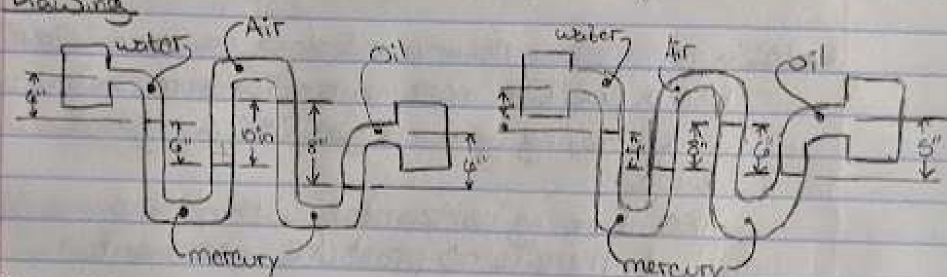
Robert Slade
MET 330
Exam 1

Problem 1
Purpose:
Compute the pressure differential (PA-PB) of the manometer. Also compute after a pressure drop of oil be 6in to 5in.
Drawing



Sources:
Mott, Robert L, Untener, Joseph A. Applied fluid mechanics 7th-2015 Reprinted by permission of Pearson Education Inc, New York New York

Design considerations
The following must be assumed.
1. Incompressible fluid
2. Isothermal process

Data and Variables
Sg oil = 0.90
Sg mercury = 13.54
γ_{water} = 62.4 lb/ft³
Dimensions of drawing
γ_{air} = 0.0764 lb/ft³

Procedure:

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

$\Delta P = \gamma * h$

We will move along the manometer starting from point A and ending at point B

Note: when moving downward along the manometer use a positive increment of pressure, but when moving upward we use a negative value
Also, if moving horizontally within the same fluid, there is no pressure increment.

Calculations

$6in \frac{1ft}{12in} = 0.5ft$ $\quad$ $5in \frac{1ft}{12in} = 0.417ft$

$10in \frac{1ft}{12in} = 0.833ft$ $\quad$ $4in \frac{1ft}{12in} = 0.333ft$

$8in \frac{1ft}{12in} = 0.666ft$

$P_A + \gamma_{oil} * 0.5ft - \gamma_m * 0.666ft + \gamma_{air} * 0.833ft - \gamma_m * 0.5ft - \gamma_{water} * 0.5ft = P_B$

$\gamma_{oil} = 0.90 * 62.4 lb/ft^3 = 56.2 lb/ft^3$

$\gamma_m = 13.54 * 62.4 lb/ft^3 = 844.9 lb/ft^3$

$P_A + 56.2 lb/ft^3 * 0.5ft - 844.9 lb/ft^3 * 0.666ft + 0.0764 lb/ft^3 * 0.833ft$
$- 844 lb/ft^3 * 0.5ft - 62.4 lb/ft^3 * 0.5ft = P_B$

$P_A + 28.1 lb/ft^2 - 562.7 lb/ft^2 + 0.064 lb/ft^2 - 422.45 lb/ft^2 - 31.2 lb/ft^2 = P_B$

$P_A - P_B = 988.19 lb/ft^2$

$$P_A + \gamma_{oil} * 0.417 ft - \gamma_m * 0.5 ft + \gamma_{air} * 0.666 ft - \gamma_m * 0.333 ft - \gamma_{water} * 0.666 ft = P_B$$

$$P_A + 56.2 \, lb/ft^3 * 0.417 ft - 844.9 \, lb/ft^3 * 0.5 ft + 0.0764 \, lb/ft^3 * 0.666 ft - 844.9 \, lb/ft^3 * 0.333 ft - 62.4 \, lb/ft^3 * 0.666 ft = P_B$$

$$P_A + 23.44 \, lb/ft^2 - 422.45 \, lb/ft^2 + 0.051 \, lb/ft^2 - 281.35 \, lb/ft^2 - 41.56 \, lb/ft^2 = P_B$$

$$P_A - P_B = 721.87 \, lb/ft^2$$

Summary:

The differential pressure in the compound differential manometer is 988.4 lb/ft^2.
The differential pressure in the compound differential manometer after the oil column is reduced from 6in to 5in is 721 lb/ft^2

Materials

water
Air
oil
mercury

Analysis:

The pressure on a certain point only depends directly on the fluid column height and on the specific weight of the fluid.

Problem 2

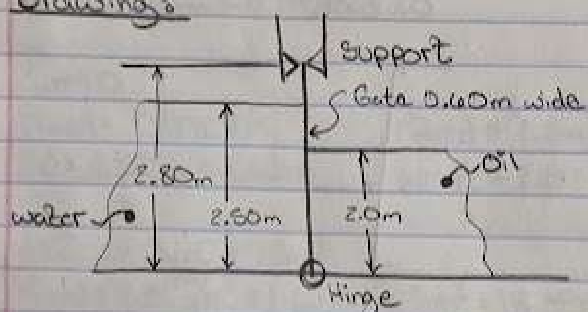
Purpose:

Compute the Net Force on gate

Compute the Force on hinge

Compute the Force on support

Drawing:



Sources:

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Design Considerations

The following must be assumed.

1. Incompressible fluid
2. Isothermal process

Data and Variables

Dimensions on gate and water / Oil as fluids

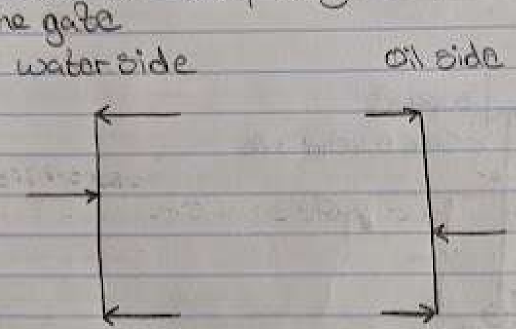
$\gamma_{water} = 9.81\ kN/m^3$

$Sg_{oil} = 0.90$

Procedures:

The Support is holding the gate in position and that is the reason it excerts a force on the wall. The hinge helps.

Create free body diagrams for each side of the gate



Apply extended version of Newton's law

$\sum M = 0$ (With respect to hinge location)

Find the fluid force

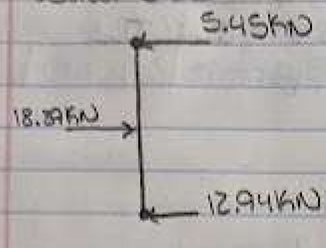
$F_{fluid} = \gamma * h_c * A$

Find the force location

2/3 of Depth of fluid (L_p)

Calculations:

water side



$\Sigma m = 0$

$F_{fluid} = \gamma * h_c * A$

$h_c = \frac{2.50m}{2} = 1.25m$

$A = 2.5 \times 0.60 = 1.5m^2$

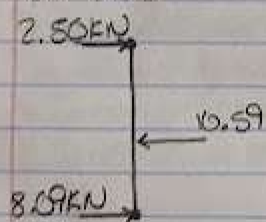
$F_{fluid} = 9.81^{kN}/m^3 * 1.25m * 1.5m^2 = 18.39kN$

$F_{fluid} * (2.5m - L_p) = Support * 2.8m$

$L_p = \frac{2}{3} * 2.5 = 1.67m$

$F_{support} = \frac{18.39kN * (2.5 - 1.67)}{2.8m} = 5.45kN$

Oil side



$\gamma_{oil} = 9.81^{kN}/m^3 * 0.90 = 8.829^{kN}/m^3$

$F_{fluid} = \gamma * h_c * A$

$h_c = \frac{2.0}{2} = 1m$

$A = 2.0m * 0.60m = 1.2m^2$

$F_{fluid} = 8.829^{kN}/m^3 * 1m * 1.2m^2 = 10.59$

$F_{fluid} * (2.0m - L_p) = Support * 2.80m$

$L_p = \frac{2}{3} * 2.0 = 1.34m$

$F_{support} = \frac{10.59kN * (2.0m - 1.34m)}{2.8m} = 2.50kN$

Summary:

The net force acting on the gate is 7.8 kN to the right. The force on the hinge is 4.85 kN to the left. The force on the support is 2.95 kN.

material

water

Oil

Analysis

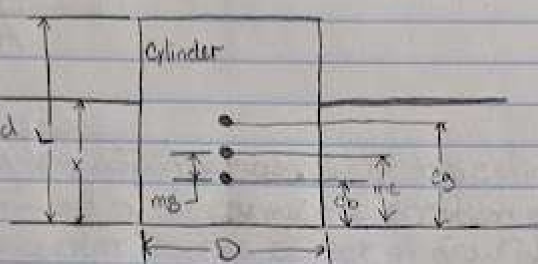
The resultant force due to pressure, depends directly on the height of fluid on the surface and on the geometry of such surface.

Problem 3

Purpose:

Calculate the position, center of buoyancy, metacenter, and center of gravity of a cylinder.

Drawing:



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Design Considerations

The following must be assumed

1. Incompressible fluid
2. Isothermal process

Data and Variables

D = diameter of cylinder
L = Length of cylinder
W = weight of cylinder
γ_c = Specific weight of cylinder
γ_F = Specific weight of fluid
X = position of cylinder
mB = distance between metacenter and center of buoyancy
cb = Center of buoyancy
mc = Position of metacenter
Cg = center of gravity cylinder

Procedures:

Use the equilibrium equation to solve for x

$\sum F_v = 0$ (Volume forces)

$\omega = F_b$ (buoyancy force) $= \gamma_f V_d$ (submerged volume) $= \gamma_f \frac{\pi D^2}{4}(x)$

$x = \frac{4\omega}{\pi D^2 \gamma_f}$

Solve for cb

$cb = \frac{x}{2}$

Use the moment of Inertia to solve for mb

$mb = \frac{I}{V_d}$

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

$V_d = A * x$

$A = \frac{\pi D^2}{4}$

Use mb to solve for mc

$mc = cb + mb$

Find the center of gravity

$cg = \frac{L}{2}$

Calculations

NA

* see excel for calculations

Summary:

Using the procedure, the position, center of buoyancy, metacenter and center of gravity of a cylinder given the diameter, Length, weight, specific weight of the cylinder and specific weight of the fluid.

Material

N/A

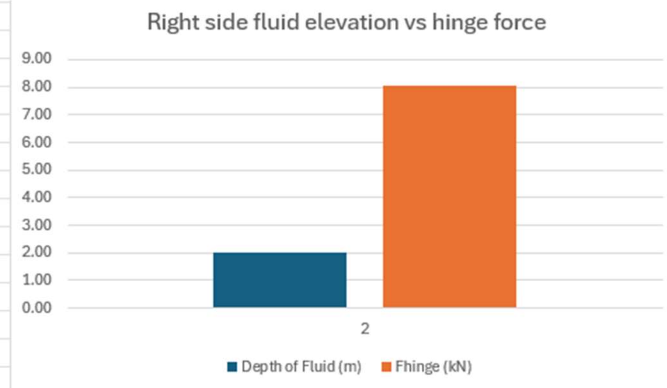
Analysis

Using this data the stability of the cylinder can be determined by comparing the position of the metacenter to the center of gravity.

Support (m)	
Length	2.8
Width	0.6

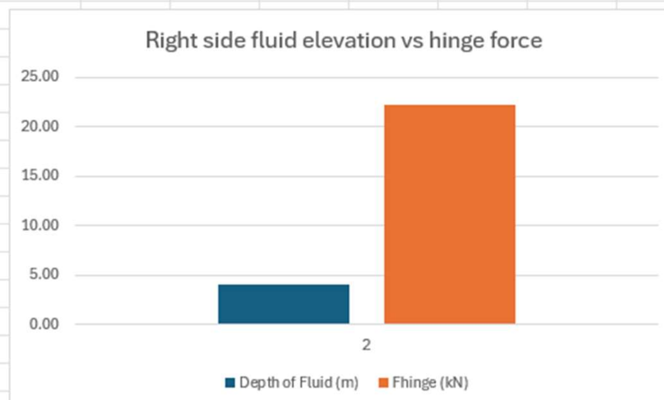
Hydrostatic Pressure		
[redacted]	Left Side	Right Side
Depth of Fluid (m)	2.50	2.00
Specific Gravity (kN/m^3)	9.81	8.83
hc (m)	1.25	1.00
Area of Surface (m^2)	1.50	1.20
Lp (m)	1.67	1.33
Ffluid (kN)	18.39	10.59
Fsupport (kN)	5.47	2.52
Fhinge (kN)	12.92	8.07

Net Forces (kN)		
Acting on Gate	7.80	to the right
Acting on Support	2.95	to the left
Acting on Hinge	4.85	to the left



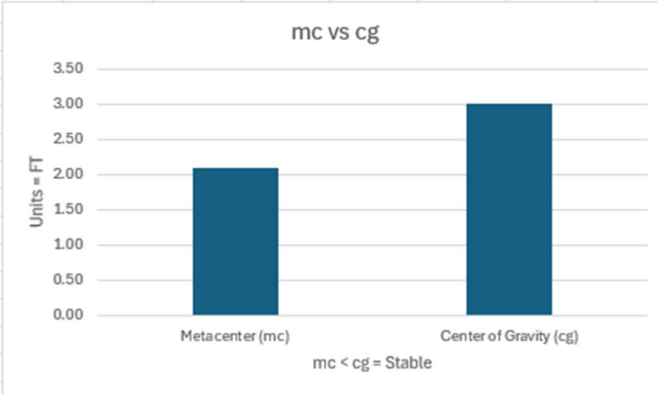
Hydrostatic Pressure		
[redacted]	Left Side	Right Side
Depth of Fluid (m)	2.50	4.00
Specific Gravity (kN/m^3)	9.81	8.83
hc (m)	1.25	2.00
Area of Surface (m^2)	1.50	2.40
Lp (m)	1.67	2.67
Ffluid (kN)	18.39	42.38
Fsupport (kN)	5.47	20.18
Fhinge (kN)	12.92	22.20

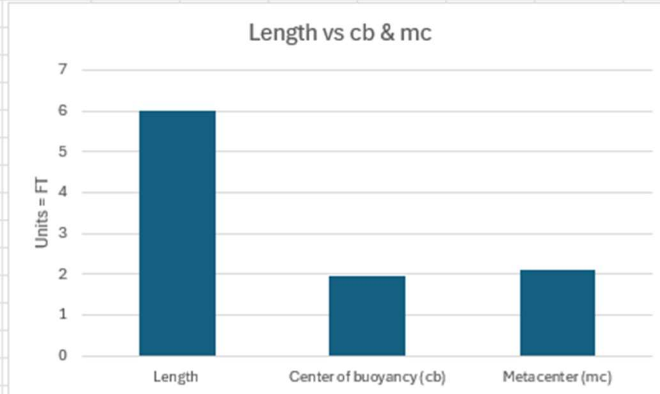
Net Forces (kN)		
Acting on Gate	23.99	to the left
Acting on Support	14.71	to the right
Acting on Hinge	9.28	to the right



Inputs	
Diameter	3
Length	6
Weight of Cylinder	1550
Specific Weight of cylinder	N/A
Specific Weight of Fluid	56.2

Calculations	
Position of cylinder (X)	3.90
Center of buoyancy (cb)	1.95
Moment of Inertia (I)	3.98
Area of cylinder (A)	7.07
Displaced Volume of Fluid (Vd)	28.11
Distance between mc & cb (mb)	0.14
Metacenter (mc)	2.09
Center of Gravity (cg)	3.00





Inputs	
Diameter	2
Length	6
Weight of Cylinder	1550
Specific Weight of cylinder	N/A
Specific Weight of Fluid	56.2

Calculations	
Position of cylinder (X)	8.79
Center of buoyancy (cb)	4.39
Moment of Inertia (I)	0.79
Area of cylinder (A)	3.14
Displaced Volume of Fluid (Vd)	2.47
Distance between mc & cb (mb)	0.32
Metacenter (mc)	4.71
Center of Gravity (cg)	3.00