ENGR 292 Fluids and Thermodynamics

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ENGR 292

- ***Course Schedule (see attached revised course schedule for details)***
  - *Fluid Statics*
  - *Fluid Dynamics*
  - *Midterm (Feb.28)*
  - *Thermodynamics*
  - *Others*
  - *Final (Apr.18, Tentative)*

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ENGR 292

- ***Course Notes on Web vs PPT***
  - *Notes for reading in detail*
  - *PPT is easy to present and to control the time in the class.*
  - *Whiteboard will be used to support PPT to explain the details, and derivation and Figures.*

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ENGR 292

- ***Fluid Statics***
  - *Start with Concepts*
  - *Then Examples*

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ENGR 292

- ***Fluid Dynamics***
  - *Start with an Example (a project)*
  - *Talk about the concepts, principles and equations during the problem-solving*
  - *You need to read books or other references of fluid dynamics to brush up on your memory to fully understand all the relevant stuffs, such as:*
    - *Control volume analysis*
    - *Bernoulli's Equation*
    - *Navier-Stokes Equation (NS Equation)*
    - *...*

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ENGR 292

- ***Thermodynamics***
  - *Mix the above style*

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Review of Last Class

- **Absolute and Gage Pressure**

$$P_{abs} = P_{gage} + P_{atm}$$

where

P_{abs} = Absolute pressure

P_{gage} = Gage pressure

P_{atm} = Atmospheric pressure

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Review of Last Class

- **Absolute and Gage Pressure**
  - *In the course, we will assume the atmospheric pressure to be 101 kpa (abs) or 14.7 psia.*
  - *Gage Pressure is the default pressure.*

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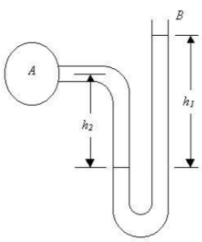
Review of Last Class

- ***Manometer – Pressure Measurement; As a default, we use gage pressure.***



$$p_A = p_B + \gamma_B h_1 - \gamma_A h_2$$

If $P_B = P_{atm} = 0$ psig

P_A = gage pressure

If $P_B = P_{atm} = 14.7$ psig

P_A = Absolute pressure

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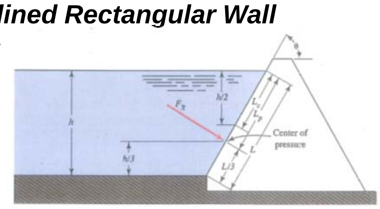
Review of Last Class

- ***Forces due to static Fluids***
- ***Inclined Rectangular Wall***



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Review of Last Class

- ***Inclined Rectangular Wall***
  - *Average Pressure (P_{avg})*

$$P_{avg} = \gamma\left(\frac{h}{2}\right)$$

  - *Magnitude of the Force*

$$F_R = P_{avg}A = \gamma\left(\frac{h}{2}\right)A$$

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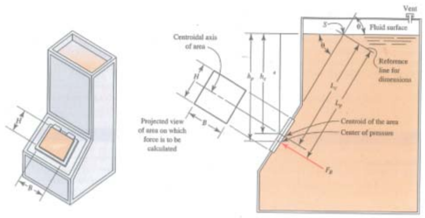
Review of Last Class

- ***Submerged Plane Areas – General***
  - *Either Vertical or Inclined Rectangular Wall*



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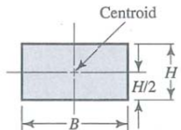
Review of Last Class

- **Key Equations:**
  - $F_R = \gamma h_c A$
  - $L_p = L_c + \frac{I_c}{L_c A}$
  - $h_P = L_p sin\theta$
  - $h_P = h_c + \frac{I_c \sin^2\theta}{h_c A}$



$I_c = \frac{BH^3}{12}$

$A = BH$

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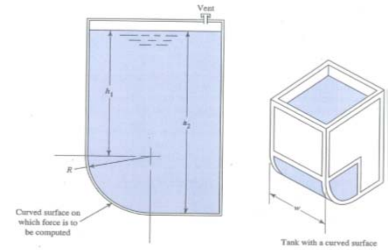
Review of Last Class

- **Submerged Curved Surface :**
- **Tank with a curved surface containing a static fluid**



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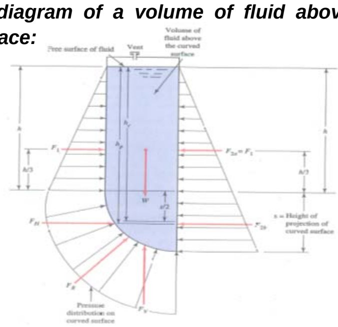
Review of Last Class

- **Free-body diagram of a volume of fluid above the curved surface:**



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Review of Last Class

- **Horizontal Component, Key Equations:**

$F_H = F_{2b}$

$F_{2b} = \gamma h_c A = \gamma sw(h + \frac{s}{2})$

$h_p - h_c = I_c/(h_c A)$

$I_c = ws^3/12$

$A = sw$

$$h_p - h_c = I_c/(h_c A) = \frac{ws^3}{12(h_c)(sw)} = \frac{s^2}{12h_c}$$

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Review of Last Class

- **Vertical Component, Key Equation:**

$$F_V = \gamma(volume) = \gamma A_v w$$

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Review of Last Class

- **Resultant Force**

$$F_R = \sqrt{F_H^2 + F_V^2}$$

The resultant force acts at angle ϕ relative to the horizontal found from:

$$\phi = \tan^{-1}(F_V/F_H)$$

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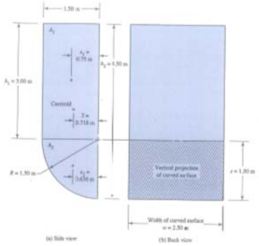
Example 17

- **Given:** $h_1 = 3.00\,m;\ h_2 = 4.50\,m;\ w = 2.50\,m;$ $\gamma = 9.81\,kN/m^3$(water)



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Composite-Area Technique

- $x_1 = \frac{1.5}{2} = 0.75$
- $x_2 = 0.424R = 0.424 * 1.5 = 0.636$
- $\bar{x} = \frac{A_1x_1 + A_2x_2}{A_1 + A_2} = 0.718$

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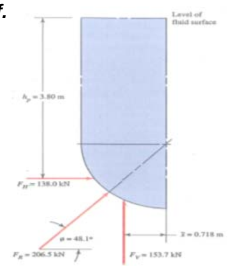
Example 17

- ***Compute the horizontal and vertical components of the resultant force on the curved surface and the resultant force itself.***



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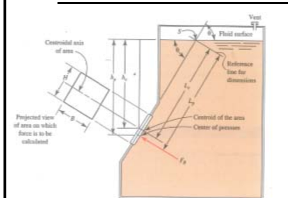
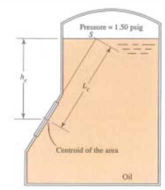
Piezo-metric Head



Vs.



- ***In all the problem demonstrated so far, the free surface of the fluid was exposed to the ambient pressure, where p=0 (gage).***
- ***A change is required in our procedure if the pressure above the free surface of the fluid is different from the ambient pressure outside the area.***

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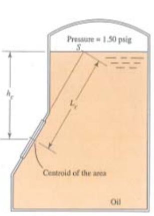
Piezo-metric Head



$h_a = \frac{p_a}{\gamma}$

Showing piezometric head equivlent to pressure above oil

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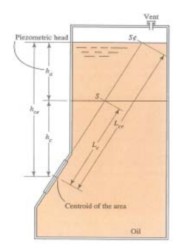
Piezo-metric Head

- ***The convenient method would be to use the concept of piezo-metric head, in which the actual pressure above fluid p_a, is converted into an equivalent depth of the fluid, h_a, that would create the same pressure.***



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Buoyancy Material

- The design of floating bodies often requires the use of light-weight materials that offer a high degree of buoyancy.

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Buoyancy Material

- The Buoyancy material should typically have the following properties:
  - Low Specific weight and density
  - Little or no tendency to absorb the fluid
  - Compatibility with the fluid in which it will operate
  - Ability to be formed to appropriate shapes
  - Ability to withstand fluid pressures to which it will be subjected
  - Abrasion resistance and damage tolerance
  - Attractive appearance

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Stability of Completely Submerged Bodies

- A body in a fluid is considered stable if it will return to its original position after being rotated a small amount about a horizontal axis.

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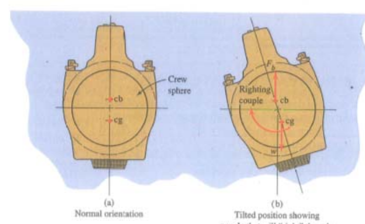
Stability of Completely Submerged Bodies



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Stability of Completely Submerged Bodies

- Condition of Stability for Submerged Bodies

  The completely submerged body is stable in a fluid if the center of gravity of the body is below the center of buoyancy

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Stability of Completely Submerged Bodies

- Center of Gravity

  The weight of the body acts vertically downward through the center of Gravity

- Center of Buoyancy

  The center of buoyancy of a body is at the centroid of the displaced volume of the fluid, and it is through this point that the buoyant force acts in a vertical direction.

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Stability of Floating Bodies

- **Condition of Stability for Floating Bodies**

  A floating body is stable if its center of gravity is below the metacenter

  Metacenter (mc) is defined as the intersection of the vertical axis of a body when in its equilibrium position and a vertical line through the new position of the center of buoyancy when the body is rotated slightly.

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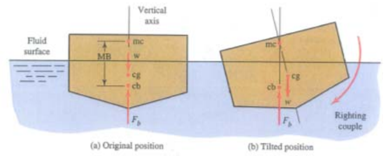
Stability of Floating Bodies



(a) Original position (b) Tilted position

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Stability of Floating Bodies

- ***The Location of the metacenter***
  - ***The distance to the metacenter from the center of buoyancy is called MB and is calculated from***

$$MB = \frac{I}{V_d}$$

In this equation, V_d is the displaced volume of fluid and I is the least moment of inertia of a horizontal section of the body taken at the surface of the fluid. If the distance MB places the metacenter above the center of gravity, the body is stable.

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Stability of Floating Bodies

- ***Procedure for Evaluating the Stability of Floating Bodies***
  - ***Determine the position of the floating body, using the principles of buoyancy***
  - ***Locate the center of buoyancy, cb; compute the distance from some reference axis to cb, called y_{cb}. Usually, the bottom of the object is taken as the reference axis.***
  - ***Locate the center of gravity, cg; compute y_{cg} measured from the same reference axis.***

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Stability of Floating Bodies

- ***Procedure for Evaluating the Stability of Floating Bodies***
  - ***Determine the shape of the area at the fluid surface and compute the smallest moment of inertia I for that shapes.***
  - ***Compute the displaced volume V_d***
  - ***Compute MB = I/V_d***
  - ***Compute $y_{mc} = y_{cb} + MB$***
  - ***If $y_{mc} > y_{cb}$, the body is stable***
  - ***If $y_{mc} < y_{cb}$, the body is unstable***

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Example 18

- ***Figure below shows a flat boat hull that, when fully loaded, weight 150 kN. Parts (b)-(d) show the top, front, and side views of the boat, respectively. Note the location of the center of gravity, cg. Determine whether the boat is stable in fresh water …***

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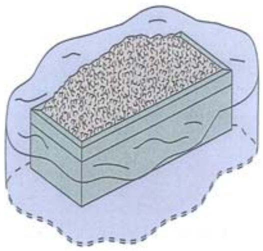
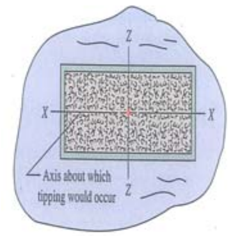
Example 18

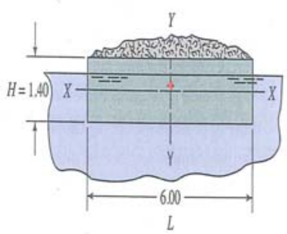


Example 18



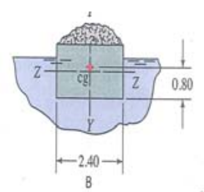
(b) Top view and horizontal

Example 18



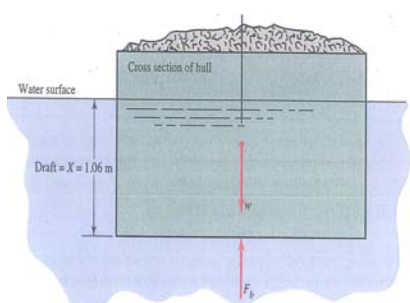
(d) Side view

Example 18

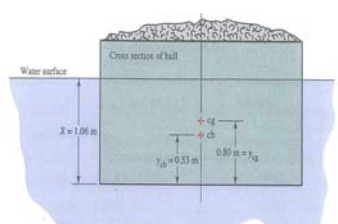


(c) Front view and vertical cross section

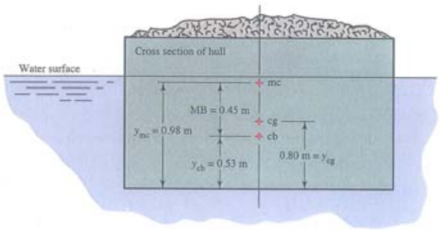
Example 18



Example 18



Example 18



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Example 19

- A solid cylinder is 3.0ft in diameter, 6.0 ft high, and weighs 1550 lb. If the cylinder is placed in oil (sg=0.9) with its axis vertical, would it be stable?

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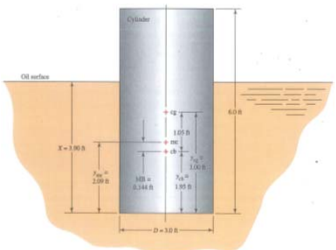
Example 19



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Summary of Stability

- Completely submerged bodies are stable if the center of gravity (cg) is below the center of buoyancy (cb)
- Floating bodies are stable if the center of gravity (cg) is below the metacenter.

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Degree of Stability

- One measure of relative stability is call the metacentric height, defined as the distance to the metacenter above the center of gravity and called MG.
- An object with a larger metacentric height is more stable than one with a smaller value.

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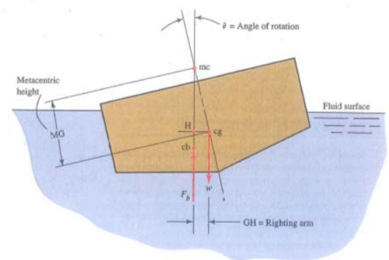
Degree of Stability



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Degree of Stability

- Refer to the figure above, the metacentric height is labeled MG. Using the procedures discussed in this chapter, we can compute MG from:

$$MG = y_{mc} - y_{cg}$$

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Degree of Stability

- Some references state that small seagoing vessels should have a minimum value of MG of 1.5 ft. (o.46 m); Large ships should have MG >3.5 ft. (1.07 m)
- The metacentric height should not be too large, however, because the ship may then exhibit the uncomfortable rocking motions that cause seasickness.

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Static Stability Curve

- One measure of relative stability is call the metacentric height, defined as the distance to the metacenter above the center of gravity and called MG.
- An object with a larger metacentric height is more stable than one with a smaller value.

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Static Stability Curve

- Another measure of the stability of a floating object is the amount of offset between the line of action of the weight of the object acting through the center of gravity and that of the buoyant force acting through the center of buoyancy.

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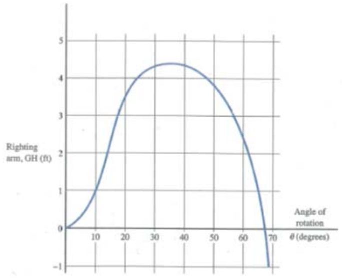
Static Stability Curve



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Static Stability Curve

- As long as the value of GH remains positive, the object is stable
- Conversely, when GH becomes negative, the ship is unstable, and it will overturn.

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What is next?

- **Any Questions?**
- **Next class, we will start Fluid Dynamics**

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Review of Fluid Statics

- **Key Equations:**
  - **Pressure:**

$$P = \frac{F}{A}$$

  - **Weight-Mass Relationship:**

$$W = mg$$

  - **Bulk Modulus:**

$$E = \frac{-\Delta P}{\frac{\Delta V}{V}}$$

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Review of Fluid Statics

- **Key Equations:**
  - **Density:**

$$\rho = \frac{m}{V}$$

  - **Specific Weight:**

$$\gamma = \frac{W}{V}$$

  - **Specific Gravity**

$$sg = \frac{\gamma_s}{\gamma_w @ 4℃} = \frac{\rho_s}{\rho_w @ 4℃}$$

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Review of Fluid Statics

- **Key Equations:**
  - **$\gamma - \rho$ relation:**

$$\gamma = \rho g$$

  - **Dynamic Viscosity:**

$$\eta = \frac{\tau}{\frac{\Delta v}{\Delta y}} = \tau\left(\frac{\Delta y}{\Delta v}\right)$$

  - **Kinematic Viscosity:**

$$v = \frac{\eta}{\rho}$$

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Review of Fluid Statics

- **Key Equations:**
  - **Absolute and Gage Pressure**

$$P_{abs} = P_{gage} + P_{atm}$$

  - **Pressure-Elevation Relationship**

$$\Delta p = \gamma h$$

  - **Resultant force on a rectangular wall**

$$F_R = \gamma \left(\frac{h}{2}\right) A$$

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Review of Fluid Statics

- **Key Equations:**
  - **Location of Center of Pressure**

$$L_p = L_c + \frac{I_c}{L_c A}$$

  - **Buoyant force**

$$F_b = \gamma_f V_d$$

  - **Piezometric Head**

$$h_a = p_a/\gamma$$

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Assignment 1

- ***Due: Midnight Jan.31, 2017***
  - ***D2L Dropbox***

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