Unit 1 Exam

Problem 1

Purpose: To compute the pressure differential of the compound manometer between A and B. Also to compute the pressure differential of the compound manometer when the pressure at A drops which causes the oil column to reduce from 6in to 5in.

Drawings

Figure 1: Intial Pressure

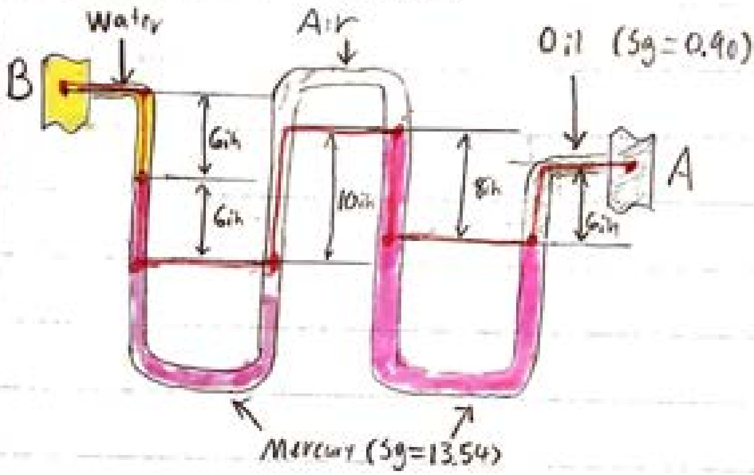
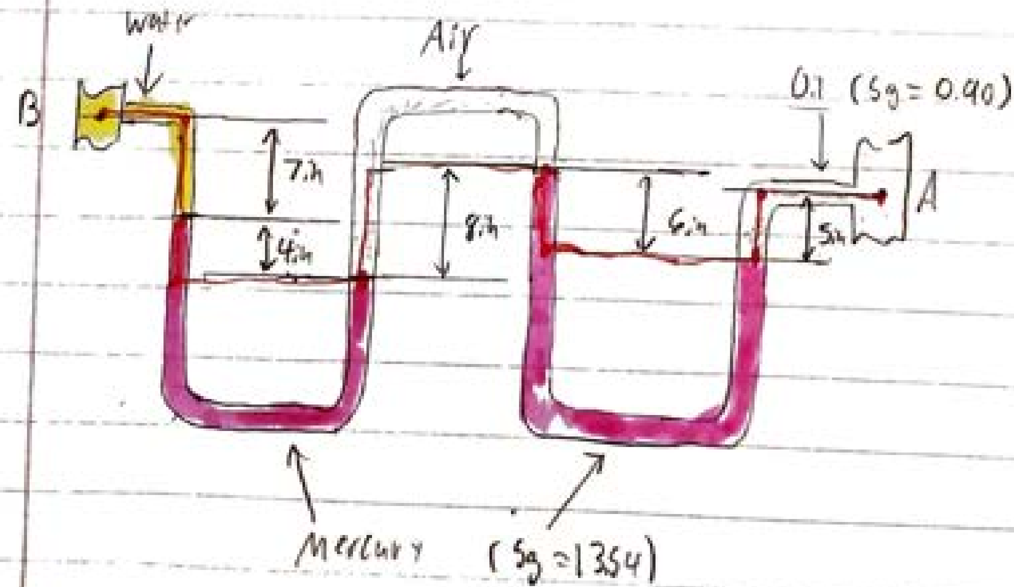


Figure 2: After Pressure Change



Source: Unit 1 Exam

Design Considerations

The following must be true
1) Incompressible fluid
2) Isothermal process

Data and Variables

Sg(oil) = 0.90
Sg (mercury) = 13.54
All dimensions are in drawings

Procedure

- This problem is solved using the simple equation of increment of pressure

$$\Delta p = \gamma \cdot h$$

- To solve this problem, I will start at one side of the manometer and end at the other side. This will be done for the initial conditions as shown in figure 1 and for the final conditions after the pressure change as shown in figure 2.
- When I move down the manometer, there will be a positive increase in pressure. When I move up the manometer, there will be a negative value of pressure

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Calculations:

Initial Condition (Figure 1)

- First convert inches to feet

$$6in \cdot \left(\frac{1ft}{12in}\right) = 0.5ft \quad 10in\left(\frac{1ft}{12in}\right) = 0.833ft \quad 8in\left(\frac{1ft}{12in}\right) = 0.667ft$$

Starting at Point A

$$P_A + \gamma_{oil} \cdot 0.5ft - \gamma_{mercury} \cdot 0.667ft - \gamma_{mercury} \cdot 0.5ft - \gamma_{water} \cdot 0.5ft = P_B$$

$$\gamma_{water} = 62.4\ lb/ft^3$$

$$\gamma_{oil} = Sg(oil) \cdot \gamma_{water} = 0.90 \cdot 62.4\ lb/ft^3 = 56.16\ lb/ft^3$$
$$\gamma_{mercury} = Sg(Hg) \cdot \gamma_{water} = 13.54 \cdot 62.4\ lb/ft^3 = 844.896\ lb/ft^3$$

$$P_A - P_B = -\gamma_{oil} \cdot 0.5ft + \gamma_{mercury} \cdot 0.667ft + \gamma_{mercury} \cdot 0.5ft + \gamma_{water} \cdot 0.5ft$$

$$P_A - P_B = \left(-56.16\frac{lb}{ft^3} \cdot 0.5ft\right) + \left(844.896\frac{lb}{ft^3} \cdot 0.667ft\right) + \left(844.896\frac{lb}{ft^3} \cdot 0.5ft\right) + 62.4\frac{lb}{ft^3} \cdot 0.5ft$$

$$\boxed{P_A - P_B = 989.1\ \frac{lb}{ft^2}}$$

$$P_A - P_B = 989.1\frac{lb}{\cancel{ft^2}} \cdot \frac{\cancel{1ft^2}}{144in^2}$$

$$\boxed{P_A - P_A = 6.87\ Psi}$$

Final Conditions (Figure 2)

Convert inches to feet

$4in \times \frac{1ft}{12in} = 0.333ft$ $5in \times \frac{1ft}{12in} = 0.417ft$ $6in \times \frac{1ft}{12in} = 0.5ft$

$7in \times \frac{1ft}{12in} = 0.583ft$

Starting at A

$P_A + \gamma_{oil} \cdot 0.417ft - \gamma_{mercury} \cdot 0.5ft - \gamma_{mercury} \cdot 0.333ft - \gamma_{water} \cdot 0.583ft = P_B$

$P_A - P_B = -\gamma_{oil} \cdot 0.417ft + \gamma_{mercury} \cdot 0.5ft + \gamma_{mercury} \cdot 0.333ft + \gamma_{water} \cdot 0.583ft$

$P_A - P_B = (-56.16 \frac{lb}{ft^3} \cdot 0.417ft) + (844.896 \frac{lb}{ft^3} \cdot 0.5ft) + (844.896 \cdot 0.333ft) + (62.4 \cdot 0.583ft)$

$\boxed{P_A - P_B = 716.76 \frac{lb}{ft^2}}$

$P_A - P_B = 716.76 \frac{lb}{\cancel{ft^2}} \cdot \frac{1ft^2}{144in^2}$

$\boxed{P_A - P_B = 4.977 \, psi}$

Summary

The difference in pressure for the compound manometer in the initial condition is 989.1 lb/ft^2 or 6.87 psi.

The difference in pressure for the compound manometer in the final condition is 716.76 lb/ft^2 or 4.977 psi.

This makes sense because after the pressure reduces at A, the pressure difference would also decrease. Pressure at A is reduced by 1.89 psi.

Materials

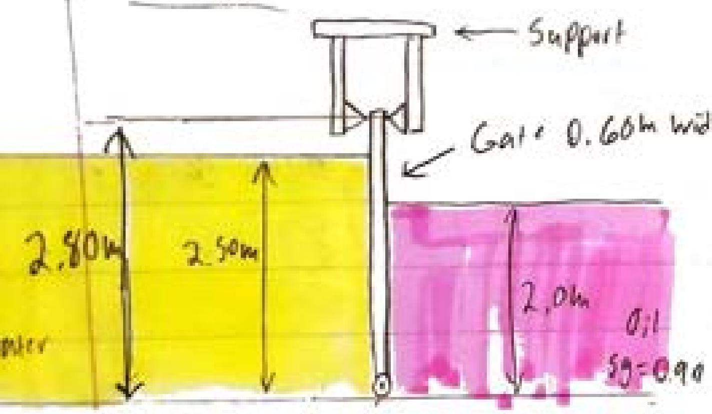
- water, oil, mercury

Analysis - The pressure on a point due to fluid column above is proportional to the height of the fluid column and specific weight of the fluid in the column.

Problem 2

Purpose: To compute the net force on the gate, Force on the hinge, and force on the support due to fluids on each side of the gate. Also to produce a graph of force on the hinge vs. elevation of fluid on the right.

Drawings:



Sources: Unit 1 Exam

Design Considerations

The following must be assumed

1) Incompressible Fluid
2) Isothermal Process

Data and Variables

$Sg(oil) = 0.90$

$\gamma_{water} = 9.81\ KN/m^3$

All dimensions are in drawings

Procedure: To solve this problem, we must first start by finding the net fluid force using the formula:

- $F = \gamma \cdot H_c \cdot A$
- The location of the fluid force will be 2/3 the height of the fluid from the surface, L_p
- Use a Free Body Diagram to help find the net force

Next, to find the force on the support, I will use Newton's law of moments and the fluid forces and locations found in the first step

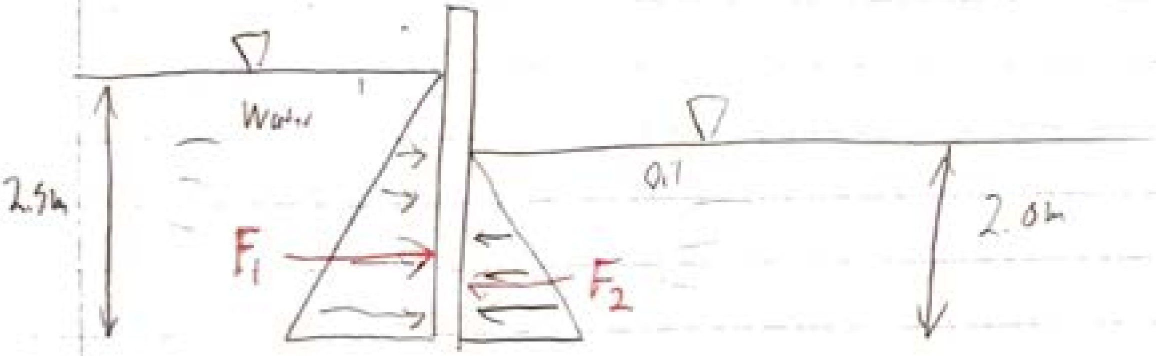
$$\Sigma M = 0$$

Finally, using Newton's First Law which states that the sum of forces must be zero and by using the fluid forces and force on the support, I can now solve for the force on the hinge

$$\Sigma F_x = 0$$

Calculations

1. FBD to find net force on gate due to fluids



· $F = \gamma \cdot h_c \cdot A$ · Force is located 2/3 height of fluid measured from surface

$F_1 = 9.81 \frac{kN}{m^3} \cdot \frac{2.5m}{2} \cdot 2.5m \cdot 0.6m$

$F_1 = 18.394 kN$

$LP_1 = \frac{2}{3} \cdot 2.5m = 1.67m$

$\gamma_{oil} = Sg(oil) \cdot \gamma_{water} = 0.90 \times 9.81 \frac{kN}{m^3} = 8.829 \frac{kN}{m^3}$

$F_2 = 8.829 \frac{kN}{m^3} \cdot \frac{2.0m}{2} \cdot 2.0m \cdot 0.6m$

$F_2 = 10.595 kN$

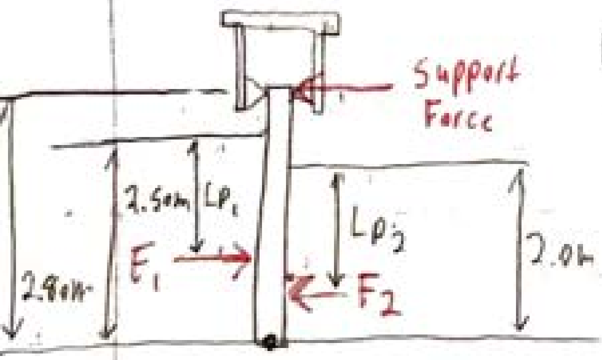
$LP_2 = \frac{2}{3} \cdot 2.0m = 1.33m$

$F_{Net} = F_1 - F_2$

$= 18.394 kN - 10.595 kN$

$\boxed{F_{net} = 7.80 kN}$

2. Use Newtons law of moments to find the force on the support next since I can't solve for the hinge force yet because it is unknown. Can't use Newton's law of force because I have 2 unknowns, force on support and force on hinge



$$\sum M = 0$$

$$F_1 \cdot (2.5 - Lp_1)m = F_2 \cdot (2.0 - Lp_2)m + F_{support} \cdot 2.8m.$$

$F_1 = 18.394 kN$ $\quad Lp_1 = 1.67m$

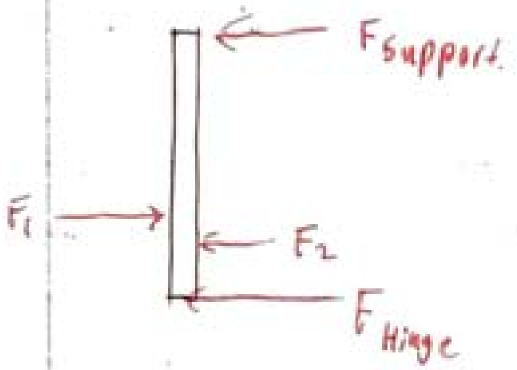
$F_2 = 10.595 kN$ $\quad Lp_2 = 1.33m$

$$F_{support} = \frac{F_1 \cdot (2.5 - Lp_1)m - F_2 \cdot (2.0 - Lp_2)m}{2.8m}$$

$$F_{support} = \frac{18.394 kN \cdot (2.5m - 1.67m) - 10.595 kN \cdot (2.0m - 1.33m)}{2.8m}$$

$$\boxed{F_{support} = 2.452 kN}$$

3. Use Newtons law of force to find Support on hinge using the forces due to liquids and the force on the support



$\Sigma F_x = 0$

$F_1 = F_{Support} + F_2 + F_{Hinge}$

$F_{hinge} = F_1 - F_2 - F_{Support}$

$F_{Hinge} = 18.394\,KN - 10.595\,KN - 2.952\,KN$

$\boxed{F_{Hinge} = 4.85\,kN}$

See excel SpreadSheet for graph of forceon hinge vs elevation of fluid on the right

Summary:

The net force acting on the gate due to the force of fluid, is 7.80KN. The force acting on the support is 2.952 KN due to the net force of fluids acting acting on the right. The force acting on the hinge is 4.85KN and is due to the force of fluids and force on the support.

- If we decrease elevation of the fluid on the right, we see that the force on the hinge will decrease

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- Materials:

water and oil

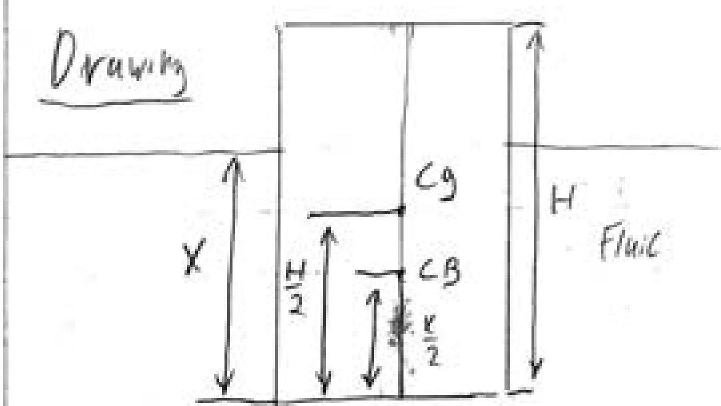
Analysis: Net force on the gate depends on the height of the fluid on each side, specific weight of the fluids, and area of the gate. The force on the support depends on its distance from the hinge. Using Newton's First law, we can determine that the sum of forces must equal zero. Thus, any force that isn't acting on the support due to the net fluid force must be acting on the hinge at the bottom of the gate.

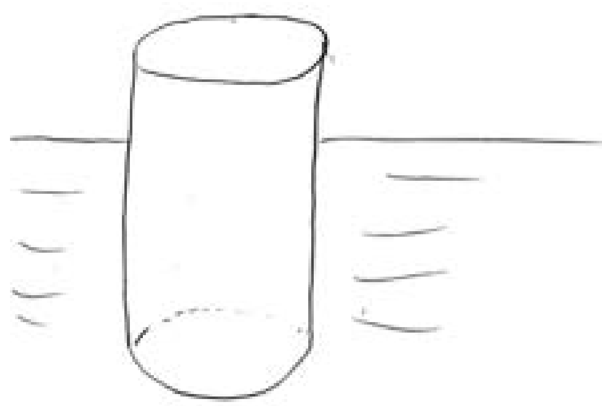
Problem 3.

Purpose:

- To calculate the positon of a cylinder when floating, Location of Center of Buoyancy, and Meta-Center location using any value of diameter, length, weight (or specific weight) of a cylinder and specific weight of fluid.
- To compare location of the metaCenter with Center of gravity
- Also to produce a graph of metaCenter location and Center of Buoyancy location versus cylinder length.

Drawing





Sources
- Unit 1 Exam

Design Consideration
The following must be assumed
1) Incompressible Fluid
2) Isothermal process

1

Data and Variables

This problem did not provide any dimensions or material properties since the problem is asking for an excel file made so that any cylinder dimensions or material specific weights can be entered.

Procedure

- First step is to find the position of the cylinder when floating
- In order to do that, we can use the formula for the displaced volume by the cylinder in the fluid.

$$V_d = A \cdot X$$

- Where X is the position of the cylinder in the fluid

$$V_d = \frac{\pi}{4} \cdot D^2 \cdot X$$

- Next, we know that weight of the cylinder must be equal to the Buoyancy Force in order for it to float. We can use this relationship to solve for X

$$W = F_b$$

$$W = \gamma_{Fluid} \cdot V_d$$

$$W = \gamma_{Fluid} \cdot \frac{\pi}{4} \cdot D^2 \cdot X$$

$$X = \frac{4 \cdot W}{\pi \cdot D^2 \cdot \gamma_{Fluid}}$$

$\boxed{X = \text{Position of Cylinder}}$

- Using the Position of the Cylinder that we found, we can Calculate the Center of Buoyancy
- The Center of Buoyancy is located at the centroid of the Volume of the Cylinder that is in the fluid.
  - For this Cylinder, this is located one half the height of the portion of the Cylinder in the fluid.

$$CB = \frac{X}{2}$$

- Next, we need to find the location of the Center of gravity. Assuming that the cylinder is Solid and has a Uniform specific weight, the Center of gravity will be located at one half the height of the cylinder.

$$Cg = \frac{H}{2}$$

- Next, We need to Calculate the location of the Meta center. The meta Center is located at a distance MB from the center of buoyancy.

$$MB = I / V_d$$

- I is moment of inertia of the cylinder and is an imaginary plane at the intersection of the Cylinder and the surface of the fluid

$$I = \frac{\pi D^4}{64}$$

- Combining these equations together, we can calculate the distance MB to find the location of the meta center.

$$MB = \frac{\frac{\cancel{\pi} D^{\cancel{4}2}}{64}}{\frac{\cancel{\pi}}{4}\cdot \cancel{D^2}\cdot x} = \frac{\frac{D^2}{64}}{\frac{x}{4}} = \frac{D^2}{16x}$$

$$MC = CB + MB$$

Calculations

- Use Excel Spreadsheet to Calculate the position of the cylinder, Location of Center of Buoyancy and meta center location.

Summary: Using different cylinder dimensions, cylinder weight, and specific weight of the fluid we can calculate the position of the cylinder, the location of Center of Buoyancy, and meta center location.

- If we find that the location of the meta center is below the location of the center of gravity, then the cylinder will be unstable.
- Looking at the graphs, we can determine that the location of the Metacenter and Center of Bouyancy are only dependent on cylinder weight, specific weight of fluid, weight of cylinder, and diameter of the cylinder

Summary cont.

The location of the Metacenter and Center of buoyancy are not dependent on the height of the cylinder since the lines don't change with cylinder height. This makes sense because the height of the cylinder is not in the calculations of the metacenter or center of buoyancy.

Materials:

Any material you may choose to enter in the spreadsheet.

Analysis

- The location of CB and MC depend on the weight and diameter of the cylinder and the specific weight of the fluid
- The center of gravity depends on the height of the cylinder.

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I understand that when asked to follow the Honor Code on exams or homework assignments I must follow the rules below.

1. When following the Honor Code a student must work entirely alone on exams.

2. When following the Honor Code a student may not share information about any aspect of the exam with other members of the class, other faculty members, or other people who has not already taken the exam this year, or its equivalent in future years.

3. When following the Honor Code a student must direct all questions concerning the exam or homework assignment to the course instructor or teaching assistant.

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6. When following the Honor Code a student cannot access, neither ask for help, from websites such as coursehero, chegg, and any other similar website, while taking the test.

I understand that failure to follow this Honor Code imply that the professor will immediately report my case for academic dishonesty to the ODU Office of Student Conduct & Academic Integrity.

Student Name: Jacob Leonard

Student Signature: Jacob Leonard

Date: 6/4/23