 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. 4 Initial Transverse Stability

1. Transverse Metacentric Height (GM)
2. Derivation of Transverse Metacentric Radius (BM_T)
3. Change of the Metacenter for Large Angle of Inclination
4. Another Approach to Derive the Following Formula

$$\delta y'_B \cdot \nabla = y'_{vp} \cdot v_p + y'_{vs} \cdot v_s$$



Righting Arm (GZ, Restoring Arm)

$$\tau_{righting} = F_B \cdot GZ$$

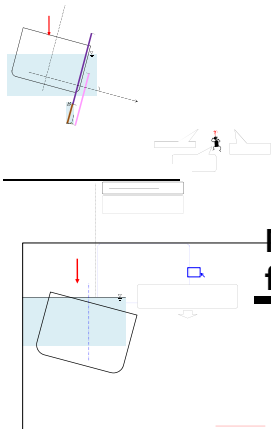
- Transverse Righting Moment

How can we find GZ in small angle



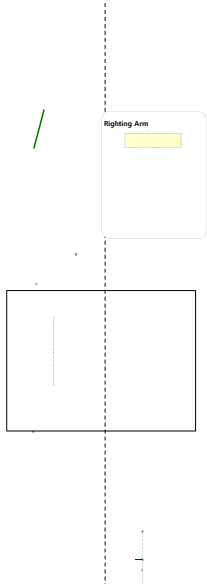
Definition of M (Metacenter)
 The theoretical point of the vertical line through the center of buoyancy and the vertical line through the center of gravity at small angles.

GM
 The term used to describe a ship's stability. It is the distance between the center of buoyancy and the metacenter.



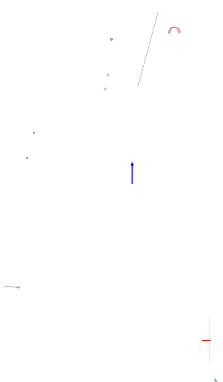
Metacentric Height (GM) of a Ship for **Small Angle** of Inclination

$$\tau_{\text{righting}} = F_B \cdot GZ$$

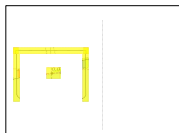


* From the geometrical configuration of the ship, GM is made up of follow:

* Transverse Righting Moment



* Transverse Righting Moment

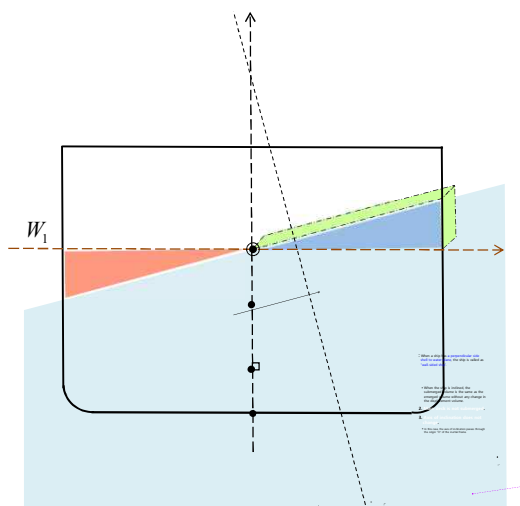


2. Derivation of Transverse Metacentric Radius (BM_T)

Derivation of BM_T (1/12) (BM_T : Transverse Metacentric Radius)

Let us derive the transverse metacentric radius " BM " in case of a **wall-sided ship** with a simple section shape.

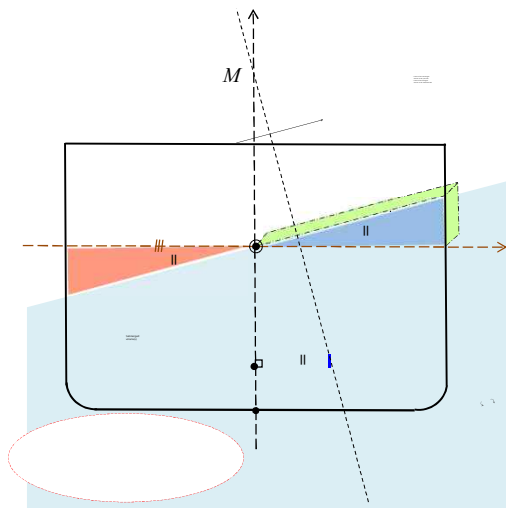
▪ **Wall sided ship**



Assumption

1.

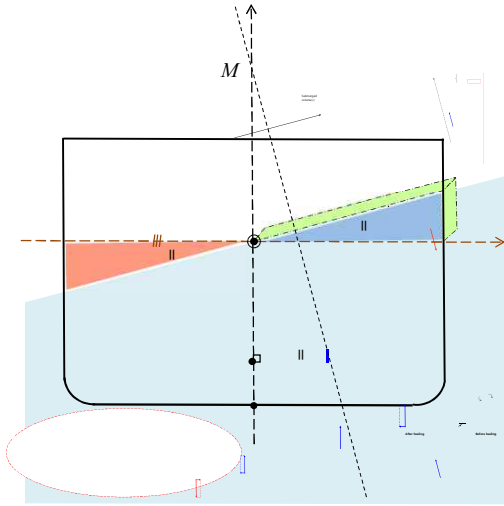
Derivation of BM_T (2/12)



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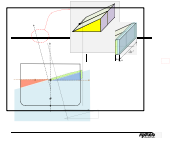
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Derivation of BM_T (4/12)

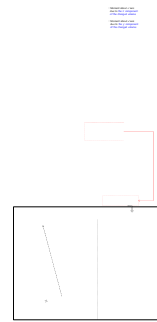
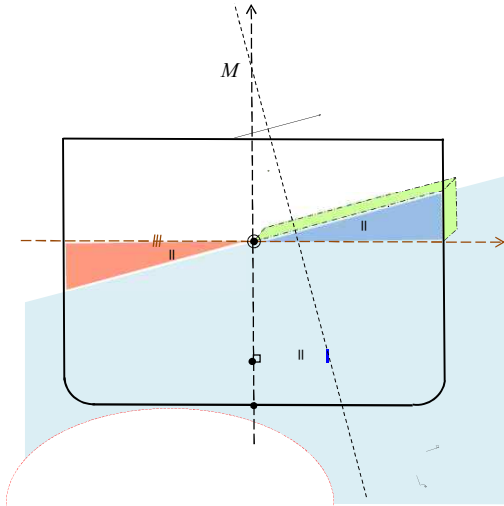


13

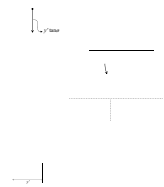
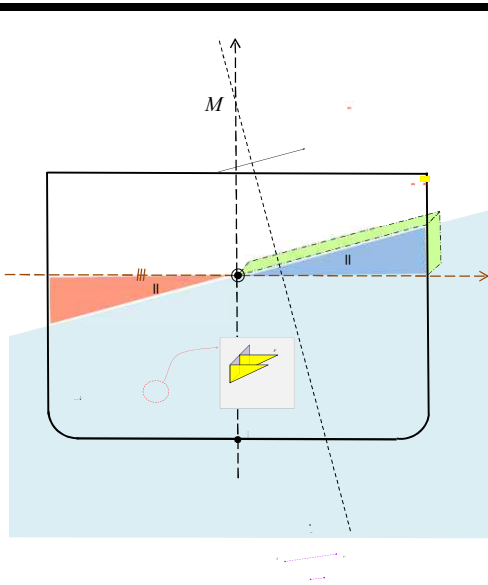
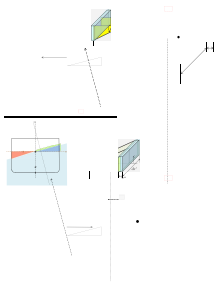


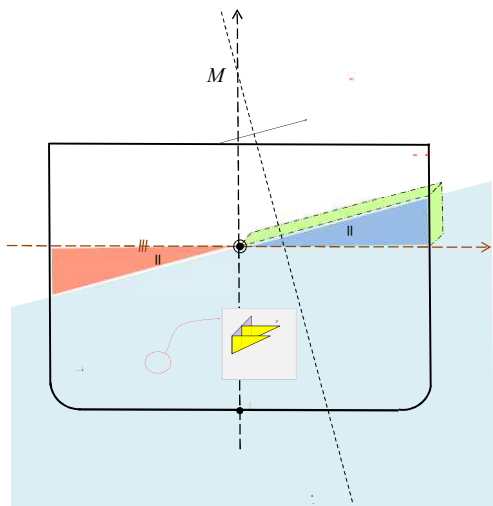
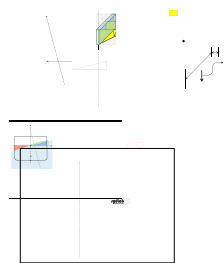


Derivation of BM_T (6/12)

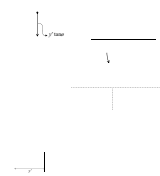


15

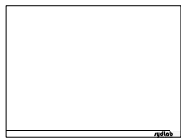
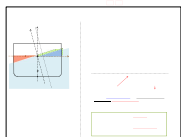




Derivation of RM_1 (10/12)

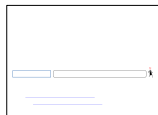


19

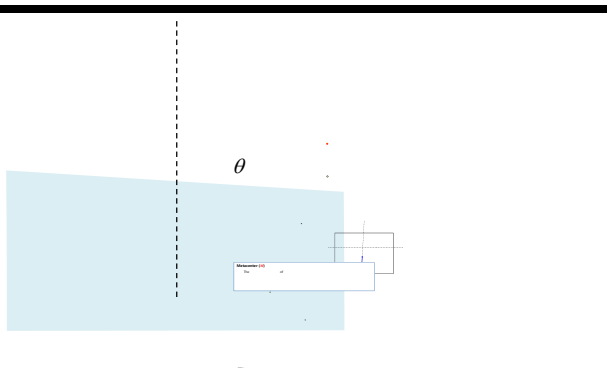
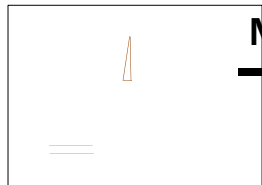


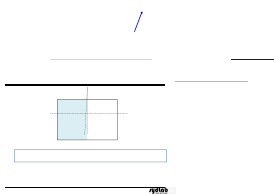
Derivation of BM, (12/12)

$$BM = \frac{I_x}{\nabla} \left(1 + \frac{1}{2} \tan^2 \phi \right)$$

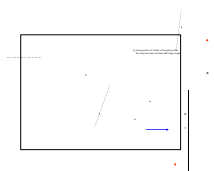
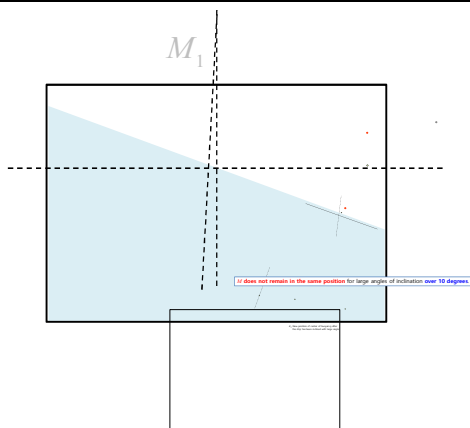


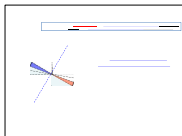
Metacenter (M)





Metacenter (M) at Large Angles





Example of Metacenter (M)

B-B': Trajectory of the center of buoyancy as function of the inclination angle

Typical locus of metacenter and centers of buoyancy for an average form merchant ship

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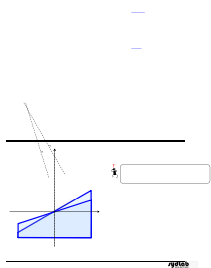
27

Metacenter (M) of Circular Section

τ_c

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28

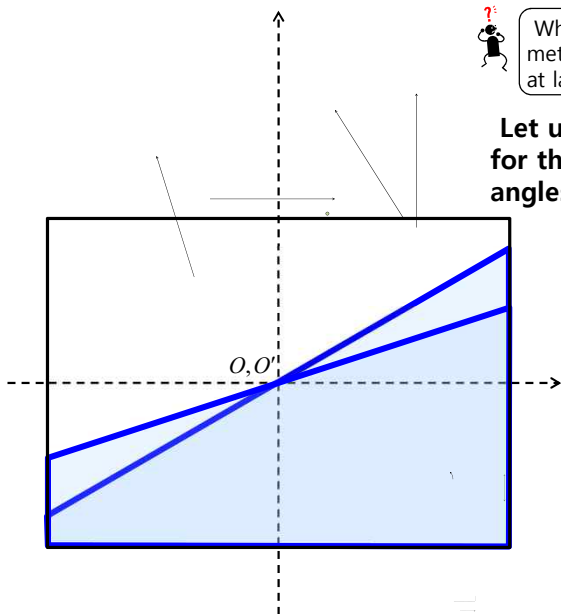


Metacenter (M) of a Box-shaped Ship (1/4)



What will be the location of the metacenter (M) for the box-shaped ship at large angles of heel?

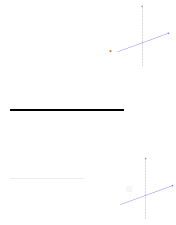
Let us calculate the metacenter (M) for the barge-shaped ship at various angles of heel.



29

Metacenter (M) of a Box-shaped Ship (2/4)





Metacenter (M) of a Box-shaped Ship (3/4)
- Center of Buoyancy at a Given Angle of Heel

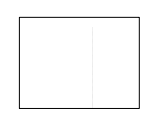
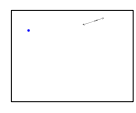


What will be the location of the metacenter (M) for the box-shaped ship at large angles of heel?

(1) Center of Buoyancy (B) at a given angle of heel ϕ



31

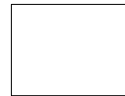


Metacenter (M) of a Box-shaped Ship (3/4)
- Metacenter at Given Angles of Heel (1/4)

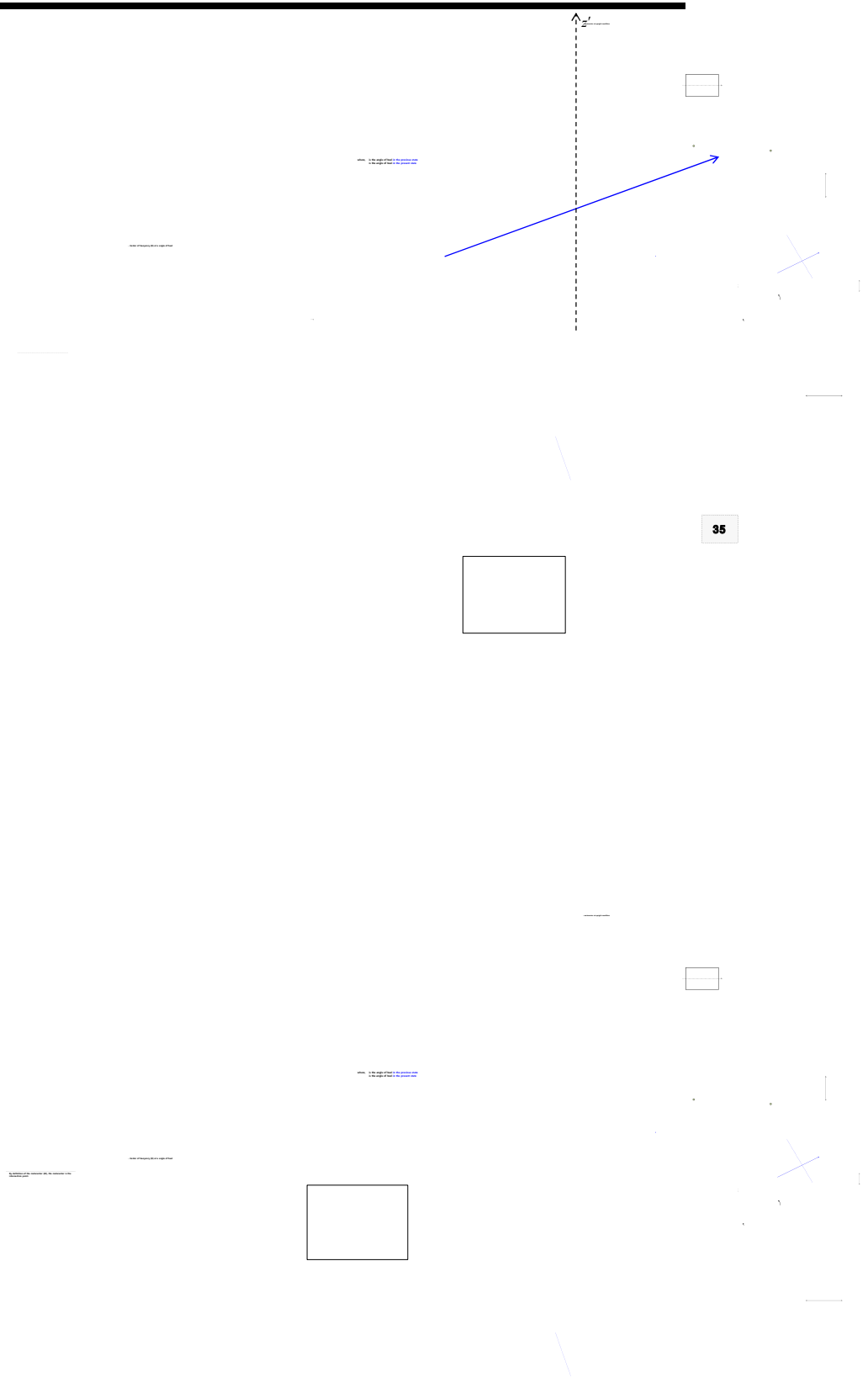
(3) Metacenter (M) at given angles of heel ϕ_1, ϕ_2

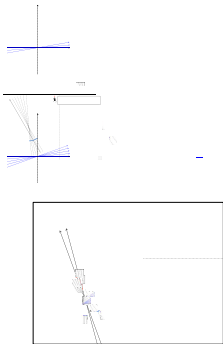


33



Metacenter (M) of a Box-shaped Ship (3/4) - Metacenter at Given Angles of Heel (3/4)



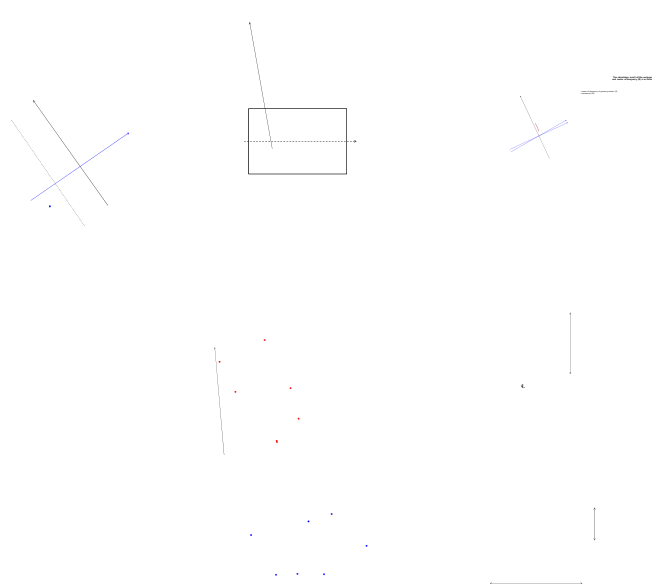


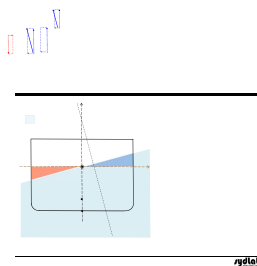
Metacenter (M) of a Box-shaped Ship (4/4) - Result (1/2)

What will be the location of the metacenter (M) for the box-shaped ship at large angles of heel?

ϕ : angle of heel at present position
 ϕ' : angle of heel at next position

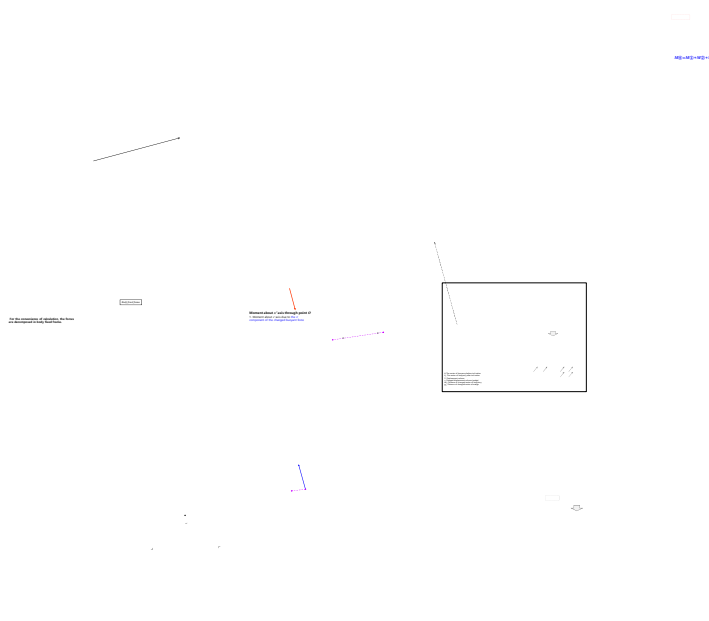
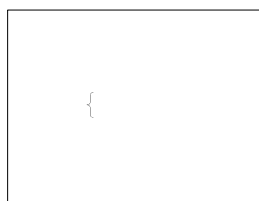
37

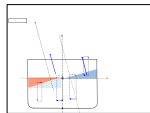




4. Another Approach to Derive the Following Formula

$$\delta y'_B \cdot \nabla = y'_{vp} \cdot v_p + y'_{vs} \cdot v_s$$

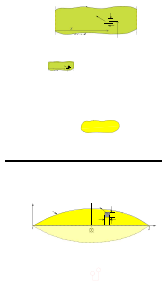




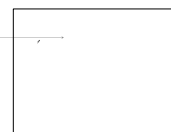
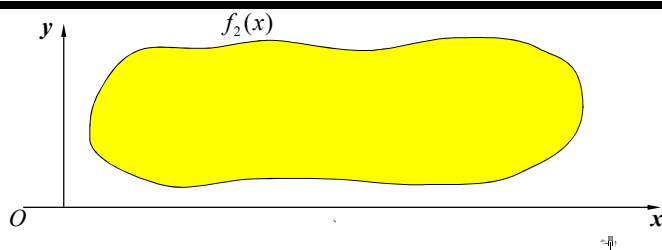
$(\delta z'_B) \cdot (\rho g \nabla \cdot \sin \phi) = z'_{vp} \cdot (\rho g v_p \cdot \sin \phi)$
 $+ z'_{vs} \cdot (\rho g v_s \cdot \sin \phi)$

Derivation of BM: (2/2)

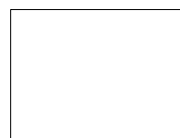


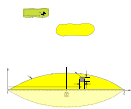


[Reference] Area, Moments, Centroid, and Moments of Inertia



43





[Reference] Area, Moments, Centroid, and Moments of Inertia
 - Longitudinal Moment of Inertia (I_L)

$$x_1 \rightarrow 0, x_2 \rightarrow L, f_1(x) \rightarrow 0, f_2(x) \rightarrow b(x)$$