TEST QUESTIONS - CHAPTER #2

Short Answer Questions

1. State Pascal's law.
   Ans. A pressure applied at any point in a liquid at rest is transmitted equally and undiminished in all directions to every other point in the liquid.

2. (T or F) The difference in pressure between any two points in still water is always equal to the product of the density of water and the difference in elevation between the two points.
   Ans. False – specific weight, not density.

3. Gage pressure is defined as
   a) the pressure measured above atmospheric pressure.
   b) the pressure measured plus atmospheric pressure.
   c) the difference in pressure between two points.
   d) pressure expressed in terms of the height of a water column.
   Ans. (a) is true

4. Some species of seals dive to depths of 400 m. Determine the pressure at that depth in N/m^2 assuming sea water has a specific gravity of 1.03.
   Ans. $P = \gamma \cdot h = (1.03)(9790\ N/m^3)(400\ m) = 4.03 \cdot 10^6\ N/m^2$

5. Pressure below the surface in still water (or hydrostatic pressure)
   a) is linearly related to depth.
   b) acts normal (perpendicular) to any solid surface.
   c) is related to the temperature of the fluid.
   d) at a given depth, will act equally in any direction.
   e) all of the above.
   f) (a) and (b) only.
   Ans. (e)

6. (T or F) A single-reading manometer makes use of a reservoir of manometry fluid with a large cross sectional area so that pressure calculations are only based on one reading.
   Ans. True.

7. What is an open manometer?
   Ans. A manometer is a pressure measurement device that utilizes fluids of known specific gravity and differences in fluid elevations. An open manometer has one end open to the air.

8. (T or F) The total hydrostatic pressure force on any submerged plane surface is equal to the product of the surface area and the pressure acting at the center of pressure of the surface.
   Ans. False. The total hydrostatic pressure force on any submerged plane surface is equal to the product of the surface area and the pressure acting at the centroid of the plane surface.

9. A surface of equal pressure requires all of the following except:
   a) points of equal pressure must be at the same elevation.
   b) points of equal pressure must be in the same fluid.
   c) points of equal pressure must be interconnected.
   d) points of equal pressure must be at the interface of immiscible fluids.
   Ans. (d); points of equal pressure do not need to be at and interface of fluids.

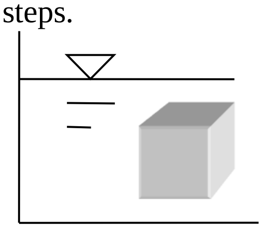
10. The center of pressure on inclined plane surfaces is:
    a) at the centroid.
    b) is always above the centroid.
    c) is always below the centroid.
    d) is not related to the centroid.
    Ans. (c); points of equal pressure do not need to be at and interface of fluids.

11. (T or F) The location of the centroid of a submerged plane area and the location where the resultant pressure force acts on that area are identical.
    Ans. False. The resultant force acts at the center of pressure.

12. The equation for the determination of a hydrostatic force on a plane surface and its location are derived using all of the following concepts except
    a) integration of the pressure equation b) moment of inertia concept
    c) principle of moments d) Newton's 2^{nd} Law
    Ans. Since this deals with hydrostatics (i.e., no acceleration), (d) is the answer.

13. The equation for the righting moment on a submerged body is $M = W \cdot GM \cdot \sin\theta$, where $GM = MB - GB$ or $MB + GB$. Under what conditions is the sum used instead of the difference?
    Ans. Use the sum when the center of gravity is below the center of buoyancy.

14. Given the submerged cube with area (A) on each face, derive the buoyant force on the cube if the depth (below the surface of the water) to the top of the cube is x and the depth to the bottom of the cube is y. Show all steps.



    Ans. $F_{bottom} = P_{avg} \cdot A = \gamma \cdot y \cdot A$; $F_{top} = P_{avg} \cdot A = \gamma \cdot x \cdot A$; $F_{bottom} - F_{top} = \gamma \cdot (y-x) \cdot A = \gamma \cdot Vol$

15. A 3 ft x 3 ft x 3 ft wooden cube (specific weight of 37 lb/ft^3) floats in a tank of water. How much of the cube extends above the water surface? If the tank were pressurized to 2 atm (29.4 psi), how much of the cube would extend above the water surface? Explain.
    Ans. $\sum F_y = 0$; $W = B$; $(37\ lb/ft^3)(3\ ft)^3 = (62.3\ lb/ft^3)(3\ ft)^2(y)$; $y = 1.78$ ft *Note: The draft does not change with pressure. That is, the added pressure on the top of the cube would be compensated by the increased pressure in the water under the cube.*

16. The derivation of the flotation stability equation utilizes which principles? Note: More than one answer is possible.
    a) moment of a force couple   b) moment of inertia
    c) Newton's 2nd Law   d) buoyancy
    Ans. It utilizes (a), (b), and (d).

17. Rotational stability is a major concern in naval engineering. Draw the cross section of the hull of a ship and label the three important points (i.e., centers) which affect rotational stability.
    Ans. See Figure 2.16.

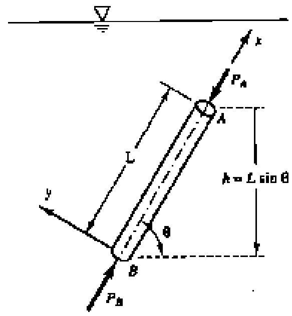
18. A 4 m (length) by 3 m (width) by 2 m (height) homogeneous box floats with a draft 1.4 m. What is the distance between the center of buoyancy and the center of gravity?
    Ans. G is 1 m up from bottom and B is 0.7 m up from bottom. Thus, GB = 0.3 m.

19. Determine the waterline moment of inertia about the width of a barge (i.e., used to assess stability from side to side about its width) if it is 30 m long, 12 m wide, and 8 m high?
    Ans. $I_o = (30m)(12m)^3/12 = 4320\ m^4$

20. (T or F) Floatation stability is dependent on the relative positions of the center of gravity and the center of buoyancy.
    Ans. True.

Problems

1. Given the submerged, inclined rod with a top and bottom area (dA), a length of L, and an angle of incline of θ, derive an expression that relates the pressure on the top of the rod to the pressure on the bottom. Show all steps and define all variables.



Ans. Because the prism is at rest, all forces acting upon it must be in equilibrium in all directions. For the force components in the inclined direction, we may write

$$\sum F_x = P_A dA - P_B dA + \gamma L dA \sin\theta = 0$$

Note that $L \cdot \sin\theta = h$ is the vertical elevation difference between the two points. The above equation reduces to

$$P_B - P_A = \gamma h$$

2. Collapse depth (or crush depth) is the submerged depth that a submarine can't exceed without collapsing due to the surrounding water pressure. The collapse depth of modern submarines is not quite a kilometer (730 m). Assuming sea water to be incompressible (S.G. = 1.03), what is the crush depth pressure in N/m^2 and psi (lb/in^2). Is the pressure you computed absolute or gage pressure?

Ans. P = γ·h; where γ = (1.03)(9810 N/m^3) = 1.01x10^4 N/m^3 (using the specific weight of water at standard conditions since water gets very cold at great depths)

P = γ·h = (1.01x10^4 N/m^3)(730 m) **= 7.37x10^6 N/m^2 = 1,070 psi (gage pressure)**

To get absolute pressure, atmospheric pressure must be added.

3. Mercury (Hg) is a preferred measurement fluid in simple barometers since its vapor pressure is low enough to be ignored. In addition, it is so dense (S.G. = 13.6), the tube height can be shortened considerably. If a barometric pressure reading is 29.9 inches of Hg, determine the pressure (in lb/in.^{2}) and the comparable reading if the measurement fluid was water..

Ans. From Eq'n 2.4: P = (γ_{Hg})(h)

P = (13.6)(62.3 lb/ft^3)(29.9 in.)(1 ft/12 in.)^3 **=14.7 lb/in.^{2}**

Also, **h** = P/γ = [(14.7 lb/in.^{2}) / (62.3 lb/ft^3)]·(12 in./1 ft)^3 = 408 in. = **34.0 ft**

4. A storage tank (6 m x 6m x 6m) is filled with water. Determine the force on the bottom and on each side.

Ans. The force exerted on the tank bottom is equal to the pressure on the bottom times the area of the bottom. $P = \gamma \cdot h = (9.79\ kN/m^3)(6\ m) = 58.7\ kN/m^2$

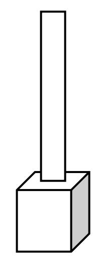
F $= P \cdot A = (58.7\ kN/m^2)(36\ m^2)$ **= 2,110 N**

The force exerted on the sides of the tank may be found in like manner (pressure times the area). However, the pressure is not uniform on the tank sides since $P = \gamma \cdot h$. Therefore, the average pressure is required. Since the pressure is a linear relationship, the average pressure occurs at half the depth. Now,

$P_{avg} = \gamma \cdot h_{avg} = (9.79\ kN/m^3)(3\ m) = 29.4\ kN/m^2$

F $= P_{avg} \cdot A = (29.4\ kN/m^2)(36\ m^2)$ **= 1,060 N**

5. A water container consists of a 10-ft-high, 1-ft-diameter pipe welded on top of a cube (3ft x 3ft x 3ft). The container is filled with water (20°C). Determine the weight of the water and the pressure forces on the bottom and sides of the bottom cube.



Ans. $W_{total} = \gamma \cdot Vol = (\gamma)[Vol_{cube} + Vol_{pipe}]$

$\mathbf{W_{total}} = (62.3\ lb/ft^3)[(3\ ft)^3 + (\pi)(0.50\ ft)^2(10\ ft)] =$ **2,170 lb**

$P_{bottom} = \gamma h = (62.3\ lb/ft^3)(13\ ft) = 810\ lb/ft^2$; $\mathbf{F_{bottom}} = (810\ lb/ft^2)(9\ ft^2) =$ **7,290 lb**

Note: The weight of the water is not equal to the force on the bottom. Why? (Hint: Draw a free body diagram of the 3 ft x 3 ft x 3 ft water body labeling all vertical forces acting on it. Don't forget the pressure from the container top. Now, the side force is:

$P_{avg} = \gamma \cdot h_{avg} = (62.3\ lb/ft^3)(11.5\ ft) = 716\ lb/ft^2$

F $= P_{avg} \cdot A = (716\ lb/ft^2)(9\ ft^2)$ **= 6,440 lb**

6. A weight of 5,400 lbs is to be raised by a hydraulic jack. If the large piston has an area of 120 in.^{2} and the small piston has an area of 2 in.^{2}, what force must be applied through a lever having a mechanical advantage of 6 to 1?

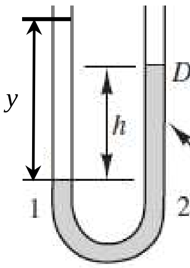
Ans. From Pascal's law, the pressure on the small piston is equal to the pressure on the large.

$F_{small}/A_{small} = F_{large}/A_{large}$

$F_{small} = [(F_{large})(A_{small})]/(A_{large}) = [(5400\ lb)(2\ in^2)]/(120\ in^2) = 90\ lb$

$\therefore$ The **applied force** = 90 lb/6 = **15 lb** based on the mechanical advantage of the lever.

7. Carbon tetrachloride (manometer liquid, M, in the figure below, S.G. = 1.6) is poured into a U-tube with both ends open to the atmosphere. Then water is poured into one leg of the U-tube until the water column (y) is 20 cm high. Determine the height of the carbon tetrachloride (h) above the water-carbon tetrachloride interface (point 1).



Note: y = height of water. Air is above the Hg at point D.

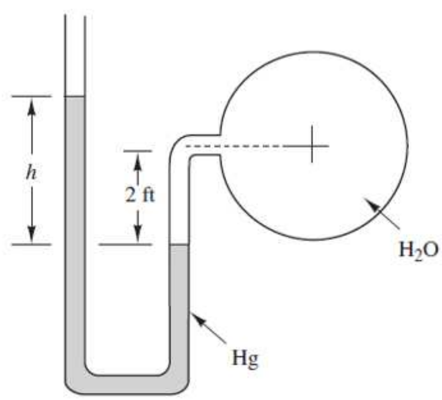
Ans. A surface of equal pressure surface can be drawn at the interface (1-2).

Therefore, $P_1 = P_2$; $(0.2\text{ m})(\gamma) = (h)(\gamma_M)$

$h = [(0.2\text{ m})(\gamma)]/(\gamma_M) = [(0.2\text{ m})(\gamma)]/[(\gamma)(SG_M)] = (0.2\text{ m}) / (1.6)$

h = 0.125 m = 12.5 cm

8. The manometer depicted below is mounted on a city water supply pipe to monitor water pressure. However, the field engineer suspects the manometer reading of h = 3 feet (Hg) may be incorrect. If the pressure in the pipe is measured independently and found to be 16.8 lb/in.^{2} (psi), determine the correct value of the reading ***h***.



Ans. A surface of equal pressure can be drawn at the mercury-water meniscus. Therefore,

$P_{pipe} + (2\text{ ft})(\gamma) = (h)(\gamma_{Hg})$

$(16.8\text{ lb/in}^2)(144\text{ in}^2/\text{ft}^2) + (2\text{ ft})(\gamma) = (h)(\gamma)(\text{S.G.}_{Hg})$

$(2.42 \times 10^3\text{ lb/ft}^2) + (2\text{ ft})(62.3\text{ lb/ft}^3) = (h)(62.3\text{ lb/ft}^3)(13.6)$

h = 3.00 ft (manometer is correct)

9. Manometer computations for the figure above yield a pressure of 16.8 lb/in.[2] (psi) if h = 3 ft. If the fluid in the pipe was oil (S.G. = 0.80) under the same pressure, would the manometer measurements (2 ft and 3 ft) still be the same? If not, what would the new measurements be?

Ans. The measurements will not be the same since oil is now in the manometer instead of water. A surface of equal pressure can be drawn at the mercury-oil interface.

$P_{pipe} + (2\text{ ft} + \Delta h)(\gamma_{oil}) = (3\text{ ft} + 2\Delta h)(\gamma_{Hg})$

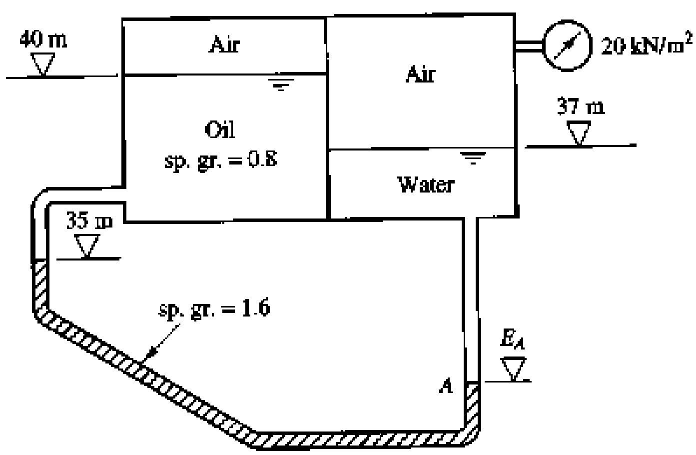
This is based on volume conservation. If the mercury-oil meniscus goes down Δh on the right, it must climb up Δh on the left making the total difference 2Δh. Now

$(2.42 \times 10^3\text{ lb/ft}^2) + (2\text{ ft} + \Delta h)(0.80)(62.3\text{ lb/ft}^3) = (3\text{ ft} + 2\Delta h)(13.6)(62.3\text{ lb/ft}^3)$

Δh = -0.0135 ft New measurements:

2 feet becomes 2 – 0.0135 = 1.99 ft and 3 feet becomes 3 - 2(0.0135) = 2.97 ft

10. Determine the air pressure (in kPa and cm of Hg) in the sealed left tank depicted in the figure below if E_A = 32.5 m.



Ans. Using the "swim through" technique, start at the sealed right tank where the pressure is known. Then "swim through" the tanks and pipes, adding pressure when "swimming" down and subtracting when "swimming" up until you reach the left tank where the pressure is not known. The computations are as follows:

$20\text{ kN/m}^2 + (4.5\text{ m})(9.79\text{ kN/m}^3) - (2.5\text{ m})(1.6)(9.79\text{ kN/m}^3) - (5\text{ m})(0.8)(9.79\text{ kN/m}^3) = P_{left}$

$\mathbf{P_{left} = -14.3\text{ kN/m}^2}$ **(or -14.3 kPa).** Now to determine the pressure in cm of Hg, since

$P = \gamma h$ or $h = P/\gamma$; $h = (-14.3\text{ kN/m}^2) / [(SG_{Hg})(\gamma)]$

$h = (-14.3\text{ kN/m}^2) / [(13.6)(9.79\text{ kN/m}^3)]$ **= -0.107 m = 10.7 cm (Hg)**

11. A vertical gate keeps water from flowing in a triangular irrigation channel. The channel has a 4-m top width and a 3-m depth. If the channel is full, what is the magnitude of the hydrostatic force on the triangular gate and its location?

Ans. The hydrostatic force and its locations are (based on Table 2.1):

$F = \gamma \cdot \bar{h} \cdot A$= = (9790 N/m^3)[(3m)/(3)]·[6 m^2] **= 5.87 x 10^4 N = 58.7 kN**

$$y_P = \frac{I_0}{A\bar{y}} + \bar{y} = \frac{\left[(4m)(3m)^3/36\right]}{\left[(4m)(3m)/2\right](1.00m)} + 1.00m$$

y_p = 1.50 m (depth to center of pressure)

12. A 3-ft square (plane) gate is mounted into an inclined wall (45°). The center of the gate is located 4 feet (vertically) below the water surface. Determine the magnitude of the hydrostatic force (in lbs) and its location with respect to the water surface along the incline.

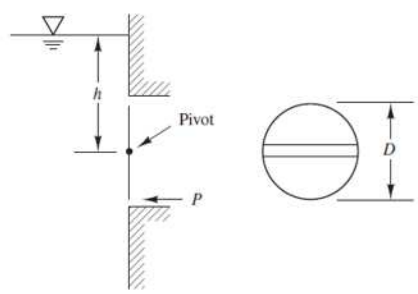
Ans. $F = \gamma \cdot \bar{h} \cdot A$= (62.3 lb/ft^3)(4 ft)(3 ft)^2

F = 2,240 lbs; Now noting that $\bar{y} = \bar{h}/\sin 45°$ = 4ft/(sin 45°) = 5.66 ft

$$y_P = \frac{I_0}{A\bar{y}} + \bar{y} = \frac{\left[(3\,ft)^4/12\right]}{\left[(3\,ft)^2\right](5.66\,ft)} + 5.66\,ft$$

y_p = 5.79 ft (distance from water surface to the center of pressure along incline)

13. A circular gate is installed on a vertical wall as shown in the figure below. Determine the horizontal force, *P*, necessary to hold the gate closed if the gate diameter is 6 feet and *h* = 7 feet. Neglect friction at the pivot.



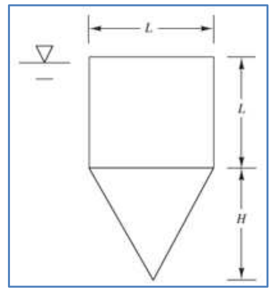
Ans. **F =** $\gamma \cdot \bar{h} \cdot A$= (62.3 lb/ft^3)[(7 ft)]·[π(6 ft)^2/4] **= 1.23 x 10^4 lbs**

$$y_P = \frac{I_0}{A\bar{y}} + \bar{y} = \frac{\left[\pi(6\,ft)^4/64\right]}{\left[\pi(6\,ft)^2/4\right](7\,ft)} + 7\,ft$$; **y_p = 7.32 ft** (depth to the center of pressure)

Thus, summing moments: $\sum M_{hinge} = 0$

P(3 ft) – (1.23 x 10^4 lbs)(7.32 ft – 7 ft) = 0; **P = 1.31 x 10^3 lbs**

14. A vertical plate, composed of a square and a triangle, is submerged so that its upper edge coincides with the water surface (Figure P2.5.5). What is the value of the ratio H/L such that the pressure force on the square is equal to the pressure force on the triangle?



Ans. $F_{square} = \gamma \cdot \bar{h} \cdot A = \gamma(L/2)(L^2) = (\gamma/2)\cdot L^3$

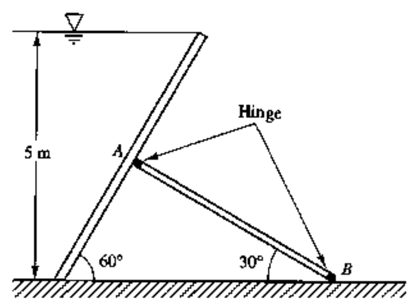
$F_{tri} = \gamma \cdot \bar{h} \cdot A = \gamma(L+H/3)(LH/2) = (\gamma/2)[L^2H + LH^2/3]$; Setting the two forces equal:

$F_{square} = Y_{tri}$; substituting yields; $(\gamma/2)\cdot L^3 = (\gamma/2)[L^2H + LH^2/3]$

$L^2 - HL - H^2/3 = 0$; divide by H^2 and solve quadratic

$(L/H)^2 - (L/H) - 1/3 = 0$; L/H = 1.26 or **H/L = 0.791**

15. The wicket dam, pictured on the right, is 5 m high and 3 m wide and is pivoted at its center. Determine the reaction force in the supporting member *AB*.



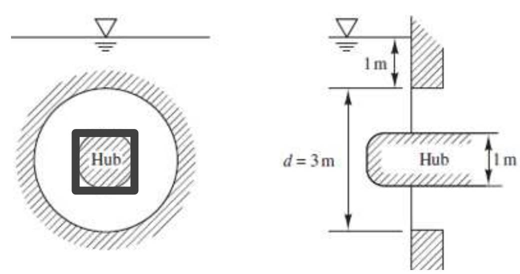
Ans. $\mathbf{F} = \gamma \cdot \bar{h} \cdot A = (9790\ \text{N/m}^3)(2.5\text{m})[(5/\cos 30^\circ)(3\ \text{m})]$ **= 4.24 x 10⁵ N = 424 kN**

$\mathbf{y_P} = \dfrac{I_0}{A\bar{y}} + \bar{y} = \dfrac{[(3m)(5.77m)^3/12]}{[(3m)(5.77m)](2.89m)} + 2.89m$ **= 3.85 m** (inclined depth to pressure center)

Summing moments about the base of the dam; $\sum M = 0$

(424 kN)(5.77 m – 3.85 m) – (F_{AB})(5.77m/2) = 0; $\mathbf{F_{AB}}$ **= 282 kN**

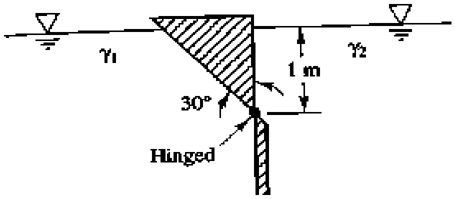
16. Calculate the magnitude and the location of the resultant pressure force on the annular gate shown in the figure to the right if the cross-section of central hub is a square that is 1 m by 1 m.



Ans. $\mathbf{F} = \gamma \cdot \bar{h} \cdot A = (9790\ \text{N/m}^3)(2.5\ \text{m})[(\pi)(1.5\ \text{m})^2 - (1.0\ \text{m})^2]$ **= 1.49 x 10⁵ N = 149 kN**

$\mathbf{y_P} = \dfrac{I_0}{A\bar{y}} + \bar{y} = \dfrac{[\{\pi(3m)^4/64\} - \{(1m)(1m)^3/12\}]}{[\pi(1.5m)^2 - (1m)^2](2.5m)} + 2.5m$ **= 2.76 m** (below the water surface)

17. Determine the relationship between γ_1 and γ_2 in the figure to the right if the weightless triangular gate is in equilibrium in the position shown. (Hint: Use a unit length for the gate.)



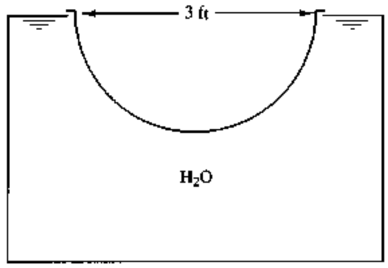
Ans. $F_{incline} = \gamma \cdot \bar{h} \cdot A$= ($\gamma_1$)(0.5 m)[(1m/cos30˚)(1m)] = 0.577·γ_1 N; Since (1m/cos 30˚)=1.15 m

$$y_P = \frac{I_0}{A\bar{y}} + \bar{y} = \frac{[(1m)(1.15m)^3/12]}{[(1m)(1.15m)](1.15m/2)} + (1.15m/2) = 0.767 \text{ m}$$ (inclined distance to center of pressure)

$F_{right} = \gamma \cdot \bar{h} \cdot A$ = (γ_2)(0.5 m)[(1m)(1m)] = 0.500·γ_2 N; and y_P = 0.667 m

$\sum M_{hinge} = 0$; (0.577·γ_1 N)(1.15m - 0.767 m) – (0.500·γ_2 N)(1 m - 0.667 m) = 0; **γ_2 = 1.33·γ_1 N**

18. An inverted hemispherical shell of diameter d = 3 feet as shown in the figure to the right is used to cover a tank filled with water at 20°C. Determine the minimum weight the shell needs to be to hold itself in place (i.e., not be lifted up).

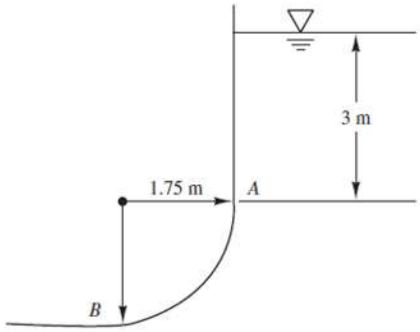


Ans. The vertical component of the total hydrostatic pressure force is equal to the weight of the water column above it to the free water surface. In this case, it is the virtual or displaced weight of water above the shell since the pressure is from below.

$F_V = \gamma \cdot Vol$ = (62.3 lb/ft^3)[(1/2)(4/3)(π)(1.5 ft)^3] = 440 lb

The weight of the cover must balance this upward pressure; thus **W = 3,520 lb**

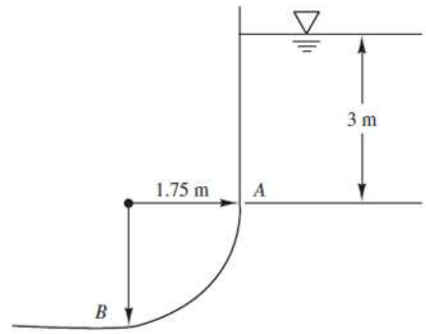
19. The corner plate of a barge's hull is curved with a radius of 1.75 m. The depth of submergence (draft) is depicted in the figure. However, the barge is leaking and the water on the inside is up to level *A* producing hydrostatic pressure on the inside as well as the outside. Determine the resultant horizontal hydrostatic pressure force on plate *AB* per unit length of the hull.



Ans. $F_H = (\gamma \cdot \bar{h} \cdot A)_{right} - (\gamma \cdot \bar{h} \cdot A)_{left}$ = (9790 N/m^3) [(1.75 m)(1 m)] (3.875 m – 0.875 m)

F_H = 5.14 x 10^4 N = **51.4 kN 🡸 (towards the barge)**

20. The corner plate of a barge's hull is curved with a radius of 1.75 m. The depth of submergence (draft) is depicted in Figure P2.6.4. The barge is leaking and the water on the inside is up to level *A* producing hydrostatic pressure on the inside as well as the outside. Determine the resultant **vertical** hydrostatic force on plate *AB* per unit length of hull.

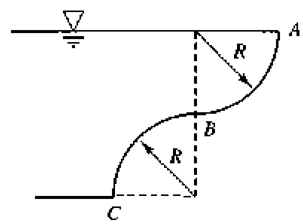


Ans. The resultant vertical component of the total hydrostatic force is the weight of the water column above the curved surface (water in the barge) subtracted from the virtual weight of the water column above the curved surface up to the water level outside. Note that this equals the water column above the curved surface between the two water levels.

$F_V = (\gamma \cdot Vol)_{outside} - (\gamma \cdot Vol)_{inside}$ = (9790 N/m^3)[(1.75 m)(1 m)(3 m)]

F$_V$ = 5.14 x 10^4 N **= 51.4 kN** ↑

21. Calculate the horizontal and vertical hydrostatic forces on the curved surface *ABC* in the figure to the right.



Ans. The horizontal component of the total hydrostatic pressure force equals the total pressure on the vertical projection of the curved surface ABC:

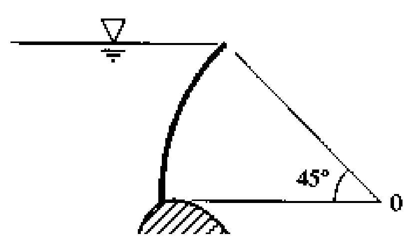
$F_H = \gamma \cdot \bar{h} \cdot A$ = (γ)(R)[(2R)(1)] **= 2(γ)(R)^2**

The vertical component of the total hydrostatic pressure force equals the weight of the water above the curved surface ABC. The volume of water above this surface is:

Vol = ($A_{\text{quaarter circle}} + A_{\text{rectangle}} - A_{\text{quarter circle}}$)(unit length)

Vol = ($A_{\text{rectangle}}$)(unit length) = (2R)(R)(1) = 2(R)^2; $F_V = \gamma \cdot Vol$ = γ[2(R)^2] **= 2(γ)(R)^2**

22. The tainter gate section shown in figure to the right has a cylindrical surface with a 12-m radius and is supported by a structural frame hinged at *O*. The gate is 10 m long (in the direction perpendicular to the page). Determine the magnitude, direction, and location of the total hydrostatic force on the gate



Ans. First find the height of the vertical projection of area: (R)(sin 45˚) = 8.49 m. Thus,

$F_H = \gamma \cdot \bar{h} \cdot A$ = (9790 N/m^3)(4.25m)[(10 m)(8.49 m)]; F_H = 3.53 x 10^6 N = 3,530 kN

The vertical component of the total pressure force is the weight of the water column above the curved gate. The volume of water above the gate is:

Vol = ($A_{rectangle}$ - $A_{triangle}$ - A_{arc})(length)

Vol =[(12m)(8.49m) - (1/2)(8.49m)(8.49m) - (π/8)(12m)^2](10 m) = 92.9 m^3

Now, $F_V = \gamma \cdot Vol$ = (9790 N/m^3)(92.9 m^3) = 9.09 x 10^5 N = 909 kN; and the total force is: **F** = [(3,530 kN)^2 + (909 kN)^2]$^{1/2}$ = **3650 kN;** **θ** = tan^{-1} (F_V/F_H) **= 14.4°** .

Since all hydrostatic pressures pass through point O (i.e., they are all normal to the surface upon which they act), then the resultant must also pass through point O.

23. A piece of irregularly shaped metal weighs 301 N. When the metal is completely submerged in water, it weighs 253 N. Determine the specific weight and the specific gravity of the metal.

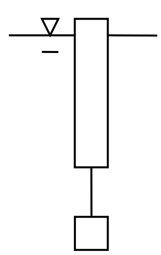
Ans. The buoyant force equals the weight reduction. Thus, B = 301 N – 253 N = 48.0 N

In addition, B = wt. of water displaced = γ·*Vol* = (9790 N/m^3)(*Vol*); Thus,

Vol = 4.90 x 10^{-3} m^3 and $\boldsymbol{\gamma_{metal}}$ = W/Vol = 301N/(0.00490 m^3) = **6.14 x 10^4 N/m^3**

S.G. = (6.14 x 10^4 N/m^3)/(9,810 N/m^3) **= 6.26**

24. A concrete block that has a total volume of 12 ft^3 and a specific gravity of 2.67 is tied to one end of a long cylindrical buoy as depicted in the figure below. The buoy is 10 ft long and is 2 ft in diameter. Unfortunately the water level has risen and the buoy is floating away with 1 ft sticking above the water surface. Determine the specific gravity of the buoy. The fluid is brackish bay water (S.G. = 1.02).



Ans. W = 2.67γ(12 ft^3) + (SG)γ·π(1 ft)^2(10 ft); B = 1.02γ(12 ft^3) + 1.02γ·π(1 ft)^2(9 ft)

∑F_y = 0; or W = B; 32.0 + 31.4(SG) = 12.2 + 28.8; **SG = 0.287**

25. A cube of ice measures 10 inches on each side. It has a density of 1.76 slugs/ft^3. Determine the weight of the ice and the percentage of the cube below the waterline when it is floating.

Ans. Since ρ = m/Vol; m = (Vol)(ρ) = [(10/12)ft^3](1.76 slugs/ft^3) = 1.02 slugs

Also, W = mg = (1.02 slugs)(32.2 ft/sec^2) = 32.8 lbs

γ_{ice} = W/Vol = 32.8 lbs/[(10/12)ft^3] = 56.7 lbs/ft^3

S.G. = γ_{ice}/γ = 56.7 lbs/ft^3/ 62.4 lbs/ft^3 = 0.909

Therefore, 90.9% of the cube will be below the waterline.

26. A rectangular barge is 14 m long, 6 m wide, and 2 m deep. The center of gravity is 1.0 m from the bottom and the barge drafts 1.5 m of seawater (S.G. = 1.03). Find the metacentric height and the righting moments for a 8° angle of heel (or list).

Ans. The center of gravity (G) is given as 1 m up from the bottom of the barge.

The center of buoyancy (B) is 0.75 m up from the bottom since the draft is 1.5 m.

Therefore GB = 0.25 m, and GM is found using

$\overline{GM} = \overline{MB} \pm \overline{GB} = \dfrac{I_0}{\text{Vol}} \pm \overline{GB}$; where I_o is the waterline moment of inertia about the tilting axis. Chopping off the barge at the waterline and looking down we have a rectangle which is 14 m by 6 m. Thus,

$$\overline{GM} = \overline{MB} \pm \overline{GB} = \frac{I_0}{\text{Vol}} \pm \overline{GB} = \frac{\left[(14m)(6m)^3/12\right]}{(14m)(6m)(1.5m)} - 0.25m = \mathbf{1.75\ m};$$

Note: Vol is the submerged volume and a negative sign is used in the equation since G is located above the center of buoyancy.

$M = W \cdot \overline{GM} \cdot \sin\theta$

M = [(1.03)(9790 N/m^3)(14 m)(6m)(1.5m)](1.75m)(sin 8°)

M = 309 kN·m (for a heel angle of 8°)