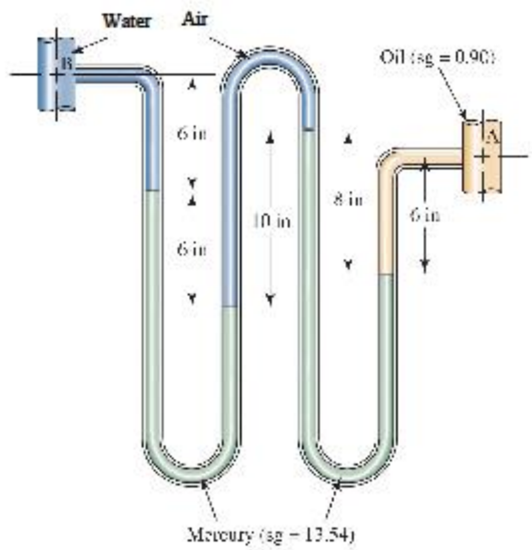
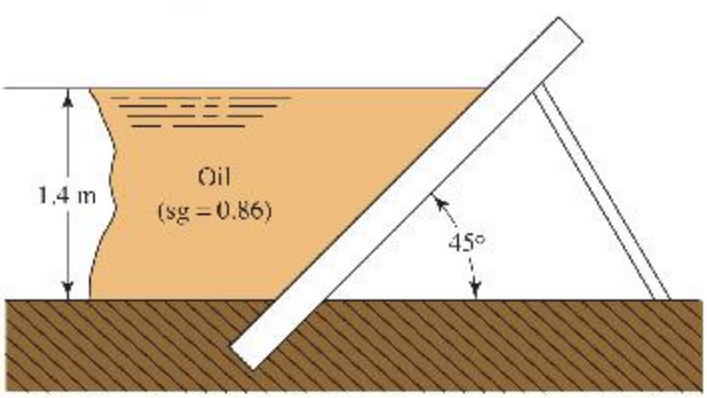
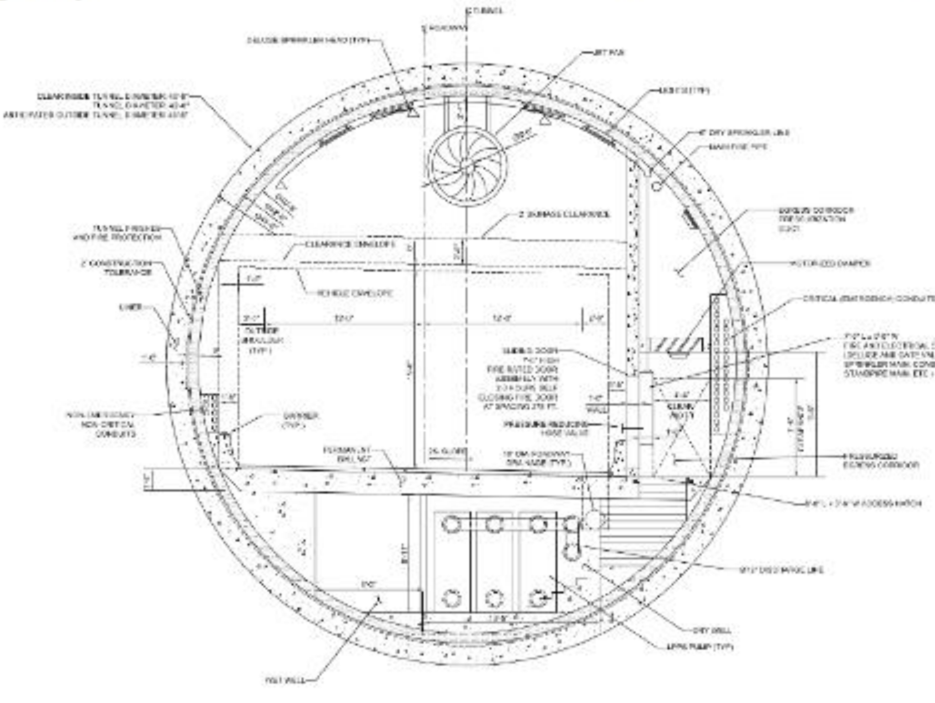
1) For the differenttial manometer below, calculate (p_A-p_B). Please note that the system has trapped air in it. What is the pressure of that air if p_A=80 psig?

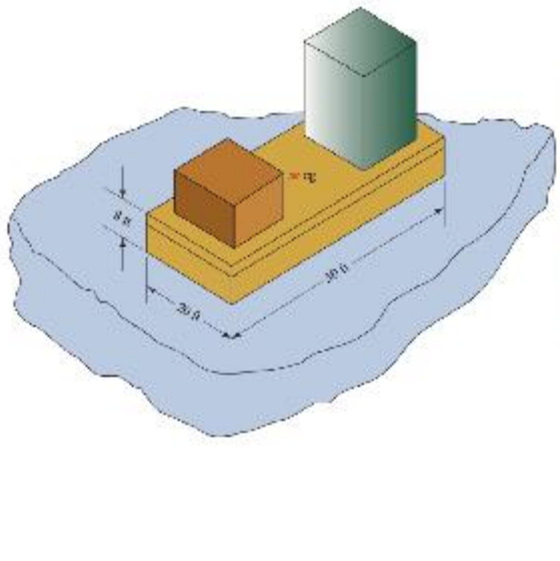


2) In one of the HW assignment of this class, you calculated the force and center of pressure location of the figure below. Someone modified the system and changed the angle of the platform. The person measured the magnitude of the new force and noticied that the force was reduced by 20%. What is the new angle of the platform? What is the new location of the center of pressure?



3) The method used to build the old tunnels in the CBBT is the cut-and-cover method. To use this method, builders dig a trench in the ocean floor. They then sink pre-made steel or concrete tubes in the trench. **After the tubes are covered with a thick layer of rock**, workers connect the sections of tubes and pump out any remaining water. The figure below shows the tunnel tube cross section (it can also be found at: https://www.tunneltalk.com/Chesapeake-Bay-Bridge-Tunnel-25May2016-Thimble-Shoals-Tunnel-bid-spreads.php). For a 290 ft long section of tunnel, what is the weight of the thick layer of rock that must be placed on top of the section to maintain it steady at the bottom of the ocean? Assume the tunnel is made out of concrete only. Make any reasonable approximation you need to simplify the geometry.



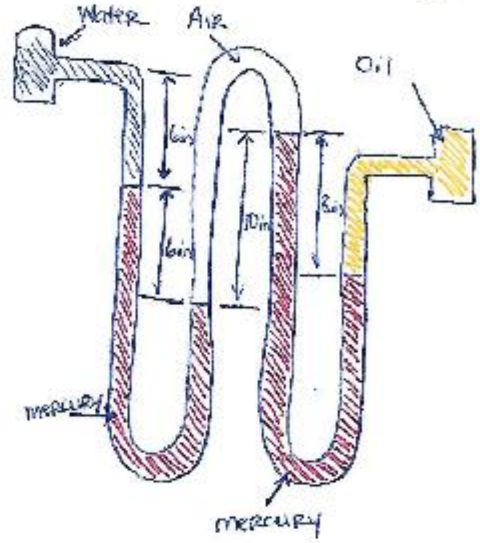


4) In the system shown in the figure to the left, the platform was found to be stable when the total weight of the system is 450,000 lbf. If the platform were 40 ft long (instead of 50 ft long), what is the maximum weight the platform can hold? Would the platform be still stable? Assume the center of gravity remains on the top of the platform (8 ft from the bottom).

A

1. Purpose: Determine the manometer reading: $P_A - P_B$
Determine the pressure of the trapped air if $P_A = 80$ psig

Diagram:



mercury – $sg = 13.54$
oil – $sg = 0.90$

water – $\gamma = 62.4\ lb/ft^3$

Sources: Mott & Untener. Applied Fluid Mechanics. 7th edition. Pearson. 2016. (global edition)

Design Considerations:

Based on the problem description, I assume the following:

1.) Incompressible fluids
2.) steady state
3.) Water & mercury do not mix
4.) Isothermal process at 77°F

Data & Variables:

$\gamma_w = 62.4\ lb/ft^3$

$1\ ft^3 = 1728\ in^3$

Materials:

water
mercury
oil

(Sopher)

B

Procedure:

I will first find the equation for $P_A - P_B$ using manometry. I am given each height change between liquids & I know the specific gravity of each. I also know the specific weight of air for $T = 77°F$.

&

specific weight of oil $= (0.90)(62.4 \frac{lb}{ft^3}) = 56.16\ lb/ft^3$

specific weight of ~~water~~ air (for 77°F) $= 0.074\ lb/ft^3$

specific weight of water $= 62.4\ lb/ft^3$

specific weight of mercury $= (13.54)(62.4) = 844.9\ lb/ft^3$

Calculations:

Using the following equation, I can use the above variables & the heights.

$$P_A + \gamma_o(6in) - \gamma_m(8in) + \gamma_A(10in) - \gamma_m(6in) - \gamma_W(6in) = P_B$$

The steps that decrease in elevation are added, those that increase are subtracted.

$$P_A + (56.16)(6in)\left(\frac{1ft^3}{1728in^3}\right) - (844.9)(8in)\left(\frac{1ft^3}{1728in^3}\right) + (0.074)(10in)\left(\frac{1ft^3}{1728in^3}\right) - (844.9)(6in) \cdot \left(\frac{1}{1728}\right) - (62.4)(6in)\left(\frac{1}{1728}\right) = P_B$$

* I need to convert the specific weight into inches → I use the conversion:

$$\frac{1\ ft^3}{1728\ in^3}$$

$$\rightarrow P_A + 0.195 - 3.912 + 0.000428 - 2.934 - 0.217 = P_B$$

$$P_A - 6.868 = P_B$$

Now, I assume $P_A = 80\ psig$ is true for both this scenario as well as the next calculation to find the trapped air pressure.

$$80 - 6.868 = P_B$$

$$\boxed{P_B = 73.13\ psig}$$

(Sopher)

C

Now, I will solve for the pressure in the trapped air.

This is simply the first part of the previous equation.

$$P_A + \gamma_o(6in) - \gamma_m(8in) = P_{AIR}$$

$$80 + 0.195 - 3.912 = P_{AIR}$$

$$\boxed{P_{AIR} = 76.28\ psig}$$

Summary:

The air has a higher pressure as is expected because the point where it starts is lower than the final point B. However, both found pressures are lower pressures than the starting pressure at A because the points are both higher than point A.

Analysis:

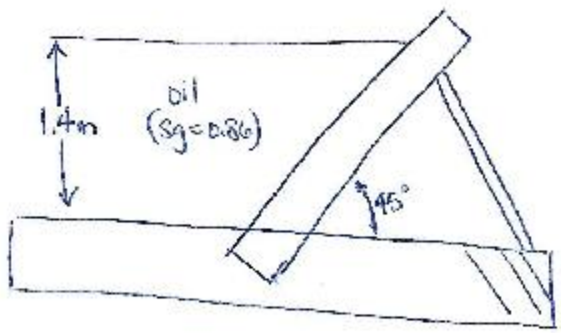
Due to very little elevation change, the pressures did not change much & the mercury had the largest effect on decreasing the pressure because it has a very large specific weight (compared to the other fluids & air). Despite air filling a very large section of the tubing, it did not have much of an effect on the final pressure because of it's low specific weight. (~~Its pressure was extremely~~ If a different fluid had been in that part of the tubing, I likely would have ended up with larger pressure than I started with. For example, if the air & mercury sections switched.

(Sophee)

D

② **Purpose:** Determine the new angle of the platform based on a force reduced by 20%. Also, find the new location of the center of pressure.

Diagram:



Sources: Mott & Untener, Applied Fluid Mechanics. Global Edition. Pearson. 2016.

Design Considerations:

For this problem, I assume:

1) incompressible fluid
2) steady state
3) isothermal problem with T=25°C
4) original force of 46.8 kN (from homework problem)

Data & Variables:

$\gamma_w = 9.81\ kN/m^3$

20% of force = 37.44 kN

$sg_{oil} = 0.86$

(Sopher)

$\boxed{E}$

Procedure:

The height of the liquid & specific gravity of the liquid remain the same (as previous problem from homework) & the system is not moving.

I can use $\boxed{F_R = \gamma_0 \left(\frac{h}{2}\right)(A)}$

I do not know the new width of the wall but I have the force (20% of previous calculated force). I can use this to solve for the width & find the new angle & the new center of pressure location.

Calculations:

$F_R = 37.44\,kN$
$\ell = 4m$
$h = 1.4m$
$sg = 0.86$
$\gamma_W = 9.81\,kN/m^3$

$$37.44\,kN = 0.86\left(\frac{9.81\,kN}{m^3}\right)\left(\frac{1.4m}{2}\right)\left(4m \cdot X_m\right)$$

$$37.44\,kN = 23.62\,(X_m)$$

$$\boxed{1.585m = X}$$

I can then use the formula

$\sin\theta = \frac{h}{L}$ — h is the height of the liquid still & L is the number I just solved for

I can use this to find the new angle ~~, but first, I'm going~~

$$\sin\theta = \frac{1.4}{1.585}$$

$$\sin\theta = 0.88328$$

$$\theta = \sin^{-1}(0.88328)$$

$$\boxed{\theta = 62^\circ}$$

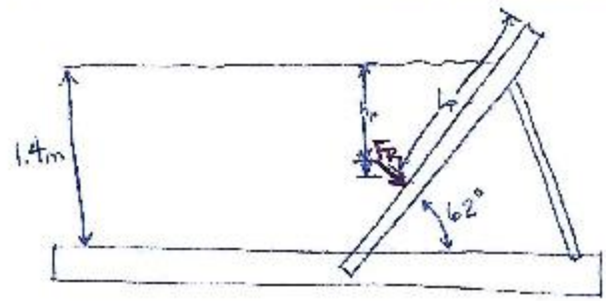
I can also use the numbers for h & L to solve for the new center of pressure.

$h_p = \frac{2}{3}h = \frac{2}{3}(1.4) = \boxed{0.933\,m}$ [the height hasn't changed, so this number hasn't changed.]

$L_p = \frac{2}{3}L = \frac{2}{3}(1.585) = \boxed{1.057\,m}$

(Sopher)

Now, I can draw in this new information. [F]



<u>Summary:</u>

The new angle is 62° and the new center of pressure is located 0.933 m from the surface of the liquid & 1.057 m down the length of the platform.

<u>Materials used:</u>

<u>oil</u>

<u>Analysis:</u>

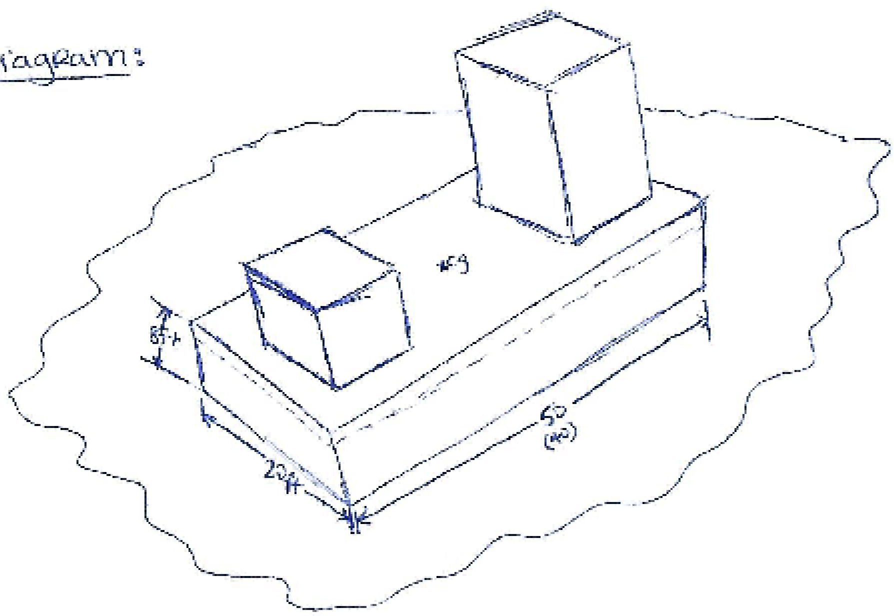
The higher angle decreased the force exerted on the platform by the liquid. It also brought the center of pressure higher on the platform.

(Sopher)

G

(4) <u>Purpose</u>: Determine the maximum weight the platform can hold if it's shortened from 50ft to 40ft. Determine if it is still stable.

<u>Diagram</u>:



<u>Sources</u>: Mott & Untener. Applied Fluid Mechanics. Global edition. Pearson. 2016.

<u>Design Considerations</u>:

For this problem, I will assume the following:

1) constant properties
2) initially stable
3) $T = 77°F$
4) the fluid is water

<u>Data & variables</u>:

$\gamma_w = 62.4\ lb/ft^3$

$F_b = \gamma_w V_d$

W ~~[illegible]~~ (initial) = 450,000 lbf

to find the draft:

$$X = \frac{W}{B \times L \times \gamma_w}$$

B = 20

L = 50 (initial)

(Sopher)

Procedure & calculations:

First, I will find the draft so I can solve for the new volume (displaced).
I will use $X = \frac{W}{B \times L \times \gamma_w}$ to find the draft

Then, $V_d = B \times L \times X$

Then, I will be able to solve for the new Force of buoyancy.

$X = \frac{450{,}000}{(20)(50)(62.4)} = 7.21\ ft$

$V_d = 20 \times 50 \times 7.21 = 5768\ ft^3$

$F_b = \gamma_f (V_d) \qquad F_b = (62.4)(5768)$ [units are $\left(\frac{lb}{ft^3}\right)(ft^3)$, leaving us with our lb force]

$F_b = 359{,}923.2\ lbf$

This is the new maximum weight the platform can hold.

Next, I will find the new metacenter to determine if the platform is still stable.
The center of buoyancy remains the same: $y_{cb} = 3.605$ ft from the bottom of the platform.

$MB = \frac{I}{V_d} \qquad I = \frac{LB^3}{12} = \frac{40(20)^3}{12} = \frac{26{,}666.67}{5768} = 4.62$

$V_d = 5768$

MB = 4.62 ft

$y_{mc} = y_{cb} + MB$

metacenter $y_{mc} = 3.605 + 4.62$

$y_{mc} = 8.225\ ft$

Above the center of gravity = stable

(Sopher)

Summary:

Because the metacenter is still above the center of gravity, it remains stable. The new maximum weight the smaller platform can hold is 359,923.2 lbf.

~~Analysis:~~
Materials:
Water

Analysis:
The smaller size cannot hold as much weight because it has a smaller area to spread the weight over. Also, the metacenter actually remains above the center of gravity – in the same place. This makes sense as the variable that was changed effectively gets canceled out in the equation for MB (distance from center of buoyancy & metacenter).

$$\Rightarrow MB = \frac{I}{V_d} = \frac{\frac{LB^3}{12}}{B \times L \times X}$$

Other variables would need to be changed for the metacenter to change.

(Sopher)