Measurements

IB PHYSICS | SCIENCE SKILLS

Two Types of Observations

Define these types of observation data

Quantitative	"How Many" / "How Much" Numerical
Qualitative	Description

Measurement

How can you **quantify** a measurement?

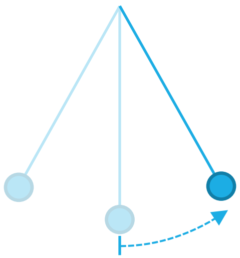
Systems and Units

Fundamental S.I. Units:

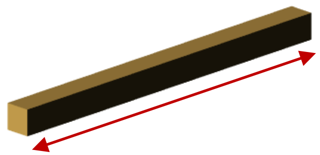
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric Current	Ampere (amp)	A
Temperature	Kelvin	K
Amount of Substance	Mole	mol
Luminous Intensity	Candela	cd

Units are Arbitrary (but have a defined standard)

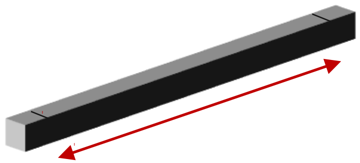
Take the history of the meter…



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

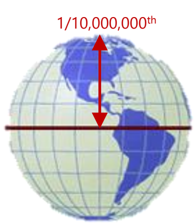


1795 - The length of an official bar of brass fabricated to be exactly one meter as determined in 1791

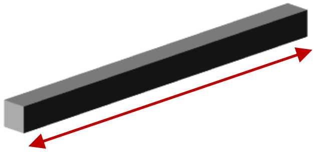


1889 – The distance between two lines on an official bar of platinum-iridium alloy, measured at 0°C

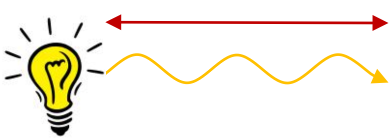
1791 - The length of one ten-millionth of the distance between the North Pole and the equator



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



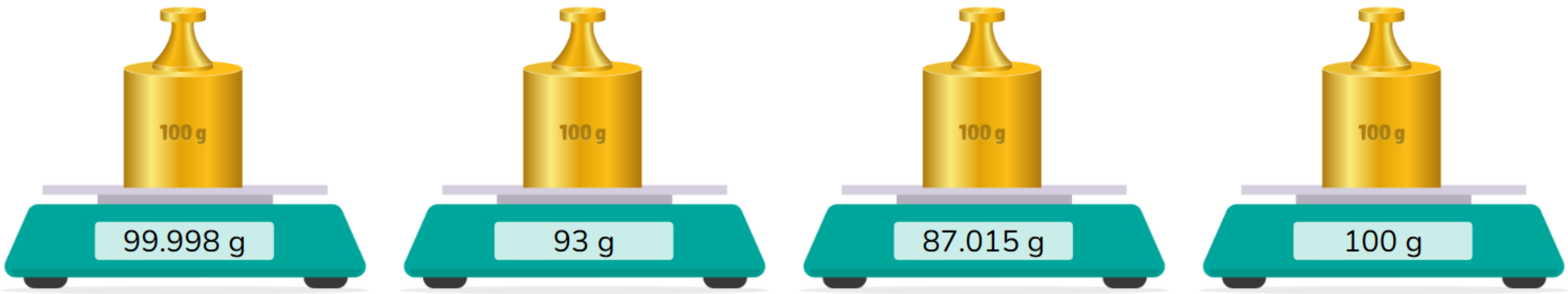
1983 – The length traveled by light in a vacuum during 1/299,792,458 of a second



Precision/Accuracy

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

Accuracy: The closeness of a measured value to the standard



99.998 g	93 g	87.015 g	100 g
☒ Precise	☐ Precise	☒ Precise	☐ Precise
☒ Accurate	☐ Accurate	☐ Accurate	☒ Accurate

Example IB Question

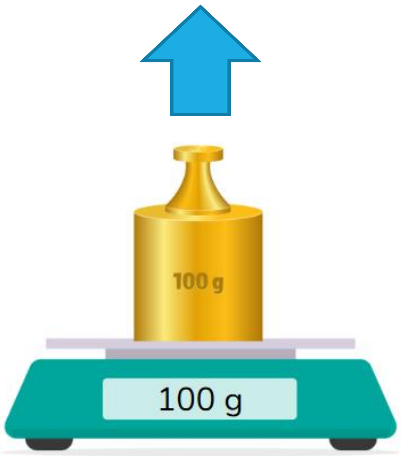
2. Which of the following is a valid statement?

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

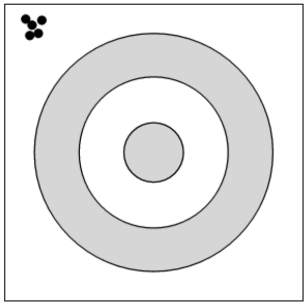
B. A measurement that is precise is always accurate.

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 ± 1 g

± (smallest division)

99.998 g ± 0.001 g

Report these Measurements!

90.0 ± 0.1

19.99 ± 0.01

Three ways to Report

2.0 ± 0.3 g

Absolute Uncertainty	$\pm 0.3\ \mathrm{g}$
Fractional Uncertainty	$\frac{Absolute}{Measurement} = \frac{0.3}{2.0} = 0.15$
Percentage Uncertainty	$Fractional \times 100\% = 15\%$

Three ways to Report

Absolute Uncertainty	$0.385 \pm \mathbf{0.001\ V}$
Fractional Uncertainty	$\frac{0.001}{0.385} = \mathbf{0.0026}$
Percentage Uncertainty	$0.0026 \times 100\% = \mathbf{26\%}$

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:

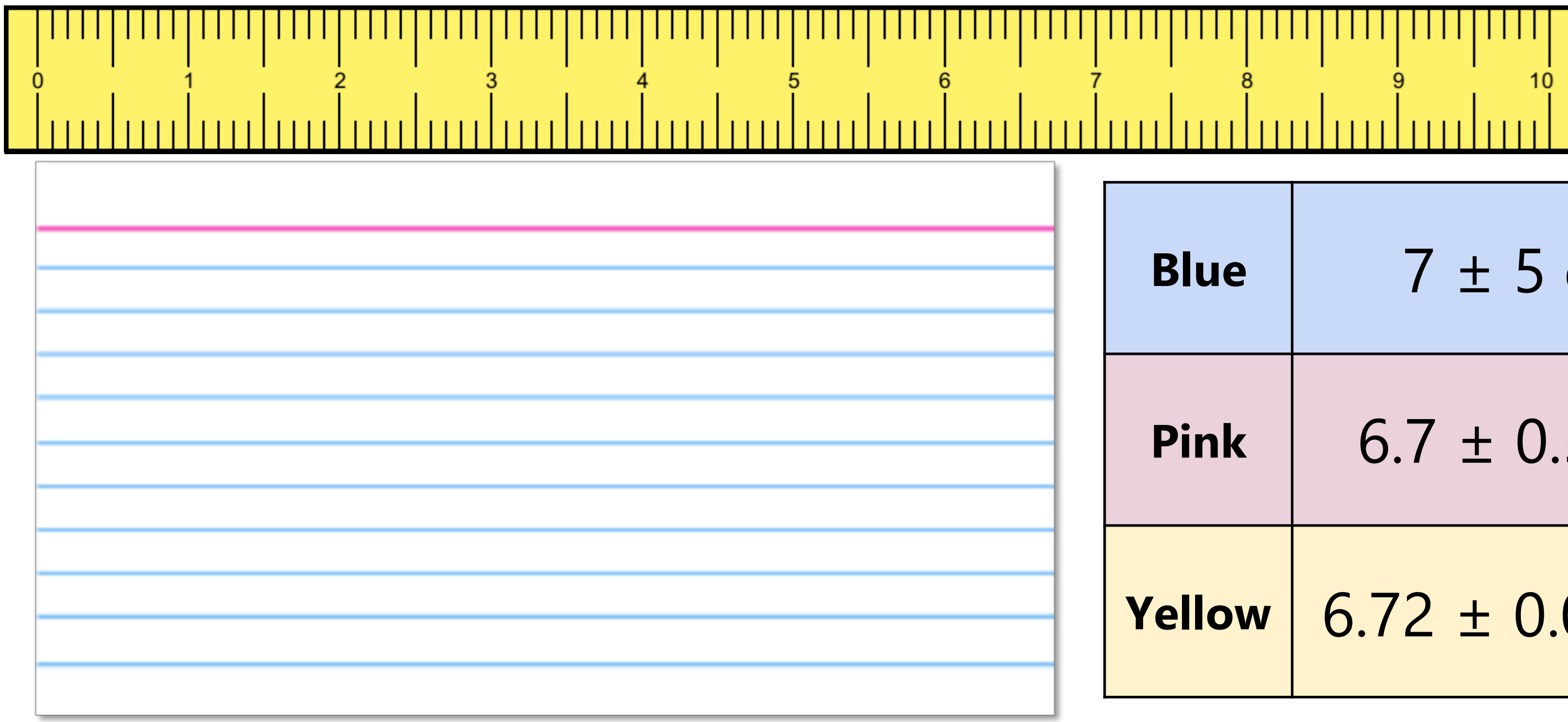
$$\pm 0.02\ A$$

Percent:

$$\frac{0.02}{2.00} \times 100\% = 1\%$$

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	7 ± 5 cm
Pink	6.7 ± 0.5 cm
Yellow	6.72 ± 0.05 cm

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
2.50×10^4 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

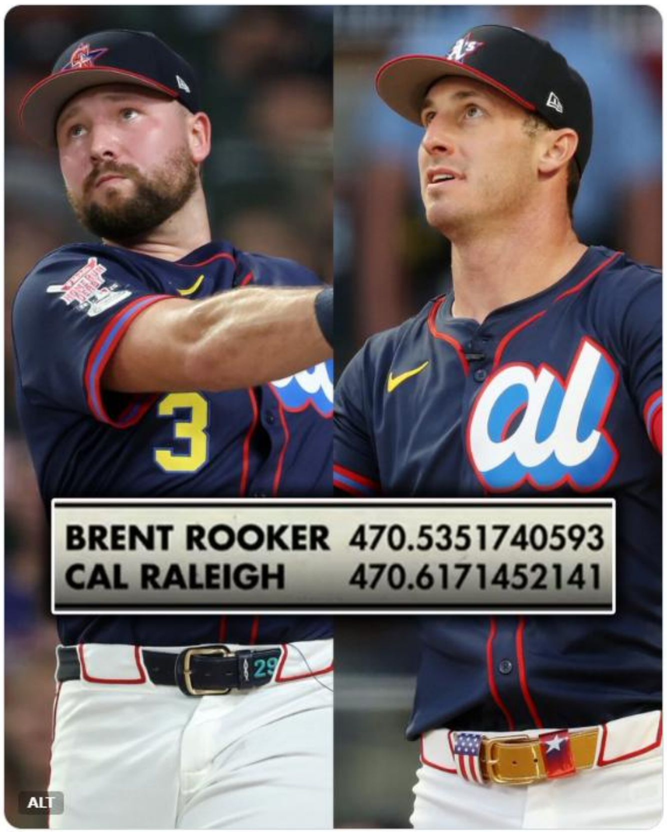
Recommendation for IB Exam:
Round all answers to 3 sig figs unless otherwise stated

**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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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 x 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