Factors Effecting Instrument selection

Selecting the right instrument is crucial for obtaining accurate, reliable, and meaningful results in any measurement process. Whether in scientific research, industrial applications, or healthcare, understanding the factors that influence this decision can optimize efficiency and ensure proper data acquisition. Below, we discuss the key factors with relevant examples.

1- Accuracy

Its represent how closeness with which an instrument reading approaches the true value of the variable being measured. The deviation of the measured value from the true value is the indication of how accurately reading has been made.

In calibration management accuracy is the first step in determining whether a measurement is good or bad, as it indicates how close a measurement is to its actual value. If you're measuring something with an inaccurate tool, then your results will be incorrect too!

Accuracy is "the degree to which the result of an observation corresponds with its true value".

Accuracy depends on several factors including:

The precision with which you take your measurements (i.e., how consistently they're repeated)

The accuracy of your measuring instrument (i.e., how well-calibrated it is).

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2- Precision

It's specified the repeatability of a set of reading each made independently with the same instrument.

An estimate of precision is determined by the deviation of different reading from the mean (average) value.

In metrology, precision refers to how well your results agree with each other when you repeat them over time or with different people doing them at different times (inter-observer variability). Precision is the closeness of agreement among multiple measurements. It's a measure of how reproducible your measurements are and can be calculated as:

Repeatability + Reproducibility = Precision

The precision of a measurement system is an indication of its ability to make repeatable and accurate measurements. It does not matter whether these results agree with some external standard; what matters is whether they agree with each other consistently enough so that if someone gets slightly different results from yours because they used slightly different equipment or did things differently somehow then those differences will cancel out when comparing your results against each other rather than adding up together (intra-observer variability).

For example, if you weigh yourself with a scale and get one reading of 150 pounds on Monday morning, and then another reading of 152 pounds on Tuesday afternoon; this would be an example of poor precision because there was not much agreement between your two weights.

- **We calculate the standard deviation to evaluate the precision.**

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Example 1:

To detect the deference between accuracy and precision of measurement for some voltage, we see the following cases:

i) V=6Volt (true or theoretical value) V=5.8Volt (measured or practical value) This instrument is accurate

ii) V=6Volt (true or theoretical value) V=4.8Volt (measured or practical value) This instrument is not accurate

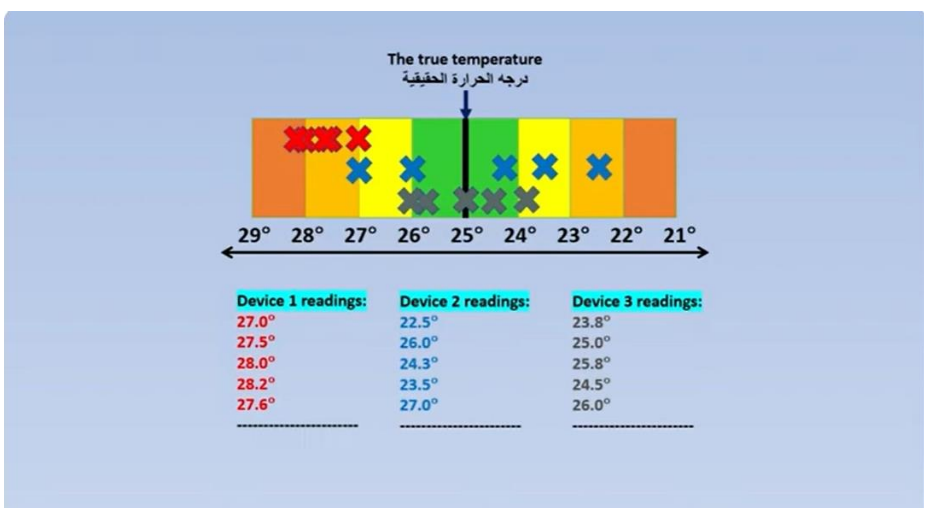
iii) V=6Volt (true or theoretical value) V=5.8Volt (measured or practical value) When we try to check the reading, we measured it again and again, and get the following results: second measure for the same reading equal V=5.8Volt, third measured V=5.8Volt, forth measured V=5.8Volt and so on.

This instrument is accurate and precise.

iv) V=6Volt (true or theoretical value) V=4.8Volt (measured or practical value) We try to check the reading, we measured it again and again, and get the following results: second measure for the same reading equal V=5Volt, third measured V=4.6Volt, forth measured V=5.2Volt and so on.

This instrument is not accurate and not precise.

Example 2:



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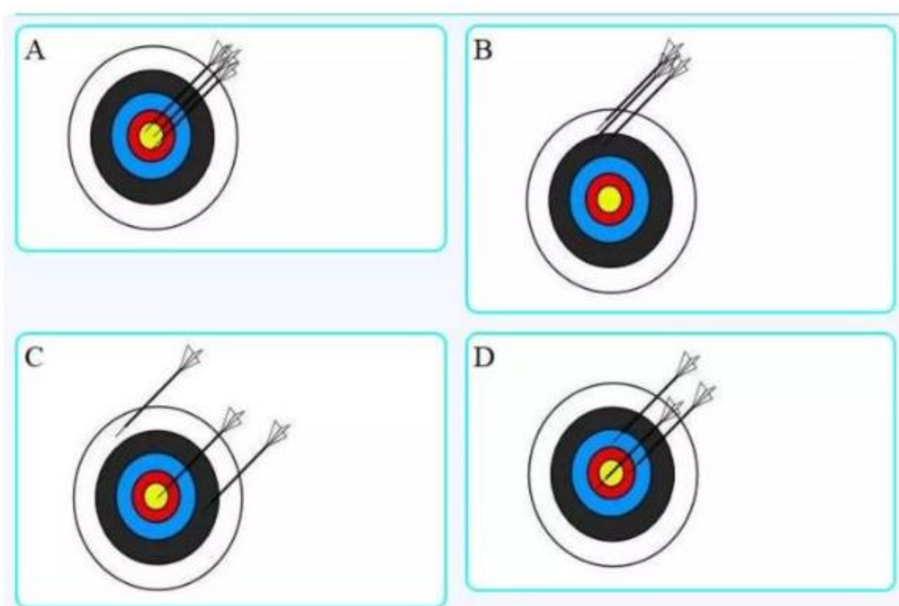
Q1 :Based on the data provided, which device has the highest accuracy in measuring the true temperature? Explain your reasoning.?

Q2: Which device show the highest precision in its readings? Support your answer with evidence from the chart.?

Q3: if the true temperature is 25°C, which device is the least reliable in terms of both accuracy and precision? Why?

Example 3:

1. Which one of the following shows low accuracy and low precision?



3. Resolution

Resolution is the smallest change in a quantity that can be detected by an instrument. It is often expressed as the ratio of the minimum resolvable distance to its least count value.

In any measurement, all digits except the last are called certain numbers. The last digit is an estimate and can vary, this is called an uncertain number. When making measurements, you should record all certain numbers plus the first uncertain number. Generally, the resolution of a device indicates the decimal place in which your uncertain number goes.

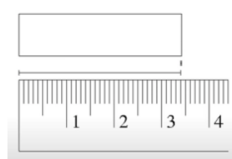
The easiest way to determine the uncertain place is to identify the smallest increment on the device and divide it by two.

- **When taking measurements, always record:**

All certain numbers, and

The first uncertain number, which represents the resolution of the instrument.

- A **ruler** with 1 mm markings can only detect changes as small as 1 mm. Its resolution is **1 mm**



- A **digital scale** that shows weight to 0.1 grams can detect changes as small as 0.1 grams. Its resolution is **0.1 g**

- **The better the resolution, the smaller the changes the instrument can detect. For example:**

  A ruler with 0.1 mm markings has better resolution than one with 1 mm markings.

4. - Range

Range is the region or interval enclosed by the minimum and maximum values that a particular instrument can measure for a given quantity. It defines the operational limits of the instrument

Examples of Range:

Thermometer:

A typical thermometer might have a range from -10°C to +50°C.

This means it can measure temperatures only within these limits.

Weighing Scale:

A scale might have a range from 0 kg to 100 kg.

Any weight outside this range cannot be accurately measured.

Voltmeter:

A voltmeter might have a range of 0 to 250 volts.

It is only designed to measure voltages within this limit.

Why is Range Important?

To avoid overloading or damaging instruments: Using a device outside its range can lead to errors or physical damage.

To choose the right instrument: Understanding the range helps in selecting an instrument that suits your measurement needs.

5. span

The term span in the context of measurement systems refers to the algebraic difference between the upper and lower limits of a range. It essentially defines the total range of measurement that an instrument can handle.

for example, if a voltmeter measures from 0 to 10 volts, the span is calculated as:

Span=Upper limit−Lower limit=10−0=10 volts

If the voltmeter measures from -10 to +10 volts, the span is calculated as

Span=10−(−10)=20 volts

This means the second voltmeter has a range of 20 volts, which is twice as large as the first.

6. Loading effect

The loading effect occurs when the operation of a measuring instrument alters the parameters, characteristics, or behavior of the circuit being measured. This happens because the instrument draws energy or interacts with the circuit, affecting its original state

For example:

- **Voltage Measurement: When a voltmeter with low input resistance is connected across a circuit, it can draw significant current. This reduces the voltage across the circuit and leads to inaccurate measurements.**
- **Current Measurement: An ammeter with high internal resistance can introduce additional resistance into the circuit, altering the current flow.**

How to Minimize the Loading Effect

1. **Use High-Resistance Instruments: For voltage measurements, instruments with high input impedance reduce current draw and maintain circuit integrity.**
2. **Use Low-Resistance Instruments: For current measurements, instruments with low internal resistance minimize their impact on the circuit.**
3. **Choose Proper Instruments: Ensure that the instrument is appropriate for the circuit's parameters to minimize interaction.**

The loading effect can significantly impact measurement accuracy, especially in sensitive or low-power circuits.

7. Sensitivity

Sensitivity represents the ability of an instrument to detect and respond to small changes in the input signal. It is defined as the ratio of the output signal to the corresponding change in the input signal.

Explanation:

- **A highly sensitive instrument will produce a significant output change for a small change in input.**
- **A less sensitive instrument will show minimal output changes for the same input variations.**

Examples:

1. **A thermometer that shows a 1°C change for every 0.1°C increase in temperature has higher sensitivity than one that changes only 0.5°C for the same temperature increase.**
2. **In an electronic system, a voltmeter that displays a voltage change of 0.01V for every 1mV input change is more sensitive than one that changes by 0.1V.**

Importance of Sensitivity:

- Precision: High sensitivity is crucial in applications requiring precise measurements of small variations.
- Suitability: Sensitivity must be matched to the application; overly sensitive instruments can produce noise or instability, while insufficient sensitivity can result in unnoticeable changes.

8. Error

Error is the deviation of the measured value from the true or actual value. It represents the inaccuracy introduced during the measurement process due to various factors.

Mathematical Expression:

Error=Measured Value−True Value

Example:

If the true value of a resistor is 100Ω and the measured value is 98Ω, the error is:

Error=98−100=−2Ω

Importance of Understanding Error:

- Accuracy Assessment: Helps in determining the reliability of measurements.
- System Improvement: Identifying error sources enables optimization of instruments and methods to minimize inaccuracies.
- Error Analysis: Necessary for scientific experiments, engineering designs, and quality control processes.