ChemE 436: Course objectives

- To develop or expand upon your:
  - Understanding of fundamental chemical engineering concepts
  - Experimental skills
  - Ability to function as a team
  - Technical writing skills
  - Oral presentation skills

- Specifically, you will:
  - Learn to deal with open-ended team assignments
  - Plan and execute safe and efficient experiments
  - Analyze and interpret experimental data using statistics
  - Make appropriate conclusions and recommendations
  - Write persuasive technical reports and give effective talks

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Expectations

- Be on time
- Make full use of the lab sessions (replicate, replicate, replicate)
- Behave professionally
- Learn to deal with team dynamics and other issues
- Fulfill all requirements
  - Planning reports
  - Oral reports
  - Written reports

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Grading

- The class will be divided in teams of 3 students
- Each team will perform 3 different experiments
- Grade will be assigned as follows:
  - Planning Report (team) 60 (leader) / 20(teammates)
  - Oral report (individual) 60 (leader) / 0 (teammates)
  - Final Written report (team) 80 (leader) / 30 (teammates)

  - Maximum possible: 300 pts (60 + 60 + 80 + [2 x 20] + [2 x 30])

Experiment	Planning report	Oral report	Final report
1	a	b	c
2	b	c	a
3	c	a	b

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Things to keep in mind

- Be there
  - There are no make up provisions
  - You will need to attend all oral presentations
- Don't be late
  - Any late report is penalized at -10% per 24h
- There are no revisions
  - Make sure you do your best the first time around
- Grades will be normalized for variability in TA grading
  - Target mean 75 +/- 15
- Make sure that you do not fall 2 x SD below the mean

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Plagiarism

- Acceptable:
  - Working and consulting with team members
  - Discriminate use of the web and other references to find equations, theory, data, experimental ideas, etc.
  - Using material produced by one of your teammates

- Not acceptable:
  - Using material produced by another team
  - Copying text from references and passing it as your own
  - Copying any part of previous reports
  - Letting your teammates do all the work
    - Talk to Prof. Baneyx if needed

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Personal protection

- Google/safety glasses with side protection windows must be worn *at all times*
  - We have a limited number of loaners available on a first come first serve basis but they may be scratched and damaged
  - Consider buying a pair at a hardware store
- Wear long pants or long skirts
- No open toe shoes
- Available safety equipment in BNS35 includes:
  - Eyewash station
  - MSDS and lab safety book
  - Spill kits
  - Fire extinguisher

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Other considerations

- No food or drinks in the lab
- Dispose of chemicals by approved methods only
- Dispose of sharps in designated red sharp containers
- Avoid loose fitting clothing around rotating machinery
- Shut down equipment on time; leave safe and clean
- Save 10 min on the end of each second lab to sketch the next experiment
- No lab access outside your scheduled class time
- Do your own background research and cite your own sources
- Writing centers are available:
  - Odegaard Writing Center (http://depts.washington.edu/owrc/)
  - Center for Learning and Undergraduate Enrichment (http://depts.washington.edu/clue/dropintutor_writing.php)

http://faculty.washington.edu/baneyx/436/Info.html

In practice

- Step by step guide

  http://faculty.washington.edu/baneyx/436/Step_by_step.html

- Experimental schedule

  http://faculty.washington.edu/baneyx/436/Lab_schedule.html

- Reference material

  http://faculty.washington.edu/baneyx/436/Reference.html

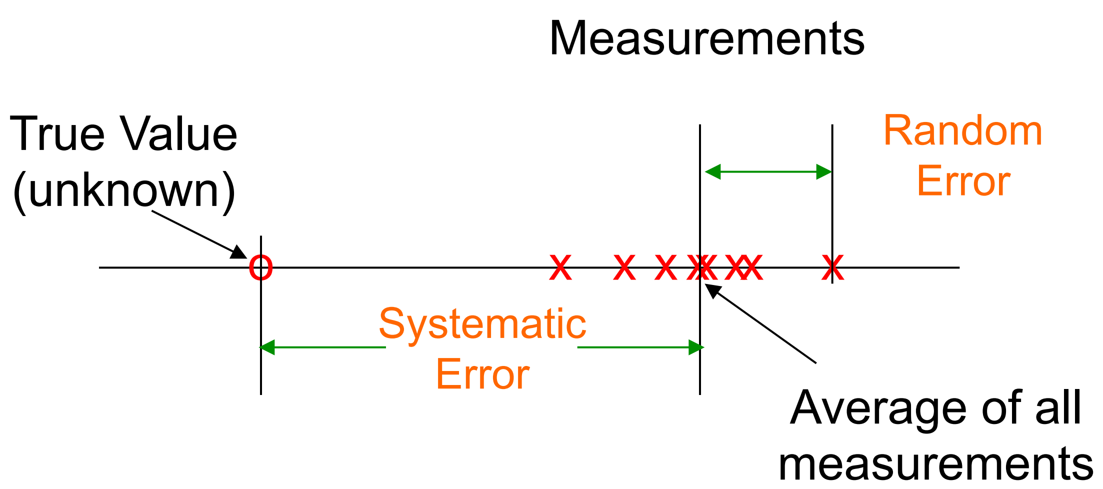
Uncertainty

- Reported values of physical quantities have little value without a statement of uncertainty
  - Average age is 30 – What is the sample size?
  - f = 0.4732751 at Re = 100 – How confident am I in this number?
  - f = 0.47 ± 0.03 provides much more information

- Assessment of uncertainty requires:
  1. A determination of the internal consistency of the data (replicates)
  2. A critical analysis of the experimental design (improvements)
  3. A knowledge of the instruments range and limitations
  4. An analysis of how the error in measured quantities is propagated into final *calculated* results

Types of errors

- Two types: random (precision) and systematic (bias)



Random errors

- "Scattering" in data caused by random variables
- Can be quantified statistically
- Not due to faulty calibration but caused by:
  - Inability to discriminate between readings (e.g., manometer)
  - Environmental fluctuations (e.g., vibrations)
  - Variation in electrical field (e.g., pumps)
  - Instrument dead band and hysteresis
  - Analog to digital conversion
- How to reduce random errors?
  - Improve instrument
  - Improve experimental environment (vibrations, temperature, etc)
  - Increase the number or measurements

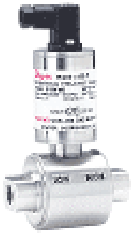
Systematic errors

- Even if randomness is eliminated by taking an infinity of measurements, the measured value may still differ from the "true" value
- These systematic errors are due to:
  - Flawed experimental technique
  - Characteristic of an instrument and how it is used
- Examples:
  - Calibration errors (rotameter, orifice, thermocouples)
  - Uncompensated instrument drift
  - Leakage of materials
  - Incomplete fulfillment of assumed conditions (e.g., steady state, 1D problem…)
  - Consistent operator error (e.g., parallax)
- How to reduce random errors?
  - Pay close attention to experimental details (instrument capabilities and limitations, data collection process and experimental design)

Instrument characteristics

Dwyer Series 450
Carbon Monoxide Monitor

Range: 0-2000 PPM.
Resolution: 1 PPM.
Accuracy: (using 2000 PPM calibration gas) ±3% of reading, ± the accuracy of the calibration gas.
Response Time: <30 seconds to 90% of reading.
Operating Temperature: 32 to 104°F(0-40)°C).
Humidity Conditions: 0-90% Relative Humidity Non Condensing.
Adjustments: Zero and Span via keypad.



Pressure Range: 5.0 inches w.c.d. (1.24 kPa).
Maximum Working Pressure: 6.89 Bar.
Output Signals: 4-20 mA.
Zero Output: 4 mA.
Span: 16 mA.
Performance @ 70ºF (21.1ºC)
Accuracy: ±0.5% Full Scale (non-linearity, hysterisis, nonrepeatability).
Stability: ±1%/year.
Warm-up Time: 10 minutes.
Operating Temperature: 5 to 50ºC.
Temperature Effects: 0.025%/ºF.

Instrument characteristics

- Range
- Accuracy
- Sensitivity
- Linearity
- Detection limit (threshold)
- Resolution
- Hysteresis and dead band
- Impedance

Input: bounds for measurements
Output: bounds for sensor/transmitter output
Span: difference between upper and lower limits
Zero: lower limit of range

Example: digital thermometer

Input range → -10 to 110^{o}C

Output range (transmitter)→ 4 - 20 mA

Input span → 120^{o}C

Output Span → 16 mA

Input Zero →-10^{o}C

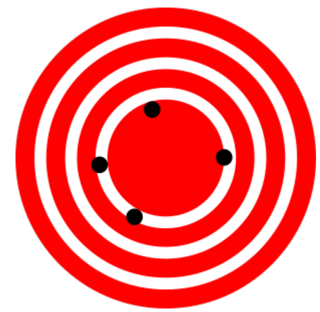
Output Zero →4 mA

Instrument characteristics

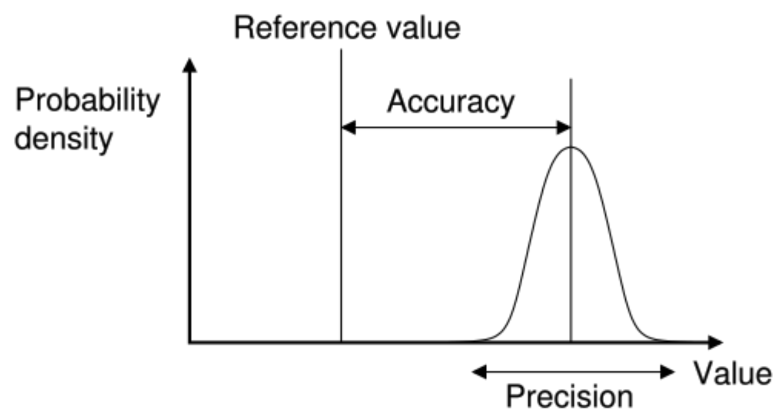
- Range
- **Accuracy**
- Sensitivity
- Linearity
- Detection limit (threshold)
- Resolution
- Hysteresis and dead band
- Impedance

Nearness to the "true" value. Unrelated to precision which is a measure of internal consistency

High Precision
Low Accuracy



Low Precision
High Accuracy



Instrument characteristics

- Range
- Accuracy
- **Sensitivity**
- Linearity
- Detection limit (threshold)
- Resolution
- Hysteresis and dead band
- Impedance

Change in output over change in input

Example: Hg vs H_2O manometer

Hg manometer provides a 760 mm change over 101 kPa

Sensitivity = 760/101 = 7.52 mm/kPa

H_2O manometer provides a 13.5 mm change over 7.52 kPa

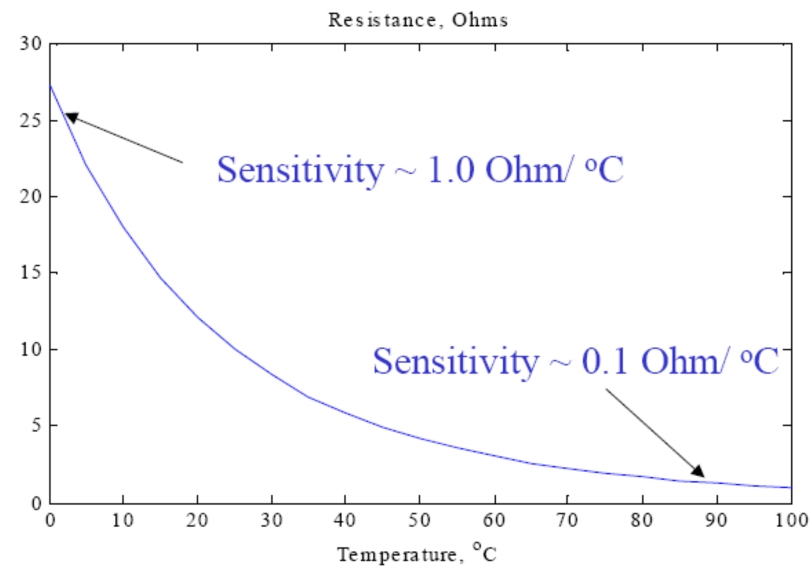
Sensitivity = 13.5/7.52 = 102 mm/kPa

Instrument characteristics

- Range
- Accuracy
- Sensitivity
- **Linearity**
- Detection limit (threshold)
- Resolution
- Hysteresis and dead band
- Impedance

Proportionality of output to input

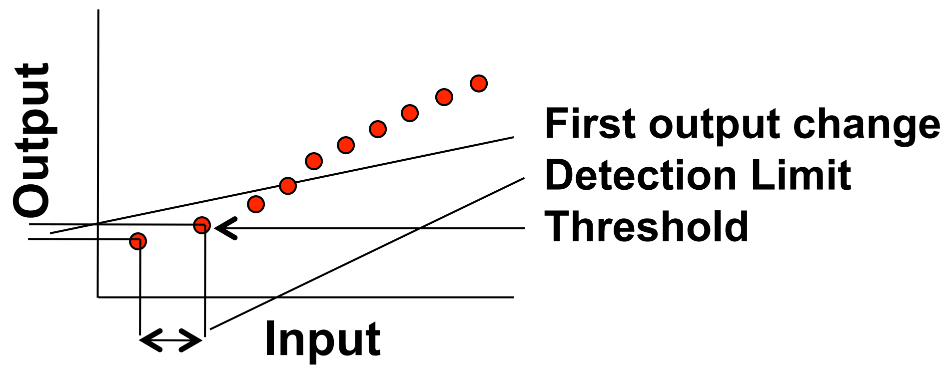
Radio Shack 271-110 thermistor



Instrument characteristics

- Range
- Accuracy
- Sensitivity
- Linearity
- Detection limit (threshold)
- Resolution
- Hysteresis and dead band
- Impedance

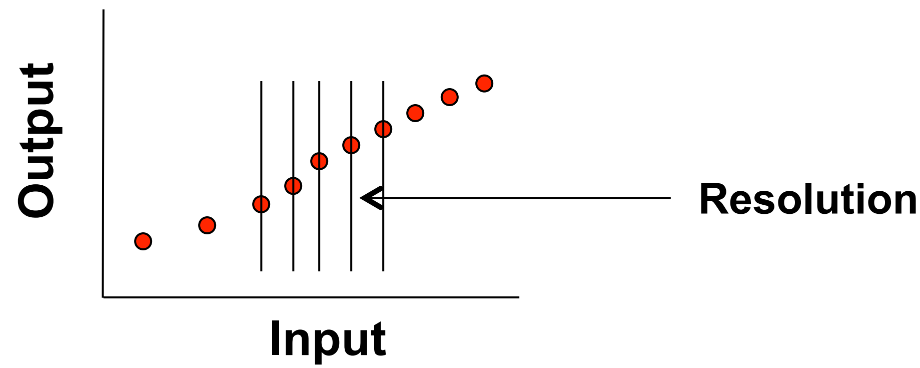
Smallest detectable change in measurement in the low end of range



Instrument characteristics

- Range
- Accuracy
- Sensitivity
- Linearity
- Detection limit (threshold)
- **Resolution**
- Hysteresis and dead band
- Impedance

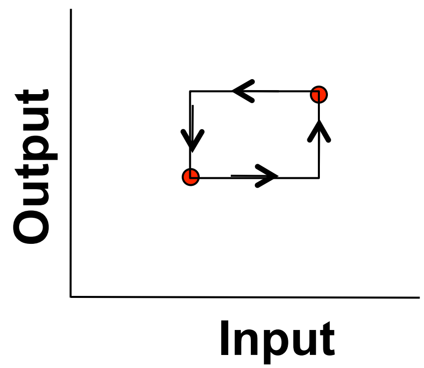
Smallest detectable change over the full range of measurements

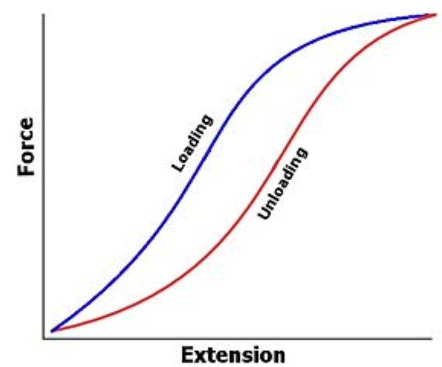


Instrument characteristics

- Range
- Accuracy
- Sensitivity
- Linearity
- Detection limit (threshold)
- Resolution
- **Hysteresis and dead band**
- Impedance

Dead band: region where there is no effective response





Hysteresis: retardation of an effect upon induced change

Instrument characteristics

- Range
- Accuracy
- Sensitivity
- Linearity
- Detection limit (threshold)
- Resolution
- Hysteresis and dead band
- Impedance — A measure of the opposition to current in an AC circuit