# Measurements

IB PHYSICS | SCIENCE SKILLS

# Two Types of Observations

*Define these types of observation data*

| | |
|---|---|
| Quantitative | |
| Qualitative | |

# Measurement

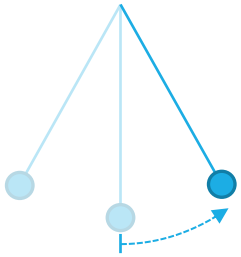
How can you **quantify** a measurement?

# Systems and Units

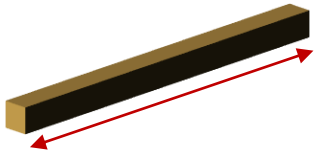
## Fundamental S.I. Units:

| | | |
|---|---|---|
| Length | | |
| Mass | | |
| Time | | |
| Electric Current | | |
| Temperature | | |
| Amount of Substance | | |
| Luminous Intensity | | |

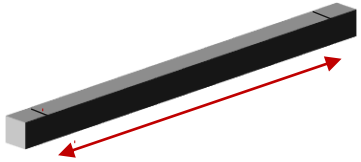
# Units are Arbitrary (but have a defined standard)



**1790** - The length of a pendulum that swings half of its maximum distance in one second



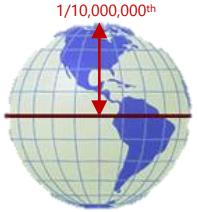
**1795** - The length of an official bar of brass fabricated to be exactly one meter as determined in 1791



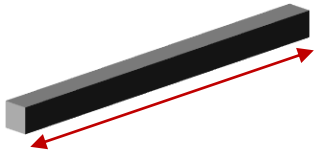
**1889** – The distance between two lines on an official bar of platinum-iridium alloy, measured at 0°C

Take the history of the meter…

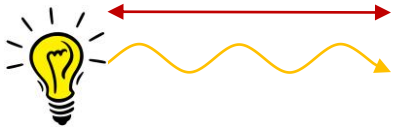
**1791** - The length of one ten-millionth of the distance between the North Pole and the equator




**1799** - The length of an official bar of platinum, measured from the brass bar and stored at the French National archives



**1983** – The length traveled by light in a vacuum during 1/299,792,458 of a second



# Precision/Accuracy

**Precision:** The degree of exactness in a measurement

**Accuracy:** The closeness of a measured value to the standard


☐ Precise
☐ Accurate


☐ Precise
☐ Accurate


☐ Precise
☐ Accurate


☐ Precise
☐ Accurate

# Example IB Question

**2.** Which of the following is a valid statement?

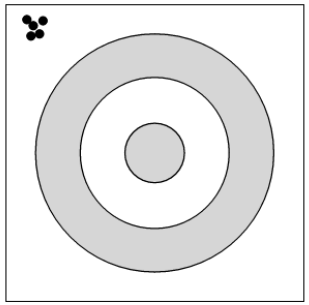
A. A measurement that is not precise can be accurate.

B. A measurement that is precise is always accurate.

C. A measurement that is not precise will always be inaccurate.

D. Repeated measurements will always increase accuracy and precision.

**2.** An archer aims five arrows at the centre of a target. The arrows strike the target as shown below.



Which of the following describes the aim of the archer?

A. Accurate and precise

B. Accurate but not precise

C. Precise but not accurate

D. Neither accurate nor precise

# Uncertainty

Every digital tool has built-in rounding so we need to present an uncertainty range that captures the “true” measurement


100 g ±


99.998 g ±

# Report these Measurements!

# Three ways to Report

$2.0 \pm 0.3$ g

| | |
|---|---|
| Absolute Uncertainty | |
| Fractional Uncertainty | |
| Percentage Uncertainty | |

# Three ways to Report


| | |
|---|---|
| Absolute Uncertainty | |
| Fractional Uncertainty | |
| Percentage Uncertainty | |

# Example IB Question

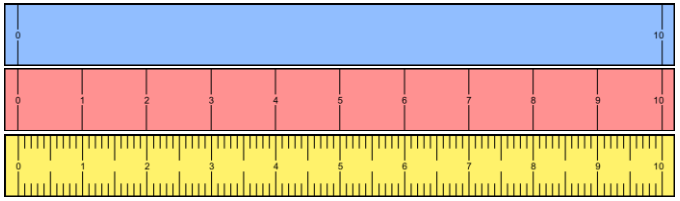
**1.** The current in a resistor is measured as 2.00 A ±0.02 A. Which of the following correctly identifies the absolute uncertainty and the percentage uncertainty in the current?

| | Absolute uncertainty | Percentage uncertainty |
|---|---|---|
| A. | ±0.02 A | ±1 % |
| B. | ±0.01 A | ±0.5 % |
| C. | ±0.02 A | ±0.01 % |
| D. | ±0.01 A | ±0.005 % |

**Absolute:** **Percent:**

# What if its Analog?

Analog tools require you to measure to one decimal beyond the increment and the uncertainty is half the increment size



| | |
|---|---|
| **Blue** | |
| **Pink** | |
| **Yellow** | |

# Significant Digits

How many significant digits?

| | |
|---|---|
| 3.45 cm | 3 |
| 226.5 cm | 4 |
| 2.50 cm | 3 |
| 0.025 cm | 2 |
| 12060 m | 4 |
| 0.0000250 km | 3 |
| 25.0 mm | 3 |
| 25000 mm | 2 |
| $2.50 \times 10^4$ mm | 3 |

1. Count the numbers
2. Zeros only count if there is a decimal and they are to the right of other non-zero numbers

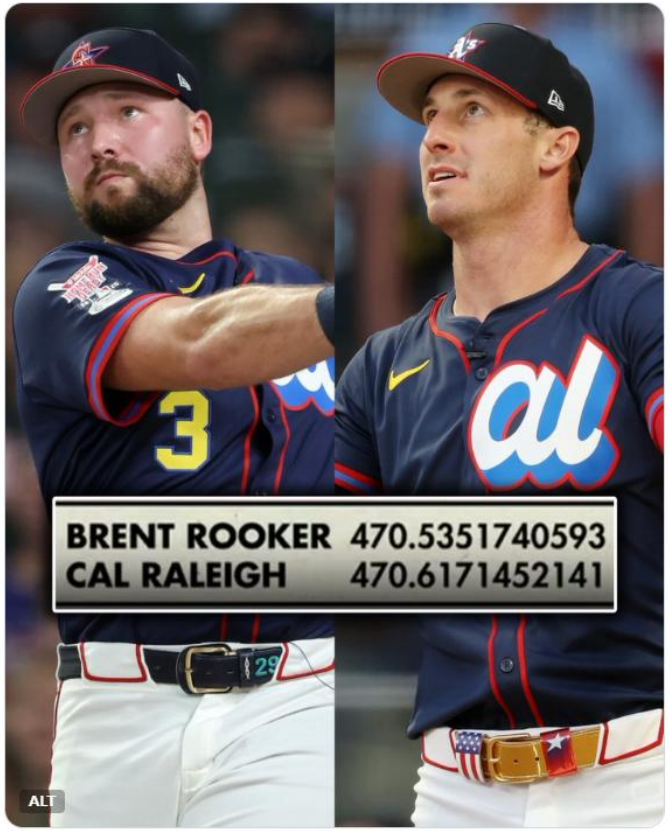
**Recommendation for IB Exam:**
Round all answers to 3 sig figs unless otherwise stated

**IB will give full credit as long as your answer is within 1 sig fig*

# Precision in the “Real World”

**MLB** ✓
@MLB

Cal Raleigh advanced by LESS THAN 0.1 FEET 🦁

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**Ryan M. Spaeder** ✓
@theaceofspaeder

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According to this graphic, MLB can measure distance down to 1.2 ten-billionths of an inch.

This is approximately 2.54 picometers

As 1 inch = 25.4 mm and 1 mm = 10^9 nm

1/12,000,000,000 inch ≈ 2.54 × 10^-12 meters = 2.54 pm

For some perspective, the diameter of an oxygen molecule is 292 pm, or 114.96 times larger than what MLB can supposedly measure with statcast.

A single oxygen atom, though, is only 59.84 times large than this supposed measurement.

Now, because I am a loser, and I hate being lied to, I have done some research...

To measure something that small, between 1–10 picometers, one would require either Atomic Force Microscopy or X-ray Crystallography, which, to the best of my knowledge, are used to study differences between cancer cells and healthy cells, create designer drugs, or improve materials for technology by revealing details about atoms and molecules.

More precisely, they would need something like Scanning Tunneling Microscopy, which can detect how much atoms wiggle. Again, using oxygen as our example, this is between 2-3 picometers—look at that! MLB's 2.54 pm accuracy falls right in there!

# Lesson Takeaways

- ❑ I can describe the difference between quantitative and qualitative measurements
- ❑ I can list the 7 fundamental SI units
- ❑ I can define precision and accuracy
- ❑ I can calculate absolute, fractional, and percent uncertainty for digital and analog measurements
- ❑ I can determine the number of significant digits in a measurement