TEXAS TECH UNIVERSITY

DEPARTMENT OF CIVIL, ENVRONMENTAL, AND CONSTRUCTION ENGINEERING

Lab Report #1: Fluid Properties

CE 3105 – Fluid Laboratory [redacted]

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Authors:

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Date of Experiment: [redacted]

Date of Submission: [redacted]

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THEORY (MH)

Background: Contains a derivation of the theory/equation behind the experiment. Typically, it will involve application of the Continuity, Energy and/or Momentum Equations to a specific control volume and will result in either an equation for flow rate, pressure change or applied force that will be measured in the experiment. Describe any equations used to perform the analysis of the experiment.

One of the most fundamental properties of a fluid is its **density**, an intensive property that describes how much mass is contained in a certain volume of fluid. To find density, we use the following equation:

$$\rho = \frac{M}{V} \tag{1}$$

$\rho = density$

$M = mass\ of\ fluid$

$V = volume\ of\ fluid$

The density of a fluid remains constant, as long as we do not change the temperature or pressure. The units of density are $\frac{kg}{m^3}$ in the SI system and $\frac{slug}{ft^3}$ in the US customary system.

Another intensive property of a fluid is **specific weight**, which describes how much force is applied by the fluid due to gravity (in other words, how much it **weighs**) for a certain volume of fluid. To find the specific weight, we can use the following equations:

$$\gamma = \frac{W}{V} = \frac{mg}{V} = \rho g \tag{2}$$

$\gamma = specific\ weight$

$W = weight\ of\ fluid$

$m = mass\ of\ fluid$

$g = acceleration\ due\ to\ gravity$

$\rho = density$

Much like density, specific weight remains constant if the temperature and pressure are also constant.

Specific gravity, another intensive property, relates the density of a given fluid to the density of water. Specific gravity can be calculated using the following equations:

$$s_{fluid} = \frac{\rho_{fluid}}{\rho_{water}} = \frac{\gamma_{fluid}}{\gamma_{water}} \tag{3}$$

$s_{fluid} = specific\ gravity\ of\ fluid$

$\rho = density$

$\gamma = specific\ weight$

Note that both density and specific weight can be used to calculate specific gravity. This is because, as shown in Equation 2, specific weight is simply density multiplied by gravity. In a ratio of two specific weights, the constant *g* appears in both the numerator and the denominator. This, in effect, multiplies the whole ratio by $\frac{g}{g}$, which is equal to 1. The remaining fraction is simply a ratio of the densities of the two fluids.

Because water is always in the denominator for the specific gravity ratio, the specific gravity of water is exactly 1. Also note that specific gravity is unitless; it contains the same units in the numerator and denominator. If a fluid has a specific gravity < 1, it will float in water; if it has a specific gravity > 1, it will sink in water.

Fluids, unlike solids, have faulty resistance to shear stress. Applying shear stress to a fluid will cause it to flow. The same shear stress, when applied to different fluids, will result in different flow rates. This is due to the fluid property of **viscosity**, an intensive property that describes the fluid's internal resistance to shear stress. More specifically, **dynamic viscosity** describes the tangential force per unit area that is required for the fluid to begin deformation. Below is a visualization of this property.

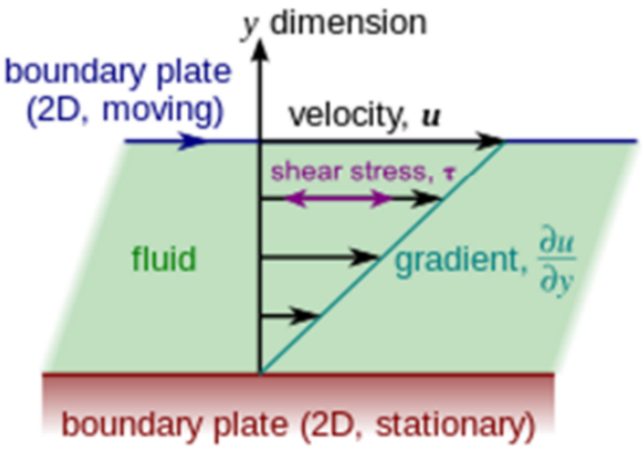


Figure 1. Visualization of dynamic viscosity.

Dynamic viscosity can be found using the following equation:

$$\tau = \mu \frac{du}{dy} \tag{4}$$

$\tau = shear\ stress$

$\mu = dynamic\ viscosity$

$\frac{du}{dy} = velocity\ gradient$

If Equation 4 is rearranged, it demonstrates that shear stress is proportional to the velocity gradient, and that the dynamic viscosity is a constant that describes this proportionality:

$$\mu = \frac{\tau}{du/dy} \tag{5}$$

The units of dynamic viscosity, therefore, are $\frac{kg}{m*s}$ in the SI system and $\frac{slug}{ft*s}$ in the US customary system.

Another type of viscosity, **kinematic viscosity**, is an intensive fluid property that varies slightly from dynamic viscosity. While dynamic viscosity describes the fluid's resistance to deformation, (i.e. the fluid's resistance to a foreign body traveling through it), kinematic viscosity describes the fluid's resistance to motion. In other words, kinematic viscosity is a measure of how much shear force is required to cause the fluid to begin flowing. Kinematic viscosity can be found using the following equations:

$$\nu = \frac{\mu}{\rho} = \frac{\tau}{\rho * {du}/{dy}} \tag{6}$$

$\nu = kinematic\ viscosity$
$\mu = dynamic\ viscosity$
$\rho = density$
$\tau = shear\ stress$
${du}/{dy} = velocity\ gradient$

As seen in the equation, kinematic viscosity can be found by dividing the fluid's dynamic viscosity by the fluid's density. The units of kinematic viscosity, therefore, are $\frac{m^2}{s}$ in the SI system and $\frac{ft^2}{s}$ in the US customary system.

To find the kinematic viscosity of a fluid experimentally, we can record the velocity of a sphere falling through the fluid. **Stokes Law** allows us to relate the sphere's weight to the viscosity of the fluid applying friction forces to the sphere. Assuming equilibrium, Stokes Law states that the magnitude of the friction forces on the sphere will be equal the sphere's weight, and the sphere will fall at terminal velocity, allowing us to use the following equation:

$$u = \frac{gd^2}{18\nu}\left(\frac{\sigma}{\rho} - 1\right) \tag{7}$$

$u = velocity\ of\ the\ sphere$
$g = acceleration\ due\ to\ gravity$
$d = diameter\ of\ the\ sphere$
$\nu = kinematic\ viscosity$
$\sigma = density\ of\ sphere$
$\rho = density\ of\ fluid$

This is the method we utilized for our experiment.

APPARATUS (RD)

Figure 2: apparatuses used for Density Measurements and Specific Gravity

The image depicts steel balls, graduated cylinders, glycerin, a thermometer, and a hydrometer that were used in the experiments. Not depicted is the scale used to find the mass of a beaker and then the beaker and fluids combined masses.

EXPERIMENT PARAMETERS

1. Temperature (°C)

The temperature of the water, salt water, and glycerin were all measured with a thermometer.

2. Mass (g)

A scale was used to record the masses of a beaker and then the combined mass of the beaker and the fluids used in the experiment.

3. Volume (mL)

The volume of the fluids being tested were measured with the graduated cylinders.

4. Density (g/mL)

The density of the test fluids was calculated after finding their respective masses and volumes. The density of the steel balls was given.

5. Specific Gravity (unitless)

The Hydrometer was used to find the specific gravity of the water, salt water, and glycerin.

6. Time (s)

An iPhone was used to time and record the steel balls sinking to the bottom of a graduated cylinder.

7. Dynamic Viscosity (kg/(ms))

The dynamic viscosity of the test fluids was found in the calculations shown below.

8. Kinematic Viscosity (m^2/s)

The kinematic viscosity of the test fluids was found in the calculations shown below.

RESULTS (RD)

Table 1: Recorded and Calculated results from the Density Measurements portion

The table shows all the recorded and calculated properties measured in the first part of the experiment. This includes the temperature of the sample fluids, the mass of the beaker used to find the mass of the samples, the combined mass of the beaker and samples, the volume of the sample, the density of the sample fluids calculated from the mass and volume, and the specific gravity found with the hydrometer.

Fluid	**Trial**	**Temp**	**Mass of Beaker**	**Mass of Beaker and Fluid**	**Volume**	**Density**	**Specific Gravity**
Water	1	20	46.165	109.793	62	1.026	1.02
	2	20	"”	131.731	84	1.018	1.02
	3	20	“”	118.639	71	1.02	1.02
Salt water	1	19	“”	119.881	72	1.024	1.04
	2	19	"”	“”	“”	“”	1.04
	3	19	“”	“”	“”	””	1.04
Glycerin	1	20	“”	156.976	82	1.351	1.34
	2	20	“”	“”	“”	“”	1.34
	3	20	“”	“”	“”	“”	1.34

Table 2: Mean and Standard Deviations for estimated density of all sample fluids

Table 2 shows the mean and standard deviation of the sample fluids. There is not a standard deviation calculated for salt water and glycerin because the lab section did not record more than one volume and mass for those samples.

Fluid	**Mean**	**Standard Deviation**
water	1.021	.004
Salt water	1.024	---
glycerin	1.351	---

Table 3: Recorded results from the Viscosity portion

The table below shows the needed values to find the dynamic and kinematic viscosities of the sample fluids. This includes the diameter of the balls dropped, the diameter of the graduated cylinders used, the volume of fluid the balls passed through, the corresponding length dropped through the liquid, the density of the spheres, and the time recorded in seconds it took for the balls to sink to the bottom of the graduated cylinder used in their trial.

Fluid	**Steel Ball d**	**Density of sphere**	**Change in volume**	**Graduated Cylinder d**	**Volume (mL)**	**L (cm)**	**Time of trial 1 (s)**	**Time of trial 2 (s)**
Water	5/32”	7800kg/ m^3	0	70mm	950	24.7	.35	.40
	1/16”	"”	“”	“”	“”	“”	.67	.64

Salt Water	5/32”	"”	“”	“”	“”	“”	.38	.32
	1/16”	"”	“”	“”	“”	“”	.65	.55
Glycerin	5/32”	"”	“”	30mm	82	11.6	2.89	3.29
	1/16”	"”	“”	“”	“”	“”	16.31	16.81

Table 4: Calculated results from the Viscosity portion

The table shows the Dynamic and Kinematic viscosities calculated from the values recorded in table 3. Some of the values from table 3 are reshown in this table for ease of sorting and understanding.

Fluid	**Steel Ball d**	**Dynamic viscosity**		**Density of Fluid**	**Kinematic viscosity**	
		Trial 1	**Trial 2**		**Trial 1**	**Trial 2**
Water	5/32”	3.3	3.7	1.021	3.23	3.62
	1/16”	1.01	.965	“”	.99	.945
Salt Water	5/32”	3.58	3.01	1.024	3.5	2.94
	1/16”	.98	.829	“”	.957	.81
Glycerin	5/32”	55.2	62.8	1.351	40.9	46.5
	1/16”	49.8	51.3	“”	36.9	38

Table 5: Mean and Standard Deviations for Kinematic and Dynamic Viscosities

The table below depicts the mean and standard deviation of the kinematic and dynamic viscosities calculated in table 4.

Fluid	**Type of Viscosity**	**Mean**		**Standard Deviation**	
		5/32”	**1/16”**	**5/32”**	**1/16”**
water	Dynamic	3.5	.988	.283	.032
	Kinematic	3.43	.968	.276	.032
Salt water	Dynamic	3.3	.905	.403	.107
	Kinematic	3.22	.884	.396	.103
glycerin	Dynamic	59	50.6	5.37	1.06
	Kinematic	43.7	37.45	3.96	.778

DISCUSSION (RV)

EXPERIMENT PURPOSE

The purpose of this experiment is to explore the properties of fluids, and this includes the density, specific gravity, and viscosity. Fluid properties change due do different factors that are present or change. For example, the density of an object is dependent on the mass and volume of the fluid (M/V). Other factors we can include would be the temperature and atmospheric pressure.

In this experiment we calculate the density of the fluid by obtaining the factors needed for it(Mass & Volume). We also are looking at the viscosity of the fluid and that can be performed by dropping a steel ball in the fluid and recording the time. Using different fluids with different densities, the purpose was met because we were able to compare the different properties between the two.

Times for 5/32”

Water t1 (s)	Salt Water t1 (s)	Glycerin t1 (s)
.39	.38	2.89
.35	.32	3.29

Times for 1/16”

Water t1 (s)	Salt Water t1 (s)	Glycerin t1(s)
.67	.55	16.31
.64	.65	16.81

We can see the different properties between the fluid with the times. More dense liquids took longer time for the steel ball to travel through it meaning the viscosity is also higher as represented in the results.

REPORT QUESTIONS

1. Why is it important to measure temperature when measuring density and viscosity?

It’s important to measure the temperature because temperature changes the volume of a liquid such as water. When water is heated the volume increases due to it expanding thus slightly changing the density.

2. How do you think the density and viscosity of water would change with temperature?

As stated on number 1. The density changes because heated water expands increasing the volume. Since viscosity is dependent on density means that viscosity should change as well.

3. How do salts alter the density of groundwater? Why is measurement of brackish water density important for civil and environmental engineers?

When salt is added to water it increases the mass while keeping the same volume making it more dense. When an engineer would need to transport brackish water lets say for treatment. The density of brackish water would be denser than water resulting in different properties. The mass of brackish water should be higher than normal water in the same volume.

4. What is standard deviation? What does it tell us about the accuracy of the measurements?

Standard deviation measures the variance of values compared to the mean. The variance determines how far the values are to the mean of the values used. A standard deviation less than 1.0 or 0.5 would indicate that the values are accurate to each other, not much deviation.

5. What are some potential sources of errors in your lab experiments? Please discuss this with respect to measuring density, specific gravity and viscosity. (Sources Of Error)

Some potential sources of errors in the lab would be the slight human error of calculating the time intervals but since we used a camera the error would not be very significant. Another potential source would be the salt water not having enough salt. The density of the salt water was relatively close to the density of water. If more salt was added to the water we could've calculated a bigger jump to have a better comparison.

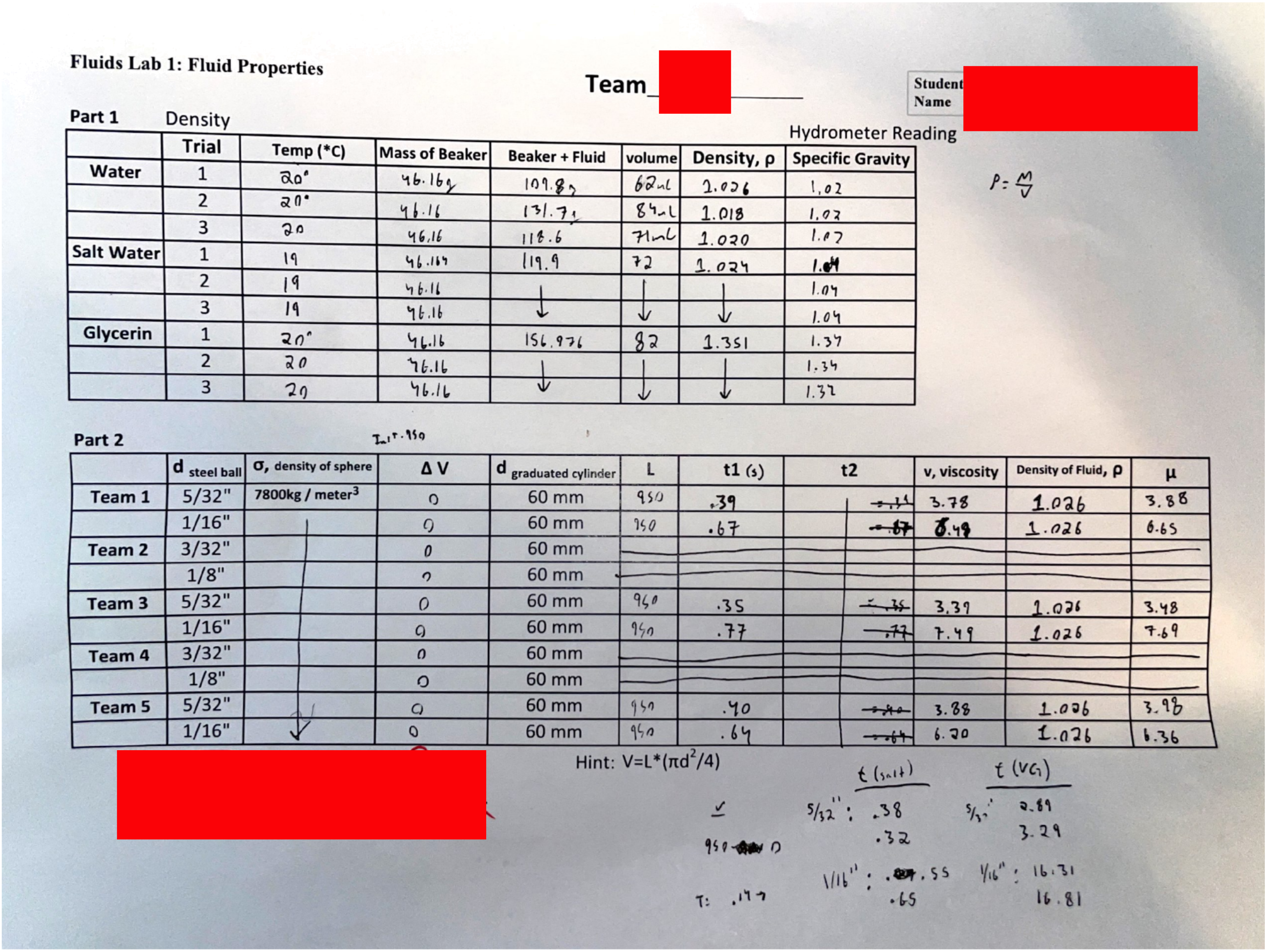
Water (density)	**Salt Water (density)**
1.026	1.024
1.018	1.024
1.020	1.024

Better values could have been obtained for salt water but are very close due to the little salt added. (More on Error Calculations)

PRACTICAL APPLICATION

This experiment has many applications that correlates when working with oil. Any machinery that requires lubrication for performance is very dependent on the density and viscosity of the oil. All machines have a desired density to achieve the max performance which is why different cars require different types (ex. SAE 5W-30 or SAE 5W-20).

DATA APPENDIX (RD, MH, RV)



Fluids Lab 1: Fluid Properties

Team [redacted]

Student Name [redacted]

Part 1 Density

Hydrometer Reading

	Trial	Temp (*C)	Mass of Beaker	Beaker + Fluid	volume	Density, ρ	Specific Gravity
Water	1	20°	46.16g	109.8g	62mL	1.026	1.02
	2	20°	46.16	131.7g	84mL	1.018	1.02
	3	20	46.16	118.6	71mL	1.020	1.02
Salt Water	1	19	46.164	119.9	72	1.024	1.04
	2	19	46.16	↓	↓	↓	1.04
	3	19	46.16	↓	↓	↓	1.04
Glycerin	1	20°	46.16	156.976	82	1.351	1.37
	2	20	46.16	↓	↓	↓	1.34
	3	20	46.16	↓	↓	↓	1.32

$\rho = \frac{M}{V}$

Part 2

Init. 950

	d steel ball	σ, density of sphere	ΔV	d graduated cylinder	L	t1 (s)	t2	v, viscosity	Density of Fluid, ρ	μ
Team 1	5/32"	7800kg / meter³	0	60 mm	950	.39	~~.39~~	3.78	1.026	3.88
	1/16"	↓	0	60 mm	950	.67	~~.67~~	6.49	1.026	6.65
Team 2	3/32"		0	60 mm						
	1/8"		0	60 mm						
Team 3	5/32"		0	60 mm	950	.35	~~.35~~	3.39	1.026	3.48
	1/16"		0	60 mm	950	.77	~~.77~~	7.49	1.026	7.69
Team 4	3/32"		0	60 mm						
	1/8"		0	60 mm						
Team 5	5/32"		0	60 mm	950	.40	~~.40~~	3.88	1.026	3.98
	1/16"	↓	0	60 mm	950	.64	~~.64~~	6.20	1.026	6.36

Hint: $V=L*(\pi d^2/4)$

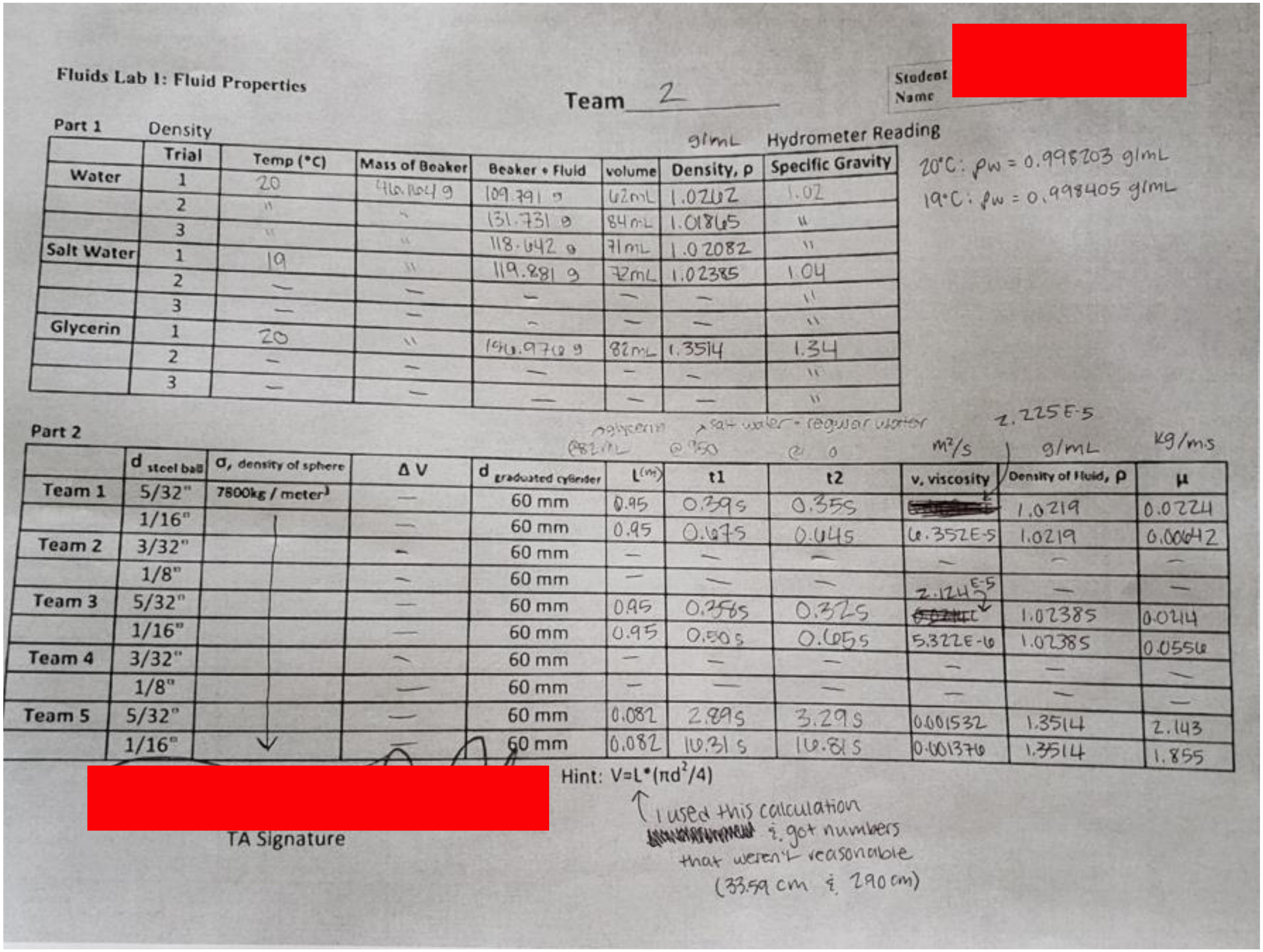
[redacted]

✓

950 ~~[illegible]~~ 0

T: .147

	t (salt)		t (VG)
5/32":	.38 .32	5/32":	2.89 3.29
1/16":	~~[illegible]~~ .55 .65	1/16":	16.31 16.81



Fluids Lab 1: Fluid Properties

Team 2

Student Name [redacted]

Part 1 Density

g/mL Hydrometer Reading

	Trial	Temp (°C)	Mass of Beaker	Beaker + Fluid	volume	Density, ρ	Specific Gravity
Water	1	20	46.604 g	109.791 g	62mL	1.0262	1.02
	2	"	"	131.731 g	84mL	1.01865	"
	3	"	"	118.642 g	71mL	1.02082	"
Salt Water	1	19	"	119.881 g	72mL	1.02385	1.04
	2	—	—	—	—	—	"
	3	—	—	—	—	—	"
Glycerin	1	20	"	156.976 g	82mL	1.3514	1.34
	2	—	—	—	—	—	"
	3	—	—	—	—	—	"

20°C: $\rho_w = 0.998203$ g/mL

19°C: $\rho_w = 0.998405$ g/mL

Part 2

↗glycerin @82mL ↗salt water @350 regular water @0

2.225 E-5

m²/s g/mL kg/m·s

	d steel ball	σ, density of sphere	Δ V	d graduated cylinder	L (m)	t1	t2	v, viscosity	Density of Fluid, ρ	μ
Team 1	5/32"	7800kg / meter³	—	60 mm	0.95	0.39 s	0.35 s	[illegible]	1.0219	0.0224
	1/16"	↓	—	60 mm	0.95	0.67 s	0.44 s	6.352E-5	1.0219	0.00642
Team 2	3/32"		—	60 mm	—	—	—	—	—	—
	1/8"		—	60 mm	—	—	—	2.124 E-5	—	—
Team 3	5/32"		—	60 mm	0.95	0.356 s	0.32 s	~~[illegible]~~	1.02385	0.0214
	1/16"		—	60 mm	0.95	0.50 s	0.65 s	5.322E-6	1.02385	0.0556
Team 4	3/32"		—	60 mm	—	—	—	—	—	—
	1/8"		—	60 mm	—	—	—	—	—	—
Team 5	5/32"		—	60 mm	0.082	2.89 s	3.29 s	0.001532	1.3514	2.143
	1/16"		—	60 mm	0.082	10.31 s	10.81 s	0.001376	1.3514	1.855

Hint: $V=L*(\pi d^2/4)$

↑ I used this calculation & got numbers that weren't reasonable (33.59 cm & 290 cm)

[redacted]

TA Signature

Fluids Lab 1: Fluid Properties

Team 2

Student Name [redacted]

Part 1 Density — Hydrometer Reading

	Trial	Temp (*C)	Mass of Beaker g	Beaker + Fluid g	volume mL	Density, ρ	Specific Gravity	
Water	1	20	46.165	109.893	62	1.026	1.02	1.02
	2	"	"	131.731	84	1.018	1.02	
	3	"	"	188.639	71	1.02	1.02	
Salt Water	1	19	"	119.881	72	1.024	1.04	
	2	"	"	~~156.926~~	"	"	"	
	3	"	"	"	"	"	"	
Glycerin	1	20	"	156.976	82	1.351	1.34	
	2	"	"	"	"	"	"	
	3	"	"	"	"	"	"	

Part 2 — 950mL ~~[illegible]~~ mL 950 → σ ~~.39~~ ~~[illegible]~~ 950

		d steel ball	σ, density of sphere	Δ V	d graduated cylinder	L	~~t1~~ s	~~t2~~ s	v, viscosity	Density of Fluid, ρ	μ	
W	Team 1	5/32"	7800kg / meter^3	0	60 mm	950	~~5.50~~ .39	~~3.89~~	3.78	1.026	3.98	X
		1/16"		"	60 mm	950	~~.67~~ ~~[illegible]~~ .33	~~[illegible]~~ .67	6.48	"	6.65	
	Team 2	3/32"		"	60 mm							
		1/8"		"	60 mm							
W	Team 3	5/32"		"	60 mm	950	.35		3.39	1.026	3.49	X
		1/16"		"	60 mm	950	.77		7.49	"	7.69	
	Team 4	3/32"		"	60 mm							
		1/8"		"	60 mm							
W	Team 5	5/32"		"	60 mm	950	.40		3.89	1.026	3.98	X
		1/16"		"	60 mm	950	.64		6.20	"	6.36	X

Hint: V=L*($\pi d^2/4$) Δt

[redacted]

TA Signature

Δt(s)

Salt water 5/32" .38 .32

1/16" ~~.67~~ .65 .55 V 950mL

Δt(s)

Glycerin 5/32" 2.89 3.29 1/16" 16.31 16.81 V 1→82

ERROR CALCULATIONS (RV)

SAMPLE CALCULATION

We can find minor inaccuracies in the data with the timing of the trials. The human error for the time trials is not very significant since we used a camera to record the time trials. We can use a standard deviation to check the significance.

Using the data times, we got for the 5/32” steel ball in water.

Using the standard deviation $\sigma = \sqrt{\left(\frac{\Sigma(X-\mu)^2}{n-1}\right)}$ --->(μ is mean)

$\sigma = \sqrt{\left(\frac{\Sigma((.39,.35,.40)-.38)^2}{3-1}\right)}$= .0265 - Human error is miniscule (std<.5)

We can also use our sample handout with more calculations as a reference to compare the variance. Using their 3 times trials for the 5/32”. (7.03,7.79,8.853)

$\sigma = \sqrt{\left(\frac{\Sigma((7.03,7.79,8.853)-7.891)^2}{3-1}\right)}$ = .750 - Sample Handout had a higher variance than our calculations.

We assume that their sample calculations were timed with visuals and a stopwatch compared to us using a camera to record the time. Although ours also has its minor human error it is still almost 1/3rd the variance of the sample handout.

ERROR TABLE

Steel ball **d**	**t1**	**t2**	**t3**
5/32”	.39	.35	.40
1/16”	.67	.77	.64

Taking the standard deviation for 1/16”

σ = .068 - Higher variance than the 5/32” but still acceptable.

We only obtained 2 times for the salt water and glycerin so taking the standard deviation of those 2 would not result in a very useful variance. We can say another “error” would be not taking a 3rd time for the designated ball to fall through those fluid. A 3rd time would result a more useful variance and would be worth comparing.

SAMPLE CALCULATIONS (MH)

DENSITY CALCULATIONS

DENSITY

Using Equation 1:

$$\rho = \frac{M}{V}$$

With values from Trial 1 of measuring the mass and volume of water, we obtain:

$$\rho = \frac{63.627\ g}{62\ mL}$$
$$\rho = 1.0262\ {}^{g}/_{mL}$$

MEAN AND STANDARD DEVIATION

Using the equation for mean:

$$\bar{x} = \frac{\sum x}{n}$$

Using values from Trial 1-3 of measuring the mass and volume of water, we obtain:

$$\bar{x} = \frac{1.0262\,{}^{g}/_{mL} + 1.0187\,{}^{g}/_{mL} + 1.0208\,{}^{g}/_{mL}}{3}$$

$$\bar{x} = 1.0219\,{}^{g}/_{mL}$$

Using the equation for standard deviation:

$$\sigma = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

Using values from Trial 1-3 of measuring the mass and volume of water, we obtain:

$$\sigma = \sqrt{\frac{\left(1.0262\,{}^{g}/_{mL} - 1.0219\,{}^{g}/_{mL}\right)^2 + \left(1.0187\,{}^{g}/_{mL} - 1.0219\,{}^{g}/_{mL}\right)^2 + \left(1.0208\,{}^{g}/_{mL} - 1.0219\,{}^{g}/_{mL}\right)^2}{3}}$$

$$\sigma = 0.003191\,{}^{g}/_{mL}$$

MASS OF SALT IN BRACKISH WATER

Using the equation:

$$M_s = V_w * (\rho_s - \rho_w)$$
$$M_s = mass\ of\ dissolved\ salt$$
$$V_w = volume\ of\ water$$
$$\rho_s = density\ of\ saltwater$$

$$\rho_w = density\ of\ water$$

Using values from Trial 1 of measuring the mass and volume of salt water, as well as values from Trials 1-3 of measuring the mass and volume of regular water, we obtain:

$$M_s = 72\ mL * \left(1.02385\ {}^{g}/_{mL} - 1.0219\ {}^{g}/_{mL}\right)$$
$$M_s = 0.1399\ g$$

SPECIFIC GRAVITY CALCULATIONS

SPECIFIC GRAVITY

Using Equation 3:

$$s_{fluid} = \frac{\rho_{fluid}}{\rho_{water}} = \frac{\gamma_{fluid}}{\gamma_{water}}$$

Using values from Trial 1 of measuring the mass and volume of water, we obtain:

$$s_{fluid} = \frac{1.0262\ {}^{g}/_{mL}}{0.9998203\ {}^{g}/_{mL}}$$
$$s_{fluid} = 1.0281$$

MEAN AND STANDARD DEVIATION

Using the equation for mean:

$$\bar{x} = \frac{\sum x}{n}$$

Using values from Trial 1-3 of measuring the mass and volume of water, we obtain:

$$\bar{x} = \frac{1.0281 + 1.0205 + 1.0227}{3}$$

$$\bar{x} = 1.0237$$

Using the equation for standard deviation:

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n}}$$

Using values from Trial 1-3 of measuring the mass and volume of water, we obtain:

$$\sigma = \sqrt{\frac{(1.0281 - 1.0237)^2 + \left(1.0205\,{}^{g}/_{mL} - 1.0237\right)^2 + \left(1.0227\,{}^{g}/_{mL} - 1.0237\right)^2}{3}}$$

$$\sigma = 0.003197$$

PLOTTING SPECIFIC GRAVITY AGAINST DENSITY

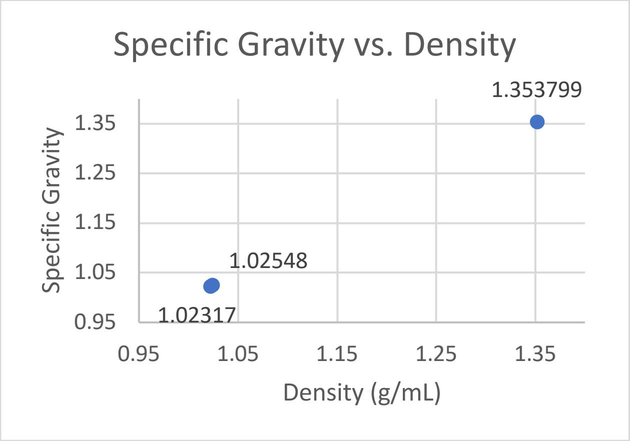


Figure 3. Specific gravity plotted against density.

VISCOSITY CALCULATIONS

KINEMATIC VISCOSITY

Rearranging Equation 7, we obtain:

$$\nu = \frac{g * d^2\left({}^{\sigma}/_{\rho} - 1\right)}{18u}$$

With values from Trial 1 of measuring the speed of a ${}^{5}/_{32}$ inch ball falling in water, we obtain:

$$\nu = \frac{\left(9.81\,{}^{m}/_{s^2}\right) * \left(\left({}^{5}/_{32}\,in\right) * \left(0.0254\,{}^{m}/_{in}\right)\right)^2 \left(\left(\left(7800\,{}^{kg}/_{m^3}\right) * \left(0.001\,{}^{g}/_{mL}\right) \Big/_{1.022}\right) - 1\right)}{18 * \left(\frac{(8.2\,cm) * \left(0.01\,{}^{m}/_{cm}\right)}{0.36\,s}\right)}$$

$$\nu = 0.0000239\,\frac{m^2}{s}$$

MEAN AND STANDARD DEVIATION

Using the equation for mean:

$$\bar{x} = \frac{\sum x}{n}$$

Using values from Trials 1-2 measuring the speed of a ${}^{5}/_{32}$ inch and ${}^{1}/_{16}$ inch ball falling in water, we obtain:

$$\bar{x} = \frac{2.337 * 10^{-5}\ {}^{m^2}/_{s} + 2.0977 * 10^{-5}\,{}^{m^2}/_{s} + 6.425 * 10^{-6}\,{}^{m^2}/_{s} + 6.137 * 10^{-6}\,{}^{m^2}/_{s}}{4}$$

$$\bar{x} = 1.4228 * 10^{-5}\ {m^2}/{s}$$

Using the equation for standard deviation:

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

Using values from Trials 1-2 measuring the speed of a ${5}/{32}$ inch and ${1}/{16}$ inch ball falling in water, we obtain:

$$\sigma = \sqrt{\frac{\left(2.337 * 10^{-5} - 1.423 * 10^{-5}\right)^2 + \left(2.098 * 10^{-5} - 1.423 * 10^{-5}\right)^2 + \left(6.425 * 10^{-6} - 1.423 * 10^{-5}\right)^2 + \left(6.137 * 10^{-6} - 1.423 * 10^{-5}\right)^2}{4}}$$

$$\sigma = 7.993 * 10^{-6}\, {m^2}/{s}$$

DYNAMIC VISCOSITY

Rearranging Equation 6, we obtain:

$$\mu = \nu * \rho$$

Using values from Trial 1 measuring the speed of a ${5}/{32}$ inch ball falling in water, we obtain:

$$\mu = 0.000023375\, {m^2}/{s} * 1.0262\, {g}/{mL} * 1000\, {kg}/{m^3}$$

$$\mu = 0.02389\, {kg}/{m * s}$$

MEAN AND STANDARD DEVIATION

Using the equation for mean:

$$\bar{x} = \frac{\sum x}{n}$$

Using values from Trials 1-2 measuring the speed of a ${5}/{32}$ inch and ${1}/{16}$ inch ball falling in water, we obtain:

$$\bar{x} = \frac{0.02389\ {kg}/{m * s} + 0.02144\, {kg}/{m * s} + 0.006566\ {kg}/{m * s} + 0.006272\ {kg}/{m * s}}{4}$$

$$\bar{x} = 0.01454\ {kg}/{m * s}$$

Using the equation for standard deviation:

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

Using values from Trials 1-2 measuring the speed of a $^{5}/_{32}$ inch and $^{1}/_{16}$ inch ball falling in water, we obtain:

$$\sigma = \sqrt{\frac{(0.02389 - 0.01454)^2 + (0.02144 - 0.01454)^2 + (0.006566 - 0.01454)^2 + (0.006272 - 0.01454)^2}{4}}$$

$$\sigma = 0.008168\, {}^{kg}/_{m*s}$$