TEXAS TECH UNIVERSITY

DEPARTMENT OF CIVIL, ENVIRONMENTAL AND CONSTRUCTION ENGINEERING

Lab Report #2: Forces on Plane Surfaces and Archimedes' Principle

Section:

Group Number: _

Instructor:

Members:

Date Of Experiment: July 13, 2022

Date of Submission: July 19,2022

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Theory

The objective of this lab is to understand how fluid statics and outside forces affect the body. Measure buoyancy force on several objects and determine the hydrostatic acting on a plane surface in water. Archimedes' principle is to measure the fluid displaced by the volume of the object. An upward buoyant force from the fluid will equal the weight of the fluid displaced. If an object sinks to the bottom of a container a buoyant force is acting on it.

Equations:

(1) $B = w_f = \rho_f \times V_f \times g$

(2) $B - w_o = (\rho_{f-}\rho_o)V_o g$

(3) $B - W_o = 0$

(4) $\rho f \times Vf \times g = \rho_o \times V_o \times g$

(5) $\frac{V_o}{V_f} = \frac{\rho_f}{\rho_o}$

(6) $\delta F = \gamma_w (y cos\theta - h) W \delta y$

(7) $\delta M = \gamma w W (y cos\theta - h) y \delta y$

(8) $M = \gamma w W \int (cos\theta y^2 - hy) dy$

(9) $M = \frac{\gamma w W cos\theta}{3}(R_2^3 - R_1^3) - \frac{(\gamma w W)}{2}(R_2^2 - R_1^2)h$

(10) $M = \frac{\gamma w W \sec^2 \theta h^3}{6} + \frac{\gamma w W cos\theta R_2^3}{3} - \frac{\gamma w W R_2^2 h}{2}$

Apparatus

Figure 1: Pictured below is a graduated cylinder(mL), concrete block, wood.

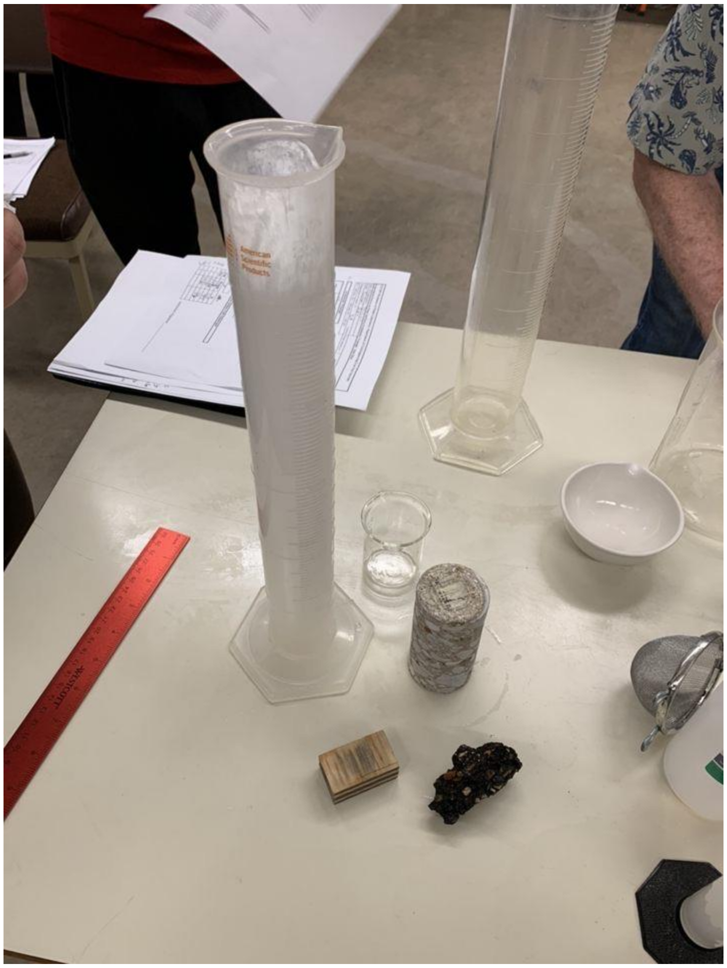
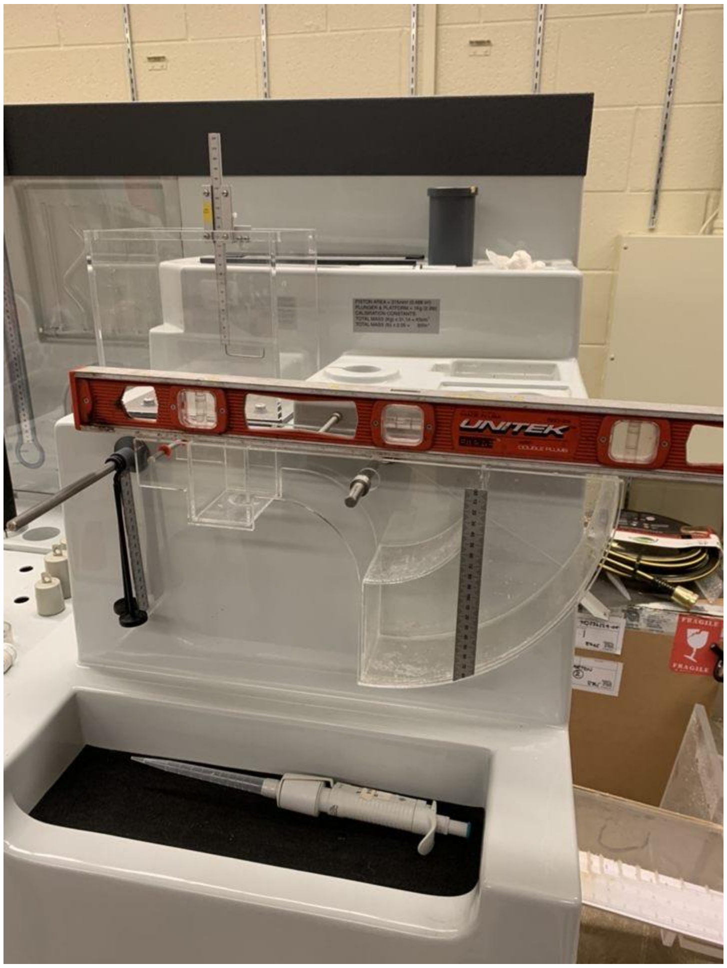


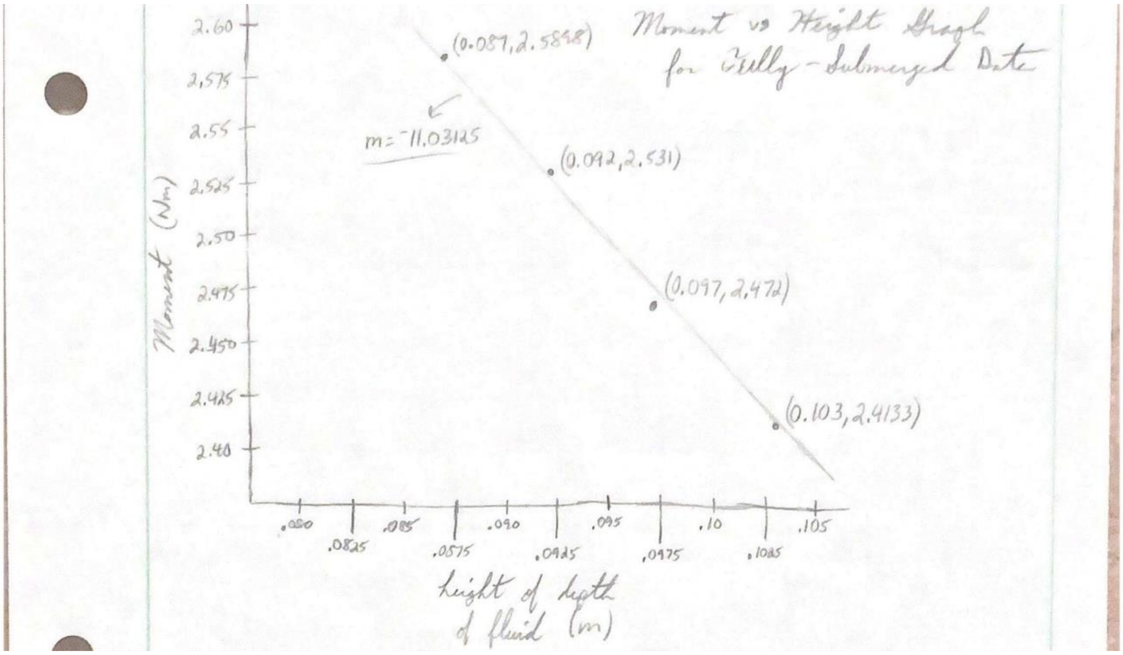
Figure 2: Pictured below is for a demonstration for fluids on a plane surface



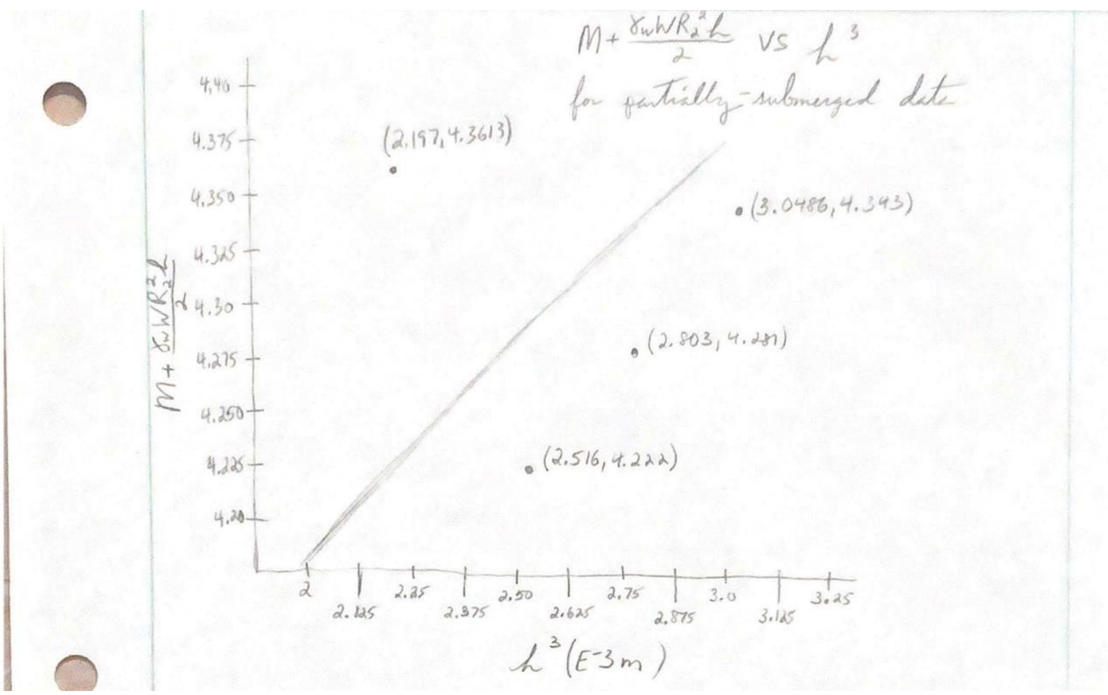
Results

Object	Initial Volume (mL)	Final Volume (mL)	Change in Volume (mL)	Measured Volume of Object (cubic cm)	Calculated Volume (cubic cm)	Mass of Object (grams)	Submerged?	Buoyant Force (N)
Asphalt	800	828	28	Irregular	32.40	70.83	Yes	0.2747
Wood	800	815	15	21.46	25.42	15.57	No	0.1527
Concrete	2001.22	2232.13	230.91	196.35	181.71	485.3	Yes	2.2652

Fully Submerged Dataset Graph



Partially Submerged Dataset Graph



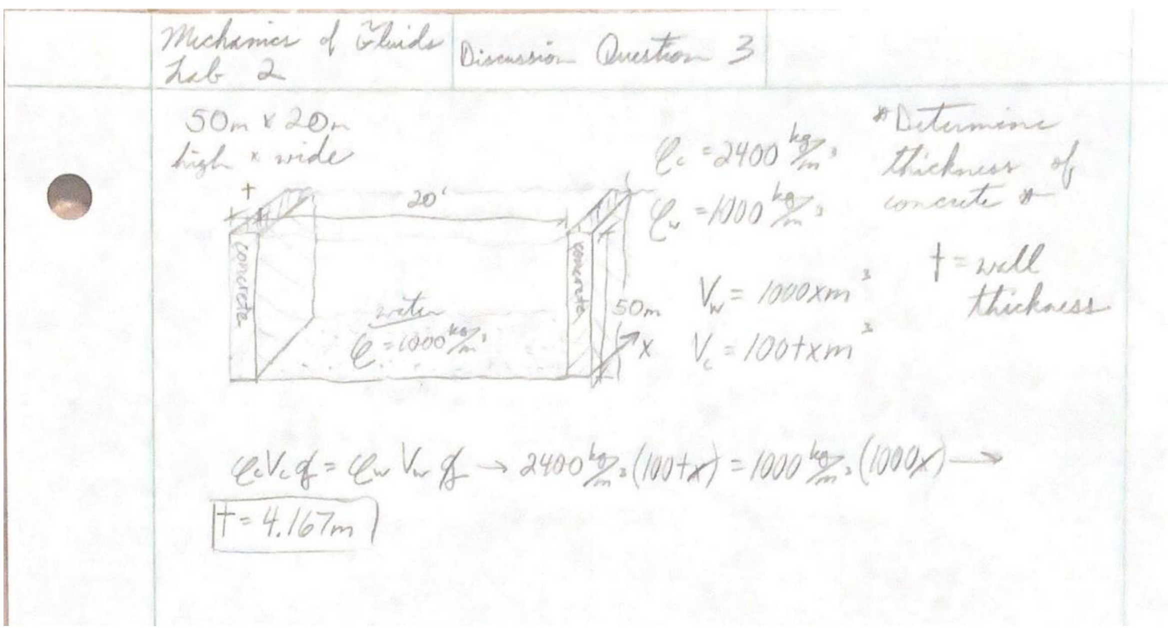
Discussion

1. What is Archimedes' Principle?

Archimedes' Principle states that an object that is fully or partially submerged in a fluid will exert its weight on the fluid, and in return, the fluid will exert an upward buoyancy force equal to the weight of the volume of fluid displaced by the object.

2. A rock is thrown in a beaker of water, and it sinks to the bottom. Is the buoyant force on the rock greater than, less, or equal to the weight of the rock?
   The buoyant force exerted on the rock is equal to the weight of the volume of water that the rock displaced. Since the rock is denser than the water, the buoyant force would be less than the weight of the rock

3. An embankment that is 50 m high x 20 m wide is to be constructed to hold water. Assuming the embankment is to be constructed using concrete of density 2400 kg/m^3, what is the minimum thickness necessary to withhold the water when full such that there is no over-turning. Assume the embankment is a cuboid.
   Concrete thickness = 4.167m



Data Appendix

CE3105 Mechanics of Fluids Laboratory, Department of Civil Engineering,Texas Tech University	
Experiment:Forces on Plane Surfaces,Archimedes' Principle - Data Sheet	
Date of Experiment:	
Name: Team 1	
Temperature of water, T= 20°C Celsius	Water density,ρ = 1000 kg/m³
R3 = 200 mm , R2 = 200 mm, R1 = 100 mm	

Archimedes' Principle

Object	Water V (Initial) (mL)	Water V (Final) (mL)	ΔV (mL)	Volume of Object (measured) (cm^3)	Volume Calculated (cm^3)	Mass of Object (g)	Submerged	F_B(N)
Asphalt 1	800	828	28	[redacted]	32.40	70.83	✓	0.27468
Asphalt 2	—	—	—	[redacted]	—	—	✓	
Wood 1	800	815	15	21.46	25.424	15.57	×	0.15274
Wood 2	—	—	—	—	—	—	×	
Concrete 1	—	—	—	—	—	—	✓	
Concrete 2	2001.22	2232.13	230.91	196.35	181.71	485.3g	✓	2.26523

Forces on Plane Surfaces -Partially Submereged

Trial	Weight (g)	h (mm)	b (mm)
Initial	1040	145	136
1	1060	141	141
2	1080	136	145
3	1160	130	150
4	—	—	—
5	—	—	—

Forces on Plane Surfaces -Fully Submereged

b= 180 mm

Trial	Weight (g)	h (mm)
Initial	1230	103
1	1260	97
2	1290	92
3	1320	87
4	—	—
5	—	—

Error Analysis

Object	Volume Error
Asphalt	15.71%
Wood	43.07%
Concreate	21.31%

Calculations

Mechanics of Fluids | Lab 2 Sample Calculations

Volume of Displaced Water

$V_f - V_i = \Delta V \rightarrow \Delta V = 828mL - 800mL = \underline{28mL}$

Buoyancy Force (F_B)

(1) $F_B = \rho_f \Delta V_f g$

(For Concrete) $\rho_w = 1000\ kg/m^3$ $\Delta V_f = 230.91mL$

$F_B = 1000\ kg/m^3 \left[230.91mL\left(\frac{1E^{-6}m^3}{mL}\right)\right](9.81\ m/s^2) \rightarrow \underline{F_B = 2.265N}$

Volume of Object (Eq 5)

(5) $\frac{V_o}{V_f} = \frac{\rho_f}{\rho_o}$

(For Wood) $V_f = 15mL = 15E^{-6}m^3$ $\rho_f = 1000\ kg/m^3$ $\rho_{wood} = 590\ kg/m^3$

$V_{wood} = 15E^{-6}m^3\left(\frac{1000}{590}\right) \rightarrow \underline{V_{wood} = 25.42cm^3}$

Volume of Object (Using mass + density)

(For Wood) $m_{wood} = .01557kg$ $\rho_{wood} = 590\ kg/m^3$

$V_{wood} = \frac{m}{\rho} = \frac{.01557kg}{590\ kg/m^3} \rightarrow \underline{V_{wood} = 26.39cm^3}$

Volume of Object (Eq 2)

(2) $F_B - W_o = (\rho_f - \rho_o)V_o g$

(For Concrete) $W_{concrete} = 4.7608N$ $\rho_{concrete} = 2400\ kg/m^3$ $\rho_f = 1000\ kg/m^3$

$F_B = 2.2652N$

$2.2652N - 4.7608N = (1000 - 2400)\ kg/m^3\ (V_{concrete})(9.81\ m/s^2)$

$\underline{V_{concrete} = 230.91cm^3}$

Moment

$\Sigma M = 0 = .2W - W_{water}(3/8\, b)$

$W = 12.0663N \quad b = .180m$

$0 = .2(12.0663N) - W_{water}(3/8(.18m)) \rightarrow W_{water} = 35.752N$

Error Analysis (asphalt)

$V_A(\text{measured}) = 28cm^3 \quad V_{asphalt}(\text{experimental}) = 32.40cm^3$

$\frac{28 - 32.40}{28} \times 100 = 15.71\%$