The difference between SCIENCE and ART is TESTING

why is physics related to all other sciences?

A/ Because all science originated from PHILOSOPHY

Physics is a branch of sciencece that aims to understand natural phenomenons and tries to get accurate and precise measurements and explains the properties of matter like mass, density, and temperature

Physics in itself, branches a lot, for example

- **Thermodynamics:** it deals with heat
- **Optics:** it deals with lights
- **Electromagnetism :** it deals with electricity and magnets
- **Relativity:** it deals with moving atoms and their collisions
- **Mechanics:** it deals with motion, friction

Testing in PHYSICS is mostly EXPERIMENTS & MEASUREMENTS

How?

- **You stumble across a behavior in nature**

- You start asking questions
- You come up with a hypotheses
- You test the hypotheses using other measurements
- You conclude a law in nature

EXAMPLE OF MESSURING

"HEIGHT OF OBJECT = 120"

IS THIS STATEMENT CORRECT?????

A/ It's not, but why?

Because **Measurement** is

The process of **comparing** an **UNKOWN QUANTITY** with another **KNOWN QUANTITY** to know how many times does the first contain the second

THE ELEMENTS OF MEASUREMENT ARE

1. The value of the quantity that is measured
2. The unit of the measurement
3. The tools that are used for measurement
4. The measurement errors

UNITS AND DIMENSIONS ARE LINKED BUT DIFFERENT

GRAM

It has 2 meanings

- **Dimension -> it means the type of the quantity, which means that we are measuring weight**
- **Unit -> it means how much of the quantity, which means that are measuring one gram worth of weight**

UNITS IN DEPTH -> it's a known value of a quantity that is used to measure another quantity from the same DIMENSION

WEIGHT = 6 KILO GRAM

Sign magnitude prefix unit

THE UNIT SYSTEM

Is a system made to set the default unit for each quantity

We will use Length, mass, and time as examples

Quantity	M.K.S	C.G.S	F.P.S
Length	Meter (m)	Centimeter (cm)	Foot (ft)
Mass	Kilogram (kg)	Gram (g)	Pound (lb)
Time	Second (s)	second (s)	second (s)

In 1960, the **International System of Units (SI)** was created

It was based on the **M.K.S (metric system)**

Fundamental Units

mass	**Kilogram (kg)**
length	**Meter (m)**
time	**Second (s)**
temperature	**Kelvin (k)**
Electric current	**Ampere (a)**
Amount of substance	**Mole (mol)**
Luminous intensity	**Candela (cd)**
Plane angle	**Radian (rad)**
Solid angle	**Steradian (sterad)**

Derived Units

area	**Square meter (m^2)**
volume	**Cubic meter (m^3)**
speed	**Meter per second (m/s)**
acceleration	**Meter per second square (m/s^2)**
Weight, force	**Newton (N)**
pressure	**Pascal (Pa)**
Energy, work	**Joule (J)**

A standard unit system was helpful because **It allowed scientists from all across the world to work together without having to translate each system**

The standard length (meter)

It was the length between two points on a rod made from a platinum/iridium alloy and saved at 0^{o}, it was redesigned as the distance light travels in a vacuum in the span of 1/299792458 seconds

The standard mass (kilogram)

It was the mass of a cylinder made from a platinum/iridium alloy and saved at 0^{o}

The standard meter

It is now defined as the 9192631700 times the period of oscillation of radiation from the cesium atom

Poyle's law

Volume and pressure are in a negative correlation

There are **2 TYPES** of quantities

Fundamental Quantities (Basic)

- They are the most basic quantities that can't be defined by other quantities

- Like **Mass**, **Length** and **Time**, you can't define them using speed or something, it's a central quantity that works with other quantities to define stuff like force, or density

Derivative Quantities

- They are quantities that can be defined by other quantities (fundamental ones)
- Like **Speed**, or **force**, they are just fundamental quantities like mass, length and time working together

Prefixes

They are used as multipliers for units

Like 1 **kilo**meter = 1000 meters

And 1 **milli**meter = .001 meters

Prefix	Symbol	Numerical Multiplier	Exponential Multiplier
yotta	Y	1,000,000,000,000,000,000,000,000	10^{24}
zetta	Z	1,000,000,000,000,000,000,000	10^{21}
exa	E	1,000,000,000,000,000,000	10^{18}
peta	P	1,000,000,000,000,000	10^{15}
tera	T	1,000,000,000,000	10^{12}
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deca	da	10	10^{1}
No prefix		1	10^{0}
deci	d	0.1	10^{-1}
Centi	c	0.01	10^{-2}
Milli	m	0.001	10^{-3}
Micro	µ	0.000001	10^{-6}
Nano	n	0.000000001	10^{-9}
Pico	p	0.000000000001	10^{-12}
Femto	f	0.000000000000001	10^{-15}
Atto	a	0.000000000000000001	10^{-18}
Zepto	z	0.000000000000000000001	10^{-21}
yocto	y	0.000000000000000000000001	10^{-24}

NOTES!

When we go to square or cubic lengths

We multiply the multiplier's power by 2 (for square) and 3 (for cubic)

So 1 cubic meter = 10^6 cubic centimeters instead of 10^2

And 1 square meter = 1^6 square millimeters instead of 1^3

As for liters

1 cubic meter = 10^3 liters

HOW TO CONVERT BETWEEN QUANTITIES

(1) Convert between prefixes

To convert from a prefix to a prefix we can use the exponential multiplier and put it in this formula

$$\frac{quantity\ number\ x\ current\ multiplier}{target\ multiplier}$$

So to convert from let’s say 10 micrometers to nanometers we do this

$\frac{10\ x\ 10^\wedge{-6}}{10^\wedge{-9}}$ = 10000 nm

(2) Convert between Units

Length

- 1 mile (mi) = 1609 m = 5280 ft
- 1 yard = 3 ft
- 1 ft = 30.48 cm = 12 in
- 1 in = 2.54 cm

Mass

- 1 Pound (lb) = 0.465 kg
- 1 ounces (oz) = 28.35 g
- 1 day = 86400s

Time

- 1 h = 3600 s

Temperature Conversions

From	To	Formula
Celsius (°C)	Fahrenheit (°F)	F = (C × 9/5) + 32
Fahrenheit (°F)	Celsius (°C)	C = (F − 32) × 5/9
Kelvin (K)	Celsius (°C)	C = K − 273.15
Celsius (°C)	Kelvin (K)	K = C + 273.15
Fahrenheit (°F)	Kelvin (K)	K = (F − 32) × 5/9 + 273.15
Kelvin (K)	Fahrenheit (°F)	F = (K − 273.15) × 9/5 + 32

MEASUREMENT TOOLS

Length

- Vernier caliper
- Micrometer
- Ruler

Weight

- Sensitive balance

Time

- Stop watch

Electric Current

- Ammeter
- Multimeter

Potential Difference

- Voltmeter
- Multimeter

Resistance

- Ohmmeter
- Multimeter

How to measure using micrometer

How to measure using vernier caliper

Measurement Errors

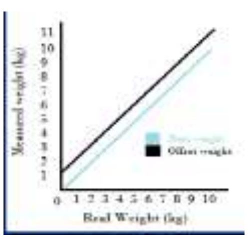
How do they happen?

- Wrong device –> using a ruler to measure a grain of sand
- Faulty Device -> weak magnet in an ammeter
- Environmental error -> air flow changing the reading of the sensitive balance
- Human error ->
    - Reading error

- Angle error
- Mathematical error

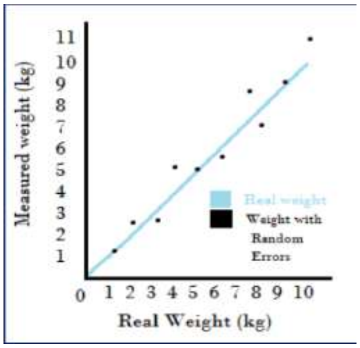
There are **2** types of them

Systematic Errors

- They are a permanent deflection in the same direction from a true value
- They are usually caused by measuring tools that are incorrectly calibrated or used incorrectly
- They can be corrected, why?
  - Because they are just offsetted from the true value
  - It’s like when you try to weigh multiple things but there is an additional object on the balance, so you just subtract that weight from everything and now you have the true value
  - 

Random Errors (noisy errors)

- They are a short-term scattering of values around the true value
- They are caused randomally by multiple forces (usually environmental)
- They can’t be corrected, why?
  - Because they are unpredictable

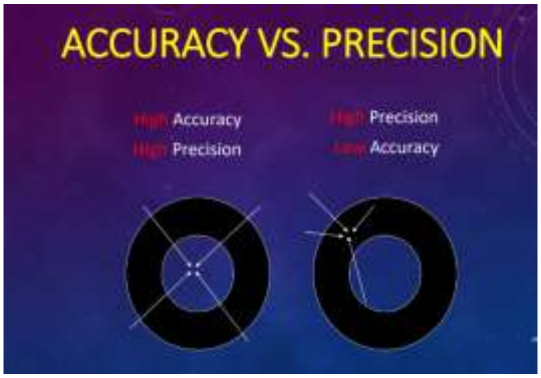
- It’s like when you try to weigh something but every time you get a new higher or lower result
- You can’t get the real value from it you just get an average
- 

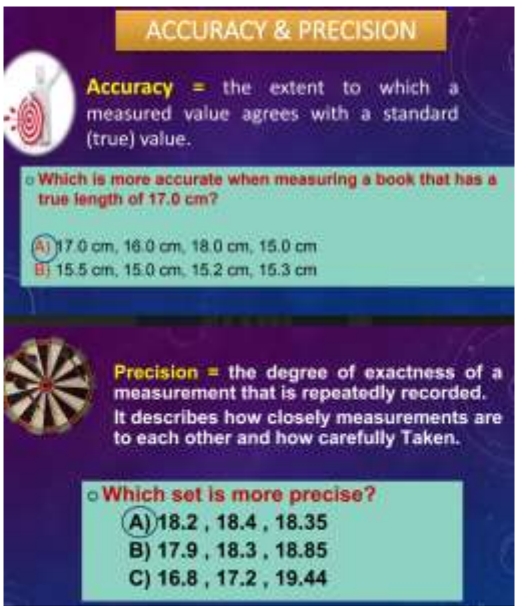
Of course, to do your testing/experimenting you will need to use tools, or in our case, they’re called **Instruments**, when we do our measuring

We have two types of results

- **Accurate results:** when we have the measured value be close to the true value
- **Precise results:** when multiple measurements give nearly identical values

The goal of science is to obtain measurements that are both precise and accurate, that will depend on the type of measurement





TYPES OF MEASUREMENTS

direct	indirect

it happens with **one** procedure or **one** tool	it happens with **multiple** procedures or tools
it can only get 1 error	it gets many errors and they stack up
we do not use mathematical equations	we use mathematical equations
using a graduated cylinder to measure the size of a cube	measuring the x, y, z lengths and doing the xyz equation to get the size

HOW TO CALCULATE ERRORS!?

Let's go over some terms first

Absolute Error (ΔX)

it is the difference between the real value (X_O) and the measured value (x)

$\Delta X = |X_O - X|$

Relative Error (r)

it is the ratio between the absolute value (ΔX) and the real value (X_O)

r = $\frac{\Delta X}{Xo} * 100\%$

you’ll see that the relative error indicates better accuracy than the absolute because it tells you the exact percentage so when you get smaller, you’re getting more accurate

when you type a measurement reading you do it like this

Quantity = (true value ± absolute error)

Q = (x ± absolute error)

Q = ($x_o \pm \Delta x$)

EXAMPLE PROBLEMS

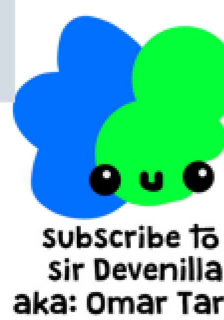
A student measured the length of pen and they measured 9.9 cm

While the true length was 10 cm, measure the absolute error, relative error and write the measurement reading?

$\Delta x = |x_o - x| = |10 – 9.9| = .1$ cm

$R = (\Delta x / x_o) * 100\% = (.1 / 10) * 100 = 1\%$

When you add/subtract errors



The new $\Delta x = \Delta x_1 \pm \Delta x_2$

The new $r = \frac{\text{new } \Delta x}{Xo1 \pm Xo2}$

When you multiply/divide errors

The new $r = r_1 + r_2 = \frac{\Delta X1}{Xo1} + \frac{\Delta X2}{Xo2}$

The new Δx = the new X_0 * R

Calculate the relative error and absolute error of the area of a rectangle, its length = (6 + 0.1) m and its width (5 + 0.2) m ?

$R_1 = .1 / 6 = .0166666 \sim .017$

$R_2 = .2 / 5 = .04$

$R = .017 + .04 = .057$

$\Delta X = (6*5) * .057 = 1.71\ M^2$

$X_O = 30\ M^2$

$Q = (30 \pm 1.71)\ M^2$

If $L_1 = (5.2 \pm .1)$ cm and $L_2 = (5.8 \pm .2)$ cm and $L = L_1 + L_2$

Calculate L

$\Delta x = .1 + .2 = .3$ cm

$R = \Delta x / (x_{o1} + x_{o2}) = .3 / 11 = .027 = 2.7\%$

$L = (11 \pm 0.3)$

We simplify **Fundamental Quantities** by using **Dimensions**

"the power to which the fundamental quantities are raised"

So instead of Mass we have (**M**), Instead of Time we have (**T**), etc etc

And we use these symbols to simplify physical laws and derivative quantities

So instead of saying **[velocity = distance / time]**

We say **[$V = L.T^{-1}$]**

Calculations using Symbols

- $M.L + M.L = M.L$
- $M.L + M.T$ = undefined
- $M.L * M.T = M^2.L.T$
- $L.T^2 / T = L.T$
- $L / L = 1$
- $M^0 = 1$

Dimensional Formula of some Physical Quantities

Physical quantity	Relation with other quantities	Dimensional formula
Areas	Length × breadth	$L \times L = L^2 = [M^0 L^2 T^0]$
Volume	Length × breadth × height	$L \times L \times L = L^3 = [M^0 L^3 T^0]$
Density	$\frac{\text{Mass}}{\text{volume}}$	$\frac{M}{L^3} = \left[M L^{-3} T^0\right]$
Speed or velocity	$\frac{\text{distance}}{\text{time}}$	$\frac{L}{T} = [M^0 L T^{-1}]$
Acceleration	$\frac{\text{velocity}}{\text{time}}$	$\frac{LT^{-1}}{T} = [M^0 L T^{-2}]$
Momentum	Mass × velocity	$M \times LT^{-1} = [M L T^{-1}]$
Force	Mass × acceleration	$M \times LT^{-2} = [M LT^{-2}]$
Pressure	$\frac{\text{Force}}{\text{area}}$	$\frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$
Work	Force × distance	$M LT^{-2} \times L = [ML^2T^{-2}]$
Energy (mechanical, heat, light etc)	Work	$M L^2T^{-2}$
Power	$\frac{\text{work}}{\text{time}}$	$\frac{ML^2T^{-2}}{T} = ML^2T^{-3}$
Stress	$\frac{\text{Force}}{\text{area}}$	$\frac{MLT^{-2}}{L^2} = \left[ML^{-1}T^{-2}\right]$
Strain	$\frac{\text{Change in dimension}}{\text{Original dimension}}$	Dimensionless
Coefficient of elasticity	$\frac{\text{stress}}{\text{strain}}$	$\frac{ML^{-1}T^{-2}}{1} = \left[ML^{-1}T^{-2}\right]$
Moment of inertia	Mass × (radius of gyration)^2	$M \times L^2 = [ML^2T^0]$
Angular momentum	Moment of inertia × angular velocity	$ML^2 \times T^{-1} = [ML^2T^{-1}]$
Torque or couple	Force × perpendicular distance	$MLT^{-2} \times L = [ML^2T^{-2}]$

Constants do not have dimensions like 2, $\frac{1}{2}$, and π

Trigonometric functions like sin, cosine, tan do not have dimensions

We can use dimensional equations to verify an equation but that does not mean that it’s always correct

EXAMPLE 1

the equation for sphere area is πr^2 so its dimensions are L^2

the area of a square is L^2

dimensions say those 2 are EQUAL but they are NOT

that’s why we can only use them to verify

EXAMPLE 2

Verify the law [Kinetic energy = .5 mass x velocity^2]

(1) Energy = work = Force x distance = $M.L.T^{-2}$ x L = $M.L^2.T^{-2}$
(2) Kinetic Energy = .5 mass x velocity^2 = M x $(L.T^{-1})^2$ = M x $L^2.T^{-2}$ = $M.L^2.T^{-2}$

so the law is correct, we have the same dimensions on both sides

because kinetic energy is taken from energy so it should have the same law

NANOSCALE

It’s where objects become so small that we can’t even see it with a microscope

The reason is that it’s dimensions are smaller than even some electromagnetic waves

Its dimensions will range from 1 nano meter to 100 nanometer

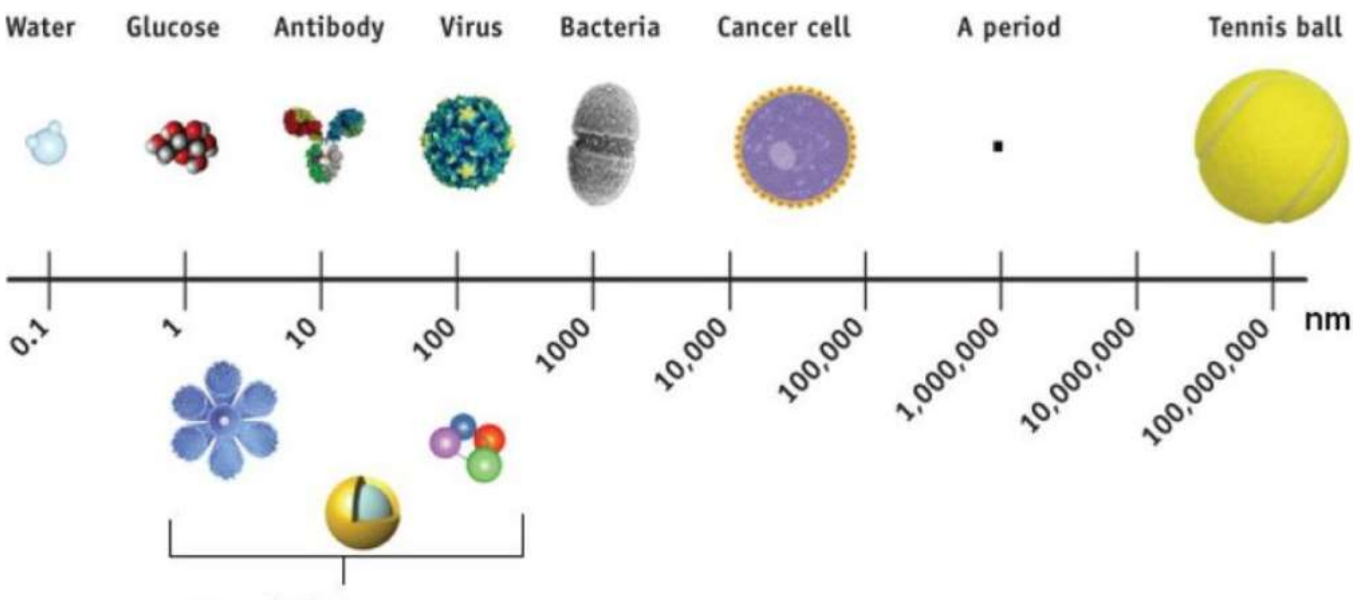
When an object enters the nano scale, it gets very new properties on the physical, chemical, and mechanical scale

These properties change within the nanoscale spectrum

For example

- **Nano-scale copper will be a lot tougher**
- **Nanoscale gold will become a liquid and will be different colors from red to orange to green to blue**
- **Nanoscale salt will react a lot quicker**

All that is because when you chop an object to the nano scale, it’s surface area will increase exponentially and the volume will stay the same leading to new effects like, very fast reaction speed



This learning out come can help a lot with

- **CAPSTONE**
  - **We can use measurements to make the capstone's prototype, then we can make it more accurate and precise to achieve our required results**
- **Exponential population growth**
  - **We can use measurements and dimensional analysis to create a data set for the pobulation growth and detect similar trends, and we can use measurement errrors to make our measurements more precise**
- **Reducing Urban Congestion**
  - **We can use measurements to see the traffic flow and congestion levels and with physical principles we can create a model to fix the problem**