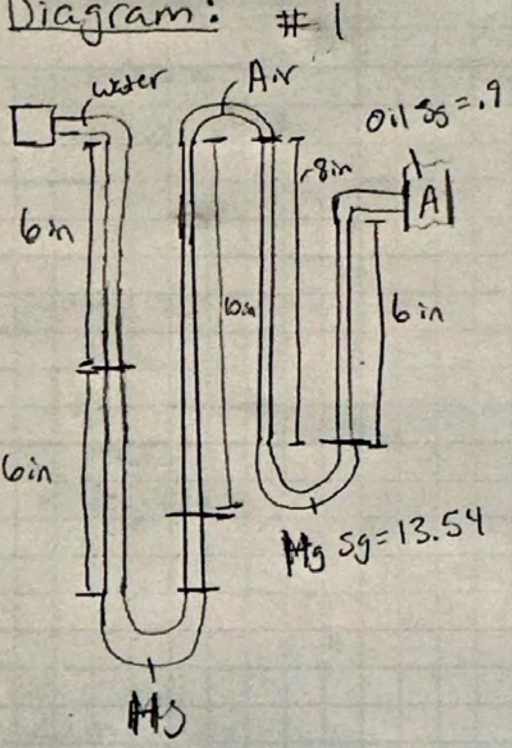
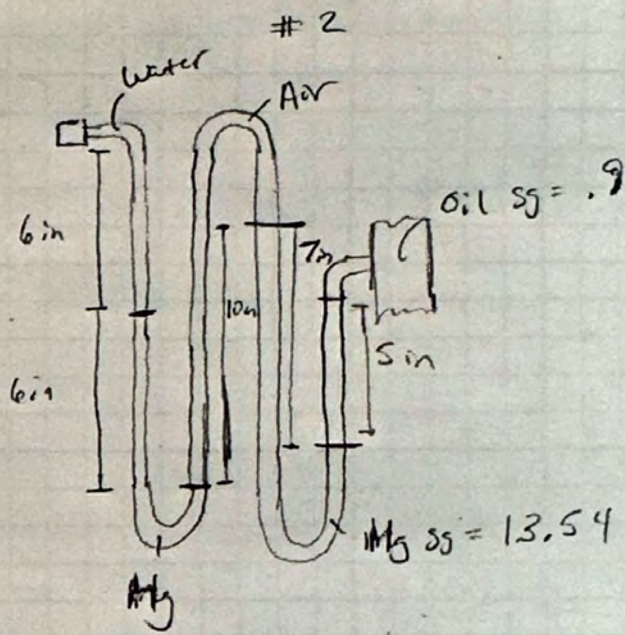
Test 1 | MET 330 | Joe Munoz | 1 Jun 2024

1. Purpose Determine press diff $P_A - P_B$ @ 6 in + @ 5in hiegnt of oil

Diagram:





Assumptions

1. incompressible fluids
2. steady state
3. Isothermal @ 70°F
4. water/mecury don't mix

Data + variables

$\gamma_{water} = 62.3\ lb/ft^3$ $\gamma_{oil} = 62.3 \cdot .9 = 56.07\ lb/ft^3$

$\gamma_{Hg} = 62.3 \cdot 13.54 = 843.54\ lb/ft^3$ $\gamma_{Air} = 0$

Materials

Water, oil, mercury, Air

Procedure for @ 6in

Use increment of height equation $\Delta p = \gamma \cdot h$
to find pressure @ P_B + P_A
moving down is positive, up is negative.

Calculations
$6in \cdot \frac{1ft}{12in} = .5\,ft$ $10in \cdot \frac{1f}{12in} = .833\,ft$ $8in \cdot \frac{1ft}{12in} = .666\,ft$

Start @ point A

$$P_A + \gamma_{oil} \cdot .5ft - \gamma_{Hg} \cdot .666ft + \cancel{\gamma_{Air} \cdot .833ft}^{\,0} - \gamma_{Hg} \cdot .5ft - \gamma_w \cdot .5ft = P_B$$

$$P_A - P_B = -56.07\,\frac{lb}{ft^3} \cdot .5ft + 884.54\,\frac{lb}{ft^3} \cdot .666ft + 884.5\,lb/ft^3 \cdot .5ft + 64.3\,\frac{lb}{ft^3} \cdot .5ft$$

$$P_A - P_B = \boxed{987.68\ lb/ft^2}$$

Summary
the differential pressure between P_A + P_B is $987.68\ lb/ft^2$

Analysis: The pressure of a certain point only depends on hieght of the fluid column + the specific weight of the Fluid.

Procedure for @ 5in

Point A reduces to 5in + causes Hg to raise up 1in, Changing the total distance from 8in to 7in.
The Air pocket expands to compensate for the Changes + doesn't affect the other measurements

Calculations

$$.5in \cdot \frac{1ft}{12in} = .416 ft$$

$$.7in \cdot \frac{1ft}{12in} = .583 ft$$

$$P_A + \gamma_{oil} \cdot .416ft - \gamma_{Hg} \cdot .583ft + \overset{0}{\cancel{\gamma_{Air} \cdot .833ft}} - \gamma_{hg} \cdot .5ft - \gamma_w \cdot .5ft = P_B$$

$$P_A - P_B = -56.07 \frac{lb}{ft^3} \cdot .416ft + 884.54 \frac{lb}{ft^3} \cdot .583ft + 884.5 \frac{lb}{ft^3} \cdot .5ft + 64.3 \frac{lb}{ft^3} \cdot .5 ft$$

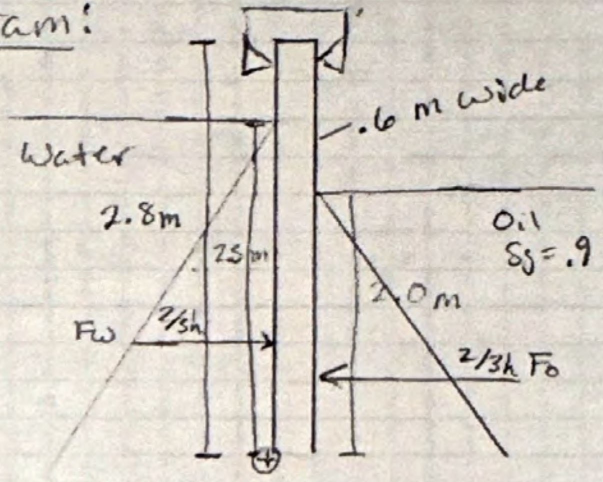
$$P_A - P_B = 972.12 \frac{lb}{ft^2}$$

Summary: Pressure diff between P_A + P_B is $972.12 \frac{lb}{ft^2}$

Problem # 2

Purpose: find net forces on the gate, hinge + support

Diagram:



Assumptions

1. incompressible fluid

2. Isothermal process + constant properties

Data + Variables

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

$h_{gate} = 2.8\,m$ $h_{water} = 2.5\,m$ $h_{oil} = 2.0\,m$

$W_{gate} = .6\,m$

Materials

Water + oil

Procedure

Compute force on both sides of door with $F = \gamma h_c \cdot A$

Center of pressure can be found a 2/3 height from the surface of liquid

With forces + pressure centers, summation of moment can be used to find forces @ support + hinge

Calculations:

$F_{water} = 9.81 \frac{kN}{m^3} \cdot \frac{2.5m}{2} \cdot (2.5m \cdot .6m) = 18.39\ kN \rightarrow$

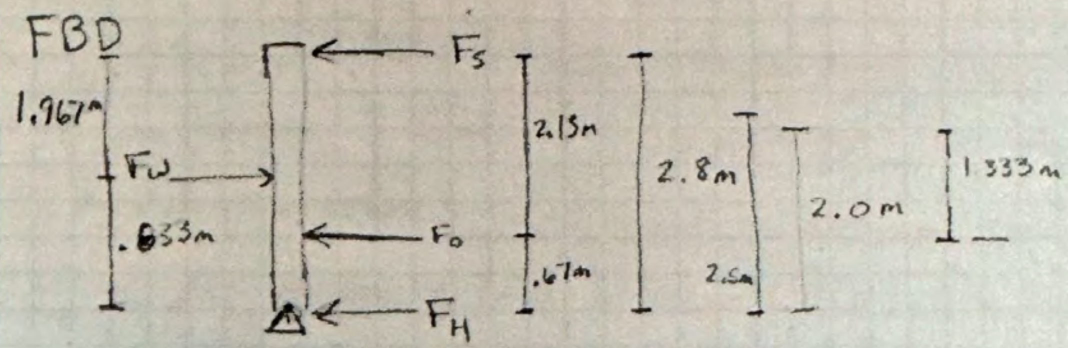
$LP_1 = 2.5m \cdot \frac{2}{3} = 1.667m$

$F_{oil} = (9.81 \frac{kN}{m^3} \cdot .9) \frac{2m}{2} (2m \cdot .6m) = 10.59\ kN \leftarrow$

$LP_2 = 2m \cdot \frac{2}{3} = 1.333\ m$

Gate Net force = $18.39\ kN - 10.59\ kN = \boxed{7.79\ kN \rightarrow}$

FBD



$\Sigma M_H: 10.59\ kN \cdot .67m - 18.39\ kN \cdot .833m + F_S \cdot 2.8m = 0$

$$\boxed{F_S = \frac{8.22\ kN \cdot m}{2.8m} = 2.94\ kN \leftarrow}$$

$\Sigma M_S: 18.39\ kN \cdot 1.967m - 10.59\ kN \cdot 2.13m - F_H \cdot 2.8m = 0$

$$\boxed{F_H = \frac{13.61\ kN \cdot m}{2.8m} = 4.863\ kN \leftarrow}$$

Summary: Net force on gate is 7.79 kN →
Net force on support is 2.94 kN ←
Net force on hinge is 4.863 kN ←

All of these forces are in equilibrium since the gate is stationary + balance out due to their differing locations.

Excel spread sheet

Positive forces are left to right $\rightarrow$
Negative forces are right to left $\leftarrow$

$$F_w = \gamma_w \cdot \underset{\frac{\text{Water height}}{2}}{h_c} \cdot (\text{Water height} \cdot .6)$$

$$F_{oil} = \gamma_w \cdot S_{g\,oil} \cdot \frac{\text{oil height}}{2} \cdot (\text{Oil height} \cdot .6)$$

$$\text{Gate Net Force} = F_{water} - F_{oil}$$

$$CoP_{water} = \text{Water height} \cdot 2/3$$

$$CoP_{oil} = \text{Oil height} \cdot 2/3$$

$$CoP_{water,\ from\ top} = CoP_{water} + (\text{Gate height} - \text{Water height})$$

$$CoP_{oil,\ from\ top} = CoP_{oil} + (\text{Gate height} - \text{Oil height})$$

$$CoP_{water,\ from\ bottom} = \text{Gate height} - CoP_{water,\ from\ top}$$

$$CoP_{oil,\ from\ bottom} = \text{Gate height} - CoP_{oil,\ from\ top}$$

$$\text{Force on Support} = \frac{(F_{oil} \cdot CoP_{oil\ from\ bottom}) - (F_{water} \cdot CoP_{water,\ Bottom})}{-\text{gate height}}$$

$$\text{Force on hinge} = \frac{(F_{water} \cdot CoP_{water,\ top}) - (F_{oil} \cdot CoP_{oil,\ top})}{\text{gate height}}$$

Analysis

as oil height increases hinge force moves towards zero & eventually the other direction. This is due to the oil Eventually Putting more force at the base as its height is greater then waters

Problem # 3

Excel spreadsheet

CoG = Lenght/2

Volume, cylender = $\frac{\pi}{4} d^2 \cdot l$

Weight, cylinder = Volcylinder $\cdot \gamma_{cylinder}$

Fluid Volume = $\frac{\pi}{4} \cdot d^2 \cdot$ floating position

$W_F = V_F \cdot \gamma_{LF}$

Floating position = $\frac{W_c}{\frac{\pi}{4} \cdot d^2 \cdot \gamma_F}$

Center of Bouyancy = $\frac{\text{Floating position}}{2}$

Volume displaced = $\frac{\pi}{4} d^2 \cdot$ Floating position

Moment of interia = $\frac{\pi \cdot d^4}{64}$

MB = $\frac{\text{Moment of Iteria}}{\text{Volume displaced}}$

Meta center = Center of bouyancy + MB

Comparison = IF metacenter > CoG = Stable
metacenter < CoG = unstable

Analysis: As diameter increases, stability increases if all other variables stay the same