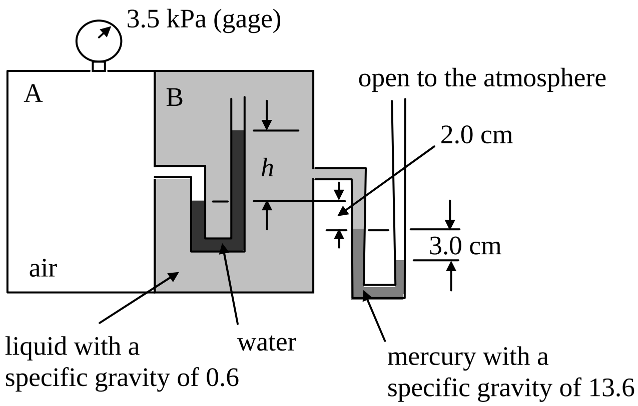
Practice Problems on Fluid Statics

manometry_01

Compartments A and B of the tank shown in the figure below are closed and filled with air and a liquid with a specific gravity equal to 0.6. If atmospheric pressure is 101 kPa (abs) and the pressure gage reads 3.5 kPa (gage), determine the manometer reading, *h*.



Answer(s):

$$\boxed{h = \frac{1}{\left(1 - SG_{\text{liquid}}\right)}\left[SG_{\text{Hg}}L_1 + SG_{\text{liquid}}L_2 + \frac{p_4 - p_1}{\rho_{\text{H20}}\,g}\right]}$$

manometry_02

Assuming that air is incompressible, determine the height of a column of air required to give a pressure difference of 0.1 psi. Assume that the density of air is $2.38*10^{-3}$ slug/ft^3.

Answer(s):

$\boxed{h = 188 \text{ ft}}$

manometry_03

What is the pressure at the bottom of the Marianas Trench (11,000 m = 36,201 ft = 6.9 mi)?

Answer(s):

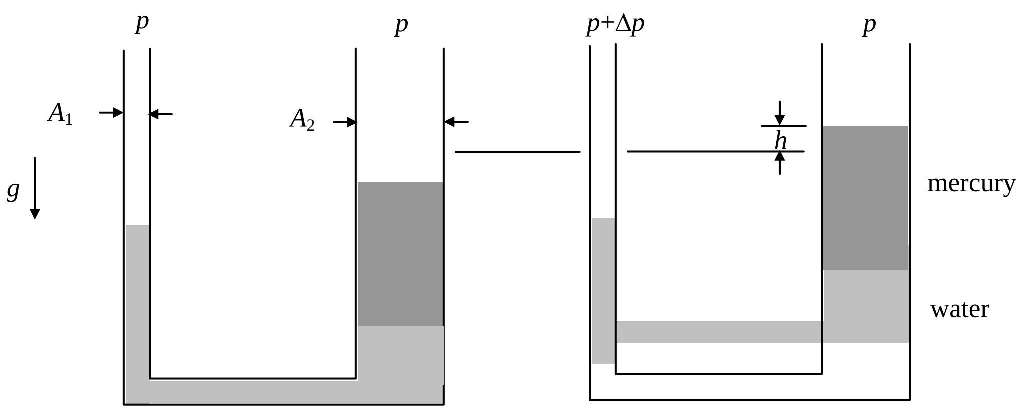
$\boxed{p_{\text{bottom}} = 110 \text{ MPa} = 1100 \text{ atm}}$

manometry_04

Determine the deflection, h, in the manometer shown below in terms of A_1, A_2, Δp, g, and ρ_{H2O}. Determine the sensitivity of this manometer. The manometer sensitivity, s, is defined here as the change in the elevation difference, h, with respect to a change in the applied pressure, Δp:

$$s \equiv \frac{dh}{d\left(\Delta p\right)}$$

Manometers with larger sensitivity will give larger changes in h for the same Δp.

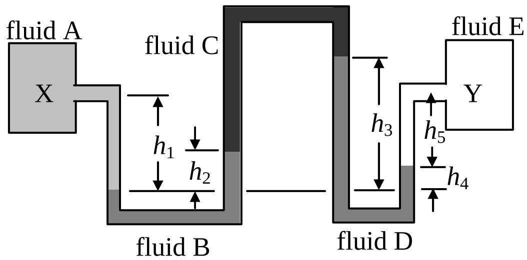


Answer(s):

$$\boxed{s = \frac{1}{1+{A_2}/{A_1}}\left(\frac{1}{\rho_{H20}\,g}\right)}$$

manometry_05

Determine the pressure difference between points X and Y in the system shown below.



Answer(s):

$$\boxed{\therefore\ p_Y = p_X + \rho_A g h_1 - \rho_B g h_2 - \rho_C g\left(h_3 - h_2\right) + \rho_D g\left(h_3 - h_4\right) - \rho_E g h_5}$$

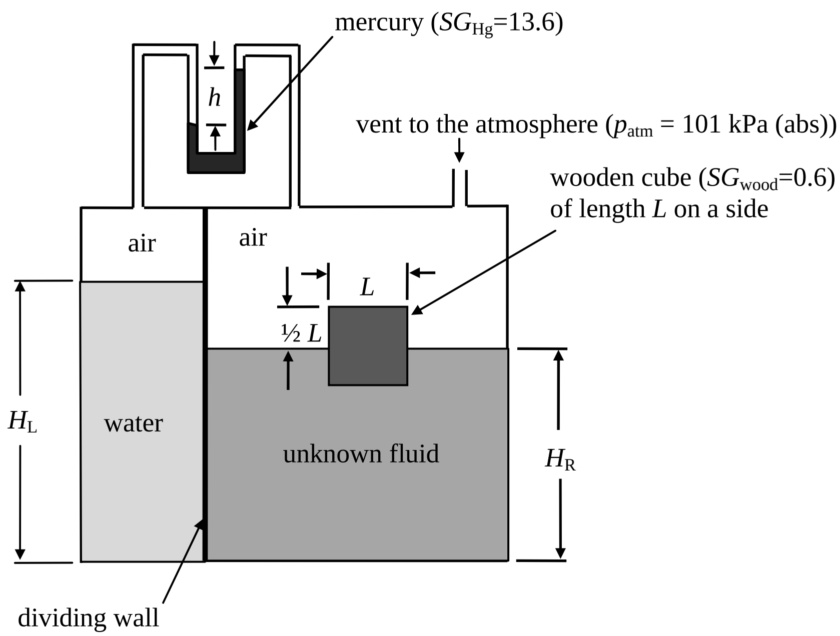
statics_02

A tank is divided by a wall into two independent chambers. The left chamber is filled to a depth of H_L=6m with water (ρ_{H20}=1000 kg/m^3) and the right side if filled to a depth of H_R=5m with an unknown fluid. A wooden cube (SG_{wood}=0.6) with a length of L=0.20m on each side floats half submerged in the unknown fluid. Air (ρ_{air}=1.2 kg/m^3) fills the remainder of the container above each fluid. The right container has a pipe that is vented to the atmosphere while the left container is sealed from the atmosphere. A manometer using mercury as the gage fluid (SG_{Hg}=13.6) connects the two chambers and indicates that h=0.150 m.

a. Determine the density of the unknown fluid.

b. Determine the magnitude of the force (per unit depth into the page) acting on the dividing wall due to the unknown fluid.

c. Determine the magnitude of the force (per unit depth into the page) acting on the dividing wall due to the water.



Answer(s):

$\boxed{\therefore \rho_{\text{fluid}} = 2\rho_{\text{wood}} = 2SG_{\text{wood}}\rho_{\text{H}_2\text{O}}}$

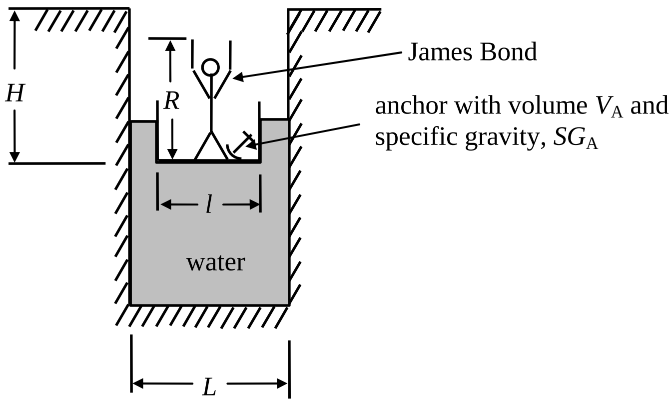
$\boxed{\rho_{\text{fluid}} = 1200 \text{ kg/m}^3}$

$\boxed{\therefore F_{p,R} = p_{\text{atm}}H_R + \tfrac{1}{2}\rho_{\text{fluid}}gH_R^2}$

$\boxed{\therefore F_{p,L} = \left(p_{\text{atm}} + SG_{\text{Hg}}\rho_{\text{H}_2\text{O}}gh\right)H_L + \tfrac{1}{2}\rho_{\text{H}_2\text{O}}gH_L^2}$

statics_03

James Bond is trapped on a small raft in a steep walled pit filled with water as shown in the figure. Both the raft and pit have square cross-sections with a side length of l=3 ft for the raft and L=4 ft for the pit. In the raft there is a steel anchor (SG_A=7.85) with a volume of V_A=1 ft^3. In the current configuration, the distance from the floor of the raft to the top of the pit is H=7.5 ft. Unfortunately, Bond can only reach a distance of R=7 ft from the floor of the raft. In order for Bond to escape, would it be helpful for him to toss the anchor overboard? Justify your answer with calculations. (Hint: The mass of water is conserved in this problem.)



Answer(s):

$$\boxed{\therefore \Delta H = \frac{V_{\text{anchor}}}{L^2}\left[SG_{\text{anchor}}\left(1-\frac{L^2}{l^2}\right)-1\right]}$$

Hence, Bond still can't reach the top of the pit.

statics_04

A rectangular block of concrete (SG=2.5) is used as a retaining wall or dam for a reservoir of water:

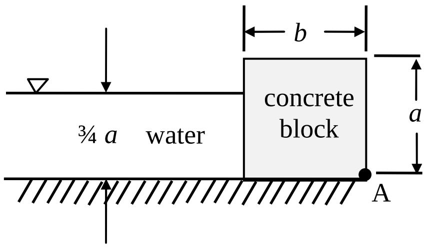


Figure (a)

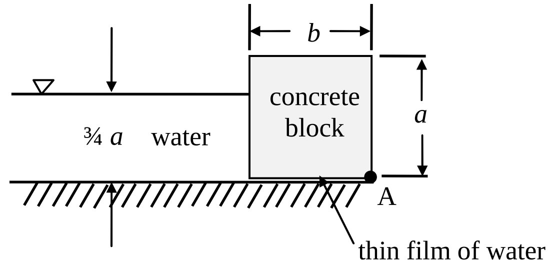


Figure (b)

The block has a height, a, a breadth, b, and the depth of the water is $3a/4$.

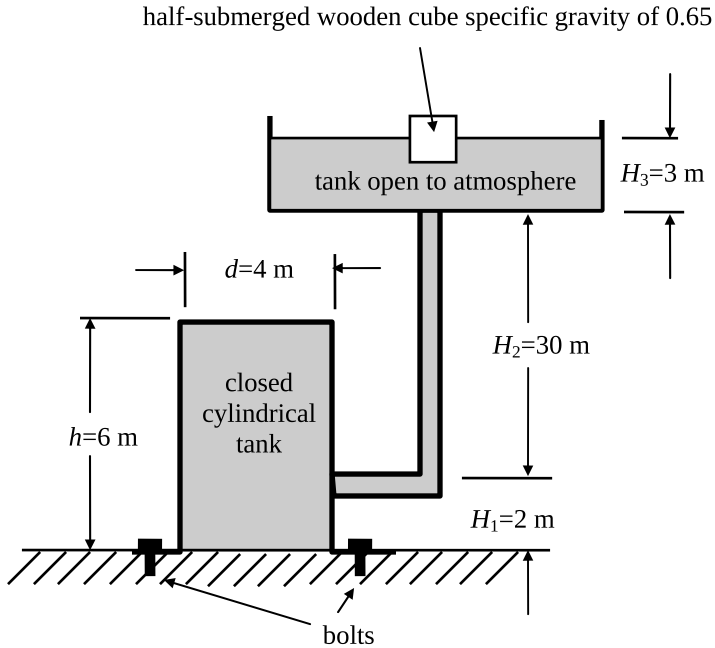
a. Determine the critical ratio, b/a, below which the block will be overturned by the water (figure a). Assume the block does not slide on the base but can rotate about the point A.
b. What is the critical ratio, b/a, if there is seepage and a thin film of water forms under the block (figure b)? Assume that a seal at point A prevents water from flowing out from underneath the block.

Answer(s):

Answers unavailable at this time.

statics_05

A closed, cylindrical tank, with a diameter of *d*=4 m, a height of *h*=6 m, and an empty weight of 500 N, is completely filled with an unknown fluid. The closed tank is connected to an open tank through a pipe. The tank has no "bottom" and is instead bolted directly to the floor. A young engineer, just out of a fluid mechanics course, suggests to her colleagues that she can determine the total force in the bolts by floating a wooden cube in the open tank and performing a few calculations. If the wooden cube with a specific gravity of 0.65 is half submerged in the fluid, what will be the force in the bolts holding the closed tank to the floor?

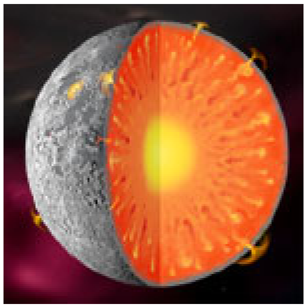


Answer(s):

Answer unavailable at this time.

statics_06

It is often conjectured that the Earth was, at one time, comprised of molten material. If the acceleration due to gravity within this fluid sphere (with a radius of 6440 km) varied linearly with distance, *r*, from the Earth's center, the acceleration due to gravity at r = 6440 km was 9.81 m/s^2, and the density of the fluid was uniformly 5600 kg/m^3, determine the gage pressure at the center of this fluid Earth.

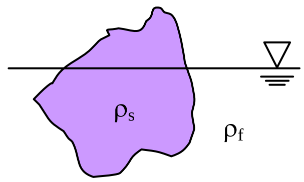


Answer(s):

$\boxed{p_0 = 1.769 \cdot 10^{11}\ \text{Pa} = 1.769 \cdot 10^{6}\ \text{atm}}$

buoyancy_03

a. Determine the buoyant force and center of buoyancy for a partially submerged object as shown below.



b. Using your result from part (a), determine what percentage of an iceberg's volume remains below the water line. The specific gravity of ice is 0.890 and the specific gravity of sea water is 1.028.

Answer(s):

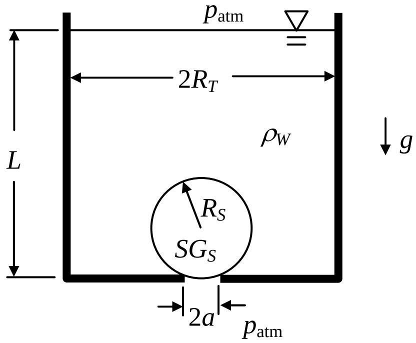
$$\boxed{F_{\text{buoyant}} = F_{\text{pressure,net}} = -\rho_f g V_{\text{submerged}}}$$

$$\boxed{x_B = \frac{1}{V_{\text{submerged}}} \int_{V_{\text{submerged}}} x\,dV}$$

$$\boxed{V_{\text{submerged}}/V_{\text{total}} = 0.87 = 87\%}$$

buoyancy_05

Consider a rigid sphere of radius R_S made from a material with specific gravity SG_S. The sphere is completely submerged in a tank of water with radius R_T and initial depth L as shown in the figure. The sphere is placed over a small hole of radius a in the bottom of the tank that is open to the atmosphere.



a. Find an inequality specifying over which range of parameters (SG_S, R_S, a, L, R_T, g, and ρ_W, or a subset thereof) the sphere will remain sitting on the bottom of the tank plugging the hole. You may assume that $a \ll R_S$.

b. If the tank has depth L = 80 cm, the sphere has radius R_S = 2 cm, the hole has radius a = 0.2 cm, and the tank as a radius of R_T = 100 cm, determine the minimum specific density, SG_S, for which the sphere will remain at the bottom of the tank. Explain briefly in words what will happen if the level of water in the tank drops below a height of 80 cm for this specific gravity?

Answer(s):

$$\boxed{\therefore SG_S \geq 1 - \frac{3}{4}\left(\frac{L}{R_S}\right)\left(\frac{a}{R_S}\right)^2}$$

$$\boxed{SG_S \geq -\frac{3}{4}\left(\frac{L}{R_S} - \cos\theta_0\right)\sin^2\theta_0 + \frac{1}{2}\left(1 + \cos^3\theta_0\right)}$$