VG100: INTRODUCTION TO ENGINEERING

Engineering Measurement & Engineering Report

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Preview

- Some basics
- Measurement uncertainty
- Engineering report

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Some Basics

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Significant Digits

- Engineering measurements are generally accurate to at most only a few digits.
  - Three digits of accuracy is considered "standard" for engineering analysis.
- The number of significant digits is defined as **the number of relevant or useful digits in a measurement**.
- The best way to illustrate is to write the number in standard exponential (scientific) notation instead of common real number (engineering) notation, and then count the number of digits.

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Example of Significant Digits

Common notation	Underlined notation	Exponential notation	# significant digits	Comments
134.2	134.2	1.342×10^2	4	just count the number of digits
0.0056	0.0056	5.6×10^{-3}	2	the leading zeroes are not significant
0.00506	0.00506	5.06×10^{-3}	3	the leading zeroes are not significant, but any zeroes between two numbers *are* significant
0.00560	0.00560	5.60×10^{-3}	3	the leading zeroes are not significant, but the trailing zeroes *are* significant
400	400	4×10^2	infinite	integer values have an infinite number of significant digits
400.	400	4.00×10^2	3	a decimal point (or underline) indicates that all digits to the left of the decimal point are significant, and that this is *not* an integer value
400.0	400.0	4.000×10^2	4	the zero to the right of the decimal point *is* significant
40,300.	40,300	4.0300×10^4	5	a decimal point (or underline) indicates that all digits to the left of the decimal point are significant, and that this is *not* an integer value
40,300	40,300	403×10^2	infinite	integer values have an infinite number of significant digits; do not use a decimal point when writing an integer in exponential notation
400 (to 2 significant digits)	400	4.0×10^2	2	words in parenthesis are necessary to indicate a smaller number of significant digits in common notation whenever trailing zeroes are present

Examples of Significant Digits

Number	No. of Significant Digits	Reason
9.835		
0.0098		
0.00980		
9800		
9800.		
9800.00		
9.800×10^3		
98×10^2		

Example of Significant Digits

When performing multiplication or division calculations, the answer has the same number of significant digits as the component with the least number of significant digits.

Problem:

A force of 9.753 N is measured, and it is applied to a mass of 3.35 kg so as to accelerate this mass. Calculate the acceleration.

Solution:

Use Newton's second law, i.e. F = ma, and solve for the acceleration

Rounding Off Values

- There are standard rules for rounding off values to a desired number of significant digits.
- First, the number is truncated to its desired length. Then, the excess (leftover) digits are examined as if they were a decimal fraction:
  - If the decimal fraction is less than 0.5, truncate the excess digits.
  - If the decimal fraction is greater than 0.5, round up the least significant digit in the number by one.
  - If the decimal fraction is equal to 0.5, the convention is to round up if the least significant digit is odd, and to truncate (round down) if the least significant digit is even.

Examples of Rounding Off Values

Round off the following numbers to <u>three significant digits</u>

653,338	653,000 => **6.53 x 10^5**	Round down since < 0.5
653,538	654,000 => **6.54 x 10^5**	Round up since > 0.5
653,500	654,000 => **6.54 x 10^5**	Round up since 3 is odd and = 0.5
654,500	654,000 => **6.54 x 10^5**	Round down since 4 is even and = 0.5

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Rounding Off Values

- When performing addition or subtraction, the number of significant digits is determined by **the leftmost decimal column that contains a least significant digit**.
- The best way to add or subtract numbers is to align the decimal point, and highlight the leftmost significant digit.
- Example: 12.18 + 0.09672

$$\begin{array}{r} 12.18 \\ +\ \ 0.09672 \\ \hline 12.27672 \end{array}$$

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Questions in Engineering Measurement

What is the problem?
How accurately do we need to know the answer?
What physical principles are involved?(physical law)
What experiment might provide the answer?
What variables must be controlled? How well?
what quantities must be measured? How accurately?
What instrumentation is to be used?
How many data points must be taken? What order?
What data analysis techniques?
Can the requirements be satisfied within the budget and time?
What is the most effective and revealing way to present data?
What unanticipated questions are raised by the data?

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There's no such thing as a perfect measurement!!

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Practical Considerations

- Record the information of the test equipment used (vendor, model number, serial number, calibration records, etc)
- Check performance of measurement devices (e.g., measuring range)
- Check that all planned runs are feasible (supply of materials, time, equipment availability, resources)
- Preserve all the raw data
- Record everything that happens (traceable if problems arise afterwards)
- Restore equipment to its original state after the experiment
- Consider other factors such as cost, schedule, personnel

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Types of Measuring Processes

- Direct Measurement
  - Human sensing is feasible or possible.
  - Use a standard to ‘compare’ with the object of interest.
  - Examples are:
    - Scale (mass)
    - Ruler or Caliper (length)
    - Rotameter (flow)

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Types of Measuring Processes

- Indirect (or Calibrated) Measurement
  - Human sensing is not feasible.
  - Make use of some form of ‘transducing’ device coupled to a chain of apparatus.
  - Requires some form of calibration
  - Examples are:
    - Thermocouple (temperature)
    - Strain gage (displacement)
    - Pressure transducer (pressure)

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Accuracy vs. Precision

- **Accuracy**
  the closeness of agreement between a measured value and the true value.
- The accuracy error of a reading (which may also be called ***inaccuracy*** or ***uncertainty***):
  bias + precision errors.

- **Precision**
  characterizes the random error of the instrument’s output.
- Precision error (of one reading) is defined as the difference between the reading and the average of readings.

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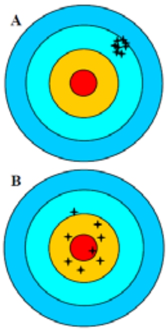
Accuracy vs. Precision



A and B, shoot guns at targets. Both people shoot eight times. Each plus sign marks the spot where a bullet hits the target. What can you say about their shootings?

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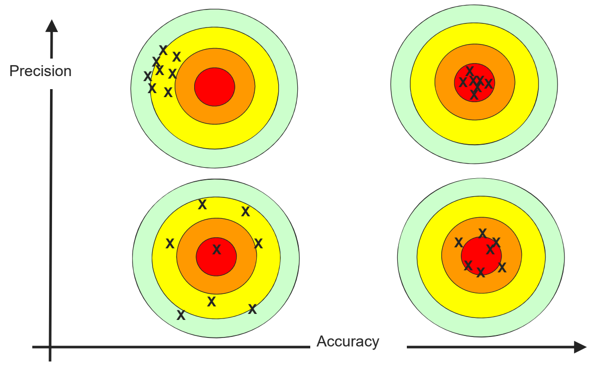
Accuracy vs. Precision



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Resolution

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Instrument Resolution

- Smallest Change or increment in the measured quantity that the instrument can detect
- For analog instruments, resolution is usually associated with the division displayed in the scale; a good rule is to use **½ of the smallest scale**
- For digital instruments, resolution is usually associated with the number of digits displayed on the output. For example, a voltmeter with 5 digits has better resolution than one with 4 digits. For digital instruments, use **½ of the last digit** as the resolution. (sometimes not a good estimate, so you need to use your own judgment.)
- Be careful – an instrument can be very precise, but not very accurate, and vice-versa. **A high-resolution instrument may be neither precise nor accurate**!

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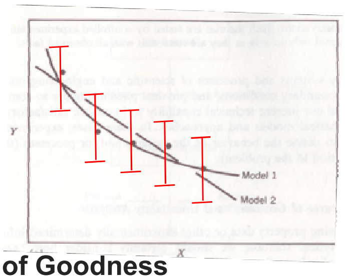


Degree of Goodness

Uncertainty analysis

Experimental Errors

Experimental Errors

Systematic (Bias) Errors	Random (Precision) Errors
• **Consistent, Repeatable**	• **Inconsistent, Unrepeatable** • The most common sign of random errors is scatter in the measured data.

Examples of Systematic (Bias) Errors

- **Calibration errors** – perhaps due to nonlinearity or errors in the calibration method.
- **Loading or intrusion errors** – the sensor may actually change the very thing it is trying to measure.
- **Spatial errors** – these arise when a quantity varies in space, but a measurement is taken only at one location (e.g. temperature in a room - usually the top of a room is warmer than the bottom).
- **Human errors** – these can arise if a person consistently reads a scale on the low side.
- **Defective equipment errors** – these arise if the instrument consistently reads too high or too low due to some internal problem or damage (such as our defective ruler example above).

Overall uncertainty in a Measurement

•Precision error P
•Systematic error B

Two methods in ANSI/ASME standard

1. Combination by root-sum-square (RSS) $U_X = \left[B^2 + P_X^{\,2}\right]^{\frac{1}{2}}$
2. Combination by straight addition (ADD) $U_X = B + P_X$

- data and results presented with their uncertainty, precise logic, relevance to practice described, and with actual accomplishments of the work plainly stated and honestly appraised.

Engineering Report

Text

- No vague words
- Clear, concise, complete
- State facts instead of your own imaginations.

Engineering Report

Illustrations

- Efficient (no need to be fancy)
- Show important information… don't show unnecessary details
- Free of all nonessential lines and lettering
- Can be easily interpreted by the reader
- *Use your own one…*

Introduction

Background

- The context of the work
- Some related fundamental theories

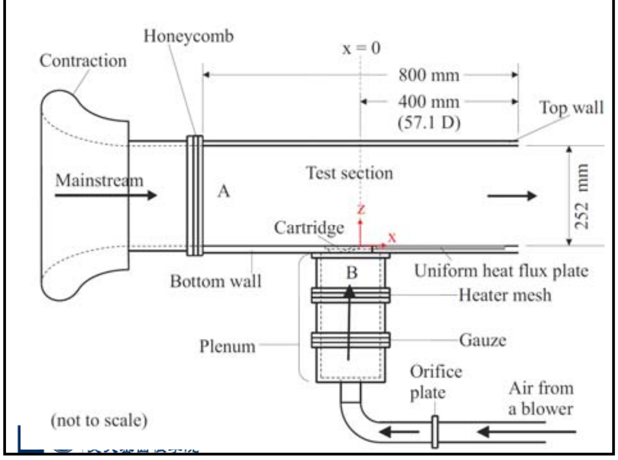
Objectives

- Objective 1: Design an efficient fan ….
- Objective 2: Evaluate fan cooling performance …
- Objective 3: A specific objective for your follow-up project (the second report)….

Report Structure

System Design and Assembly

- A schematic diagram of your overall system
- Key components function and technical information
- Design procedure and the theory behind.
- Readers should be able to re-create your system based on your write-up



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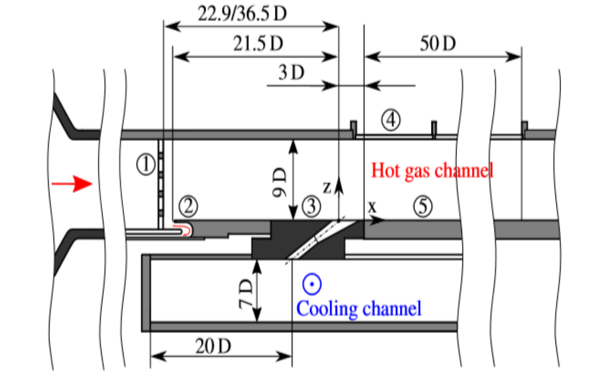

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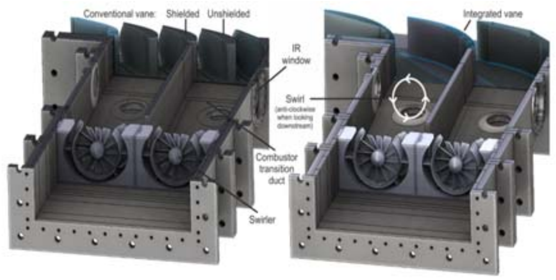

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Good practices:

- Label font size not excessively smaller or larger than the text font size
- If an image (and often a figure) were to be scaled, do so without changing its aspect ratio.
- Use color schemes but do not be too fancy or arty for an engineering report!

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Measurement Results and Discussion

- Assess critically what your results mean
- What design implication they might have to the engineering community
- Whether they make sense according to what you learned from the engineering lectures
- Do not simply repeat in words what is obvious from your figures and tables.

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Good practices:

- “Design” your figure concisely
- Use markers, line types, colors and labels (encouraged)/legend (convenient) to distinguish between different sets of data on the same figure.
- Plots generated by Excel using its default settings are universally ugly! Spend time to edit or try Matlab.

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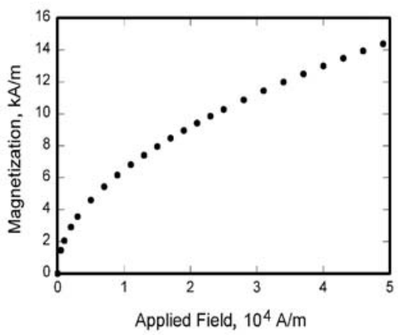

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Review

- Some basics
- Measurement uncertainty
- Engineering report

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