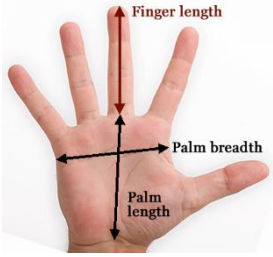
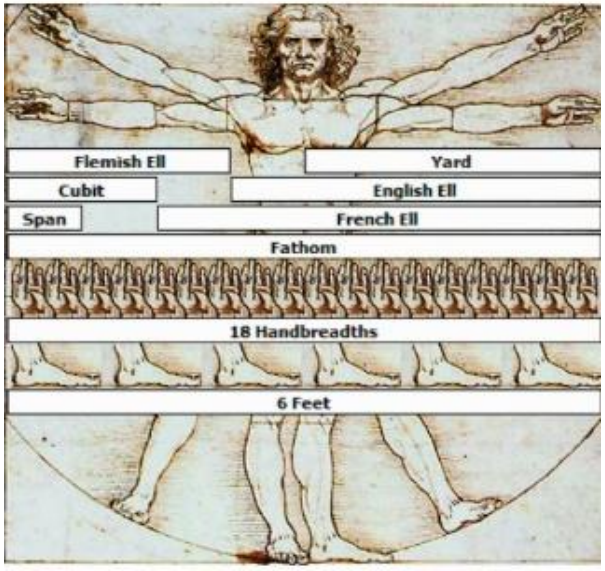


Measurement



Measurement

- the **assignment of numbers** to objects or events
- a type of **quantitative observation** made with a **measuring instrument**
- includes both a **number** and a **unit**
- **units** of measurement are essentially **arbitrary: people make them up** and then **agree to use them**

Measuring is an important part of everyday life!

What can we measure?

How can we measure?

Why do we measure?

How good can we measure?

What can we measure?

- Length
- Distance on land
- Depth of water
- Mass
- Temperature
- Time
- Light
- Electric current
- Color

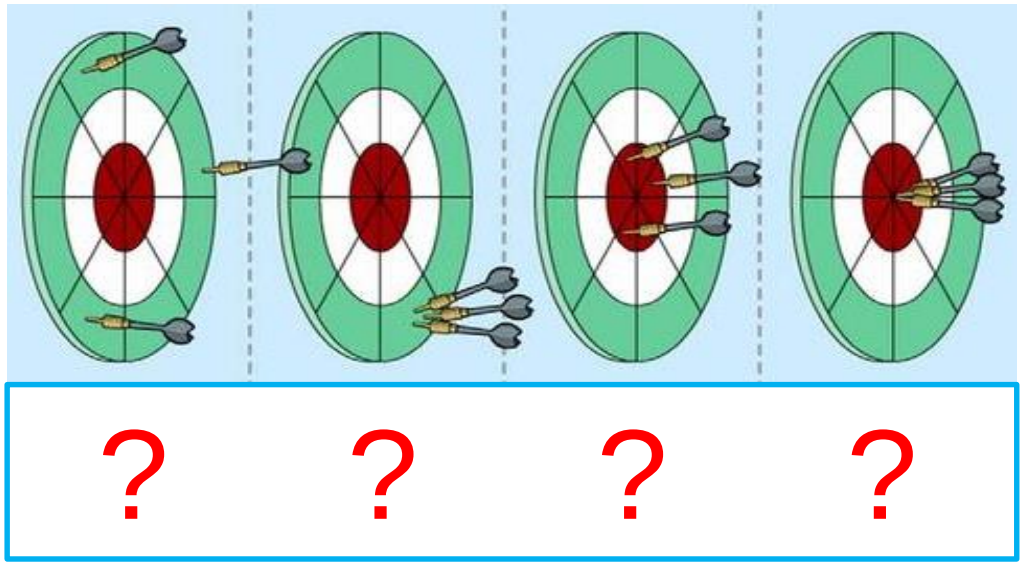
And how?

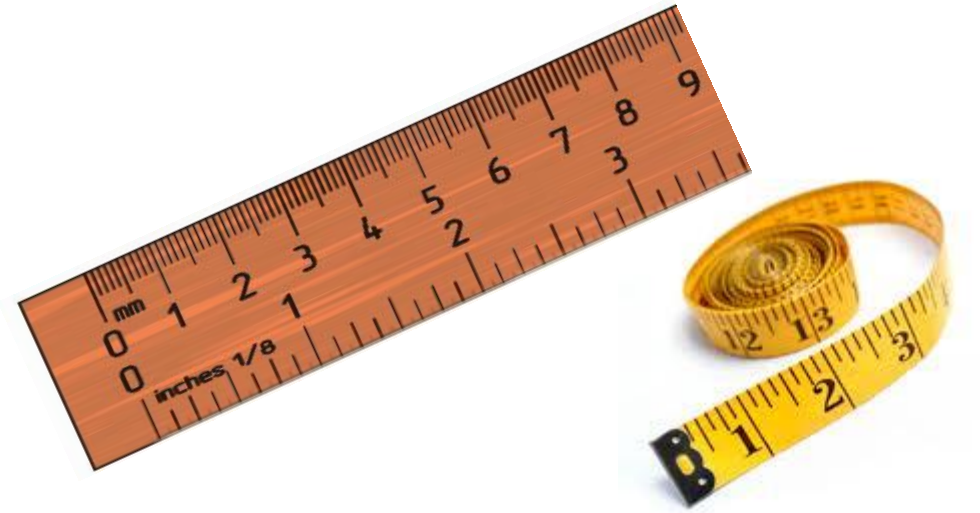
- ✓ Ruler
- ✓ Measuring Chain/Tape
- ✓ Sonar (echo sounder)
- ✓ Weighing scale
- ✓ Thermometer
- ✓ Clock, timer
- ✓ Photometer
- ✓ Ammeter
- ✓ Spectrometer

AND SO ON...

How good is the measurement?

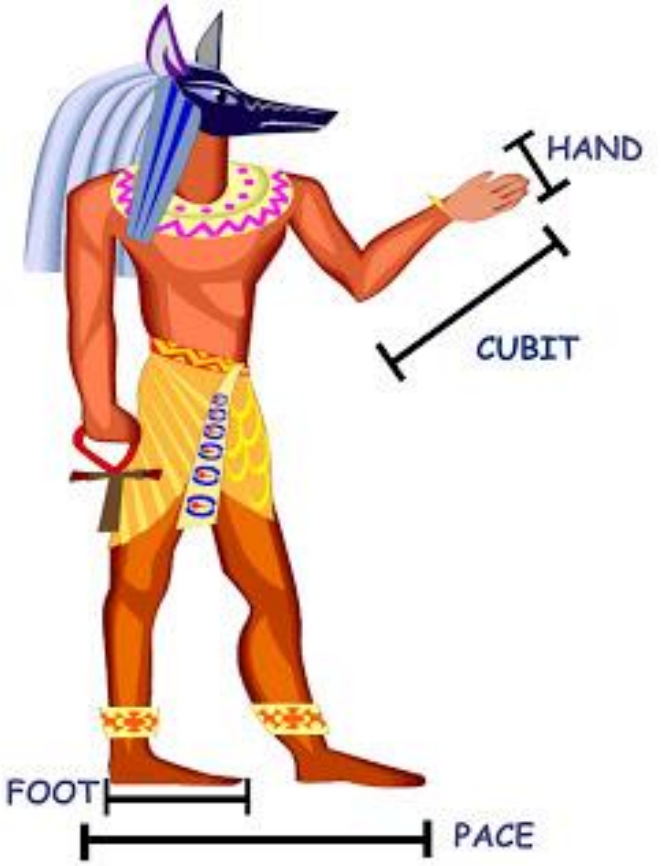
- **Accuracy** is how close a measured value is to the *actual (true) value*.
- **Precision** is how close the measured values are to *each other* (repeatability and reproducibility).
- **Bias** is a built-in (systematic) error which makes *all measurements wrong by a certain amount*.





History of Measurement

- Objects were initially measured for ***convenience***, to ***aid commerce*** and ***prevent fraud***.



- The **Egyptians** among other civilizations **were the first to begin recording measurements** around 3200 BC.
- **Early** measurements were **based on body parts** or **common objects.**

Problems with Early Measurement Units

1. People have ***different sized body parts***, as well as there is a ***variety among common objects*** like grains...

Grain, India

Barleycorn

Wheat

2. ...so measurements are ***not accurate***, especially when dealing with ***fractions*** and ***multiples***...

SOLUTION: Standard Measurement Systems!

What is a System of Measurement?

A system of measurement is a collection of units of measurement and rules relating them to each other.

- Must have **base units** defined for all major quantities that need to be measured (example: a *foot*).

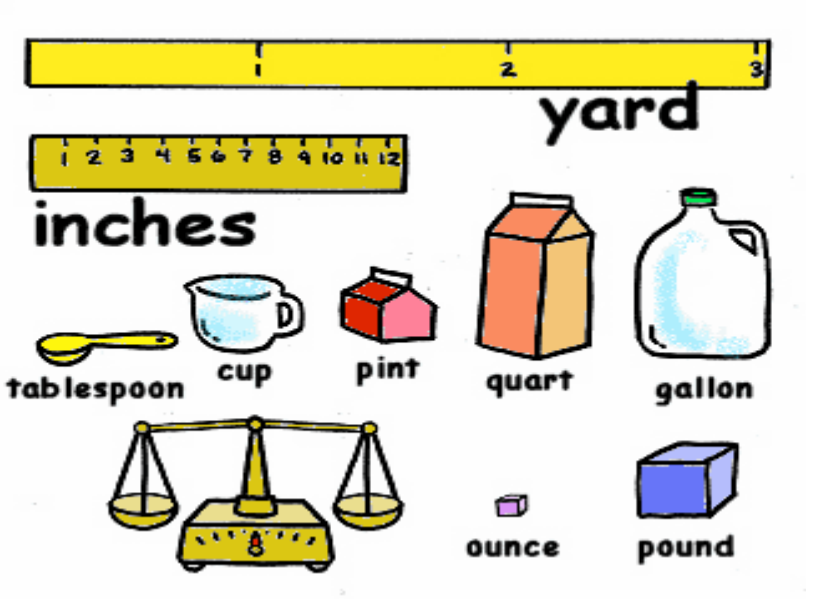
- Must specify **equivalency** relationship **for all additional units** used to measure the same quantity (example: length can also be measured in *inches* or *miles*, defined as 1 foot = 12 inches, 1 mile = 5280 feet).

Systems of measurement have historically been important, regulated and defined for the purposes of science and commerce.

English Units Based Systems

- **Imperial System of Measurement (British Empire, 1824):**
  - Distance/Length: Inch, foot, yard, mile
  - Volume: fluid ounce, pint, quart, gallon
  - Area: Acre
  - Weight/Mass (three different systems!): grain, ounce, pound, stone, ton

- **US Customary System of Measurement:**
  - Mostly *same unit names*
  - **Units are not identical!** (1 US gal=0.83 imp gal)
  - Different units for liquid and dry measures (liquid/dry ounce)



The Metric System

The metric system is an internationally agreed decimal (based on power of 10) system of measurement. It was originally introduced by France in 1799.

Modern **"Metric system"** term is a synonym for **"SI"** or the **"International System of Units" (1960)**—the **official system of measurement** in almost every country in the world.

Metric System in the USA

- The metric system has been **officially sanctioned for use in the United States since 1866**, but it remains the only country that has not fully adopted the metric system as its official system of measurement.

- Metric System was only **partially** adopted, **mostly in Science** (but not Manufacturing!)..

How good is “partially”?

Gimli Glider

July 23, 1983: Air Canada Flight 143 (Boeing 767-233 jet), ran out of fuel at an altitude of 41,000 feet (12 km), about halfway through its flight from Montreal to Edmonton.

The crew were able to glide the aircraft safely to an emergency landing at Gimli Industrial Park Airport. None of the 61 passengers were seriously hurt.

Investigation: fuel loading was miscalculated due to a misunderstanding of the recently adopted metric system which replaced the imperial system.

Loss of NASA orbiter

NASA's Mars Climate Orbiter
lost on September 23, 1999.
Cost: $125 million.

The spacecraft insertion trajectory came too close to the planet; the Orbiter disintegrated upon entering the upper Martian atmosphere.

For a key spacecraft operation, Lockheed Martin engineering team used Imperial units of measurement while the NASA's team used more conventional Metric system…