ME170b Lecture 1

Experimental Techniques

Today
> syllabus
> webpage and canvas
> logistics
> tips on experiments and how to write lab report
> Intro to Error Analysis
> individual presentation

What is an experiment?

experiment:

a procedure carried out to support or refute a _hypothesis_, determine the efficacy or likelihood of something previously untried
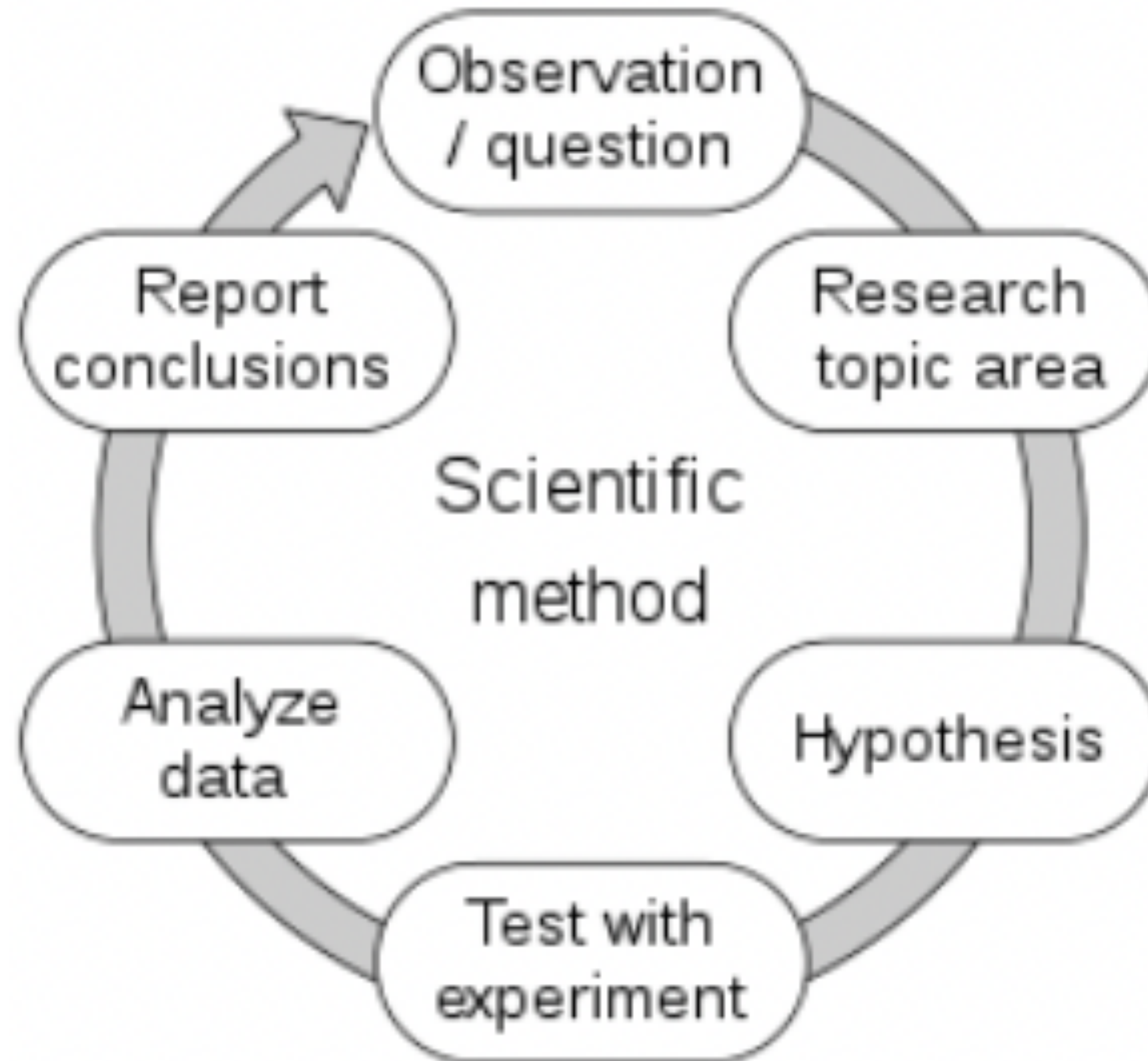
hypothesis:

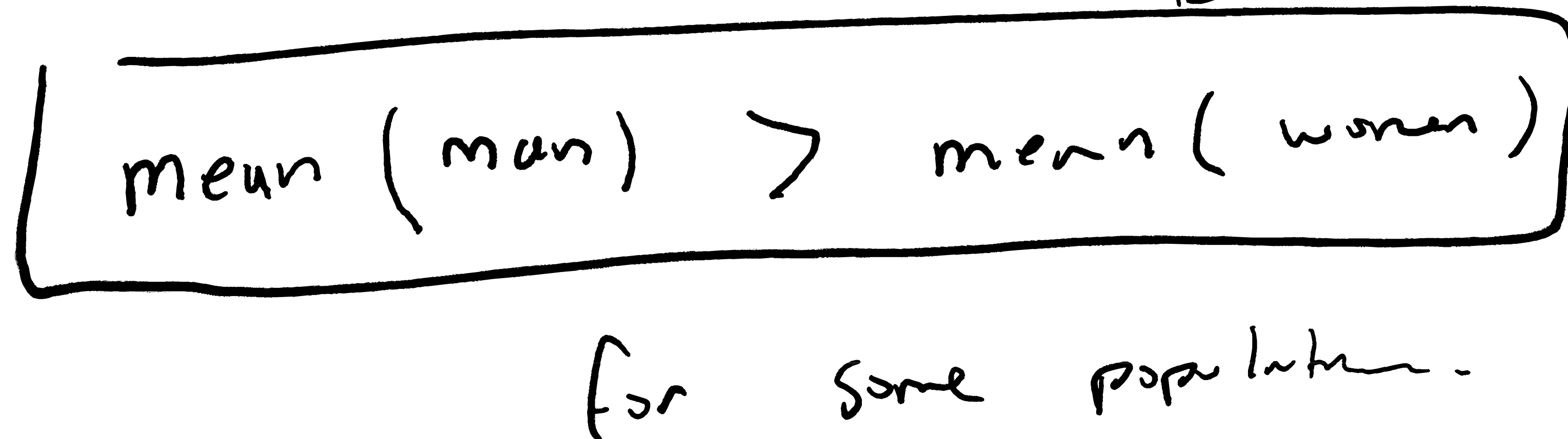a proposed explanation for a phenomenon

scientific hypothesis:

a _testable_ hypothesis, that can be confirm or refute through scientific method

The scientific method?

Suggestions for your lab experiments: <u>use the scientific method</u>

1. What is the question you're trying to answer?
   a. observation you're trying to explain, etc.
2. Research the background
3. Generate testable hypotheses
4. Design the experiment
5. Collect data
6. Analyze data
7. Refute or confirm your hypotheses

$$mean(man) > mean(women)$$

for some population.

Example: people that are right handed have better handwriting

Can we design an experiment to test this?

Better handwriting ⟶ need to __measure__ this

__Measurements__

AI ⟶ translation ⎤
random panel ⎦

Example: Archimedes and the gold crown problem

Find whether a golden crown is made of 18-carat gold, as claimed, or a cheaper alloy

Buoyancy

> Displaced volume + mass to estimate density

> compare to known sample of gold

$$\rho_{crown} \approx \rho_{18\text{-carat gold}}$$

Melting Point

> heat up till starts to melt.

$$T_{crown} \approx T_{18\text{-carat gold}}$$

How to write a lab report?

Abstract:
summary of the experiment as a whole and should familiarize the reader with the purpose of the research. Typically < 300 words! (1 paragraph)

Should address the following questions:
 > Why was the research/experiment done?
 > What problem is being addressed?
 > What are the results?
 > What do the results mean?
 > How is the problem better understood?

How to write a lab report?

Introduction:
provides <u>all</u> the requisite information for the reader to understand the experiment and results

Should address the following:
  > what is the problem being studied?
  > what is the motivation?
  > state the <u>hypotheses</u>
  > don't copy from the lab write-up, use your own words

How to write a lab report?

Methods:
provide an overview of any equipment, apparatus, or other materials used in the experiment, as well as the steps taken during the experiment (protocol).

Should address the following:
  > what is the experimental setup?
  > detail step-by-step experimental protocol
  > step-by-step description of data analysis
  > another person should be able to <u>replicate</u> the experiment just by reading your methods

How to write a lab report?

Results:

show using figures, graphs, plots, the data (in raw and analyzed form) from the experiment. Explain in words the data and reference the figures/graphs/plots

Should address the following:
   > label figures (Fig.1, Fig.2, etc) and references in text ("The results can been seen in Fig.1")
   > provide calculations (if not described in Methods)

How to write a lab report?

Discussion:
<u>most important part,</u> provide analysis and interpretation of the results.

Should address the following:
> if results are unexpected, why?
> must address <u>uncertainty,</u> where does it come from, how it was managed
> What do the result mean?
> What is the significance?
> Are there any gaps in knowledge?
> What are the new questioned raised by the results?

How to write a lab report?

Conclusion:
a summary of the entire report. summarize the problem studied, the methods used, the result found, and clearly and concisely state what was learned and it's importance

What will we do in lecture?

Error Analysis:

the study of evaluation of uncertainty in measurements

No measurement is free of uncertainties

How should we deal with uncertainties?

└→ this course!

Error vs Uncertainty

Error: the difference between
the measured value & the true value
<u>   </u>
(often unknown)

Uncertainty: best estimate of measurement
error

Uncertainty is inevitable!

Coastline Paradox is an extreme example: measured length of the coastline depends on the method used to measure it

But why is it important to estimate uncertainty?

Example: Archimedes and the gold
crown problem (ask experts to
measure density)

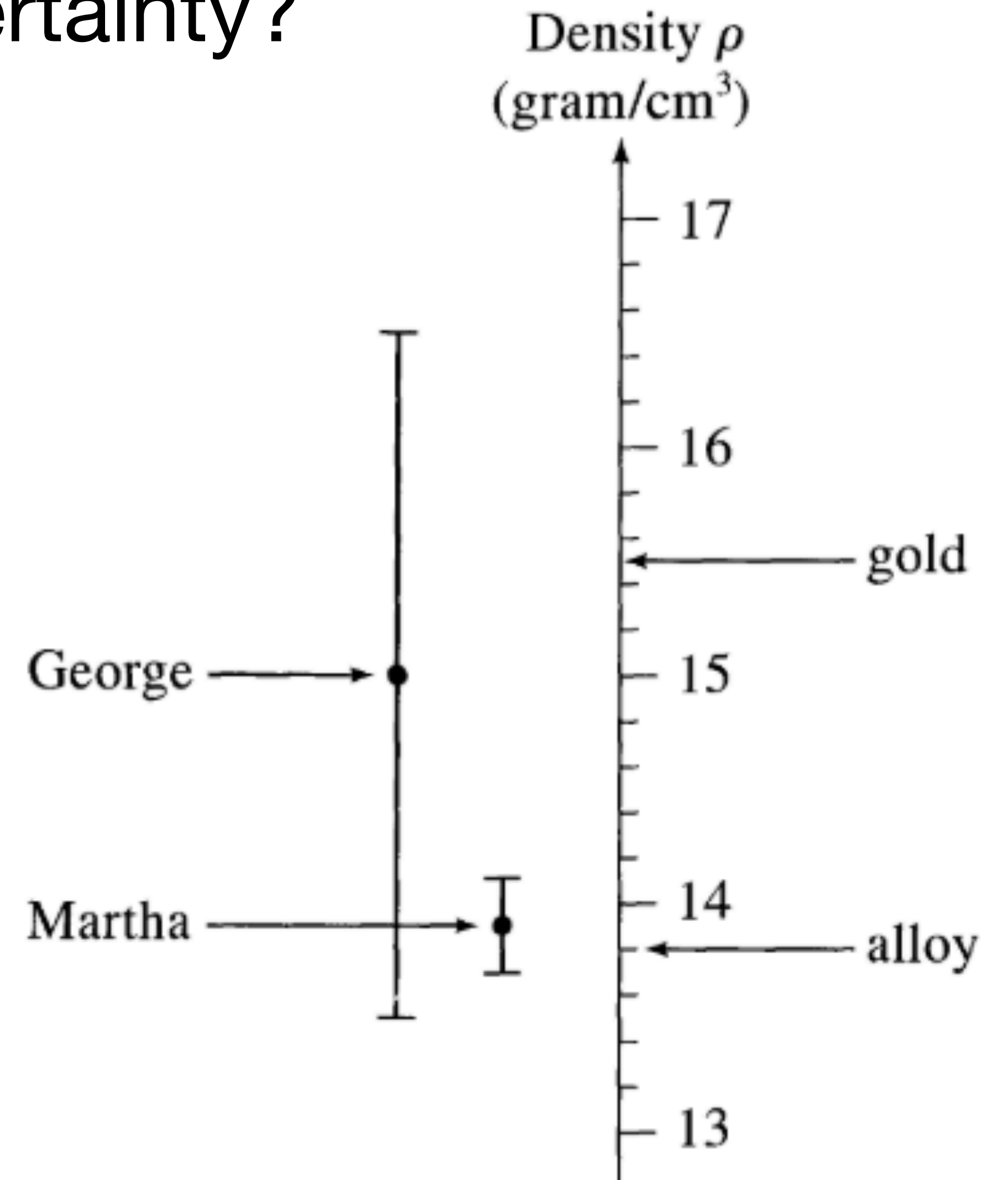$$\rho_{\text{gold}} = 15.5 \text{ gram/cm}^3$$

$$\rho_{\text{alloy}} = 13.8 \text{ gram/cm}^3$$

But why is it important to estimate uncertainty?

Example: Archimedes and the gold crown problem (ask experts to measure density)
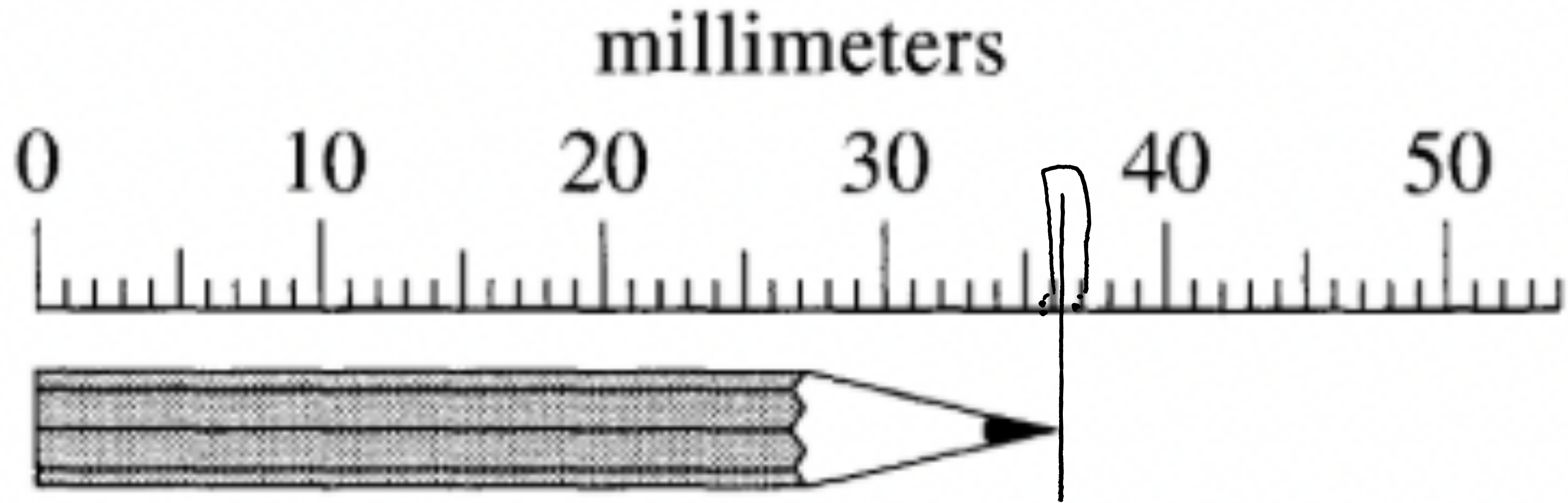
$\rho_{gold} = 15.5 \text{ gram/cm}^3$

$\rho_{alloy} = 13.8 \text{ gram/cm}^3$

Who to trust? Why?

How to estimate uncertainties while reading scales?

millimeters

0   10   20   30   40   50
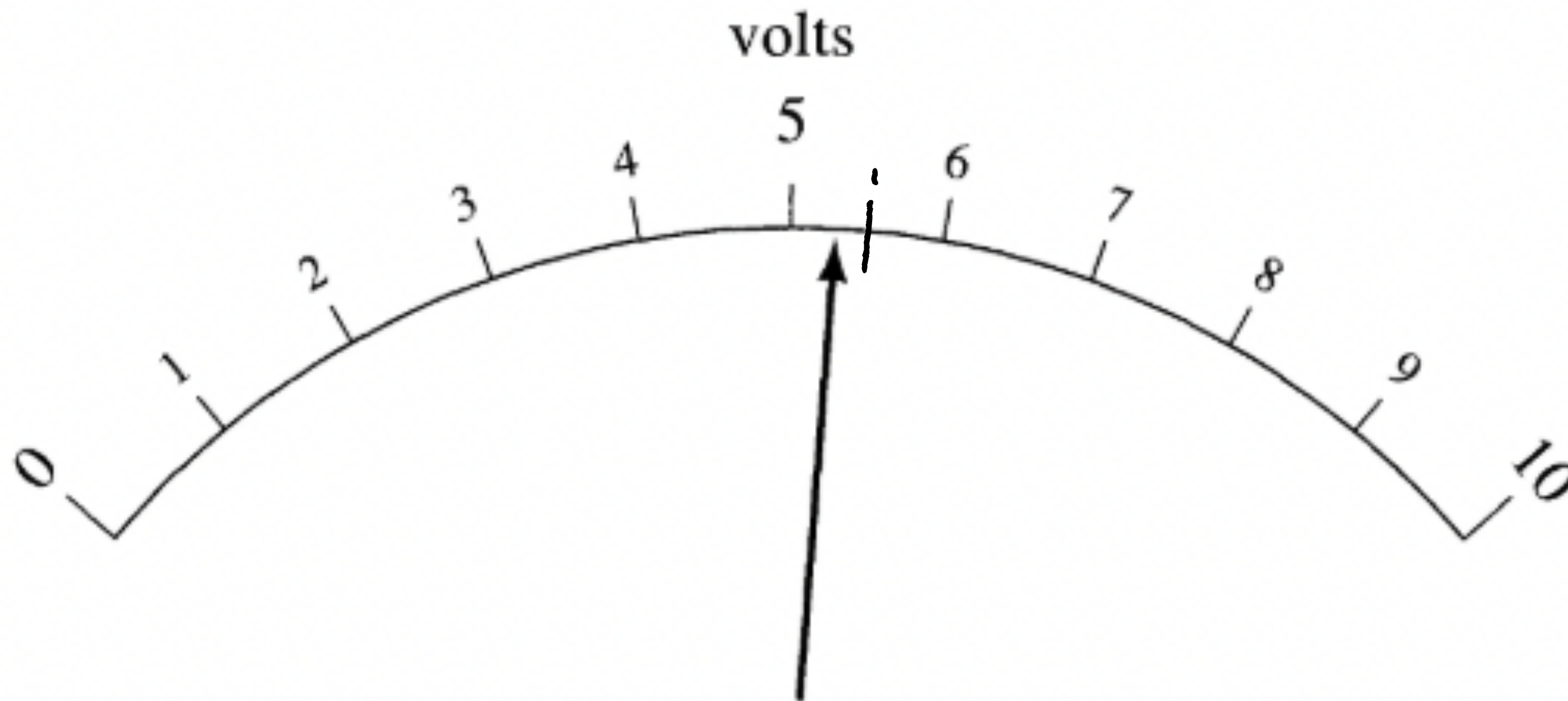
How long is the pencil?

36.5

37

36.8

$$35.5 - 36.5$$

$$36 \pm 0.5 \text{ mm}$$

How to estimate uncertainties while reading scales?

volts

5

4

3

2

1

0

6

7

8

9

10

What are the Volts?

$$V > 5V$$

$$V < 5.5V$$

uncertainty

$$5.2 - 5.4$$

best estimate

$$5.3 \pm 0.1 \, V$$

Best way to reduce uncertainty?

repeated measures !

Best way to reduce uncertainty?

repeated measures!

suppose we have the following measurements from a stop watch used to measure the swing of a pendulum 4 times

$$2.3, 2.4, 2.5, 2.4,$$

What should our "best estimate" of the true period? Why?

mean = 2.4

uncertainty

2.3 — 2.5

$$2.4 \pm 0.1$$