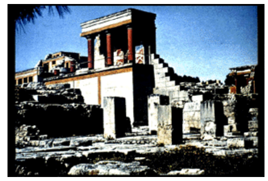
Introduction to Measurements

Why do we need measurements?

Introduction to Measurements

- Some of the earliest surviving measuring devices include gold scales recovered in present-day Greece from the tombs of Mycenaean kings.




Introduction to Measurements

- The tombs of Egyptian pharaohs — the pyramids — were constructed by builders using no more than simple rulers: the pyramids are regular, symmetric and aligned with the Earth's axis.


Introduction to Measurements

- Babylon, Egypt, and the city states of Greece all had standards for commercial measuring devices
- By about 500 B.C., Athens had its own central depository of official weights and measures — the Tholos

Introduction to Surveying

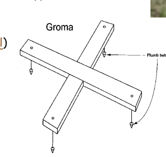
Early History of Surveying

- It is impossible to determine when surveying was first used
- "***Remove not the ancient landmark, which thy fathers have set***"
  Deuteronomy 19:14
- The word ***geometry*** is derived from the Greek meaning *earth measurements*

Introduction to Surveying

Early History of Surveying

- In Egypt, surveyors were called "rope stretchers" because they used ropes to measure
- Roman surveyors got their name gromatici from the groma (http://corinth.sas.upenn.edu/gromatxt.html)



Introduction to Surveying

Types of Surveys

- ***Land surveys*** - oldest type of surveys and have been performed since earliest recorded
- ***Topographic surveys*** - location of objects and measuring the relief, roughness, or three-dimensional variations
- ***Route surveys*** - location of natural and artificial objects along a proposed route for a highway, railroad, canal, pipeline, power line, or other utility

Introduction to Surveying

Types of Surveys

- ***City or municipal surveys*** - use to lay out streets, plan sewer systems, and prepare maps
- ***Construction surveys*** - locating structures and providing required elevation points during their construction
- ***Hydrographic surveys*** - pertain to lakes, streams, and other bodies of water

Introduction to Surveying

Types of Surveys

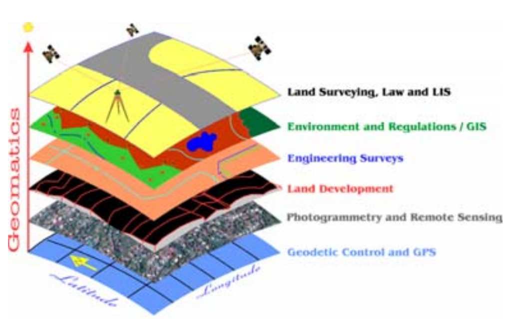
- ***Marine surveys*** - related to hydrographic surveys, but they are thought to cover a broader area
- ***Mine surveys*** - relative positions and elevations of underground shafts, geological formations, etc.
- ***Forestry and geological surveys***
- ***Photogrammetric surveys*** - photographs (generally aerial) are used in conjunction with limited ground surveys

Introduction to Surveying

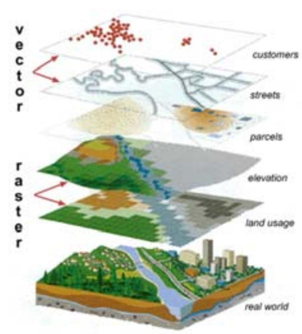
Types of Surveys

- ***As-built surveys*** - provide the positions and dimensions of the features of the project as they were actually constructed
- ***Control surveys*** - provides vertical and horizontal reference points

Introduction to Surveying



Introduction to Surveying



Introduction to Measurements

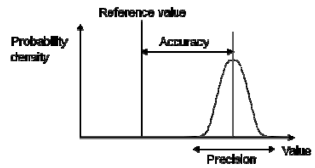
- Typically, we are accustomed to ***counting*** but not ***measuring***
- Engineers are concerned with distances, elevations, volumes, direction, and weights
- Fundamental principle of measuring:

No measurement is exact and the true value is never known

Introduction to Measurements

Accuracy and Precision

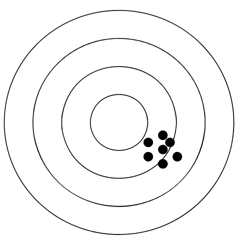
- ***Accuracy*** - degree of perfection obtained in a measurement
- ***Precision*** - the closeness of one measurement to another



Introduction to Measurements

Accuracy and Precision

Target #1

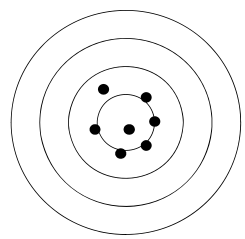


This target grouping is precise

Introduction to Measurements

Accuracy and Precision

Target #2

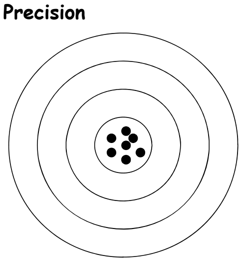


This target grouping is accurate

Introduction to Measurements

Accuracy and Precision

Target #3



This target grouping is accurate and precise

Introduction to Measurements

Accuracy and Precision

- Better precision does not necessarily mean better accuracy
- In measuring distance, precision is defined as:

$$precision = \frac{error\ of\ measurement}{distance\ measured}$$

Introduction to Measurements

Accuracy and Precision

- Here are a couple of other web sites for additional information in accuracy and precision:

http://www.colorado.edu/geography/gcraft/notes/error/error_f.html

http://en.wikipedia.org/wiki/Accuracy

Introduction to Measurements

Accuracy and Precision

- For example, if a distance of 4,200 feet is measured and the error is estimated a 0.7 feet, then the precision is:

$$precision = \frac{0.7\ feet}{4{,}200\ feet} = \frac{1}{6{,}000}$$

- The objective of surveying is to make measurements that are both ***precise*** and ***accurate***

Introduction to Measurements

Source of Errors

- **Personal Errors** - no surveyor has perfect senses of sight and touch
- **Instrument Errors** - devices cannot be manufactured perfectly, wear and tear, and compatibility with other components
- **Natural Errors** - temperature, wind, moisture, magnetic variation, etc.

Introduction to Measurements

Systematic and Accidental Errors

- **Systematic or Cumulative Errors** - typically stays constant in sign and magnitude
- **Accidental, Compensating, or Random Errors** - the magnitude and direction of the error is beyond the control of the surveyor

Introduction to Measurements

Group Problem

- **How long is the hallway outside the classroom?**
- **How did you measure this distance?**
- **What was your precision?**
- **What is your accuracy?**

Introduction to Measurements

Significant Figures

- Measurements can be precise only to the degree that the measuring instrument is precise.
- The number of significant figures the number of digits you are certain about plus one that is estimated
- For example, what if I tell you go down Central Avenue 1.5 miles and turn left, what should you do?
- What if I said instead, go down Central Avenue 1.53 miles and turn left. How is that different?

Introduction to Measurements

Significant Figures

- For example you measure a distance with a tape and the point is somewhere between 34.2 ft and 34.3 ft.

- You estimate the distance as 34.26 ft.
- What is the significance of reporting a value of 34.26 ft

Introduction to Measurements

Significant Figures

- The answer obtained by solving a problem ***cannot*** be more accurate than the information used
- For example: If you measure two loads of concrete as 23.5 cubic yards (yd^3) and 31 yd^3, what is the an estimate of the total amount of concrete?

Introduction to Measurements

Significant Figures

36.00620	7 significant figures
10.2	3 significant figures
0.00304	3 significant figures

Introduction to Measurements

Significant Figures

- Zeroes between other significant figures ***are*** significant

23.07	1007
4 significant figures	4 significant figures

Introduction to Measurements

Significant Figures

- For numbers less than one, zeroes immediately to the right of the decimal place ***are not*** significant

0.0007	0.03401
1 significant figures	4 significant figures

Introduction to Measurements

Significant Figures

- Zeroes placed as the end of a decimal number ***are*** significant

0.700	39.030
3 significant figures	5 significant figures

Introduction to Measurements

Significant Figures

- When a number ends with one or more zeros to the left of the decimal, you must indicate the exact number of significant figures

420,000

How many significant figures?

Introduction to Measurements

Significant Figures

- When a number ends with one or more zeros to the left of the decimal, you must indicate the exact number of significant figures

$4.32\ (10)^5$ — 3 significant figures

$4.320\ (10)^5$ — 4 significant figures

Introduction to Measurements

Significant Figures - Mathematical Operations

- When two numbers are multiplied or divided, the answer should not have more significant figures than those in the factor with the least number of significant figures

$$\frac{3.25 \times 4.6962}{8.1002 \times 6.152} = 0.306$$

3.25: 3 significant figures; 4.6962: 5 significant figures; 8.1002: 5 significant figures; 6.152: 4 significant figures

Introduction to Measurements

Significant Figures - Mathematical Operations

- Typically you want to carry more decimal places in the your calculations and round-off the final answer to correct number of significant figures

$$3.25 \times 4.6962 = 15.3$$

3.25: 3 significant figures; 4.6962: 5 significant figures

Introduction to Measurements

Significant Figures - Mathematical Operations

- In addition and subtraction, the final answer should correspond to the column full of significant figures

```
     3.25
   103.2
 +  34.662
   -------
   141.112  →  141.1
```

Introduction to Measurements

Significant Figures - Mathematical Operations

- When the answer to a calculation contains too many significant figures, it must be rounded off.
- One way of rounding off involves *underestimating* the answer for five of these digits (0, 1, 2, 3, and 4) and *overestimating* the answer for the other five (5, 6, 7, 8, and 9).

Introduction to Measurements

Significant Figures - Mathematical Operations

- This approach to rounding off is summarized as follows:
- If the digit is smaller than 5, drop this digit and leave the remaining number unchanged.

Thus, 1.684 becomes 1.68

Introduction to Measurements

Significant Figures - Mathematical Operations

- This approach to rounding off is summarized as follows:
- If the digit is 5 or larger, drop this digit and add 1 to the preceding digit.

Thus, 1.247 becomes 1.25

Introduction to Measurements

Significant Figures - Mathematical Operations

- In addition and subtraction, the final answer should correspond to the column full of significant figures

```
   3.200
   0.4968
+ 24
  27.6968  →  28
```

Introduction to Measurements

Significant Figures - Mathematical Operations

- When measurements are converted into another set of units, the number of significant figures is preserved

39,456 ft^2 → 0.90579 acres

Introduction to Measurements

Significant Figures - Mathematical Operations

- There is a nice interactive practice on significant figures on the web at:

  http://www.teacherbridge.org/public/bhs/teachers/Dana/SigFigOperations.html

- Some other sites you might want to check out:

http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch1/sigfigs.html

http://www.chem.tamu.edu/class/fyp/mathrev/mr-sigfg.html

Introduction to Measurements

Repeated Measurements of a Single Quantity

- When a single quantity is measured several times or when a series of quantities is measured, random errors tend to accumulate in proportion to the square root of the number of measurements.
- This is called the ***law of compensation***.

$$E_{Total} = \pm E\sqrt{n}$$

Introduction to Measurements

Repeated Measurements of a Single Quantity

- If a distance is measured 9 time and the estimated error in each measurement is ±0.05 feet, what is the estimate of the total error?

$$E_{Total} = \pm E\sqrt{n}$$

$$E_{Total} = \pm 0.05ft\sqrt{9} \quad \boxed{= \pm 0.2\ ft}$$

Introduction to Measurements

Repeated Measurements of a Single Quantity

- A surveying crew or party is capable of taping distances with an estimated error of ±0.02 ft for each 100-ft distance. Estimate total error if a distance of 2,400 ft is measured?

$$E_{Total} = \pm E\sqrt{n}$$

$$E_{Total} = \pm 0.02ft\sqrt{24} = \boxed{\pm 0.1\ ft}$$

Introduction to Measurements

Repeated Measurements of a Single Quantity

- Surveyors typically measure a series of quantities: distance, angles, elevations, etc.
- A circle is made up of 360 degrees or 360°
  A degree is made up of 60 minutes => 1° = 60 '
  A minute is made up of 60 seconds => 1' = 60"

Introduction to Measurements

Repeated Measurements of a Single Quantity

- If an angle is measured ten time and the estimated error in each measurement is ±30 seconds, what is the estimate of the total error?

$$E_{Total} = \pm 30''\sqrt{10} = \pm 95''$$

$$\boxed{= \pm 1'\,35''}$$

Introduction to Measurements

A Series of Unrepeated Measurements

- When a series of measurements are made with probable errors of $E_1, E_2, \ldots, E_n$, then the total probable error is

$$E_{Total} = \pm\sqrt{E_1^2 + E_2^2 + \ldots + E_n^2}$$

Introduction to Measurements

A Series of Unrepeated Measurements

- What is the probable error for the perimeter of a square tract of land where the probable errors for each side are ±0.09 ft, ± 0.01 ft, ± 0.15 ft, and ± 0.42 ft

$$E_{Total} = \pm\sqrt{E_1^2 + E_2^2 + \ldots + E_n^2}$$

$$= \pm\sqrt{(0.09ft)^2 + (0.01ft)^2 + (0.15ft)^2 + (0.42ft)^2}$$

$$= \pm\sqrt{0.008ft^2 + 0.0001ft^2 + 0.023ft^2 + 0.18ft^2}$$

$$= \pm\sqrt{0.21ft^2} \quad \boxed{= \pm 0.46ft}$$

Introduction to Measurements

Any Questions?