CHAPTER 1 PHYSICS & MEASUREMENTS

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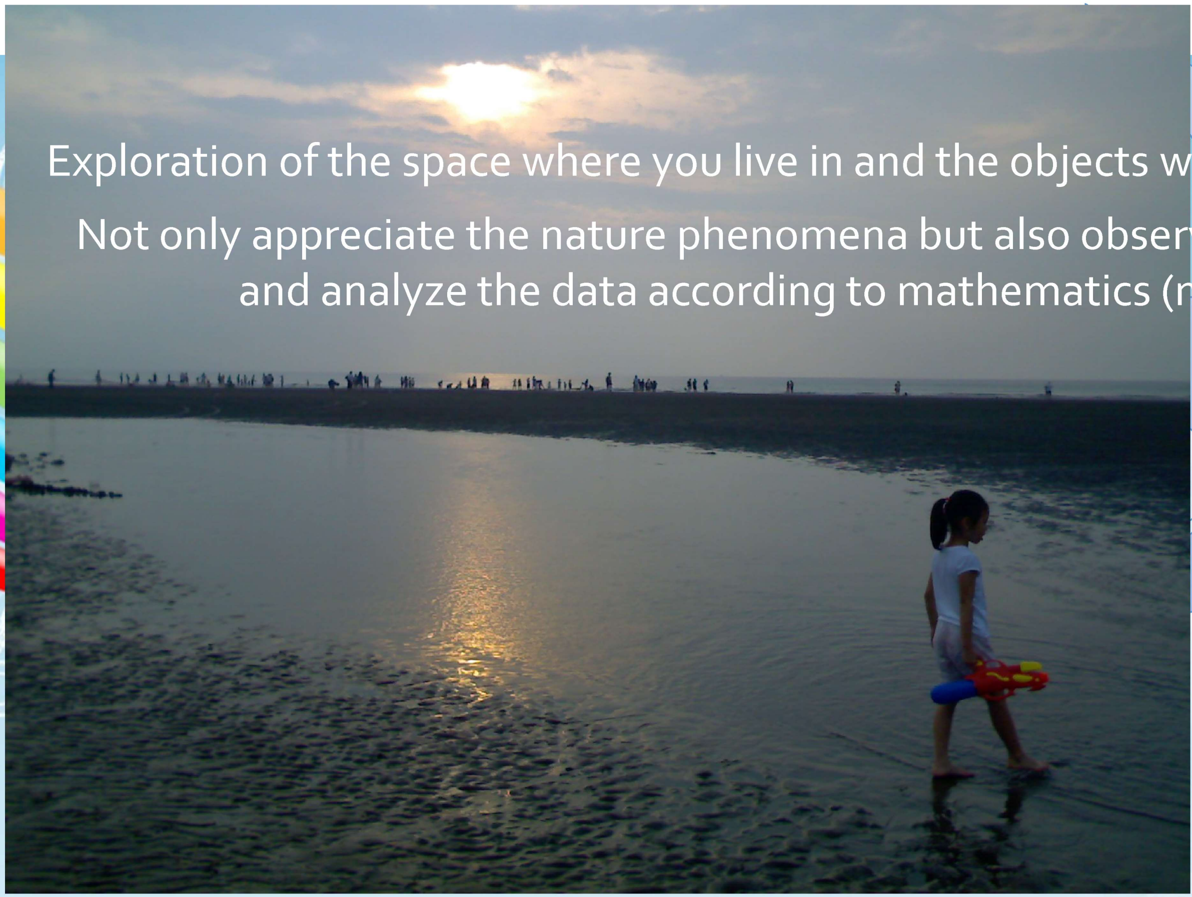
OUTLINE

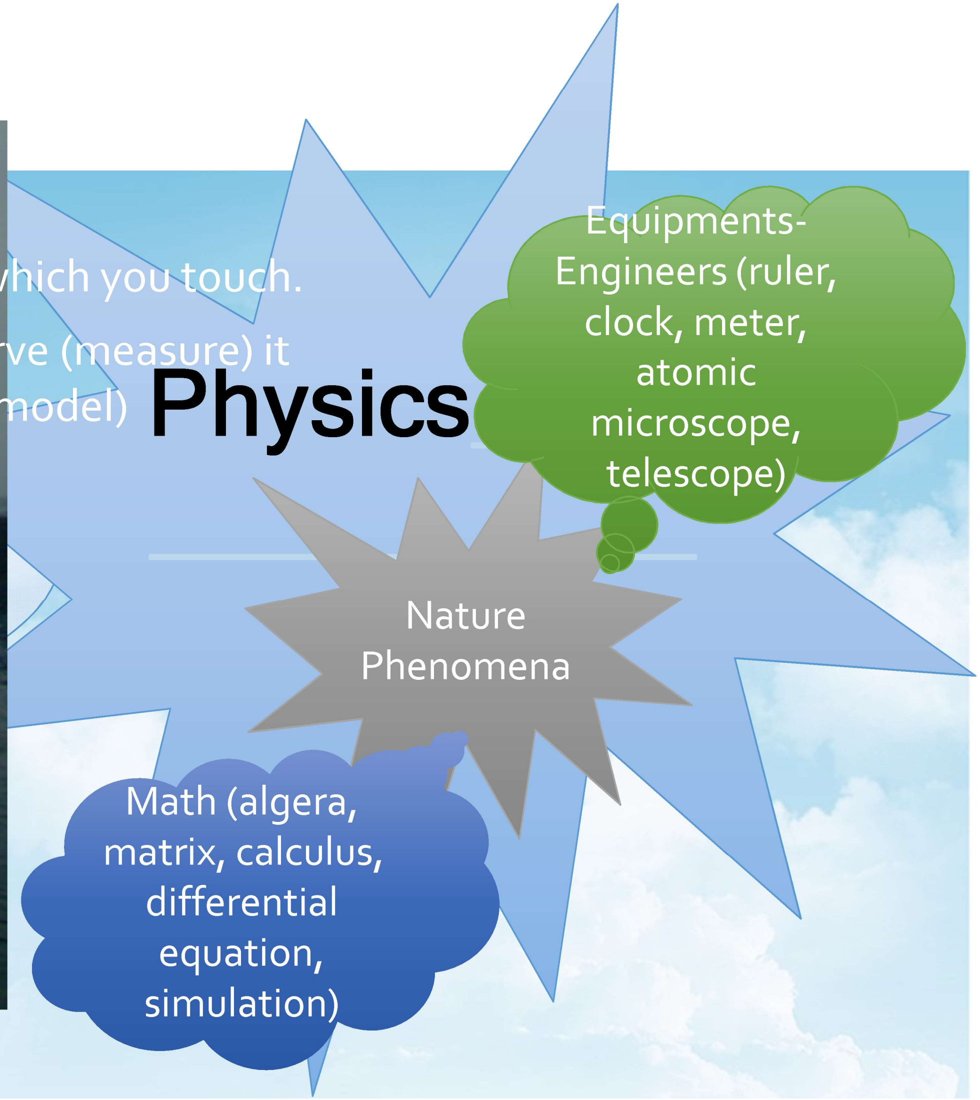
1. Measurement Standard - Length, Mass, and Time
2. Matter & Physical Model
3. Dimensional Analysis
4. Unit Conversion
5. Estimates and Order of Magnitude
6. Significant Figures

WHAT IS PHYSICS?

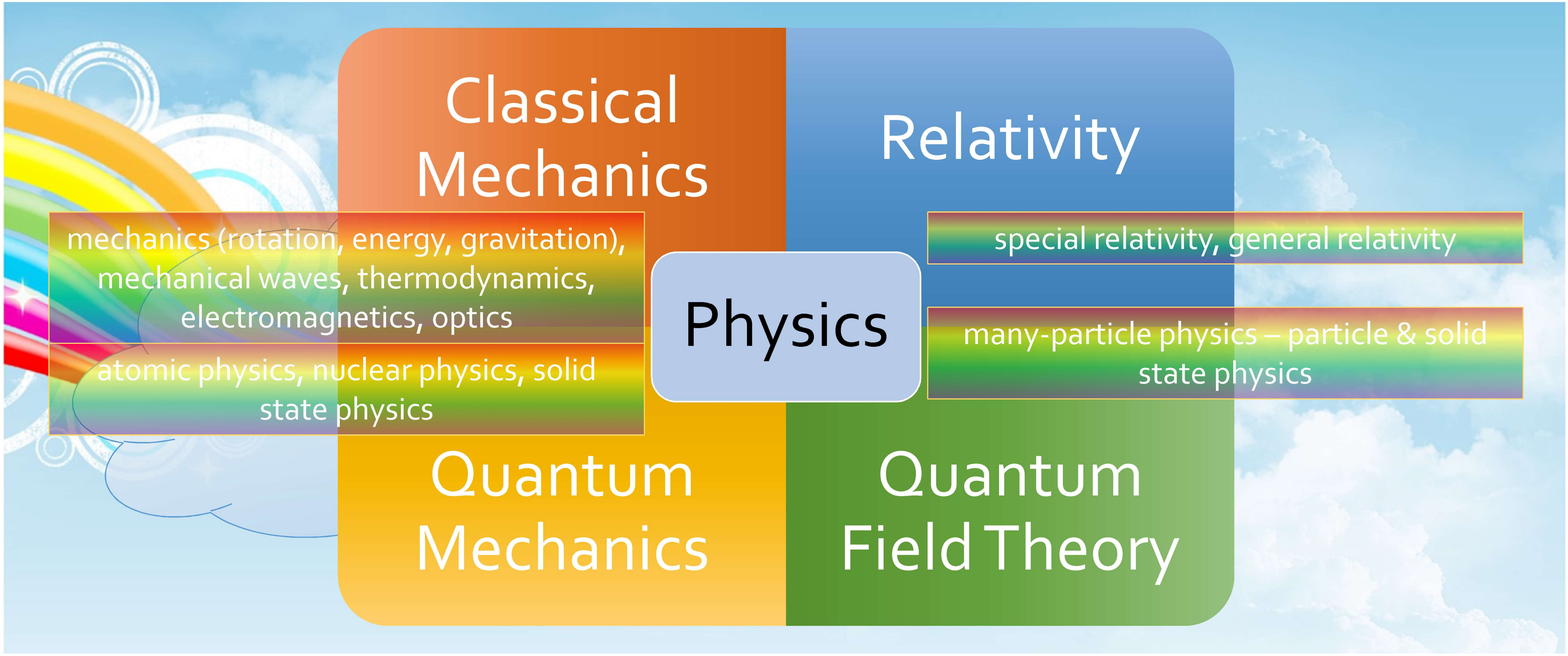
Exploration of the space where you live in and the objects which you touch.

Not only appreciate the nature phenomena but also observe (measure) it and analyze the data according to mathematics (model)





WHAT IS PHYSICS?



1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

The international system (SI) of units:

Length – Meter (m)

Mass – kilogram (kg)

Time – second (s)

The English system of units:

Length – inch (in., 2.54 cm), foot (ft., 12 inches), mile (mi, 1.609 km)

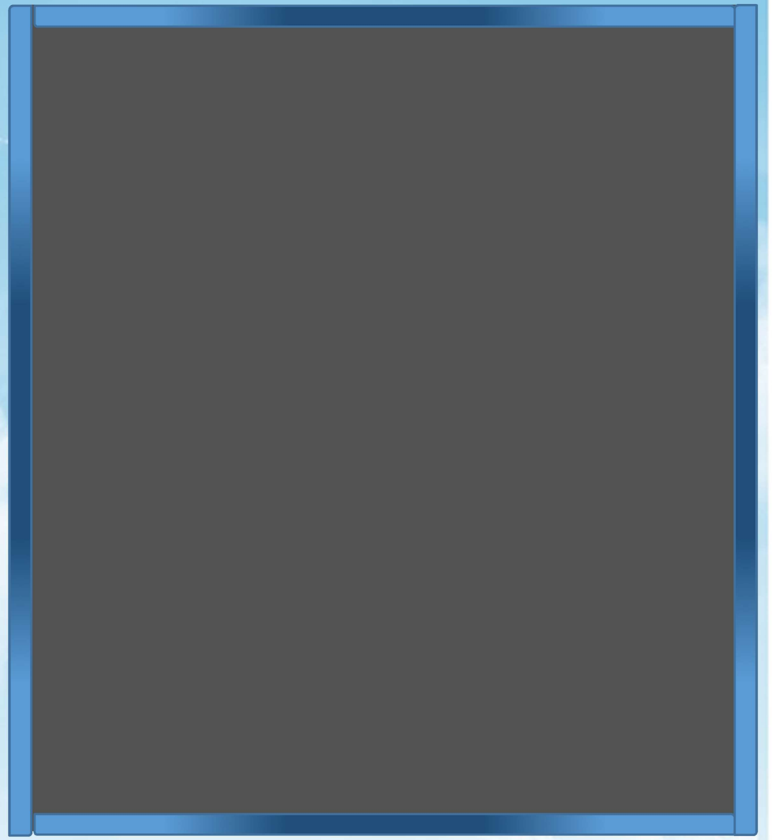
Mass – pound (lb, 0.454 kg), ounce (oz, 1 lb = 16 oz)

Time – second (s)

The derived units:

Force – Newton (N, 1 N = 1 kg m / s^2)

Energy – Joule (J, 1 J = 1 kg m^2 / s^2)



1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

The units in electromagnetics:

Ambiguous unit for electric current: ampere (A)

Charge unit: Coulomb (C, 1 C = 1 A s)

Voltage unit: Volt (V, $1\ V = 1\ J / C = 1\ kg\ m^2\ s^{-2} / A\ s$)

$1\ V = 1\ kg\ m^2\ s^{-3}\ A^{-1}$

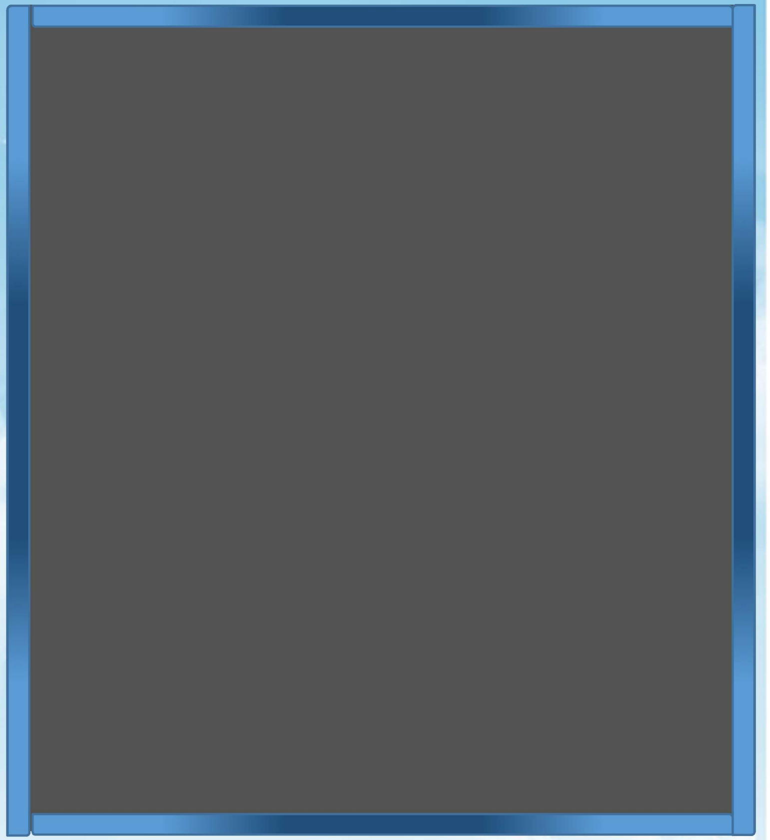
The units in thermodynamics:

Ambiguous unit for temperature: Kelvin (k)

Thermal conductivity: $W / m\ K = kg\ m / k\ s^2$

The units used in Lab:

Pressure: PSI ($lb / in.^2$, 1 atm = 14.7 PSI,
$1\ atm \cong 1\ kgw / cm^2$)



1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

The standard of length:

~1799 – 1 meter -> one ten millionth of the distance from the equator to the north pole – Earth based standard

~1960 – 1 meter -> distance between two lines on a specific PtIr alloy bar stored in France

~1970 – 1 meter -> 1 650 763.73 wavelengths of orange-red light emitted from a Krypton-86 lamp (605.78 nm visible light)

~1983 – 1 meter -> the distance traveled by light in vacuum during a time of 1/299 792 458 s, where the light is of wavelength

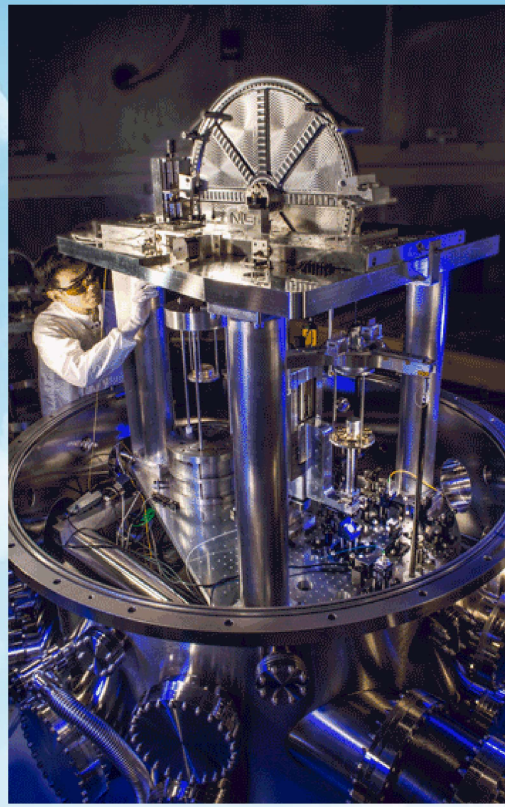
1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

The standard of mass:

- since 1887 – 1 kg -> the mass of a specific PtIr alloy cylinder, kept at the International Bureau of Weights and Measures at Severes, France
- one golf-ball-sized object – mentioned in NIST report

http://museum.nist.gov

Google map



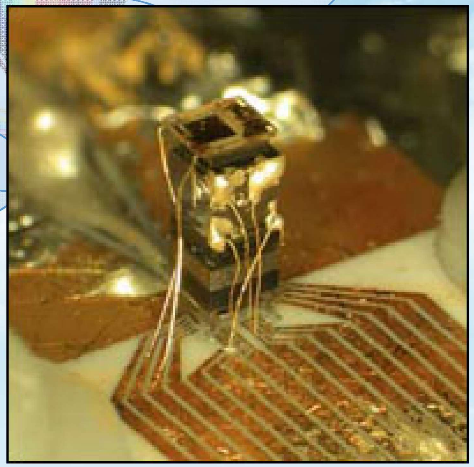
Animated Gif image from the report - "Redefining The Kilogram", NIST (http://www.nist.gov)

1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

The standard of time:

- before 1967 – mean solar day is the standard of time, a secomd is 1 / 86 400 of a mean solar day
- after 1967 – after the invention of "atomic clock", one second is 9 192 631 770 times the period of vibration of radiation from the Cs-133 atom
- 2004 Aug 27, NIST Unveils Chip-Scale Atomic Clock, "cesium vapor confined in a sealed cell and probed with light from an infrared laser"

http://phys.org/news/2004-08-chip-scale-atomic-clock.html#jCp



2016 May - http://www.walmart.com

1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

Prefix:

Factor		Prefix	Symbol				
10^{24}	E24	yotta	Y	10^{-1}	E-1	deci	d
10^{21}	E21	zetta	Z	10^{-2}	E-2	centi	c
10^{18}	E18	exa	E	10^{-3}	E-3	milli	m
10^{15}	E15	peta	P	10^{-6}	E-6	micro	µ
10^{12}	E12	tera	T	10^{-9}	E-9	nano	n
10^{9}	E9	giga	G	10^{-12}	E-12	pico	p
10^{6}	E6	mega	M	10^{-15}	E-15	femto	f
10^{3}	E3	kilo	k	10^{-18}	E-18	atto	a
10^{2}	E2	hector	h	10^{-21}	E-21	zepto	z
10^{1}	E1	deca	da	10^{-24}	E-24	yocto	y

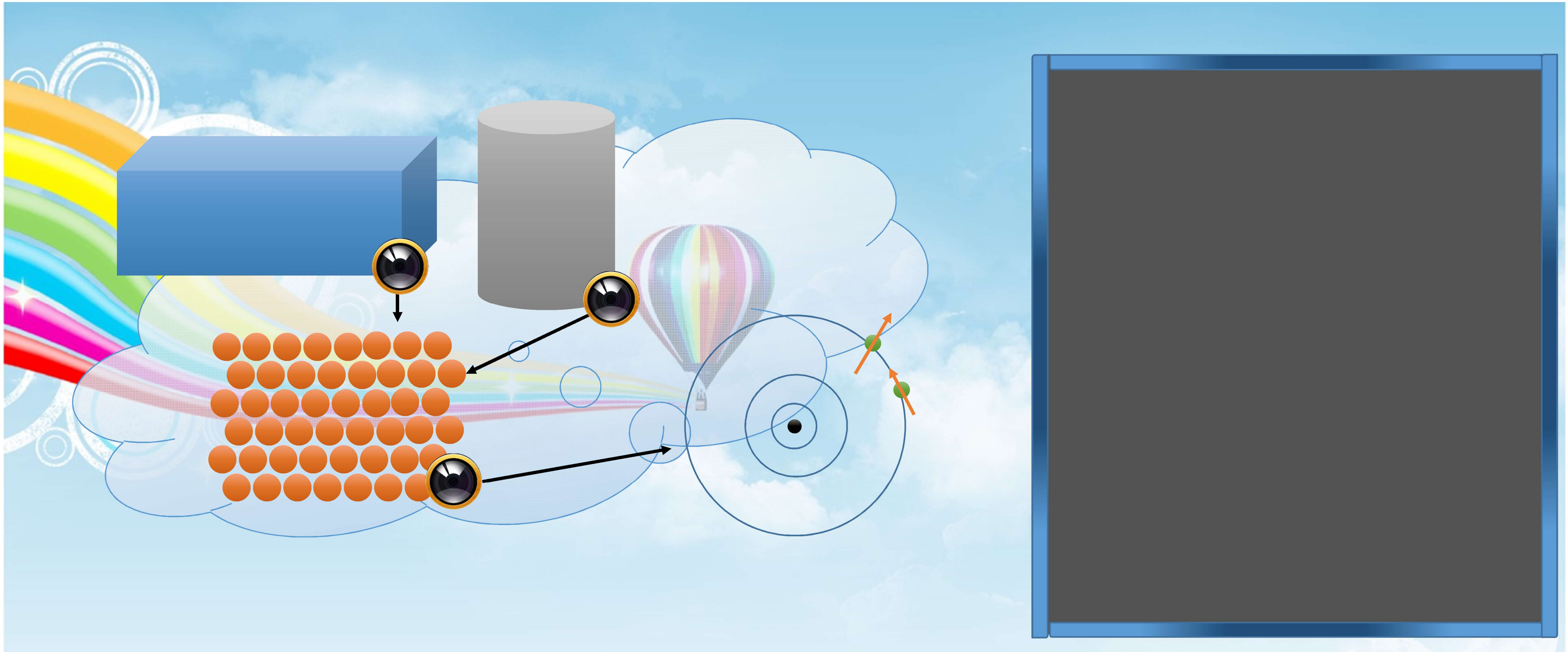
2016 May, http://physics.nist.gov/cuu/Units/prefixes.html

1. MEASUREMENT STANDARD - LENGTH, MASS, AND TIME

Some number with units that you must know:

- Length:
  - Radius of the Earth: 6400 km, 6.4×10^6 m
  - Altitude of a satellite: 200 km above the Earth surface
  - Diameter of a hydrogen atom: 10^{-10} m, r = 0.529 Å
  - Diameter of a proton: 10^{-15} m = 1 fm
- Mass:
  - Human: 7×10^1 kg
  - Hydrogen atom: $1 * 10^{-3} / 6.02 * 10^{23} = 1.67 * 10^{-27}$ kg
- Time:
  - Period of audible sound waves: 10^{-3} s
  - Period of visible light waves: 10^{-15} s
- Magnetic Field:
  - B on the Earth: 0.5 Gauss

2. MATTER & PHYSICAL MODEL

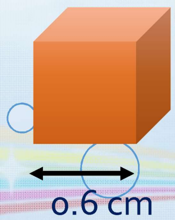


2. MATTER & PHYSICAL MODEL

Density ($\rho = m/V$) of Materials:

Example: A solid cube of aluminum has a volume of 0.216 cm^3. It is known that 27.0 g of aluminum contains 6.02 * 10^{23} atoms. How many atoms are there in the cube?

Material	Density (g/cm^3)
Gold	19.3
Lead	11.3
Copper	8.93
Iron	7.87
Aluminum	2.7



$$m = \rho V = 2.7 \times 0.216 \text{ (g)}$$

$$\frac{0.5832}{27} = 0.0216 \text{ (mol)}$$

$$0.0216 \times 6.02 \times 10^{23} = 1.30032 \times 10^{22} \cong 1.3 \times 10^{22}$$

3. DIMENSIONAL ANALYSIS

Quantity	Symbol	Dimension
Area	A	L^2
Volume	V	L^3
Speed	v	L/T
Acceleration	a	L/T^2
Force	f	ML/T^2
Pressure	p	M/LT^2
Density	d	M/L^3
Energy	E	ML^2/T^2
Power	P	ML^2/T^3

Use it to check the equation of the theory.

Example: It is proposed that the radial acceleration a_r is proportional to the speed v and the radius r as $a_r = kv^m r^n$, where n, m are two exponents and k is a dimensionless const. Please use the dimensional analysis to determine the two exponents.

$$v: L^1T^{-1} \qquad r: L^1 \qquad a_r: L^1T^{-2}$$

$$L^1T^{-2} = (L^1T^{-1})^m (L^1)^n$$

$$m = 2, n = -1$$

4. UNIT CONVERSION

Write down all the details – number & unit for conversion

$$5 \text{ in.} = 5\ in. \times \left(\frac{2.54\ cm}{1\ in.}\right) = 12.7\ cm$$

$$161 \text{ km} = 161\ km \times \left(\frac{1\ mi}{1.61\ km}\right) = 100\ mi$$

Example: The 1st car is moving with a speed of 42 m/s and the 2nd car is moving with a speed of 55 mi/h. Are the drivers exceeding the speed limit of 100 km/h?

$$1stCar: \frac{42\ m}{s} = \frac{42\ m}{s} \times \frac{1\ km}{1000\ m} \times \frac{3600\ s}{1\ h} = 151.2\ km/h$$

$$2ndCar: \frac{55\ mi}{h} = \frac{55\ mi}{h} \times \frac{1.61\ km}{1\ mi} = 88.55\ km/h$$

5. ESTIMATES AND ORDER OF MAGNITUDE

Scientific notation, two or three digits with the multiplier of the power of 10 - $N_1.N_2N_3 \times 10^{N_4}$

Order of magnitude without the prefix of digital number

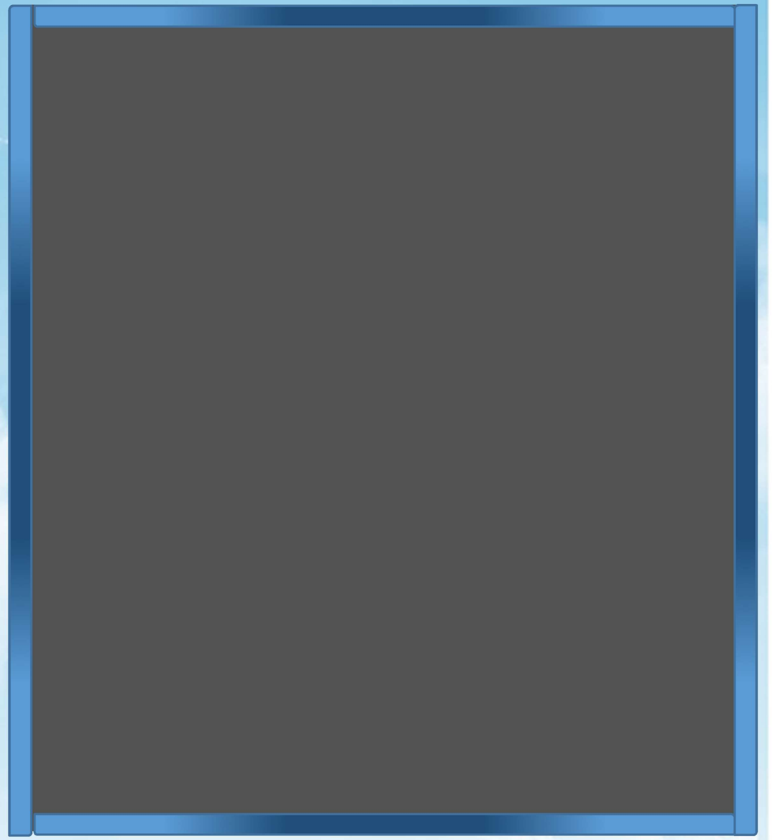
change $N_1.N_2N_3$ to 10^{N_5}

$$N_1.N_2N_3 > 10^{0.5} \rightarrow 10^1$$
$$N_1.N_2N_3 < 10^{0.5} \rightarrow 10^0$$

$$10^{0.5} = \sqrt{10} = 3.162$$

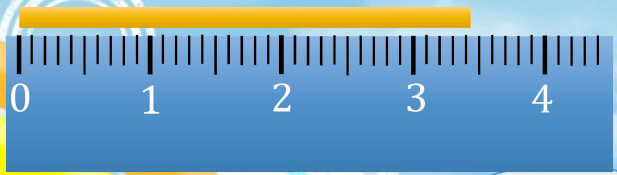
Example: There are N_A atoms in 12 g of carbon. If counting 1 atom takes 1 s, how long does it take to count all atoms in 1 g of carbon?

$$1g \times \frac{6.02 \times 10^{23}}{12\ g} \div \left(\frac{1g}{1s}\right) \times \left(\frac{1D}{86400s}\right) \times \left(\frac{1Y}{365D}\right) \cong 1.6 \times 10^{15}$$



6. SIGNIFICANT FIGURES

Measurements: precise digits with the first estimated digit.



3.43 cm

How to count the significant figure?

The rule of addition & subtraction: no significant figures beyond the last decimal place where both of the original numbers have significant figures.

$$1.002 + 11.0 = 12.0$$

$$10.25 - 1.1 = 9.15 \cong 9.2$$

The rule of multiplication & division: no greater than the least number of significant figures in any of the numbers.

$$2.12 \times 3.214 = 6.81368 \cong 6.814$$

6. SIGNIFICANT FIGURES

The standard deviation shall be less than the lowest decimal number.

3.21 ± 0.04 $\quad\quad$ 3.21 ± 0.05

Example: A rectangle has a length of 6.21 ± 0.02 m and a width of 7.8 ± 0.2 m. Please calculate the area.

$$(6.21 \pm 0.02) \times (7.8 \pm 0.2) = 48.438 \pm 0.156 \pm 1.242$$

$$= 48.438 \pm 1.398 = 48 \pm 1$$