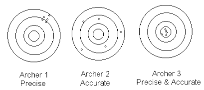
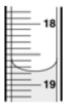




AVERAGE $= \frac{M_1 + M_2 + \dots + M_n}{n}$

Introduction to Laboratory Measurement SUSB-003

MSOffice3

? QUESTIONS ?

What are the uses and limitations of *devices* we use in the laboratory?

What is involved in *making* and *reporting* a **measurement**?

What contributes to the *accuracy* and *precision* of **measurements**?

How do we **measure** and *report accuracy* and *precision*?

What contributes to *uncertainties* in quantities *computed* from **measurements**?

Concepts:

Measurement	Uncertainty	Linear
Mass/Weight	Volume	Density
Deliver/Contain	Meniscus	Homogeneity
Intrinsic Error	Accuracy	Precision
Average	Average Deviation	Percent Error
Error Propagation	Signficant Figures	

Techniques:

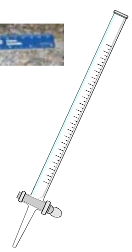
Weighing	Pipet & Syringe
Buret Use	Error Analysis

Apparatus:

Ruler
Analytical Balance
Buret

Transfer Pipet/Syringe
Top loading balance





Background - Measurement

Measuring devices have *intrinsic uncertainties*
i.e., limitations due to their design/construction

bathroom scale
± 1 lb (± 454 g)

balance
± 0.0001 g

measuring cup
± 1 fl oz (± 28 mL)

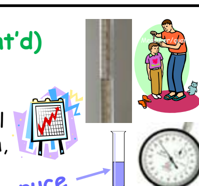
buret
± 0.02 mL

Measurement process itself may introduce additional uncertainty

e.g., try to measure temperature of *five drops* of a warm solution with a cold laboratory thermometer

$\Delta p \ \Delta x \sim h/2\pi$

Background (cont'd)



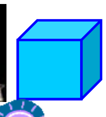
Measurer **often plays a role in the measurement process**
reading a scale or liquid level, or dial
determining a quantity from a graph,
describing the color of a solution

puce

In the physical sciences, certain entities are considered *fundamental*:

Amethyst Cerise Fuchsia Lilac Heliotrope Lavender Lilac Magenta
Mauve Orchid Periwinkle Plum Purple Thistle Violet Wisteria

length (area, volume), mass

time (intervals),

Electric Current; Temperature

Many more can be described in terms of **m**, **l**, **t**.

1 kg is defined as the mass of a prototype made of platinum-iridium and kept at the International Bureau of Weights and Measures. (Paris)

1 joule = 1 kg $m^2 s^{-2}$

Some cannot, & require additional fun...

Slide 2

MSOffice3 Tell the students that every pre-lab lecture begins by showing:

the questions that the exercise is intended to explore
the concepts involved
the techniques used
the apparatus required

Bob Schneider, 8/29/2012

Background (cont'd)

length — **1 m** is the length of the path traveled by light in vacuum during the time interval of 1/299 792 458 of a second

mass — **1 kg** is defined as the mass of a prototype made of platinum-iridium and kept at the International Bureau of Weights and Measures. (Paris)

time (intervals), — 1 sec is defined as 9,129,631,770 oscillations of the ^{133}Cs atom.

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MSOffice1

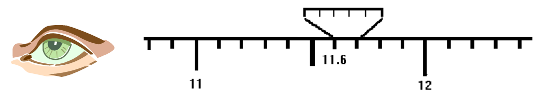
Most measuring devices are ***LINEAR***

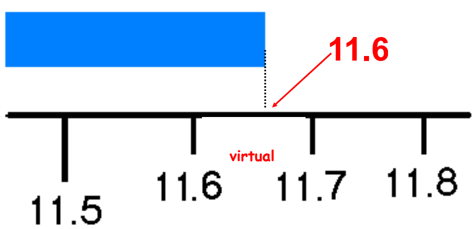
e.g. **RULER**:

ANALOG CLOCK: *1 minute = 6°* around entire dial

RULE OF THUMB:

On a LINEAR SCALE, human eye is capable of estimating location of a mark lying between two smallest divisions to the nearest 1/5 th of a division





The eye "squeezes" additional digit out of the ruler!

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Estimating measurements between values is called *INTERPOLATION*

Apparatus designers expend major effort to make a user interface *linear*, through mechanical (cams, gears) or electronic means.

When scales are not ***linear***, visual interpolation becomes difficult.

e.g., some auto fuel gauges
conical measuring cups

Rule of thumb does not apply!

Interpolation is also not possible with digital interfaces.

We may occasionally encounter non-linear scales – e.g. logarithmic

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Units & Dimensions

What distinguishes ***scientific computation*** from ***arithmetic*** primarily is that most scientific numbers include ***units***.

mol/L mL joule g cm °C sec

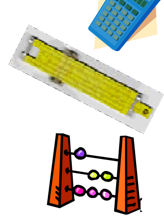
☹ **Bad news:**
calculators don't keep track of units.

☺ **"Good" news:**
Proper attention to units *by users* often shows whether or not a calculation makes sense

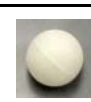
(weight / density) * concentr * molar mass

g / (~~g~~ / ~~mL~~) * ~~mmol~~ / ~~mL~~ * ~~mg~~ / ~~mmol~~ * (g / ~~mg~~)

g



SUSB-003 Procedures



1. Measure ***Diameter*** of Plastic Sphere
2. ***Weigh*** Plastic Sphere on two types of balance
3. ***Compute*** Density using ***Diameter*** & ***Weight***
4. ***Explore*** uncertainty in calculation
5. Make Direct Measurement of Liquid ***Volumes*** using ***Pipet*** & ***Buret***

Note that while this is the order in which the manual describes procedures, you may do them in any order you wish.

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Slide 8

MSOffice1 The clock is to show that Linear does not mean "in a straight line".

Rule of thumb is defined for those who may not be familiar with that idiom.
Bob Schneider, 8/6/2012

1. Measure DIAMETER, d 

From that, *compute* AREA and VOLUME of a sphere from their mathematical relationships to its diameter.

$A = \pi d^2$ $V = \pi d^3 / 6$

***Purpose*: To explore error propagation in quantities derived from diameter**

I.e., suppose we make a small error in measuring **d**. How large an error will that produce in **A** and **V**?

(Note that "π" , "2", "3" and "6" in the geometric formulas have **no associated uncertainty**. *The uncertainty in A and V will be solely due to The uncertainty in d!*)

As an illustration, let's look at a cube of side **L = 10**

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		L = 10.0
VOLUME = L^3	729	1000*

$\pm$ 1 cm uncertainty in the **edge** (1 /10 = **10%**) produces an uncertainty of ~ 300 cm^3 in the **volume** (300 / 1000 = **30%**)

10.0 $\pm$1.0

1000 $\pm$ 300

We often use the symbol ~ to indicate "approximately".

*** Significant Figures**

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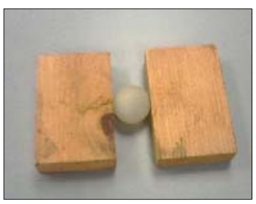

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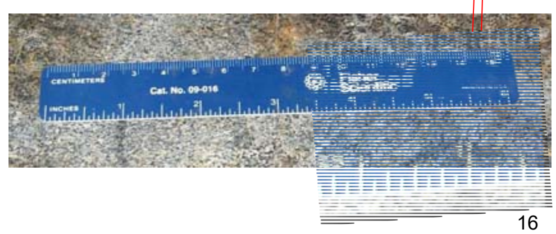
In the exercise, you perform *analogous calculation* for computed area and volume of a plastic **sphere**.

The cm scale of your ruler has its smallest markings at **1 mm** intervals.

By our **rule of thumb**, you should be able to read ruler to nearest **1/5 mm**

1 mm



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2. Weight of a Plastic Sphere 

Labs are equipped with 2 types of balances:

1. Single pan electronic Analytical Balance

used in exercises that require highly quantitative ($\pm$ 0.0001 g) results.

Capacity < 220g

2. Top loading balance

appropriate for weighing in exercises requiring less quantitative ($\pm$ 0.01 g) results

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You weigh the sphere whose diameter you measure with *both* balances.

The weights you measure should be ***consistent***, but will differ in one critical aspect

PRECISION

3.3660 For devices with digital output, our **rule of thumb** does not apply **3.37**

All we can do is to record ***all*** digits that the device provides and rely on the manufacturer's specifications of the intrinsic precision of the device.

For the analytical balance, this always includes 4 decimals. Include all zeros (0).

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SIGNIFICANT FIGURES

☹ **Bad news:**

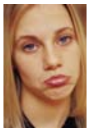
calculators don't keep track of ***significant figures***

2.3 / 7.1 = 0.323943662

☺ **Good news:**

There is ***no good news!***





You simply must learn to handle significant figures.

CHE 133 Web Page

Introduction to Significant Figures

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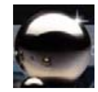
3. DENSITY OF A PLASTIC SPHERE

Density is a reproducible physical characteristic of pure materials.

For a **homogeneous** substance (uniform composition throughout), ***density*** is:



$$d = m / V$$

In this part of the exercise, we use the ***measured mass*** & ***computed volume*** of the sphere to calculate its ***apparent density***. (Is the sphere ***homogeneous***? How could you tell?)

In other parts of this exercise, you use the ***measured mass*** of a sample of water and the ***tabulated density*** of water to calculate the **volume** of the water.

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How do *uncertainties* in the

- measured **DIAMETER** (± 0.02 cm) and
- measured **MASS** (± ?)

affect the uncertainty in the density of the sphere.

From the measured data, we calculate 2 values, D_{max}, D_{min}. The uncertainty in the result, D_{avg}, is measured by:

- the **range** of the values of the density ($D_{max} - D_{min}$)

and

- the **percent deviation** of the density

$$100 \times \frac{D_{max} - D_{min}}{D_{avg}} \%$$

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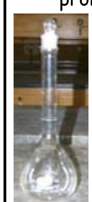
4. MEASUREMENT OF LIQUID VOLUMES

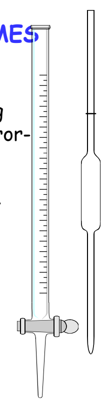
Liquids adopt the shapes of their containers.

These are often irregular objects where using rulers and geometry would be complex and error-prone.

Chemistry uses a wide variety of objects designed to measure volumes.







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These devices can be classified in a number of ways

- Precision
- Accuracy
- Fixed or variable volume
- Whether they

Contain or Deliver

a specified volume of liquid

*when filled to ONE or MORE **APPROPRIATE MARKS***


Appropriate mark is determined by comparing position of a liquid's surface, i.e, the tangent to its **meniscus**, with marks on a ***vertical*** scale.

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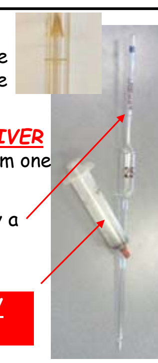
Some devices have only a single mark:

e.g., **Volumetric Flasks** are made to ***CONTAIN*** a specified volume of liquid when filled to the mark



Transfer Pipets are used to ***DELIVER*** a specified volume of solution from one container to another

most transfer pipets have only a single mark (e.g., 5 mL, 10mL, 25mL, etc.)

Pipets are to be filled ONLY by using a syringe

Mark indicates volume ***DELIVERED*** when pipet is emptied under ***ONLY THE FORCE OF GRAVITY***

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The volume markings on **beakers**, **cylinders** or **flasks** are sufficiently inaccurate that the designations "**contain**" and "**deliver**" do **not matter.**

BEAKERS, FLASKS

Used only for approximate volume measurements.

Cylinder is a somewhat more precise

Should read & record volume consistent with the rule of thumb – e.g.,0.2 mL

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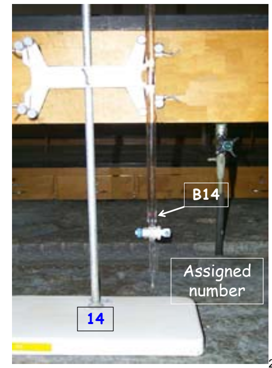
THE BURET



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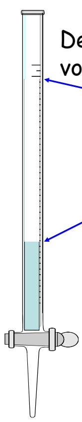
BURET

Device to measure arbitrary ***DELIVERED*** volume of liquid with high accuracy & precision



Initial Reading 4.34

Initial reading must not be 0.00

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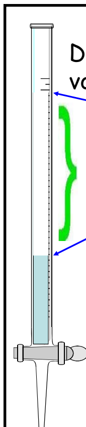
BURET

Device to measure arbitrary ***DELIVERED*** volume of liquid with high accuracy & precision



Final Reading	27.68
Initial Reading	4.34
Delivered Volume	23.34

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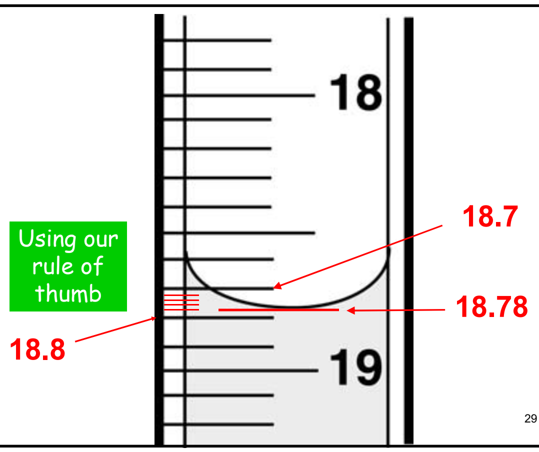

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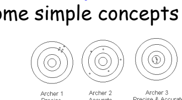
6. MEASURES OF ACCURACY AND PRECISION (SUPL-001)

Lab provides opportunity to use some simple concepts in error analysis

OPERATIONAL CONCEPTS:



ACCURACY: measured deviation from "true" value.

PRECISION: measures reproducibility of results when compared with one another

Exercises involve small numbers of repetitions.

∴ We use *simple* statistical measures:

Accuracy and precision are central to laboratory science and, therefore, to the grading of exercises.

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AVERAGE (mean):

$$\frac{M_1 + M_2 + \ldots + M_n}{n}$$

AVERAGE DEVIATION:

The **average** of the **deviations** from the mean.

$$\frac{|M_1 - AVG| + |M_2 - AVG| + \ldots + |M_n - AVG|}{n}$$

PERCENT DEVIATION:

The average deviation is what % of the mean?

$$\frac{100 \text{ X } AVG\ DEV}{AVG}$$

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AVERAGE, AVERAGE DEVIATION AND PERCENT ERROR

Suppose a measurement is reproduced three times

	WEIGHT OF STEEL BALL	DEVIATION FROM AVG
SAMPLE 1	75.63 g	| - 0.12|
SAMPLE 2	76.05 g	| +0.30|
SAMPLE 3	75.57 g	| - 0.18|
AVG	**75.75 g**	**SUM = 0.60**

where:

AVG = (75.63 + 76.05 + 75.58) / 3

So, instead, we define

AVG DEV = (⊕ 0.12 + 0.30 ⊕ 0.18) / 3 = **0.20**

Result should be reported as

WEIGHT = 75.75 ± 0.20 g

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WEIGHT = 75.75 ± 0.20 g

Suppose in weighing a *plastic* ball, we get the same average deviation (0.20 g) but the weight is only 7.57 g.

WEIGHT = 7.57 ± 0.20 g

Intuitively, the deviation is much "larger" in the second case. We can distinguish the precision by employing the measure:

***PERCENT ERROR*, which we calculate as follows:**

PERCENT ERROR = 100 X 0.20 / 7.57 = 2.6%

or, in the first case

PERCENT ERROR = 100 X 0.20 / 75.75 = 0.26%

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