WHAT IS PHYSICS?

Physics (from the Greek phýsis = nature) is the science that studies natural phenomena (excluding those involving chemical transformations of matter),

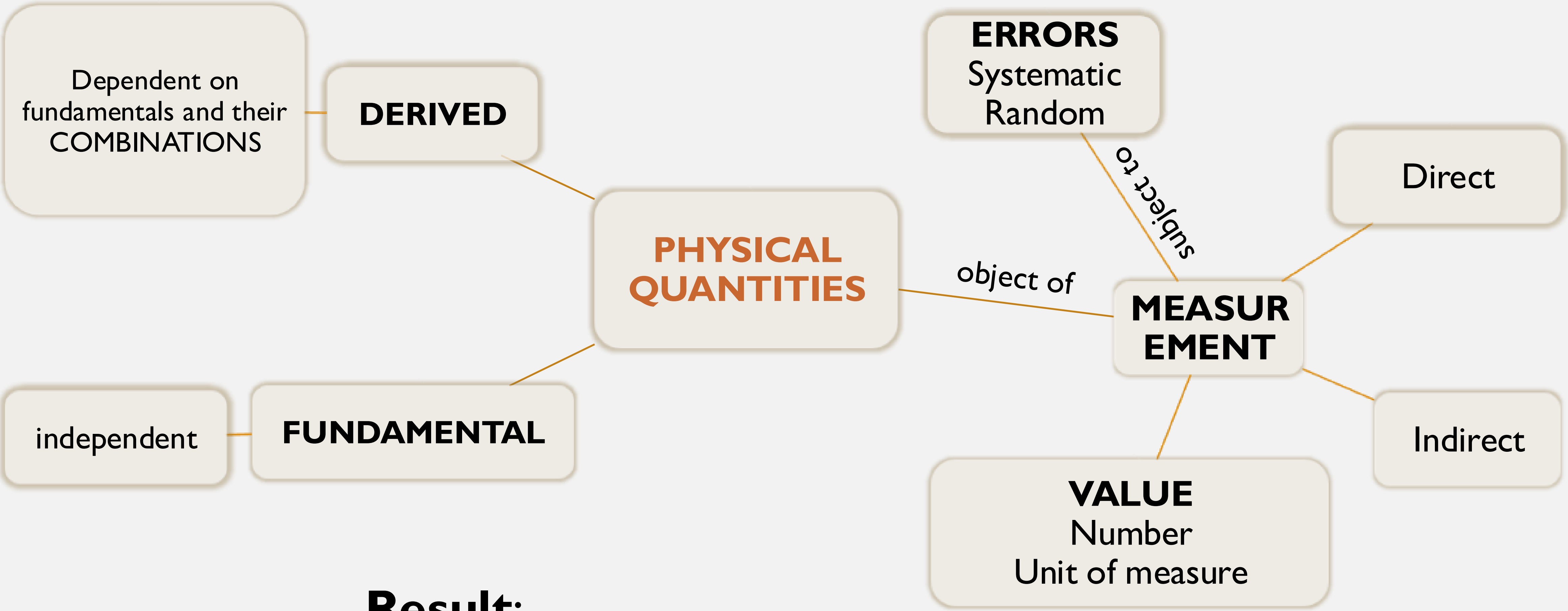
with the aim of describing them by measuring their properties → (i.e., physical quantities)

and by establishing mathematical relationships among them → (laws).

PHYSICAL QUANTITIES

PHYSICAL QUANTITIES

Any entity involved in the description of a phenomenon and that can be measured



Result:

VALUE ± ERROR (unit of measure)

INTERNATIONAL SYSTEM

The prototype units of measurement standards «historical» are kept at the ***Bureau International of Weights and Measures in Paris.***

Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole	mol
Intensity of electric current	ampère	A
Light intensity	candela	cd

Figura 1.3 Il riferimento standard internazionale della massa di 1 kg, un cilindro di platino-iridio di diametro e altezza entrambi pari a 3,9 cm.

INTERNATIONAL SYSTEM

Label of fundamental quantities

PHYSICAL QUANTITY	QUANTITY SYMBOL	UNIT NAME	UNIT SYMBOL
Length	L	Meter	m
Mass	M	Kilogram	kg
Time	T	Second	s
Amount of substance	N	Mole	mol
Temperature	Θ	Kelvin	K
Electric current	I	Ampere	A
Luminous intensity	J	Candela	cd

OPERATIONS BETWEEN PHYSICAL QUANTITIES

Sum and **subtraction** are permitted only between identical physical quantities

Multiplication and **division** are permitted also between different physical quantities→ **DERIVED physical quantities**

DERIVED PHYSICAL QUANTITIES (AND UNITS OF MEASUREMENT)

The units of measurement of derived physical quantities can be expressed as combinations of the fundamental ones.

Volume = $[L^3] = m^3$	Density = $[M] / [L^3] = kg/m^3$
Speed = $[L] / [t] = m/s$	Force = $[M]\cdot[L] / [t^2] = kg\cdot m/s^2$ = Newton

Label of derived quantities:

PHYSICAL QUANTITY	QUANTITY SYMBOL	UNIT NAME	UNIT SYMBOL	BASE SYMBOL EQUIVALENCE	BASE UNIT SYMBOL EQUIVALENCE
Density	ρ	—	kg/m^3	$[M] \cdot [L]^{-3}$	kg/m^3
Energy	E	Joule	J	$[M] \cdot [L]^2 \cdot [T]^{-2}$	$N \cdot m$

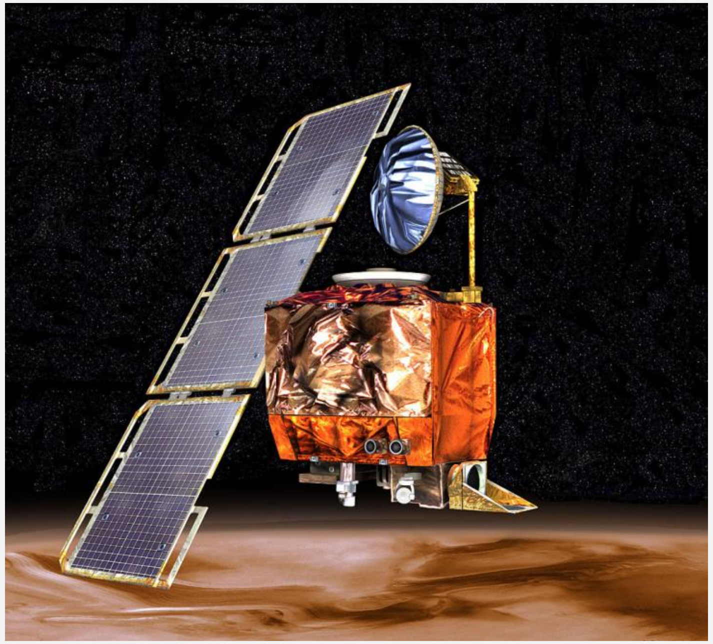
DIMENSIONAL ANALYSIS

- Analysis that allows to check the correctness of the used mathematical formulas
- If the result of a calculation is a speed and the units that we obtain are [L]*[T], the steps performed are CERTAINLY wrong

$$V = \frac{5\ (m)}{10\ (s)} = 0.5\,\frac{m}{s} \rightarrow Unit\grave{a}\ \text{is}\ \frac{[L]}{[T]}, OK$$

$$V = 5\ (m) \times 10\ (s) = 50\ m \cdot s \rightarrow [L][T], \text{wrong!}$$

THE VALUE OF THE CORRECT UNITS OF MEASUREMENT



Mars Climate Orbiter

Mission cost: **328 million dollars**

Mission outcome: **FAILED**

From wikipedia

The Mars Climate Orbiter was destroyed when, instead of positioning itself at an altitude of 140-150 km from the surface of Mars, it entered the Martian atmosphere at an altitude of only 57 km. The probe was destroyed by the stresses caused by friction present at that altitude with the atmosphere. It was discovered that some data had been calculated on Earth based on the unit of measurement of the US customary system, and reported to the navigation team, which instead expected the data expressed in units of measurement of the International System. The probe was not able to perform conversions between the two units of measurement.

EQUIVALENCES: MULTIPLES AND SUBMULTIPLES

Each quantity, whether fundamental or derived, may have associated with it a series of multiples and submultiples (e.g., meter):

Tm	Gm	Mm	km	hm	dam	m	dm	cm	mm	µm	nm	pm
10^{12}	10^{9}	10^{6}	10^{3}	10^{2}	10^{1}	10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}

Multiples:	**Submultiples**
da = deca	d = deci
h = hecto	c = centi
k = kilo	m = mili
M = mega	µ = micro
G = giga	n = nano
T = tera	p = pico

EQUIVALENCES: MULTIPLES AND SUBMULTIPLES

Expression of speed:

km/h → m/s

1 km/h = 1000 m / 3600 s

= 0.28 m/s

m/s → km/h

1 m/s = 0.001 km / (1/3600) h

= 3.6 km/h

CONVERSION FACTORS

n km/h → n · 0.28 m/s

n m/s → n · 3.6 km/h

10 m/s = 10 · 3.6 km/h = 36 km/h

120 km/h = 120 · 0.28 m/s = 33.6 m/s

DIRECT AND INDIRECT MEASUREMENTS

- **Direct measurements**
- For example, the measurement of a mass on a *balance**, or of a length with a ruler, or of a time with **a** clock.
- **Indirect measurements**
- The unknown quantity is obtained by carrying out the direct measurement of another quantity, linked to the unknown one through a known mathematical law.
- In this case, the quantity to be determined can be either fundamental (for example, the distance between the Earth and the Sun, which obviously cannot be measured directly with a ruler) or derived (for example, atmospheric pressure, for which the height of a mercury column in a vertical tube is measured: this height is directly proportional to the pressure, according to a well-known law).
- **valid only for a pan balance!*

HOW A NUMERICAL RESULT IS REPRESENTED

- A numerical result is not complete unless it consists of
- **VALUE, ACCURACY and UNIT OF MEASURE**

SCIENTIFIC NOTATION AND SIGNIFICANT FIGURES

Prefix (abbreviation)	Power ofl 10
peta (P)	10^{15}
tera (T)	10^{12}
giga (G)	10^{9}
mega (M)	10^{6}
chilo (k)	10^{3}
hecto (h)	10^{2}
deci (d)	10^{-1}
centi (c)	10^{-2}
milli (m)	10^{-3}
micro (μ)	10^{-6}
nano (n)	10^{-9}
pico (p)	10^{-12}
femto (f)	10^{-15}

The significant figures of a measurement are the certain digits and the first uncertain digit.

Identify the number of **significant figures**

(a) 409.8 s

(b) 0.058700 cm

(c) 9500 g

(d) 950.0×10^{1} ml

Using **scientific notation**

(a) 4.098×10^{2} s (4 digits)

(b) 5.8700×10^{-2} cm (5 digits)

(c) 9.500×10^{3} g or 9.5×10^{3} g (4 or 2 digits)

(d) 9.500×10^{3} ml (4 digits)

ACCURACY (OR ERROR)

- The error in a measurement has several origins. It can be random or systematic.
- It defines the precision with which we can determine the value of a physical quantity and *often* depends on the measuring instrument
- The error in a measurement **DETERMINES** the significant figures to report in a result
- It propagates in calculations

RANGE AND SENSITIVITY OF MEASURING INSTRUMENTS

SENSITIVITY (or precision):
between 80 °C and 100 °C there are 10 intervals.
The precision is therefore 2 °C

RANGE

A temperature measurement with **this** thermometer will be **for example 64 °C ± 2 °C**

RANGE AND SENSITIVITY OF MEASUREMENT INSTRUMENTS

Bilancia commerciale
sensibilità 1 g

$m = 48 \pm 1$ g

$m = 4.8(1) \times 10^{1}$ g

Bilancia di laboratorio
sensibilità 0,01 g

$m = 47.74 \pm 0.01$ g

$m = 4.774(1) \times 10^{1}$ g

Bilancia per uso analitico
sensibilità 0,0001 g

$m = 47.7438 \pm 0.0001$ g

$m = 4.77438(1) \times 10^{1}$ g

SOURCES OF ERRORS

- **Instrument sensitivity**
  - More accurate instruments allow this type of error to be reduced
- **Systematic error**
  - Errors that lead **ALWAYS** to an overestimate or an underestimate of a physical quantity (example: imperfect calibration). These errors can be ELIMINATED once identified (for example by calibrating an instrument more accurately).
- **Statistical error**
  - «Random» errors that lead **SOMETIMES** to an overestimate or an underestimate of a physical quantity. By repeating a measurement multiple times, on average these errors are reduced.

SCALAR AND VECTOR QUANTITIES

- All the examples seen so far as of now have been of SCALAR quantities, that is, characterized by a **sign**, **number** and **unit.** Examples: mass, temperature, length, etc. …
- **VECTOR** quantities are instead characterized by **number** and **unit** (which together are called **MAGNITUDE** or **INTENSITY**), **direction**, **sense** and **point of application** (or **origin**). They are vector, velocity, force, acceleration, etc. …