Name: Dylan Arnold University ID: 01166349

MET 330 Fluid Mechanics
Dr. Orlando Ayala
Summer 2023
Test 1

Take home – Due Sunday June 4th 2023 before midnight.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)

2. The total points on this test are one hundred (100). Ten (10) points are from your HW assignments. The other eighty (90) points will come from the problem solutions.

3. There are 3 problems to solve, each worth (90/3) points.

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call me, skype me, text me, email me, come to my office, if you have any question.

5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.

6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit only one file and it has to be a pdf file. For the ePortfolio you are also supposed to upload this artifact to your Google drive. When you are done solving the test, please go ahead and upload it now before you forget.

7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.

8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

   IX. PROHIBITED CONDUCT

   A. Academic Integrity violations, including:

   1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

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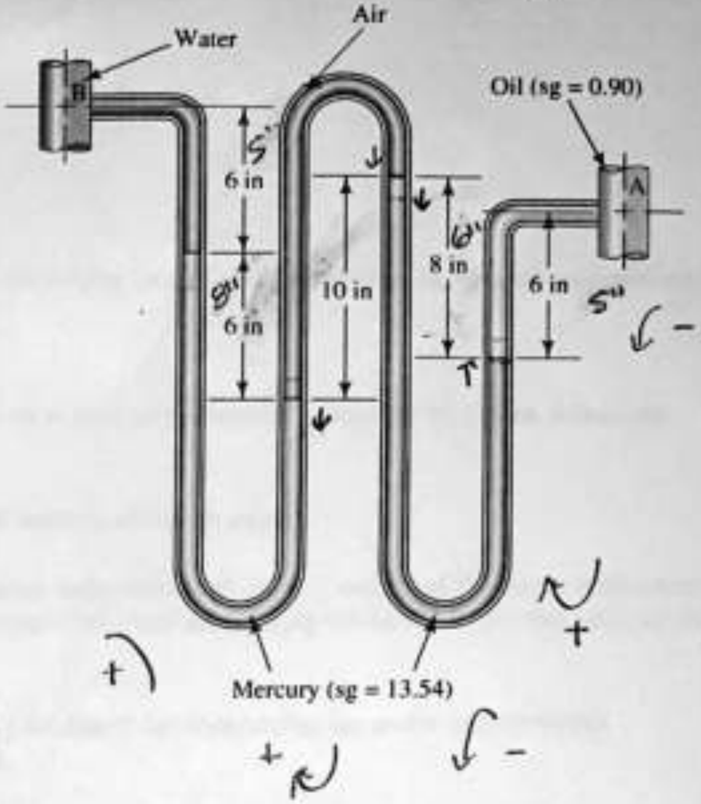
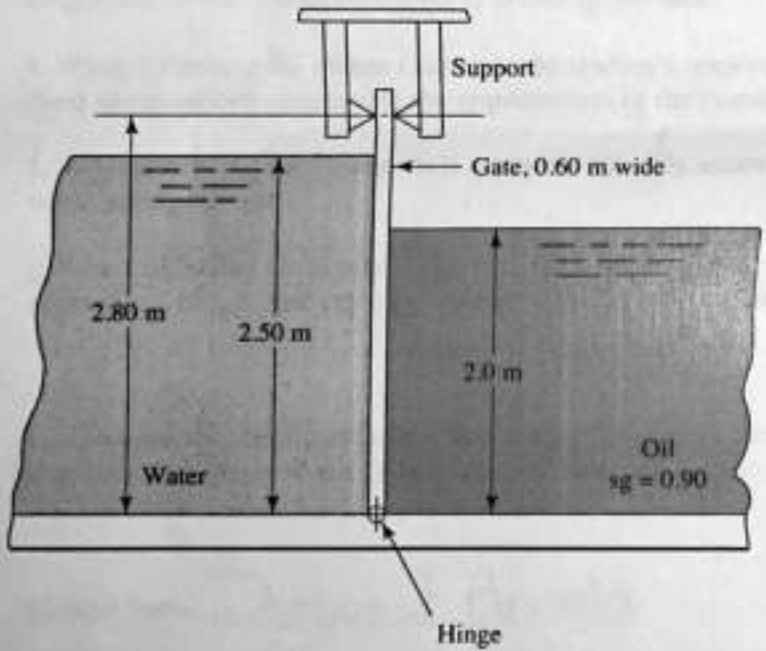


1. For the compound differential manometer in the figure, calculate (p_A-p_B). Keep in mind that the pressure in the space with air is the same (it does not change with elevation).
   At some point of the operation of the system, the pressure at A drops. That makes the oil column to reduce from 6 in to 5 in and all other fluids will adjust to the change. calculate (p_A-p_B) for the new stage of the system.
   Make sure you explain in detail the procedure you use.



2. The figure shows a gate hinged at its bottom and held by a simple support at its top. The gate separates two fluids. Create an Excel spreadsheet to compute the net force on the gate, the force on the hinge, and the force on the support due to the fluid on each side. Make the spreadsheet in such a way that you can input any combination of the depth on either side of the gate and any specific gravity of the fluids.
   Produce a graph of force at the hinge versus the elevation of the liquid on the right. You will do this plot for different elevation of the liquid on the right.
   Make sure you explain in detail the procedure and set of equations you use.

3. Create an Excel spreadsheet to evaluate the stability of a circular cylinder placed in a fluid with its axis vertical. Make the spreadsheet in such a way that you can input any combination diameter, length, and weight (or specific weight) of the cylinder, and specific weight of the fluid. The spreadsheet should provide the position of the cylinder when it is floating, the location of the center of buoyancy, and the metacenter location. Compare the location of the metacenter with the center of gravity to evaluate.
   Produce a graph of the metacenter location and center of buoyancy location versus the cylinder length. You will do this plot for different cylinder diameter for fixed specific weights of cylinder and fluid.
   Make sure you explain in detail the procedure and set of equations you use.

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HONOR CODE

I pledge to follow the Honor Code and to obey all rules for taking exams and performing homework assignments as specified by the course instructor.

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.

4. When following the Honor Code it is the student's responsibility to obtain clarification from the instructor if there are questions concerning the requirements of the Honor Code.

5. When following the Honor Code a student can only access websites related to ODU (such as Blackboard, etc.) while taking the test.

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: Dylan J Arnold

Student Signature: [signature]

Date: 6/4/2023

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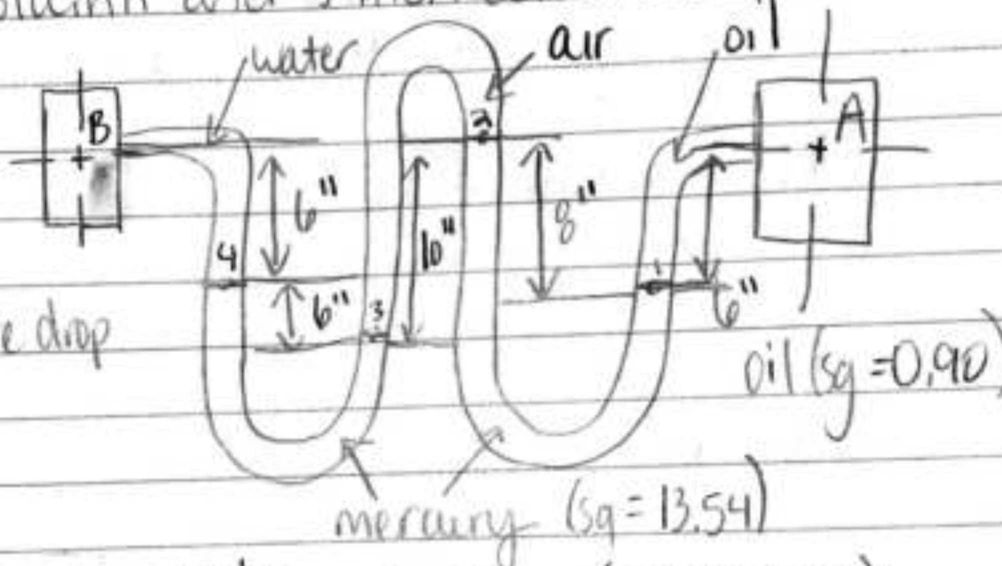
MET330 Summer 2023
Test 1
June 4th, 2023
Professor Ayala
University ID: 01164349

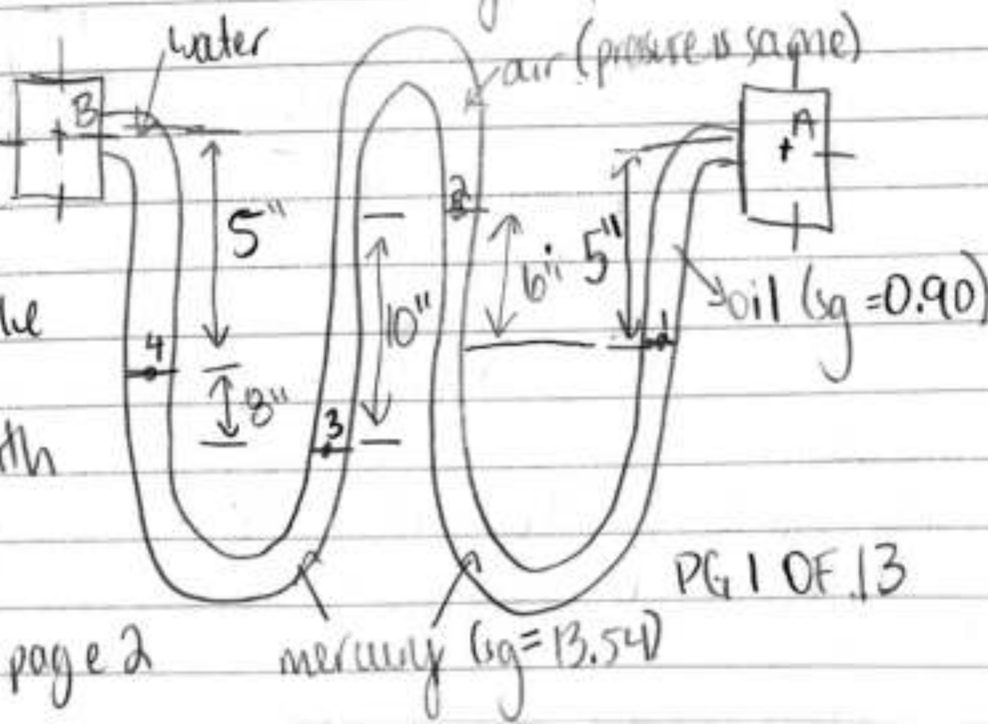
1. **Purpose:** Calculate $P_A - P_B$ for both 6 inch column and 5 inch column.

Diagram:



Before Pressure drop

After Pressure Drop



A is still 10" because it stays the same (does not change with elevation"

continued on page 2

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Problem 1 continued:
Sources: Mott and Untener. Applied Fluid Mechanics. 7th Edition. Pearson. 2015.

Design Considerations:
Based on the problem description, I assume the following:
1. Incompressible Fluids
2. Steady State
3. Isothermal process
4. Water and Mercury do not mix
5. Air Pressure stays the same (does not change)
6. Pressure drops oil column from 6" to 5"

Data and Variables:
$\gamma_{water} = 62.4\ lb/ft^3$ $sg_{oil} = 0.90$ $\frac{1 ft^3}{1728 in^3}$
$\gamma_{mercury} = 844.9\ lb/ft^3$ $sg_{mercury} = 13.54$
$\gamma_{oil} = 56.16\ lb/ft^3$ $P_{atm} = 14.9\ psia$ $\gamma_{air} = 0.764\ lb/ft^3$
P_A column before pressure drop = 6"
P_A column after pressure drop = 5" continued on PG 3

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Problem 1 Continued:

Materials:
Water, air, mercury, oil

Procedure and Calculations: Apply Manometry
Stage 1 (Pressure column at PTA (6") Start from PA
Calculate $P_A - P_B$ → standard condition air at sea level

$$P_A - \gamma_{oil}(6") + \gamma_{mercury}(8") - (0.764\ lb/ft^3)(10") + \gamma_{mercury}(8") + \gamma_{water}(6") = P_B$$

sg_{oil} $0.90 \cdot 62.4\ lb/ft^3 = 56.16\ lb/ft^3$
$sg_{mercury}$ $13.54 \cdot 62.4\ lb/ft^3 = 844.9\ lb/ft^3$

$$P_A - (56.16\ lb/ft^3)\left(\frac{6"\ ft^3}{1728\ in^3}\right) + (844.9\ lb/ft^3)\left(\frac{8"\ ft^3}{1728\ in^3}\right) - (0.764\ lb/ft^3)\left(\frac{10"\ ft^3}{1728\ in^3}\right) + (844.9\ lb/ft^3)\left(\frac{6"\ ft^3}{1728\ in^3}\right) + (62.4\ lb/ft^3)\left(\frac{6"\ ft^3}{1728\ in^3}\right) = P_B$$

$$P_A - 0.195\ psi + 3.912\ psi - 0.004\ psi + 2.933\ psi + 0.217\ psi = P_B$$

$$\boxed{P_A - P_B = -6.863\ psi \text{ stage 1}}$$

Continued on PG 4

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Problem 1 Continued:

Procedure and Calculations:
Stage 2 (Column at PtA 5")
Calculate $P_A - P_B$

$$P_A - \gamma_{oil}(5") + \gamma_m(6") - \gamma_{air}(10") + \gamma_m(8") + \gamma_w(5") = P_B$$

$$P_A - (56.16\ lb/ft^3)\left(\frac{5"\ ft^3}{1728in^3}\right) + (844.9\ lb/ft^3)\left(\frac{6"\ ft^3}{1728in^3}\right) - (0.764\ lb/ft^3)\left(\frac{10"\ ft^3}{1728in^3}\right) + (844.9\ lb/ft^3)\left(\frac{8"\ ft^3}{1728in^3}\right) + (62.4\ lb/ft^3)\left(\frac{5"\ ft^3}{1728in^3}\right)$$

$$P_A - 0.163psi + 2.934psi - 0.004psi + 3.912psi + 0.181psi = P_B$$

$$\boxed{P_A - P_B = -6.860psi \text{ at stage 2}}$$

Summary:
The pressure calculation from $P_A - P_B = -6.863psi$ when column at P_A is 6". When pressure drops and causes column at P_A to move to 5", pressure remains close but not identical at -6.860 psi. So assumption is the system is self regulating in pressure. Continued on PG5

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Problem 1 Continued:

Analysis:

The reading at "Stage 1" and "Stage 2" are nearly identical, only being off by 0.003 psi. This is because the manometer is closed instead of open to atmosphere so the system is balancing out the pressure (self regulating). If the answer on stage 2 was anything further than 0.5 psi (general +/- error), then I would conclude that I miscalculated a value somewhere in the equation.

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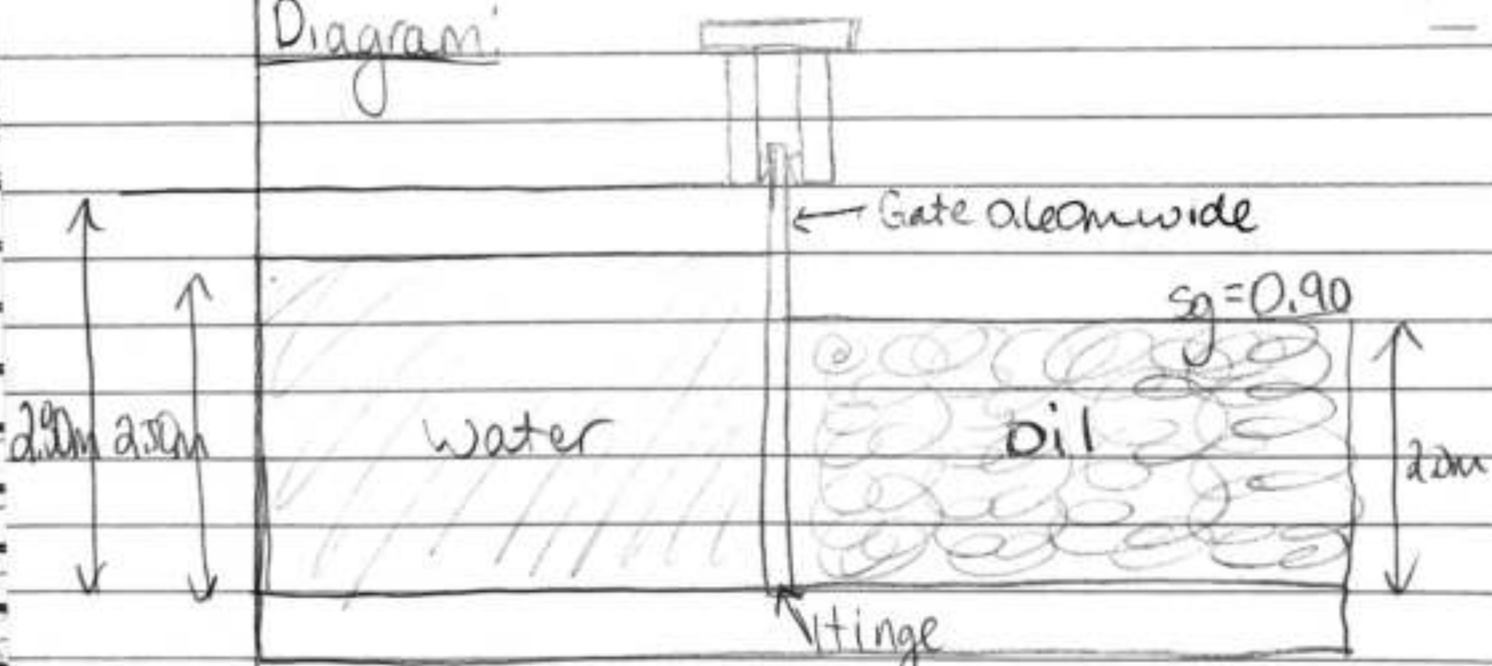
2. Purpose:
Calculate net force on gate, force on the hinge, and the force on the support due to fluid on each side. Create spreadsheet for plug and play values. Produce graph of hinge force versus liquid elevation (right).

Diagram:



Sources: Mott and Untener. Applied Fluid Mechanics. 7th Edition. Pearson. 2015

Continued on Pg 7

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Problem 2 Continued:

Design Considerations:

Based on the problem description, I assume the following:

1. Incompressible fluids
2. Steady State
3. Isothermal Process

Data and Variables:

$\gamma_{water} = 9.81 KN/m^3$ Gate Width = 0.60 m

$sg_{oil} = 0.90$ Gate Height = 2.80m

$\gamma_{oil} = 8.83 KN/m^3$ (0.90 • 9.81)

Water Height = 2.50m Oil Height = 2.0m

Materials:

Water and oil

Procedure and Calculations:

See excel sheet Problem 2

Continued on PG 8

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Problem 2 Continued:

Summary:
The force at the hinge was 4.85kN to the left and the force at the support was 2.95kN to the left. Excel sheet was set up in way for user to input values (h_{fluid} and specific gravity of fluids) that would give values for the two forces above. Force was to left because height of oil is lower than water. In case the oil was higher than water then the force would be to right. Ten data entry points were taken ranging from 1.5m-2.4m. This correlated to a range of the force at the hinge from 2.02kN - 8.02kN.

Continued on PG 9

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Problem 2 Continued:

Analysis:

Analysis based off of initial calculations is that the lower the height of the oil, the higher the force on the hinge. (Close to linear) This is accurate because the force on the hinge needs to balance out the pressure of the water acting upon that hinge. This was a fun one to set up since we deal with a lot of spreadsheets in our engineering library.

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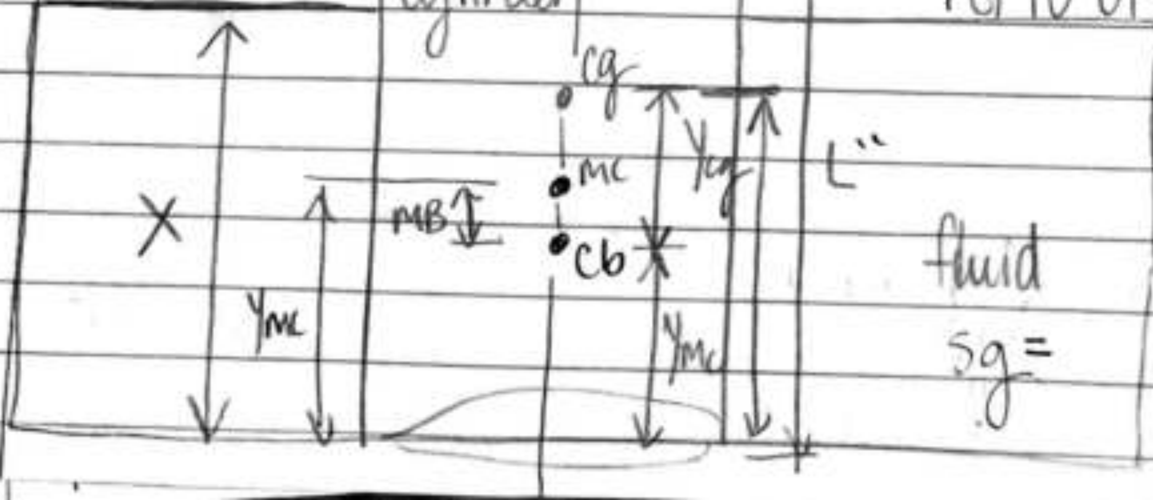
3. Purpose: Evaluate stability of circular cylinder placed in fluid with its axis vertical. Provide position of cylinder when floating, location of center of buoyancy, the metacenter location. Then compare location of metacenter with center of gravity. Create excel spreadsheet for plug and play values and produce graph of metacenter location and center of buoyancy versus the cylinder length at different cylinder length values.

Diagram:



Continued on PG 11

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Problem 3 Continued:

Sources: Mott and Untener. Applied Fluid Mechanics. 7th Edition. Pearson. 2015.

Design Considerations:
Based on the problem description, I assume the following.
1. Incompressible Fluids
2. Steady State
3. Isothermal Process
4. Fluid choice
5. Cylinder length choice
6. Unit choice
7. Excel spreadsheet setup

Data and Variables:

Fluid	Specific weight fluid
Vertical axis	C_B
Diameter of cylinder	M_C
Length of cylinder	C_G
Weight of cylinder	M_B
Specific Weight cylinder	

Continued on PG12

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Problem 3 continued:

Materials:
Fluid at user discretion
Cylinder material at user discretion

Procedure and Calculations:
See excel spreadsheet

Summary: At a diameter of 2.25ft and a length of 6ft. A cylinder floating in oil will be stable because the y_{mc} (3.52ft) is greater than y_{cg} (3ft).
Just a bit larger diameter (2.5ft) makes the cylinder unstable because y_{mc} (2.88ft) is less than y_{cg} (3ft).

Continued on PG 13

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Problem 3 Continued:

Analysis: Based on the procedure, calculations, and excel sheet, it can be determined that if y_{mc} and y_{cb} are within 0.05 ft, (for a 6ft 3"D cylinder), the cylinder will be stable. Another finding per the graph is that if the 2 lines for y_{mc} + y_{mb} are a "good ways" away from each other, then it can be concluded that without finding y_{cg}, the cylinder will not be stable.