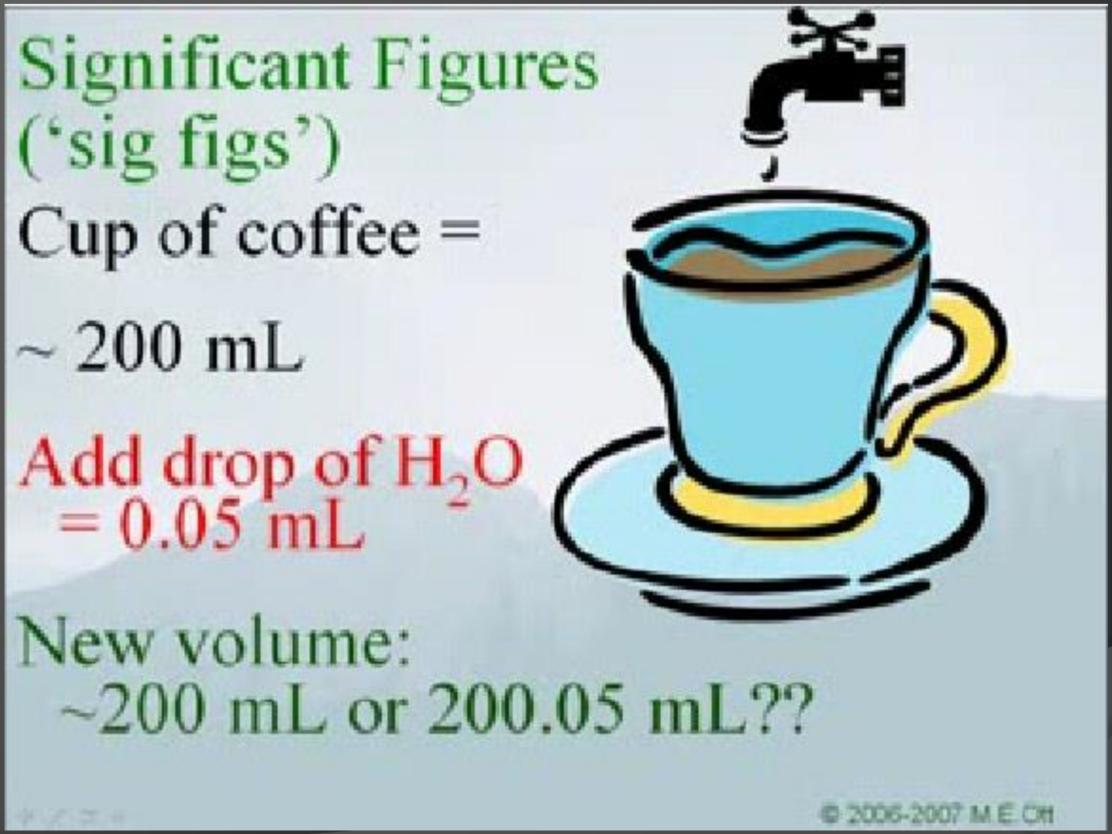
MEASUREMENT AND DATA PROCESSING
TOPIC 11



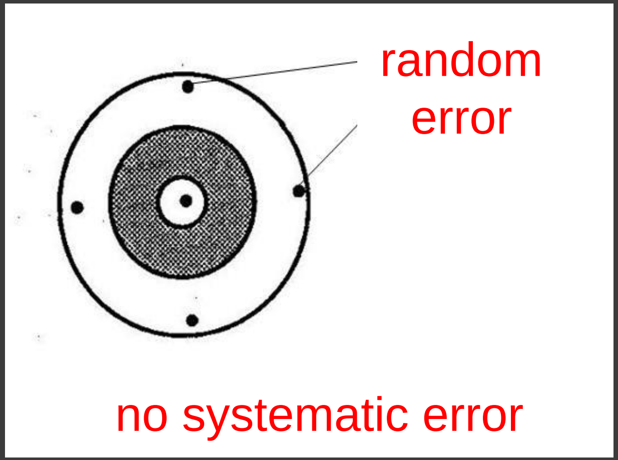

HB

Uncertainty and Error (11.1)

- error in a measurement refers to the degree of fluctuation in a measurement
- types
  - **systematic error**
    - measurements are either too high or too low because of the "system"
      - examples- scale not set to zero, thermometer with an air bubble, something on a scale you weren't aware of….
    - collecting more data will **NOT** help

I never saw
that rock in
there.
Ooops!
I guess my
measurement
is too high

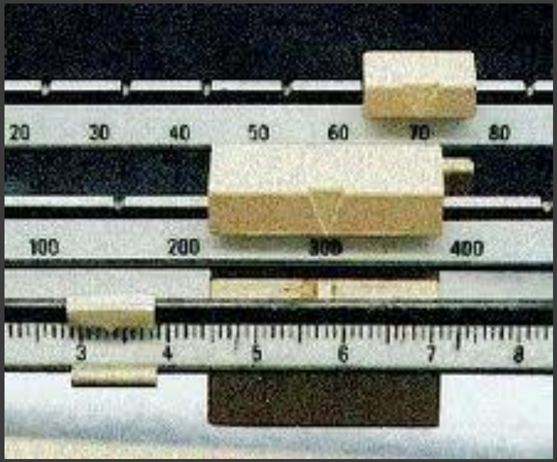
- **random uncertainties (error)**
  - a measurement could either be too high OR too low
    - human error in reading equipment
    - environmental error such as fluctuations in equipment, vibrations….



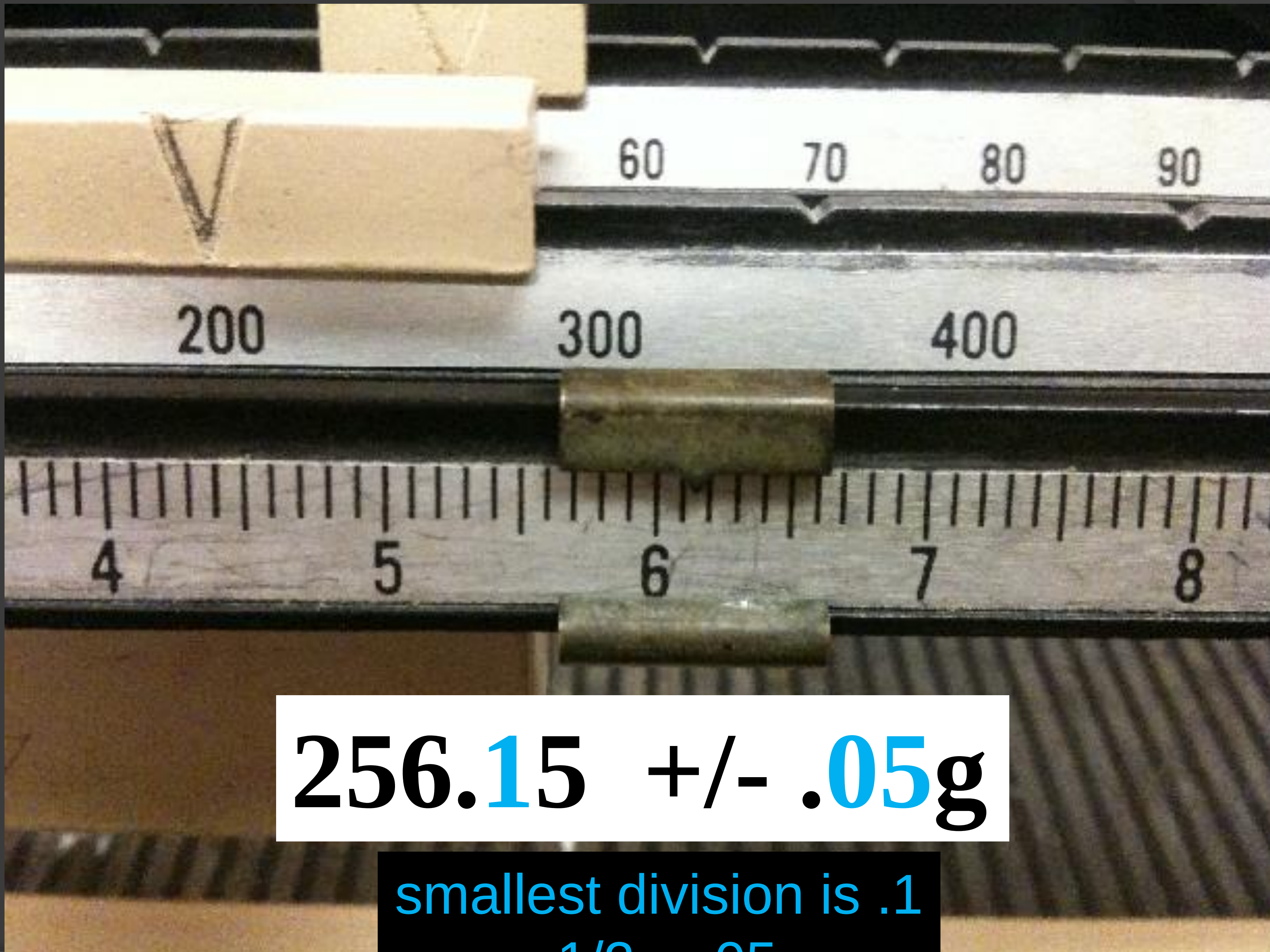
    - **can be reduced** by taking more measurements and finding an average

- range of random uncertainties (error)
  - digital equipment
    - + or – the smallest division
      - 24.8 ºC could be either 24.7 or 24.9
        - smallest division is the tenths place
      - 24.8 +/- 0.1 ºC

- analog equipment
  - + or – the smallest division divided by 2
    - 20.6 sec could be either 20.1 sec or 21.1 sec.
    - smallest division is one second
    - 20.6 +/- 0.5 sec



Don’t forget in analog equipment you can always estimate the last digit. It is still significant. The 6 was estimated by the person measuring and is NOT the smallest division capable by the equipment



256.15 +/- .05g

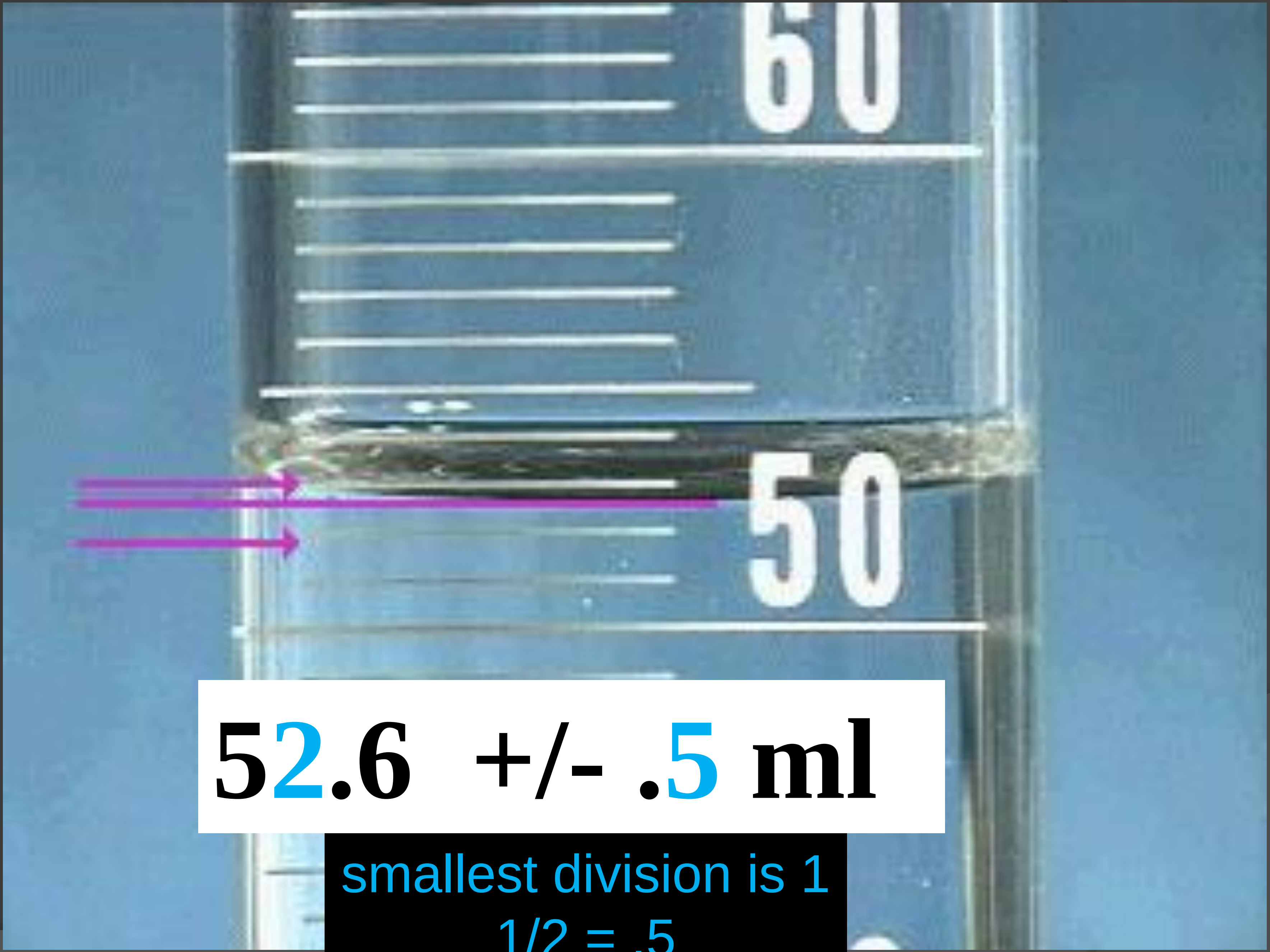
smallest division is .1
.1/2 = .05

5.55 +/- .05 cm

smallest division is .1
.1/2 = .05

smallest division is .01
.01/2 = .005

124.465 +/- .005 g

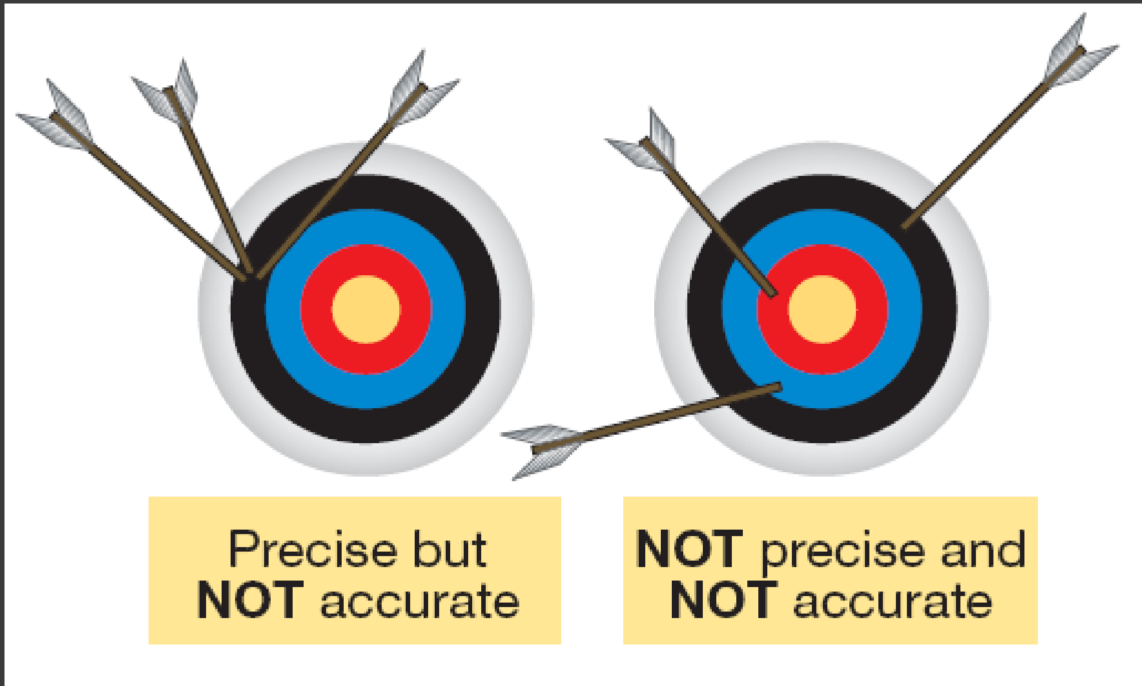


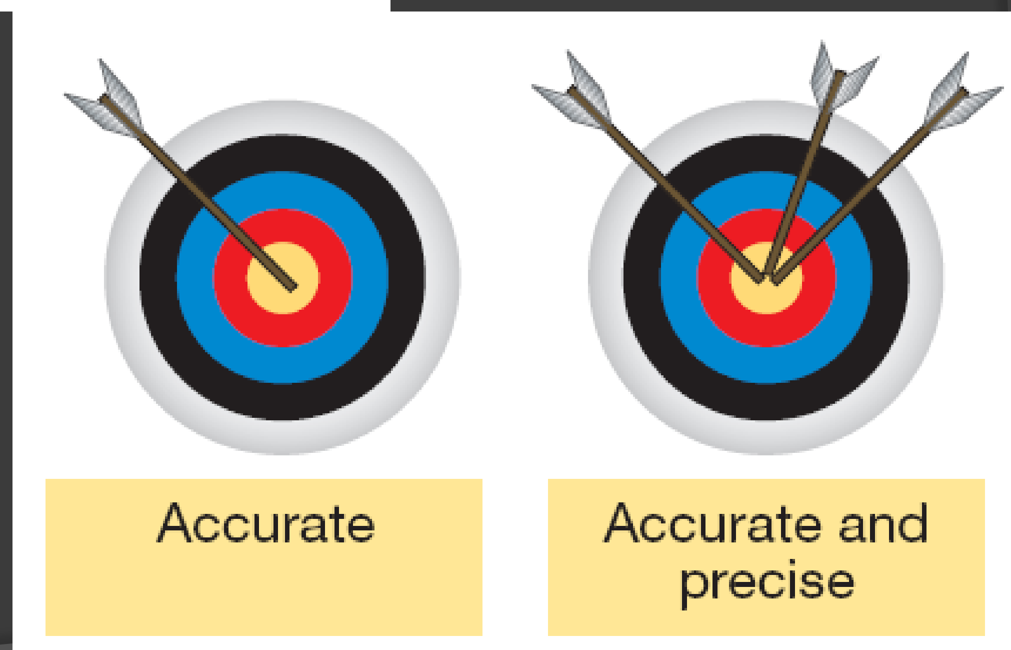
52.6 +/- .5 ml

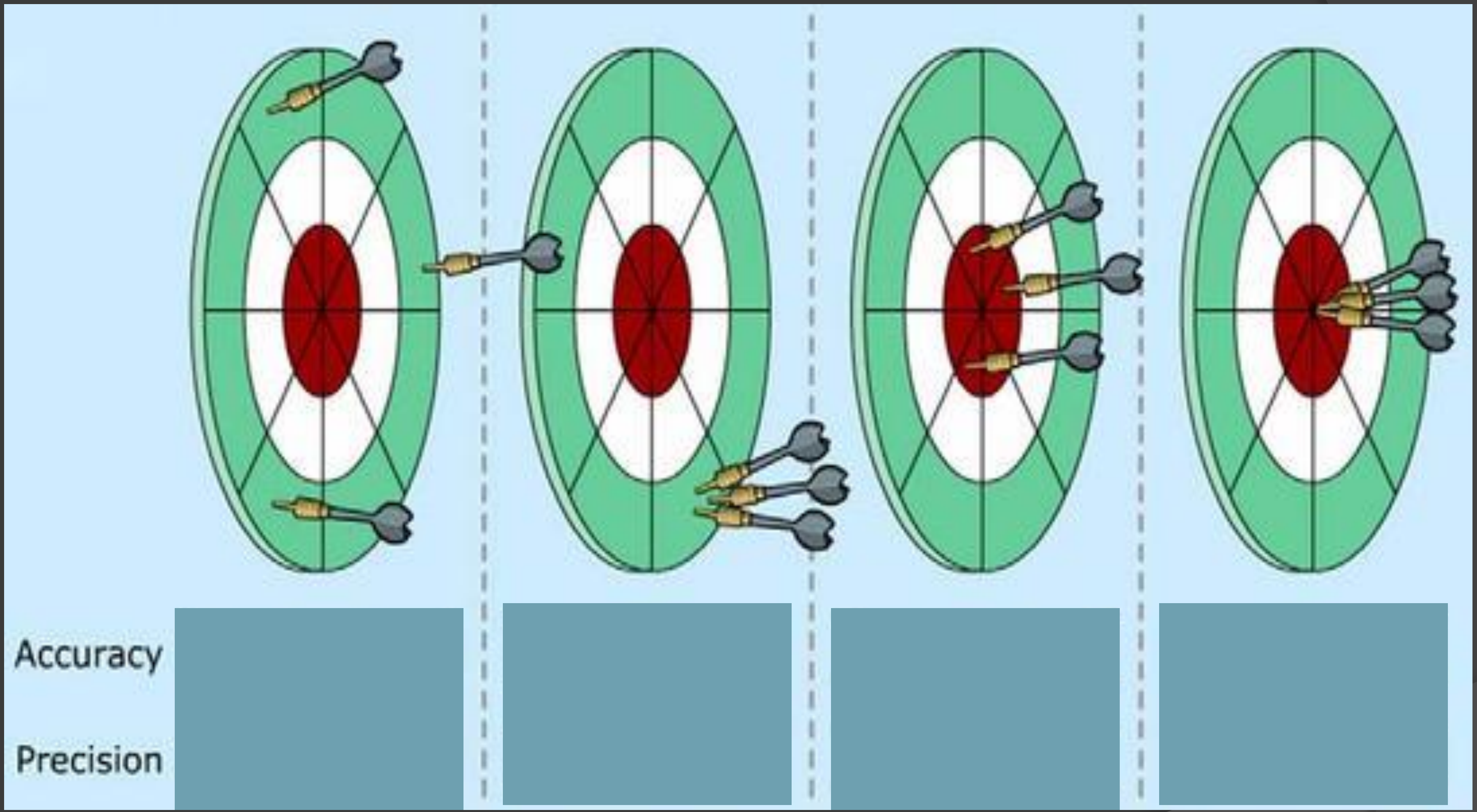
smallest division is 1
1/2 = .5

Precision vs. Accuracy

- *precision*
  - the exactness of a measurement
  - describes how close together repeated measurements or events are to one another-- *even if it is wrong*
- *accuracy*
  - how close the measurement is to the correct answer


Precise but
NOT accurate
NOT precise and
NOT accurate


Accurate
Accurate and
precise

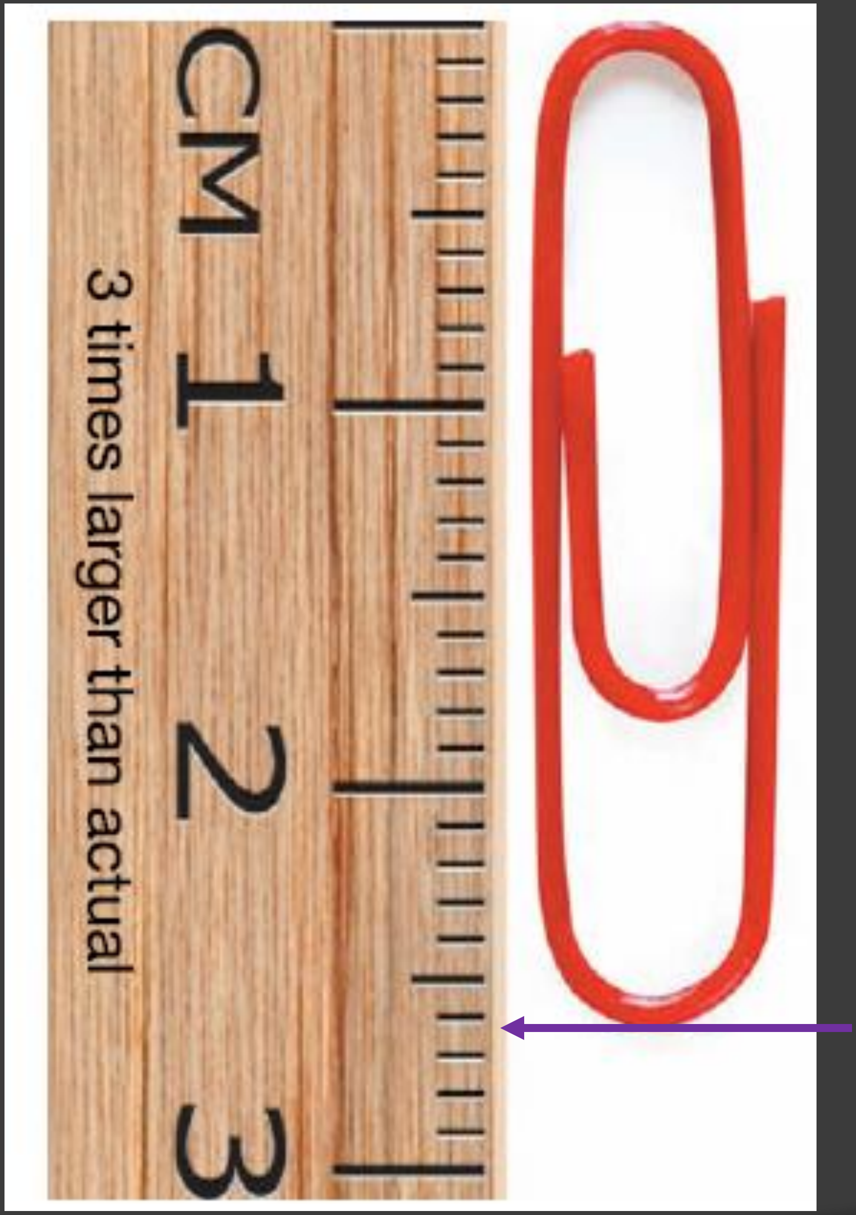

Accuracy
Precision

Significant Figures

sig fig video

- the numbers that are measured, plus one more number that is estimated
  - **Significant** figures
    1. every nonzero digit- 24.7, 0.743, 714
    2. zeros between nonzero digits- 7003, 40.79, 1.503
    3. zeros at the end of a number and to the right of a decimal point= 43.00, 1.010, 9.000
  - **Non-significant** figures
    1. leftmost zeros acting as place holders- 0.0071, .00090
    2. rightmost zeros acting as place holders- 300, 7000, 27,210

- How would you show 7000 with two sig figs?
  - 7.0×10^3
- With four sig figs?
  - 7.000×10^3 or 7000.



- best answer is around 2.63 cm
- to a scientist this number means “between 2.60 and 2.70 cm.”
- the last digit, 3, representing the smallest amount, is uncertain, but it is still significant
- always “push it” one more decimal place by estimating

Number (m)	Significant figures
47.7	
0.43	
1.304	
0.00023	
8.00	
300	
$3.00X10^2$	

Significant Figures When Calculating:

- ***Addition and Subtraction***
  - an answer should not be more accurate than your measurements!
  - the answer should be rounded to the **same number of decimal places** as the measurement with the **least number of decimal places**
    - 22.75 cm + 98.457 cm + 10**.1** cm
    - = 131.307 on your calculator
    - however, 10**.1** cm has the least number of decimal places
      - therefore, the answer is 131**.3** cm

Multiplication and Division

- an answer should not be more accurate than your measurements!
- the answer should be rounded to the **same number of significant figures** as the measurement with the **least number of significant figures**
  - 0.**7** m x 98.457 m
  - = 68.9199 m^2 on your calculator
  - however, 0.**7** m has the least number of significant figures
    - therefore, the answer is **7**0 m^2

Percentage Error

$$\% \text{ error} = \frac{[\text{error}]}{\text{accepted value}} \times 100\%$$

What is the percent error if the boiling point of water is measured at 99.2° Celsius?

$$\% \text{ error} = \frac{99.2°C - 100.0°C}{100.0°C} \times 100\%$$

$$= \frac{0.8°C}{100.0°C} \times 100\%$$

$$= 0.008 \times 100\%$$

$$= 0.8\%$$

Uncertainties in calculated results (11.2)

Addition/Subtraction:

- the maximum uncertainty is the sum of the individual uncertainties
- add the **absolute uncertainties**

111.28 ± **0.01** g - 101.23 ± **0.01** g =	10.05 ± **0.02** g
111.29 ± **0.01** g - 101.23 ± **0.01** g =	10.06 ± **0.02** g
111.31 ± **0.02** g - 101.23 ± **0.02** g =	10.09 ± **0.04** g

total 30.20 ± **0.08**g

Or, “simply” put….

- add up the absolute uncertainties for each measurement and use this with your final answer

Multiplication/Division:

- **% uncertainties** have to be used (to account that some measurements may have different units)
- the maximum uncertainty is the sum of the **% uncertainties** for each individual quantity
- Problem: 2.4 $\pm$ **0.2** cm x 1.3 $\pm$ **0.2** cm
- Steps:
  - 1. divide the **absolute uncertainty** by the given measurement to give a **percentage uncertainty**

    0.2/2.4 = 0.083 which is **8.3%**

    0.2/1.3 = 0.154 which is **15.4%**
  - 2. **% uncertainties** can then be added

    8.3% +15.4% = **23.7%**
  - 3. perform math and then convert **percent uncertainty** *back to an* ***absolute value***

    2.4 x **1.3** = 3.12 $\pm$ 23.7%

    3.12 x 23.7% = **0.739**

    3.12 $\pm$ **0.739** → **(sig figs) 3.1 $\pm$ 0.7 cm^2**

Or, “simply” put….

- use absolute uncertainties in order to calculate the percentage uncertainties for each measurement
- then add up
- convert back to an absolute uncertainty when you have the final answer (don’t forget sig figs in final answer) (uncertainty can be only one sig fig if it makes you happy)