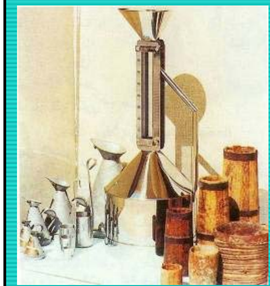
How we measure things!

ولد القياس منذ وجد الإنسان على وجه الأرض وتطوّر بتطوره . وأسهمت معظم الحضارات القديمة في تطور القياس بما فيها الحضارة الإسلامية ، حيث سجلت كتب التراث العلمي ما قام به العلماء المسلمون من قياسات علمية على مستوى عالٍ من الدقة ، مثل قياس طول محيط الكرة الأرضية في عهد الخليفة المأمون في القرن الثالث الهجري ، وكذلك قياس كثافة بعض المواد الصلبة في القرن الخامس الهجري .

وحدات القياس الإسلامية القديمة



كان لدى المسلمين عدد كبير من المقاييس الخاصة بهم ، ومنها :

مقاييس الطول :

الذراع والقدم والإصبع والشعيرة والباع والميل والفرسخ والبريد والحبل والقبضة والقصبة . والعلاقة بينها كما يلي :

الإصبع = ٦ شعيرات	الباع = ٤ أذرع
الميل = ١٠٠٠ باع	الفرسخ = ٣ أميال
القصبة = ٢٢ قبضة	القبضة = ٤ أصابع

مقاييس الوزن :

المثقال والدرهم والشعيرة والخردلة والفلس والفتيل والنقير والقطمير والذرة وغيرها والعلاقات بينها كما يلي :

الدرهم = $\frac{٧}{١٠}$ مثقال	المثقال = ٩٦ شعيرة
الشعيرة = ٦ خردلة	الخردلة = ١٢ فلس
الفلس = ٦ فتيل	الفتيل = ٦ نقير
النقير = ٨ قطمير	القطمير = ١٢ ذرة

(علماً بأن الذرة تساوي ٢,٦٣ × ١٠$^{-٧}$ جرام)

مقاييس الكيل :

الصاع والمد والأردب والجريب والخروبة والصحفة والقدح والقسط والقفيز والقيراط والكيلة والمختوم والمرزبان والمكوك والوسعة والويبة .

مقاييس المساحة :

الجريب والفدان والسهم والدانق والقفيز والمرجع .

المسلمون والقياسات الدقيقة المبكرة

كان « أبو الريحان البيروني » هو أول عالم عربي مسلم عكف على دراسة كثافة الأجسام بشكل علمي دقيق وذلك في القرن الحادي عشر للميلاد .

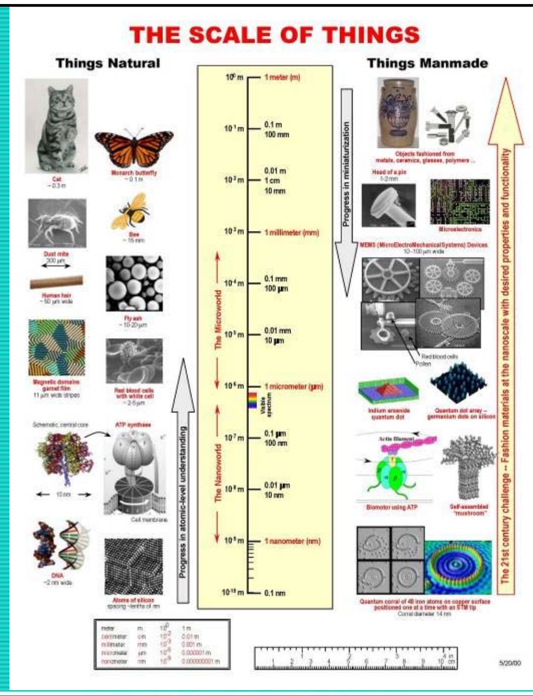
ولقد توصل البيروني إلى نتائج أكثر دقة مما توصل إليه العلماء الغربيون بعده بخمسة قرون .

الآلة المخروطة التي صممها البيروني لقياس الكثافة النسبية للأجسام الصلبة .

- How we measure things!
- All things in classical mechanics can be expressed in terms of the fundamental dimension or unit:

	Dimension	Unit
Length	L	meter (m)
Mass	M	kilogram (kg)
Time	T	second (s)

- For example:
  - Speed has dimension of L / T (i.e. km per hour).
  - Force has dimension of ML / T^2 etc... (as you will learn).



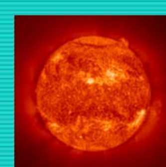
Length:

Distance	Length (m)
Radius of visible universe	1×10^{26}
To Andromeda Galaxy	2×10^{22}
To nearest star	4×10^{16}
Earth to Sun	1.5×10^{11}
Radius of Earth	6.4×10^{6}
Sears Tower	4.5×10^{2}
Football field	1.0×10^{2}
Tall person	2×10^{0}
Thickness of paper	1×10^{-4}
Wavelength of blue light	4×10^{-7}
Diameter of hydrogen atom	1×10^{-10}
Diameter of proton	1×10^{-15}

Time:

Interval	Time (s)
Age of universe	5×10^{17}
Age of Grand Canyon	3×10^{14}
32 years	1×10^{9}
One year	3.2×10^{7}
One hour	3.6×10^{3}
Light travel from Earth to Moon	1.3×10^{0}
One cycle of guitar A string	2×10^{-3}
One cycle of FM radio wave	6×10^{-8}
Lifetime of neutral pi meson	1×10^{-16}
Lifetime of top quark	4×10^{-25}

Mass:



Object	Mass (kg)
Milky Way Galaxy	4×10^{41}
Sun	2×10^{30}
Earth	6×10^{24}
Boeing 747	4×10^{5}
Car	1×10^{3}
Student	7×10^{1}
Dust particle	1×10^{-9}
Top quark	3×10^{-25}
Proton	2×10^{-27}
Electron	9×10^{-31}
Neutrino	1×10^{-38}

Units...

- SI (Système International) Units:
  - mks: L = meters (m), M = kilograms (kg), T = seconds (s)
  - cgs: L = centimeters (cm), M = grams (gm), T = seconds (s)
- Derived Units :
  - Newton, Joule, Watt, Ohm …. and etc.
- British Units:
  - Inches, feet, miles, pounds, slugs...
  - fps : L = foot, M = pound, T = second
- We will use mostly SI units with mks system, but you may run across some problems (rarely happen) using British units. You should know how to convert back & forth.

The 7 International System of Units (SI)

Quantity	SI Units	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	I
Temperature	kelvin	K
Luminous Intensity	candela	cd
Amount of Substance	mol	mol

Derived Units

Quantity	Unit	Abbreviation	In terms of Base Units
Force	Newton	N	$kg\ ms^{-2}$
Energy & Work	Joule	J	$kg\ m^2s^{-2}$
Power	Watt	W	$kg\ m^2s^{-3}$
Pressure	Pascal	Pa	$kg / (ms^2)$
Electric Charge	Coulomb	C	A s
Electric Potential	Volt	V	$kg\ m^2 / (A\ s^3)$
Capacitance	Farad	F	$A^2\ s^4 / (kg\ m^2)$
Inductance	Henry	H	$kg\ m^2 / (s^2\ A^2)$
Magnetic Flux	Weber	Wb	$kg\ m^2 / (A\ s^2)$

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Converting between different systems of units

- **Useful Conversion factors:**
  - **1 inch = 2.54 cm**
  - **1 m = 3.28 ft**
  - **1 mile = 5280 ft**
  - **1 mile = 1.61 km**
  - **1 mm^2 = 0.01 cm^2**
- **Example: convert miles per hour to meters per second:**

$$1\frac{mi}{hr} = 1\frac{mi}{hr} \times 5280\frac{ft}{mi} \times \frac{1}{3.28}\frac{m}{ft} \times \frac{1}{3600}\frac{hr}{s} = 0.447\frac{m}{s}$$

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Standard Prefixes : used to denote multiple of ten

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{-1}	deci	d	10^{1}	deka	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	m	10^{6}	Mega	M
10^{-9}	nano	n	10^{9}	Giga	G
10^{-12}	pico	p	10^{12}	Tera	T
10^{-15}	femto	f	10^{15}	Peta	P
10^{-18}	atto	a			

In 1971, the 14th General Conference on Weights and Measures picked seven quantities as base quantities, thereby forming the basis of the International System of Units, abbreviated SI from its French name and popularly known as the *metric system*.

Some SI Base Units

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

1-4 Length

- The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second.

$$c = 299{,}792{,}458 \text{ m/s}$$

1-5 Time

- One second is the time taken by 9 192 631 770 oscillations of the light (of a specified wavelength) emitted by a cesium-133 atom.

1-6 Mass

- The carbon-12 atom, by international agreement, has been assigned a mass of 12 atomic mass units (u). The relation between u and kg is

$$1 \text{ u} = 1.6605402 \times 10^{-27} \text{ kg}$$

Atomic Density

- In dealing with macroscopic numbers of atoms (and similar small particles) we often use a convenient quantity called Avogadro's Number, $N_A = 6.02 \times 10^{23}$.
- Molar Mass and Atomic Mass are nearly equal
  1. Molar Mass = mass in grams of one mole of the substance.
  2. Atomic Mass = mass in u (a.m.u.) of one atom of a substance, is approximately the number of protons and neutrons in one atom of that substance.
- Molar Mass and Atomic Mass are other units for density.

What is the mass of a single carbon atom ?

$$M(carbon) = \frac{12\ g/mol}{6\times10^{23}\ atoms/mol} = 2 \times 10^{-23} \text{ g/atom}$$

Basic Quantities and Their Dimension

- Dimension has a specific meaning – it denotes the physical nature of a quantity
- Dimensions are denoted with square brackets
  - Length [L]
  - Mass [M]
  - Time [T]

Dimensions and Units

Each dimension can have many actual units. Table below for the dimensions and units of some derived quantities

Dimensions and Units of Four Derived Quantities

Quantity	Area	Volume	Speed	Acceleration
Dimensions	L^2	L^3	L/T	L/T^2
SI units	m^2	m^3	m/s	m/s^2
U.S. customary units	ft^2	ft^3	ft/s	ft/s^2

Dimensional Analysis

- Technique to check the correctness of an equation or to assist in deriving an equation
- Dimensions (length, mass, time, combinations) can be treated as algebraic quantities
  - add, subtract, multiply, divide
- Both sides of equation must have the same dimensions
- Any relationship can be correct only if the dimensions on both sides of the equation are the same
- Cannot give numerical factors: this is its limitation

Dimensional Analysis

- An extremely useful concept in solving physical problems
- Good to write physical laws in mathematical expressions
- No matter what units are used the base quantities are the same
  - **Length (distance) is length whether meter or inch is used to express the size: Usually denoted as [L]**
  - **The same is true for Mass ([M])and Time ([T])**
  - **One can say "Dimension of Length, Mass or Time"**
  - **Dimensions are used as algebraic quantities: Can perform algebraic operations, addition, subtraction, multiplication or division**

Dimensional Analysis

- **This is a very important tool to check your work**
  - **It's also very easy!**
- **Example:**

  Doing a problem you get the answer for distance $d = v\,t^2$ (velocity x time^2)

  Quantity on left side = L
  Quantity on right side = L / T x T^2 = L x T

- **Left units and right units don't match, so answer must be wrong !!**

Dimensional Analysis

One can use dimensions only to check the validity of one's expression:

Dimensional analysis

eg: Speed [v] = [L]/[T]=[L][T^{-1}]

Distance (L) traveled by a car running at the speed V in time T

L = V*T = [L/T]*[T]=[L]

More general expression of dimensional analysis is using exponents:

eg. [v]=[$L^n T^m$] =[L][T-1] where n = 1 and m = -1

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Dimensional Analysis

- **The force (F) to keep an object moving in a circle can be described in terms of the velocity (v, dimension L/T) of the object, its mass (m, dimension M), and the radius of the circle (R, dimension L).**
  - **Which of the following formulas for *F* *could* be correct ?**

(a) $F = mvR$ (b) $F = m\left(\frac{v}{R}\right)^2$ (c) $F = \frac{mv^2}{R}$

Remember: *Force* has dimensions of ML/T^2

- **There is a famous Einstein's equation connecting energy and mass (relativistic). Using dimensional analysis find which is the correct form of this equation :**

(a) $E = mc$ (b) $E = mc^2$ (c) $E = mc^3$

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Density

- Every substance has a density, designated ρ = M/V
- Dimensions of density are, $\rho \equiv \frac{M}{L^3}$ units (kg/m^3)
  - Some examples,

Substance	ρ (10^3 kg/m^3)
Gold	19.3
Lead	11.3
Aluminum	2.70
Water	1.00

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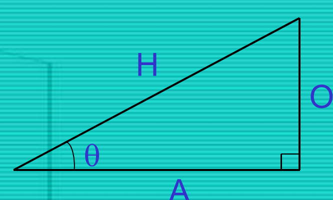
Review of Trigonometry

For right triangles only!

$$\sin\theta = \frac{O}{H}$$

$$\cos\theta = \frac{A}{H}$$

$$\tan\theta = \frac{O}{A}$$



Pythagorean Theorem $H^2 = A^2 + O^2$

SOHCAHTOA

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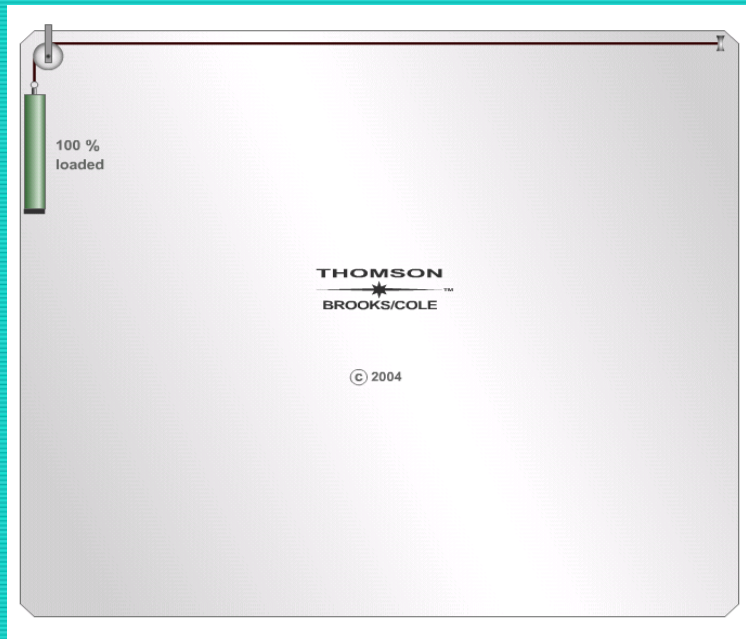

Scalars and Vectors

Vocabulary:

Scalars are numbers

Examples: 10 meters

75 kilometers/hour

Vectors are numbers with a direction

Example: 10 meters *to the right*

75 kilometers/hour *north*

Scalar: 25 meters
Vector: 25 meters *north*

Scalar: 25 meters
Vector: 25 meters *east*

More about vectors will be discuss later