Simple Measurements & Buoyancy Force

1st year physics laboratories

University of Ottawa

https://uottawa.brightspace.com/d2l/home

SIMPLE MEASUREMENTS

The TA will go over the following tutorials.

- Error calculations
  - There is a test on error calculations on the lab website.
  - You may complete the test as many times as you want until the deadline. Only your highest mark will be recorded.

- How to use the following instruments:
  - Meter stick
  - Vernier caliper

- Rounding and significant figures.

ERROR CALCULATIONS

Propagation of errors: addition and subtraction

If the result R is obtained from a series of additions and subtractions:

$$R = \pm Ax \pm By \pm \cdots \quad ,$$

where A and B are constants, then the error on the result R is given by

$$\Delta R = \sqrt{A^2 \Delta x^2 + B^2 \Delta y^2 + \cdots}$$

See tutorial – Propagation of errors pg. 1

ERROR CALCULATIONS

Propagation of errors: multiplication and division

If the result R is obtained from a series of products: $R = x^A y^B \cdots$,

where A and B are constants, then the error on the result R is given by

$$\Delta R = R\sqrt{A^2\frac{\Delta x^2}{x^2} + B^2\frac{\Delta y^2}{y^2} + \cdots}$$

See tutorial – Propagation of errors pg. 2

REPEATED MEASUREMENTS

When dealing with multiple measurements, we use the statistical quantities: **mean** (or average), **standard deviation**, and **standard error** (*SE*) to interpret our data.

- The **mean** (or average) is an estimate of the "true" value of the measurement.

- The **standard deviation** is a measurement of the "spread" in your data. If you took one more measurement, you can be ~70% sure that this value will be one standard deviation away from your mean.

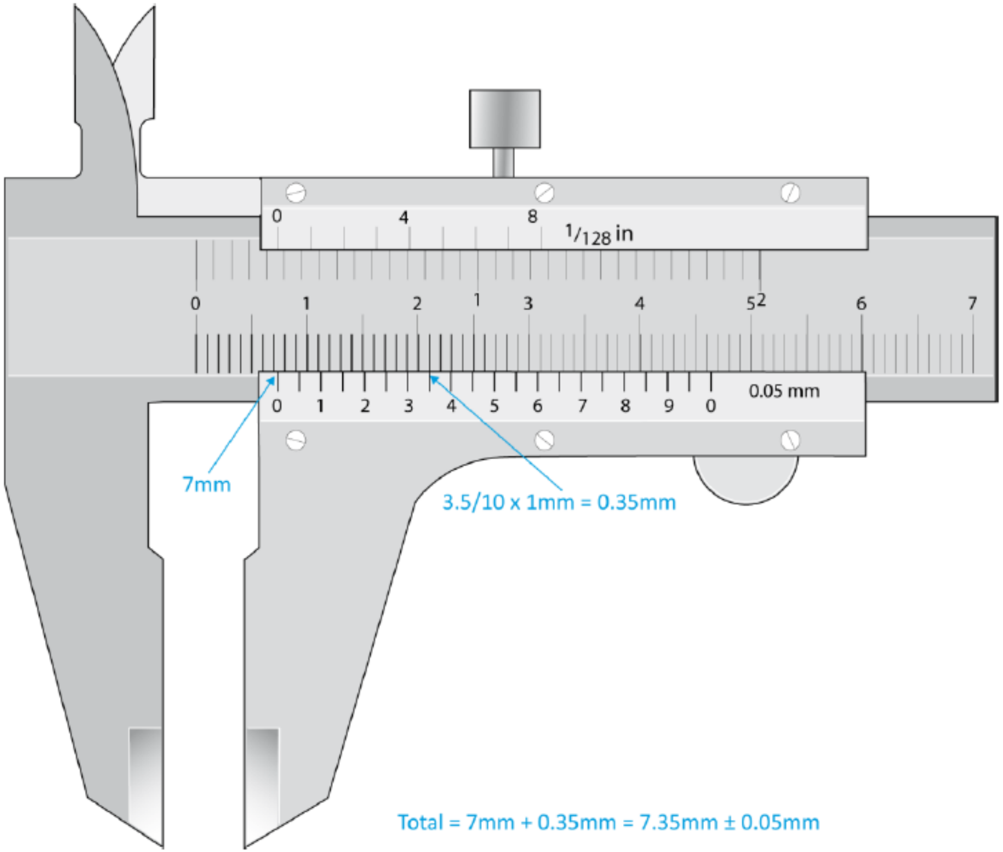
- The **standard error** is an estimate of the uncertainty in the mean value. If you repeated your experiment, you can be ~70% sure that the new mean will be one standard error away from your original mean.

See tutorial – Repeated Measurements

MEASURING INSTRUMENTS

See tutorial - Measuring techniques

Vernier caliper:
for lengths between
1 cm and 10 cm



MEASURING INSTRUMENTS 3

Absolute uncertainties:

- Meter stick: ± 0.5 mm (per reading)
- Vernier caliper: ± 0.05 mm
- Balance: ± 0.1 g
- Stopwatch: ± 0.2 – 0.5 sec

SIGNIFICANT FIGURES AND ROUNDING

- **The uncertainty on a measurement should only have ONE significant digit.**

Example 1: Suppose a relative uncertainty of 0.5% on the gravitational acceleration: $g = 978.325\text{cm/s}^2 \pm 0.5\%$.

Step 1: Multiply the measurement by 0.5%:

⇨ $(978.325 \pm 4.891625)\text{cm/s}^2$.

Step 2: Round off the uncertainty to ONE significant digit:

⇨ $(978.325 \pm 5)\text{cm/s}^2$.

Step 3: Round off the measured value such that it has the same degree of precision as the uncertainty:

⇨ $(978 \pm 5)\text{cm/s}^2$.

A measurement can never have a greater precision than the uncertainty.

See tutorial – Experimental errors pg. 6

LAB 1: OBJECTIVES

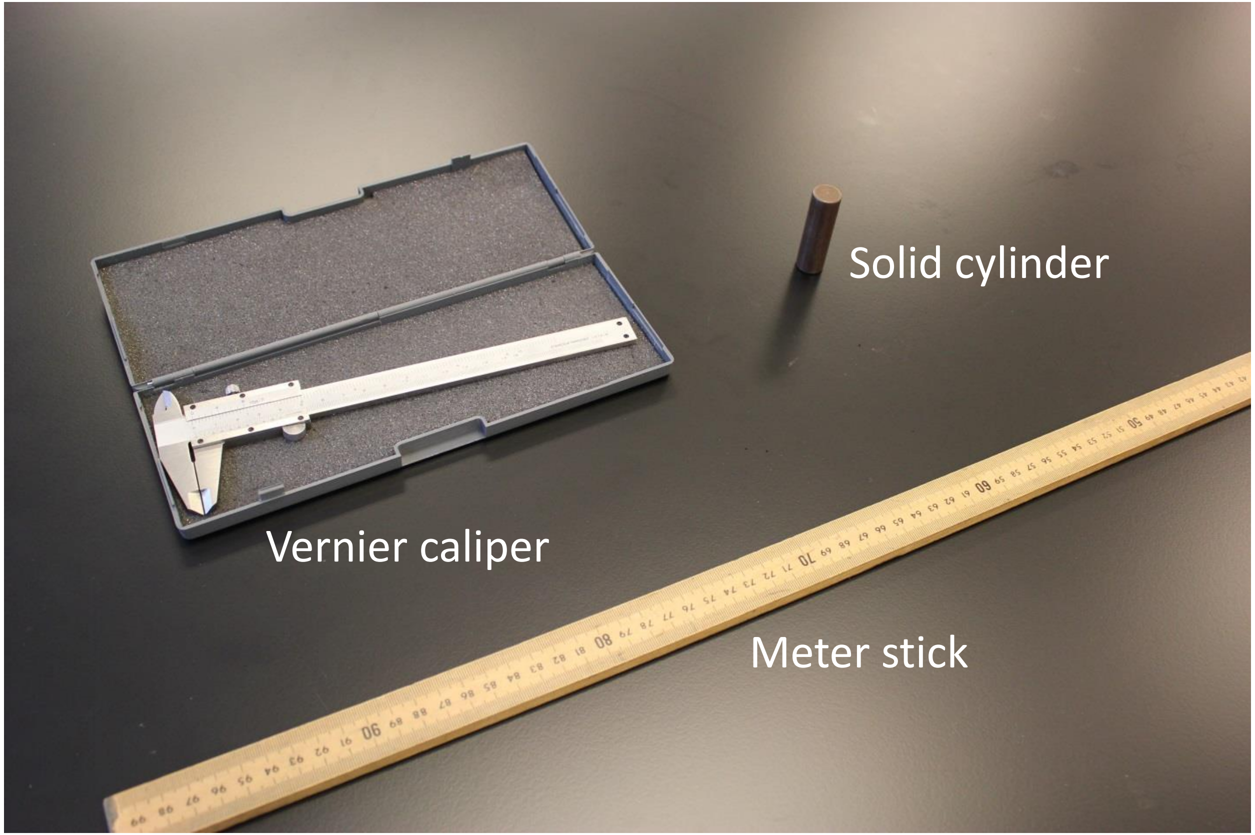
- Part 1: Length measurement
  - Measure dimensions of an object to find its volume and calculate its density
  - Determine material type from a density table
  - Use uncertainty and perform error calculations

- Part 2: Time measurement
  - Calculate the period of oscillation of a pendulum
  - Determine statistical quantities such as average, standard deviation, and standard error

- Part 3: Investigate Archimedes' principle regarding buoyant forces
  - Determine the value of the density of a liquid using a force sensor to measure the buoyancy of an object gradually being submerged in water.
  - Generate a graph of the buoyancy force vs. volume of displaced water and use a linear regression tool to determine the density of water.

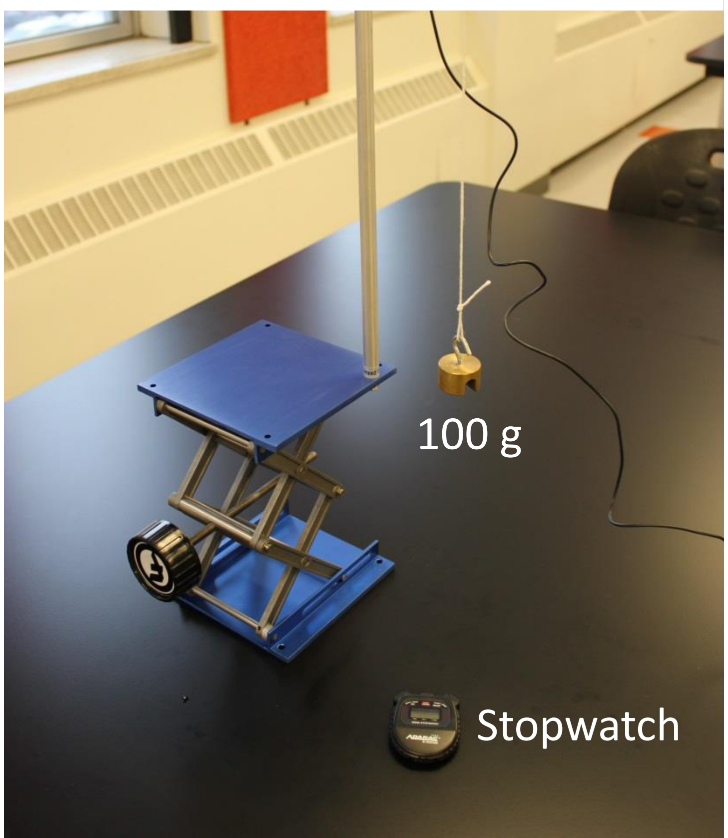
Part 1 - Length measurement

The instruments
and the cylinder:



Part 2 - Time measurement

The pendulum:



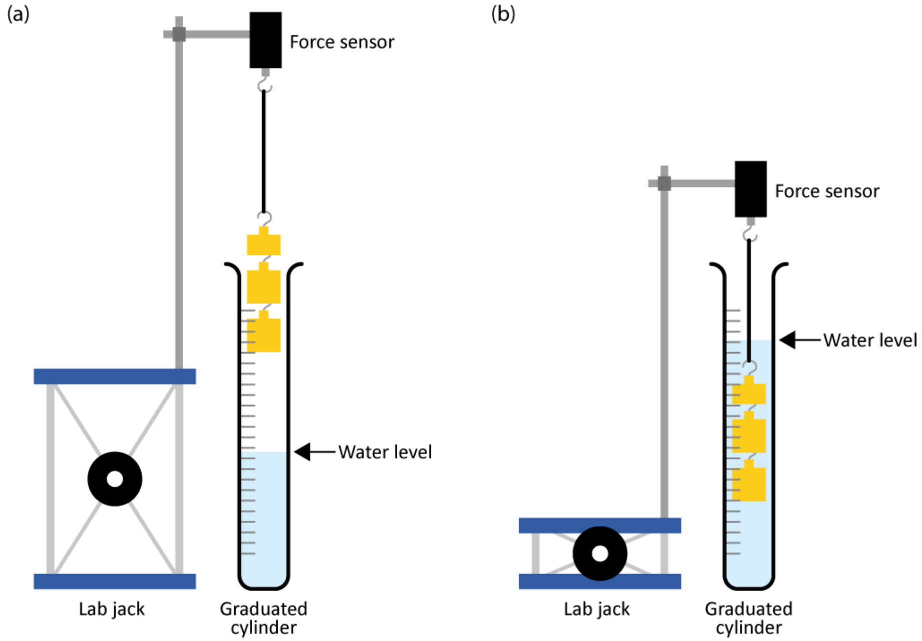
BUOYANCY FORCE

- The buoyant force, F_b, exerted on an object partially or fully submerged in a fluid is equal to the weight of the displaced fluid:

$$F_b = \rho V g$$

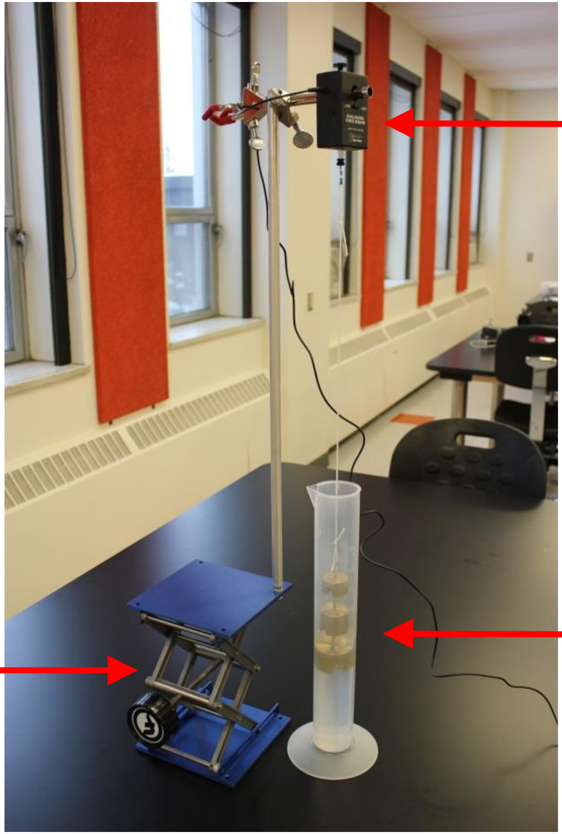
- Use a force sensor to measure F_b experienced by an object gradually immersed in water.

- Make a plot of F_b vs. V then use a linear regression to find ρ.



Part 3 – Buoyancy force setup

The setup:

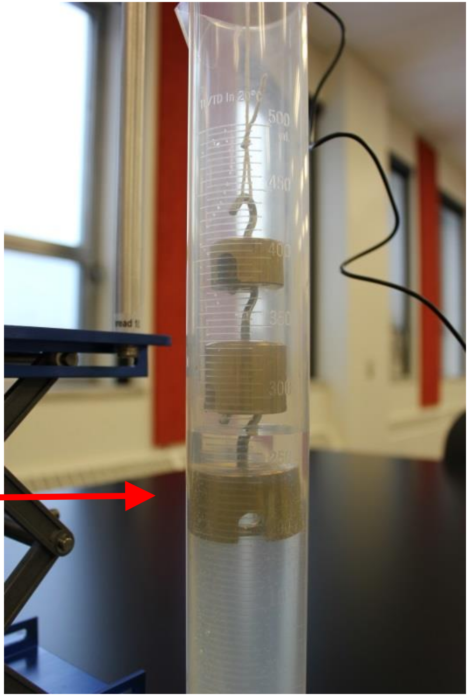


Force sensor

Lab jack

Graduated cylinder and immersed masses

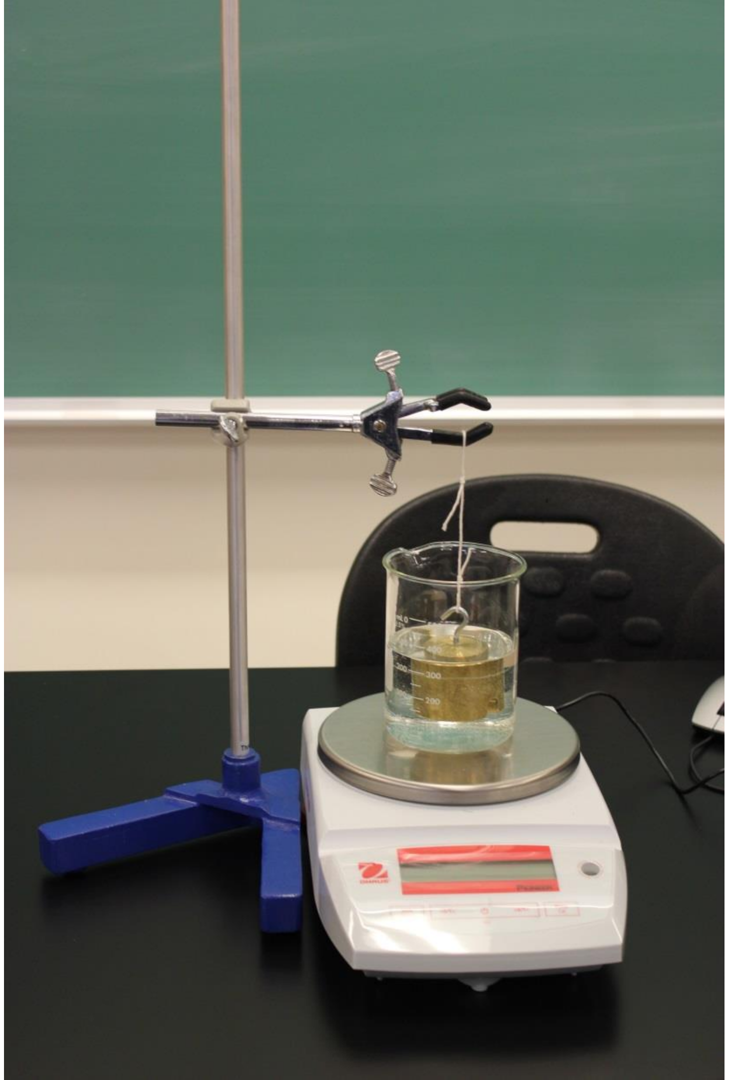
A closer look:



Buoyancy force setup (cont.)

A 500 g mass will be suspended in water over an electronic balance.

Your TA will set up this part. The balance will first be zeroed with only the beaker and water. Then the mass will be submerged in the water and you will record the reading on the balance.



CLEAN UP

- Turn off the computer.
  Don't forget to pick up your USB key if you used one!
- Throw away the water in your graduated cylinder in the sink in front of the classroom. Let your cylinder dry near the sink. **Use brown paper to dry the suspended masses (they will rust!)**.
  - *Your kind TA will clean up the setup at the front of the class for the 500 g mass submerged in the beaker on the balance.*
- Recycle scrap paper and throw away any garbage. Leave your station as clean as you can.
- Push back the monitor, keyboard and mouse. Also please push your chairs back under the table.

DUE DATE

The report is due in 1 week.

The dropbox is located in the central corridor of STM 3rd floor south tower. See the section on Brightspace “Lab report dropbox” for more instructions on how to find it.

Please make sure you put your report in the correct dropbox!

REMINDER: Exp. 0!

Do the 4 tests in Exp. 0 folder before the deadline!

PRE-LAB

Don’t forget to do your pre-lab for Exp. 2!
Don’t wait until the last minute, there will be no extension or make-up for students experiencing technical problems a few minutes before the deadline!!