Physics Lab Report Work 1
Determination of the density of the body

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Contents

Summary

In this Lab work we measure and determine the density of rectangular parallelogram and cylinder. we will measure the weight of parallelogram and cylinder with balance scale in air and then only parallelogram also in water and unknown liquid (alcohol), with 10 time measurements of diameter of the base and the height for cylinder and 3 sides of parallelogram we calculate the density. In the following pages comes the theory, calculations, formulas and the measures.

Keywords: Density, Measurements, Micrometer, Caliper, Error estimation

1 Theory

Density (ρ) is defined by following equation where m is mass and v is volume of the body.

$$\rho = \frac{m}{v}$$

According to Archimedes' principle if the weight of the water displaced is less than the weight of the object, the object will sink, Otherwise the object will float, with the weight of the water displaced equal to the weight of the object. [1] As described the buoyancy is equal to weight of displaced fluid in Archimedes' principle.

$$\rho = \frac{m_a}{m_a - m_w} . \rho_w$$

Where m_a is mass of the body that measured surrounded by air and m_l is mass of the body measured surrounded by liquid and ρ_l is density fo the liquid.

For Calculating density of rectangular parallelogram according to density formula and $v = abc$ we get:

$$\rho = \frac{m_1}{abc}$$

And for the Cylinder we substitute v in density formula $v = \frac{\pi d^2 h}{4}$.

2 Equipments

We used a variety of different equipments, the following list is the main tools we used for the tasks.

Figure 1: Micrometer

Figure 2: Caliper

1. Micrometer (Figure 1)
2. Caliper (Figure 2)
3. Balance Scale
4. Aerometer
5. Water
6. Alcohol (as unknown liquid)
7. String
8. Metal parallelogram
9. Metal Cylinder
10. Beaker

3 Measurments and Calculations

All the measurements and calculations are based on the work 1 formulas and instruction paper and signed result paper can be found on the last page of this report. on the following sections comes the detailed calculations of the lab.

3.1 Density of rectangular parallelogram

For the rectangular parallelogram we measured 3 sides of a, b and c for 10 times with Micrometer, following table shows the results of the measurements.

	a(mm)	b(mm)	c(mm)
1	20.00	20.01	14.40
2	20.01	20.00	14.38
3	20.00	20.00	14.45
4	19.98	20.02	14.47
5	20.00	20.01	14.44
6	20.00	20.00	14.39
7	20.02	19.99	14.39
8	19.99	20.00	14.42
9	20.00	19.98	14.49
10	20.00	19.99	14.37

And using balance scale we got m_1= 43.90mm with the accuracy of Δm= 0.01g. and according to density formula we have:

$$\rho = \frac{m}{v} = \frac{m}{abc} = \frac{43.90g}{20_{mm}.20_{mm}.14.42_{mm}} = \frac{43.90g}{5768_{mm^3}} \approx 7.611 \times 10^{-3}_{\frac{g}{mm^3}}$$

Also we can calculate density with Archimedes' principle for rectangular parallelogram based on our measurement for water and unknown liquid (Alcohol) that measured using aerometer:

$$\rho = \frac{m_a}{m_a - m_w}.\rho_w = \frac{43.90g}{43.90_g - 38.20_g} \times 0.0010_{\frac{g}{mm^3}} \approx 7.702 \times 10^{-3}_{\frac{g}{mm^3}}$$

3.2 Density of Alcohol (unknown liquid)

We can calculate density of unknown liquid (Alcohol) with Archimedes' principle equation and with the help of known mass of rectangular parallelogram as follow:

We derive the following equation: $\rho_u = \frac{m_a - m_u}{m_a}.\rho$, and we calculate it twice with our ρ of parallelogram form water and air.

$$\rho_{u_1} = \frac{43.90_g - 39.45_g}{43.90g} \times 7.611 \times 10^{-3}_{\frac{g}{mm^3}} \approx 7.715 \times 10^{-4}_{\frac{g}{mm^3}}$$

$$\rho_{u_2} = \frac{43.90_g - 39.45_g}{43.90g} \times 7.702 \times 10^{-3}_{\frac{g}{mm^3}} \approx 7.807 \times 10^{-4}_{\frac{g}{mm^3}}$$

And then we calculate the average:

$$\rho_{u_{av}} = \frac{7.715 \times 10^{-4}_{\frac{g}{mm^3}} + 7.807 \times 10^{-4}_{\frac{g}{mm^3}}}{2} \approx 7.761 \times 10^{-4}_{\frac{g}{mm^3}}$$

3.3 Density of cylinder

We measured height and diameter with Caliper the following table shows the result of the measurements.

	h(mm)	d(mm)
1	24.90	18.00
2	24.70	17.95
3	24.40	17.90
4	24.30	18.10
5	24.40	18.00
6	24.60	17.95
7	24.70	18.20
8	24.70	18.10
9	24.40	17.90
10	24.50	18.00

Now with the help of Cylinder density formula and average of the h and d we have:

$$\rho = \frac{m}{v} = \frac{m}{\frac{\pi d^2 h}{4}} = \frac{4m}{\pi d^2 h} = \frac{48.35_{mm}}{3.14 \times 18.01^2 \times 24.56} \approx 1.932 \times 10^{-3}_{\frac{g}{mm^3}}$$

4 Error estimation

We use equipment error and average of measured values to calculate estimated error for rectangular parallelogram and cylinder.

4.1 Rectangular parallelogram

We can write the following error function based on our values:

$$\mid \frac{\Delta\rho}{\rho} \mid \leqslant \mid \frac{\Delta m}{m} \mid + \mid \frac{\Delta a}{a} \mid + \mid \frac{\Delta b}{b} \mid + \mid \frac{\Delta c}{c} \mid$$

And then we have[1]:

$$\mid \frac{\Delta\rho}{\rho} \mid \leqslant \mid \frac{0.01_g}{43.90_g} \mid + \mid \frac{0.01_{mm}}{20_{mm}} \mid + \mid \frac{0.01_{mm}}{20_{mm}} \mid + \mid \frac{0.01_{mm}}{14.42_{mm}} \mid$$

[1]The accuracies of the gauges are listed in the measurement document

Then:

$$\mid \frac{\Delta\rho}{\rho} \mid \leqslant 1.921 \times 10^{-3}$$

Now we can calculate absolute error of density:

$$\Delta\rho = 1.921 \times 10^{-3} \times 7.611 \times 10^{-3}_{\frac{g}{mm^3}} = 1.462 \times 10^{-5}{}_{\frac{g}{mm^3}}$$

And for relative percentage of error calculates:

$$1.921 \times 10^{-3} \times 100\% = 0.1921\%$$

4.2 Cylinder

The same process goes for Cylinder so we have:

$$\mid \frac{\Delta\rho}{\rho} \mid \leqslant \mid \frac{\Delta m}{m} \mid + \mid \frac{2\Delta d}{d} \mid + \mid \frac{\Delta h}{h} \mid$$

And then we have:

$$\mid \frac{\Delta\rho}{\rho} \mid \leqslant \mid \frac{0.01_g}{48.35_g} \mid + \mid \frac{2 \times 0.05_{mm}}{18.01_{mm}} \mid + \mid \frac{0.05_{mm}}{24.56_{mm}} \mid$$

That calculates to:

$$\mid \frac{\Delta\rho}{\rho} \mid \leqslant 7.795 \times 10^{-3}$$

And we have percentage as follow:

$$7.795 \times 10^{-3} \times 100\% = 0.7795\%$$

So we can calculate the absolute error of density for Cylinder.

$$\Delta\rho = 7.795 \times 10^{-3} \times 1.932 \times 10^{-3}_{\frac{g}{mm^3}} = 1.506 \times 10^{-5}{}_{\frac{g}{mm^3}}$$

5 Results

The results table[2] is as follow[3]:

	Density	Absolute error limits	Relative error limits
RP	7.611×10^{-3}	$7.611 \times 10^{-3} \pm 1.462 \times 10^{-5}$	$7.611 \times 10^{-3} \pm 0.1921\%$
AP for RP	7.702×10^{-3}	Not determined	Not determined
Cylinder	1.932×10^{-3}	$1.932 \times 10^{-3} \pm 1.506 \times 10^{-5}$	$1.932 \times 10^{-3} \pm 0.7795\%$
Unknown liquid	7.761×10^{-4}	Not determined	Not determined

6 Conclusion

The last page of this report is the "Measurement Document" completed in class by group and signed all the data used in the report are from this document.

After completion of the measurements in class we calculated , the averages if a,b,c and h,d and density of the objects also the accuracy of the equipments are given and listed in measurement document.

We can conclude that from density of the objects that its Iron and the unknown liquid is Alcohol.

References

1. http://physics.weber.edu/carroll/archimedes/principle.htm.

[2] All the values for density and error in the table is $\frac{g}{mm^3}$

[3] RP: Rectangular parallelogram , AP: Archimedes' principle

This document created with LaTeX source code: https://github.com/shajadi/physicslab