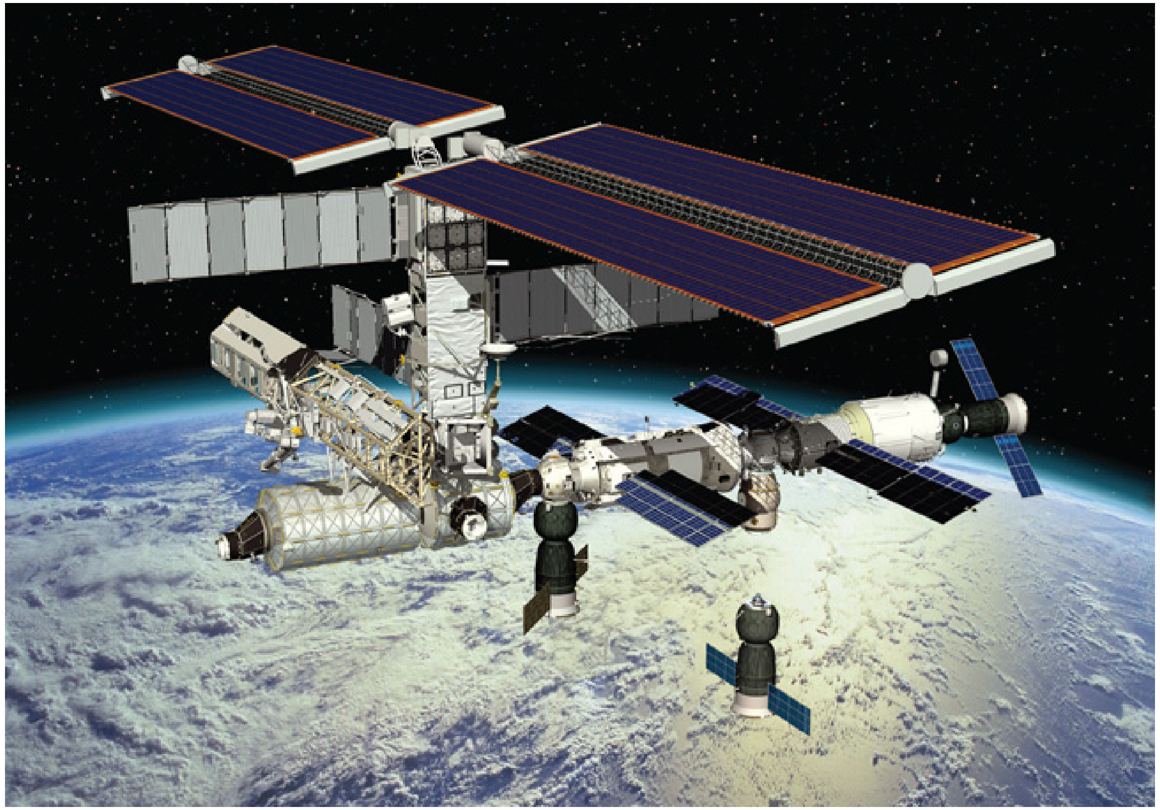
Lesson 1

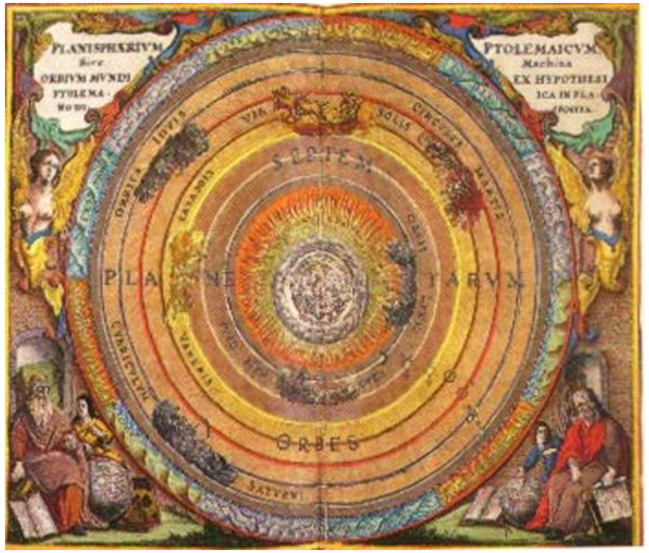
Tooling up:

- Fundamental Units
- Scientific Notation

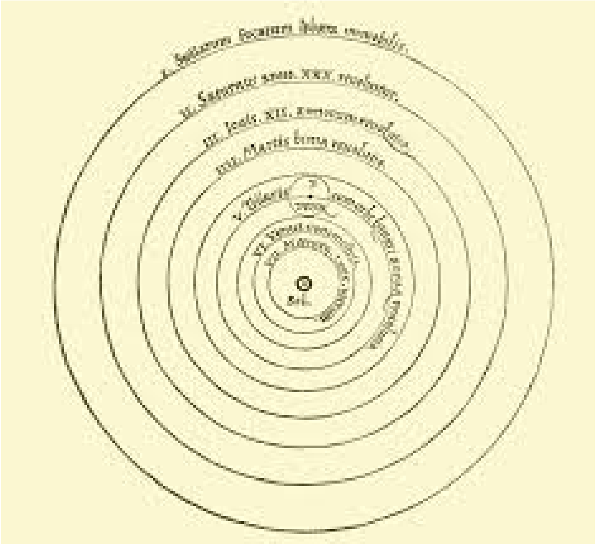
Why Science?



Copernicus, Galileo and the birth of modern science

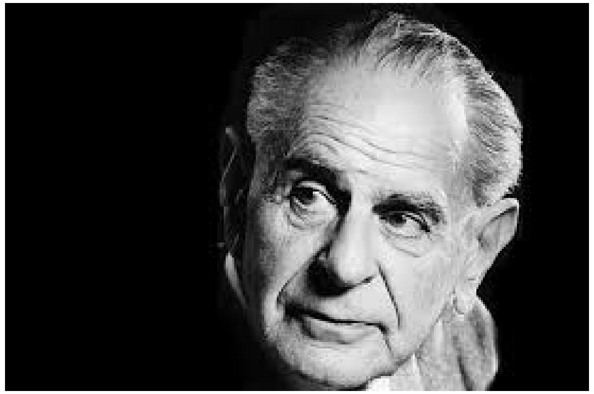


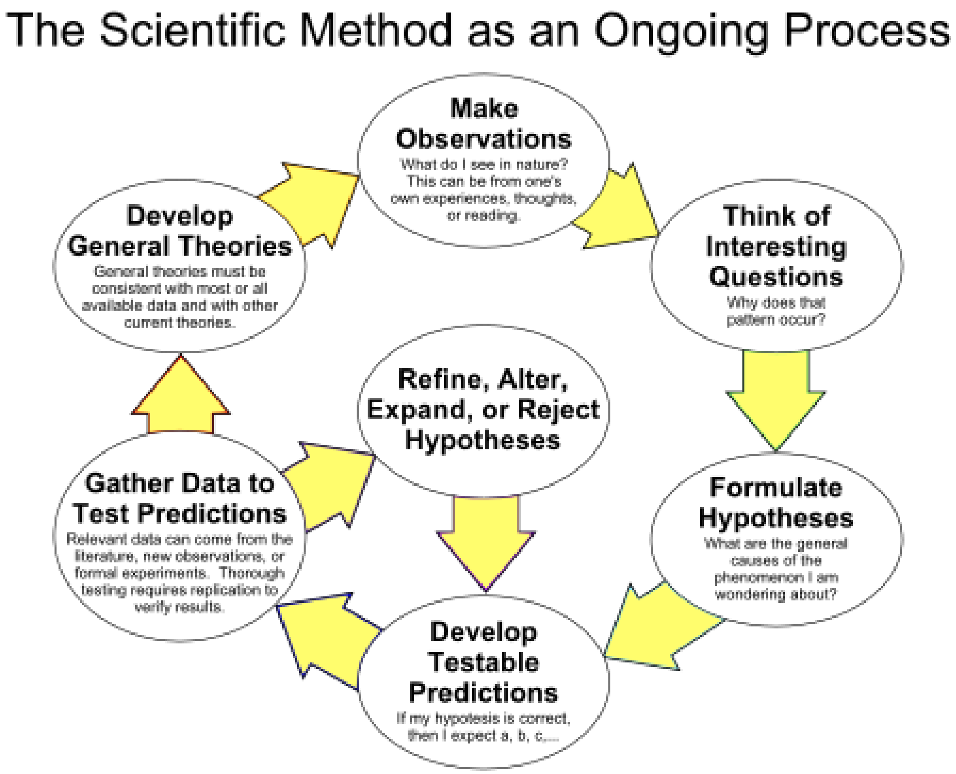
“Sun Stand Still”
Joshua 10-12



The Sun Stands Still
11As they fled from before Israel, while they were at the descent of Beth-horon, the LORD threw large stones from heaven on them as far as Azekah, and they died; there were
more who died from the hailstones than those whom the sons of Israel killed with the sword. 12Then Joshua spoke to the LORD in the day when the LORD delivered up the
Amoritesbefore the sons of Israel, and he said in the sight of Israel, "O sun, stand still at Gibeon, And O moon in the valley of Aijalon." 13So the sun stood still, and the moon
stopped, Until the nation avenged themselves of their enemies. Is it not written in the book of Jashar? And the sun stopped in the middle of the sky and did not hasten to go
down for about a whole day....

Scientific Method





Our understanding of the natural world moves along two fronts:

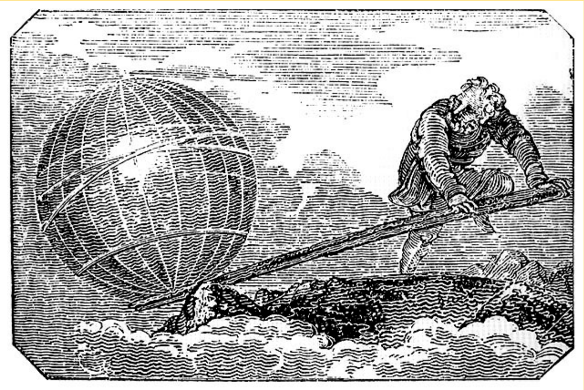
1. New concepts are built.
2. Better experimental techniques.

The 3 Periods of Physics (so far)

Physics in Antiquity

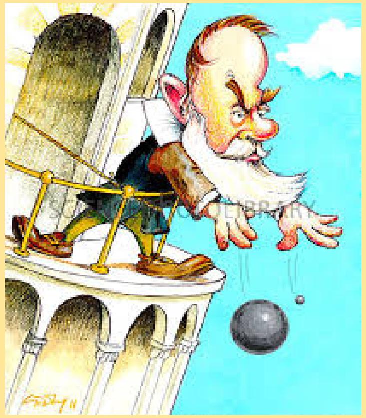
Aristotle

Archimedes

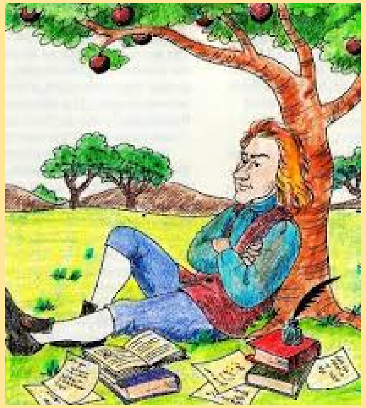


Classical Physics (Pre-1920)

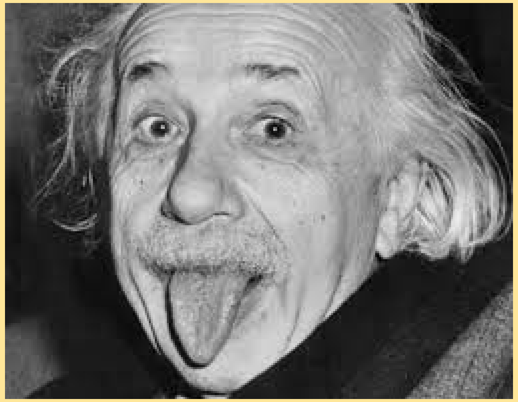
Galileo



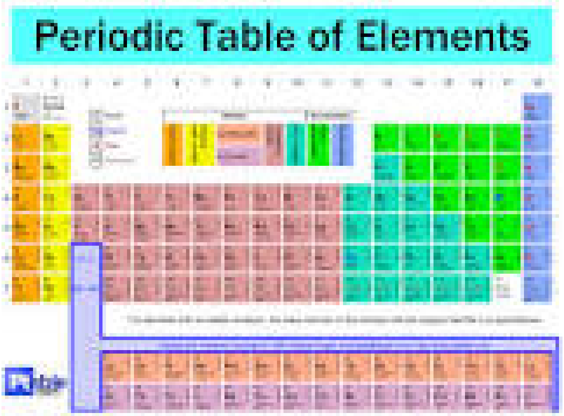
Newton



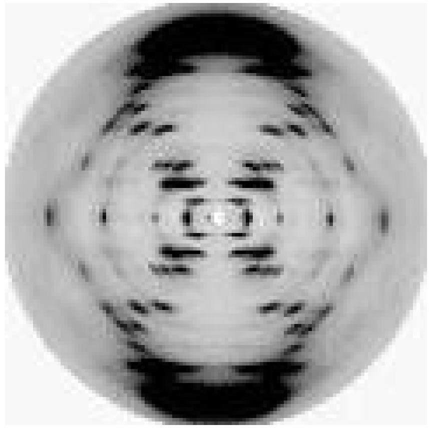
Modern Physics (post 1920)



Physics in relation to other sciences



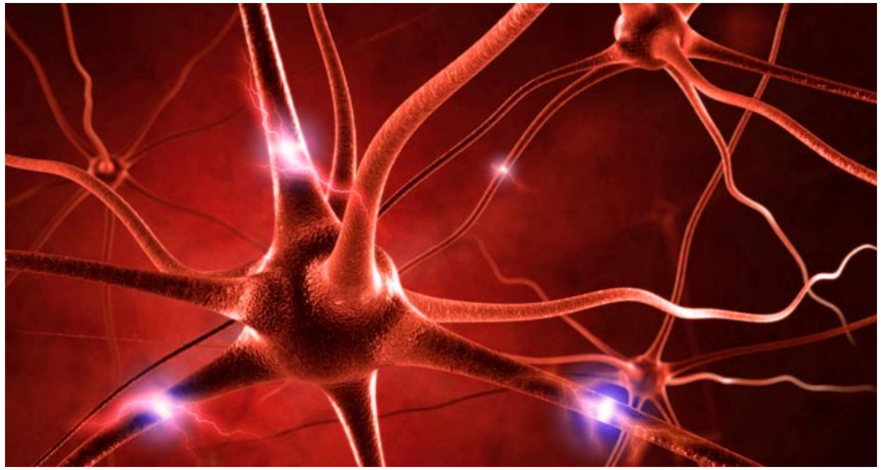
Chemistry



Biology

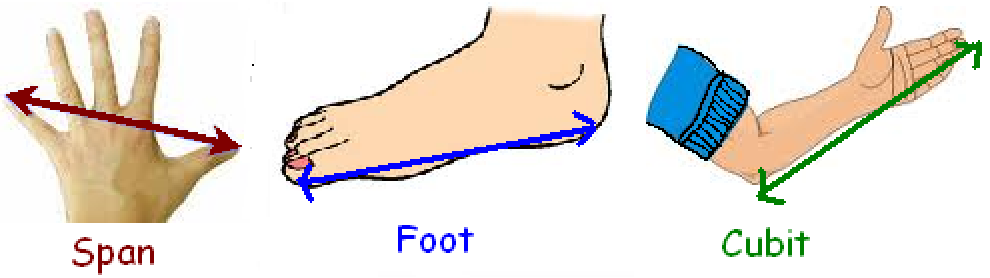
Astronomy

Geology

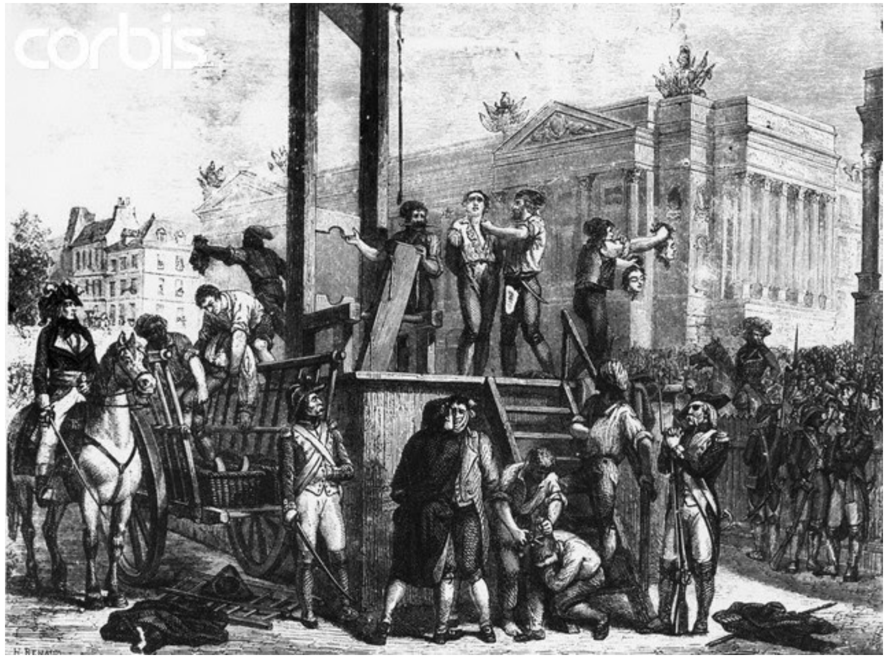


Neuro-science

The Need for Standards and Units



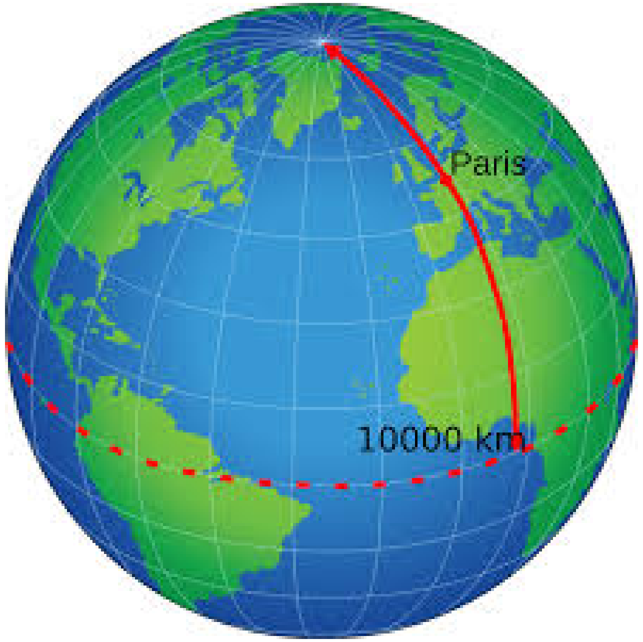
Henry I (1100-1135)



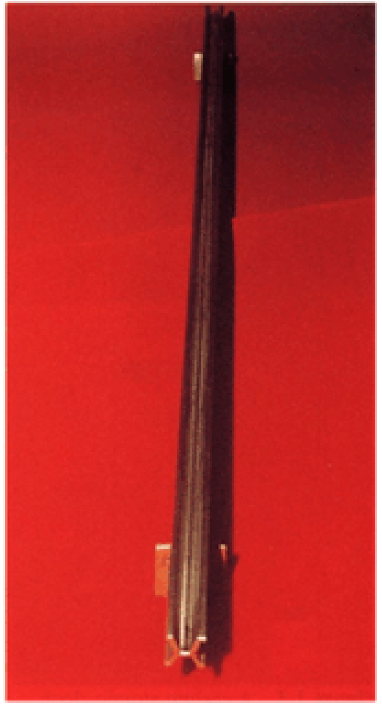
NIST

Length (m)

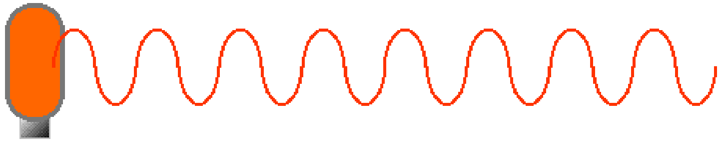
1790



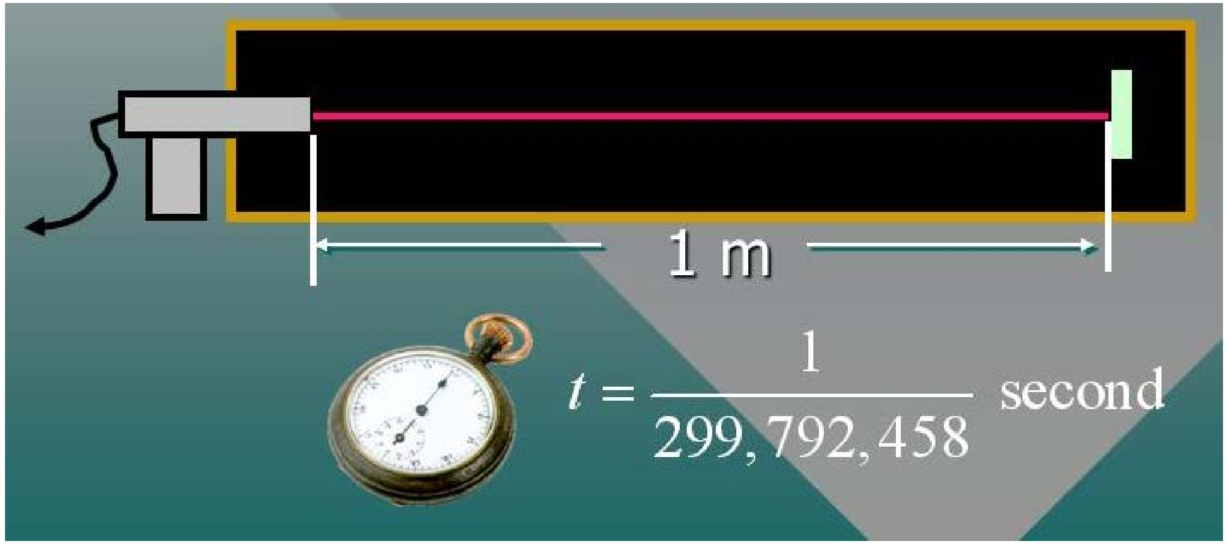
1790



1960
^{86}Kr

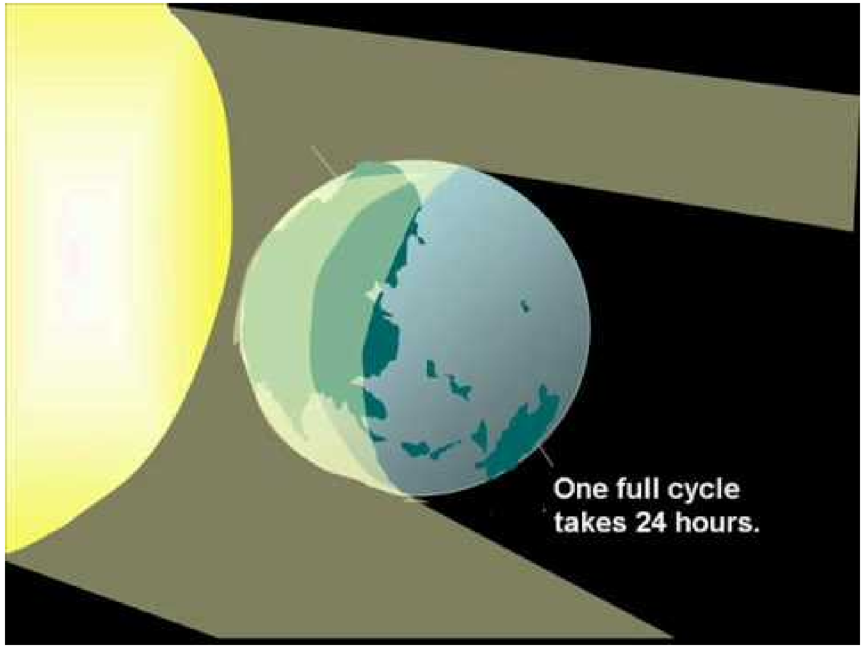


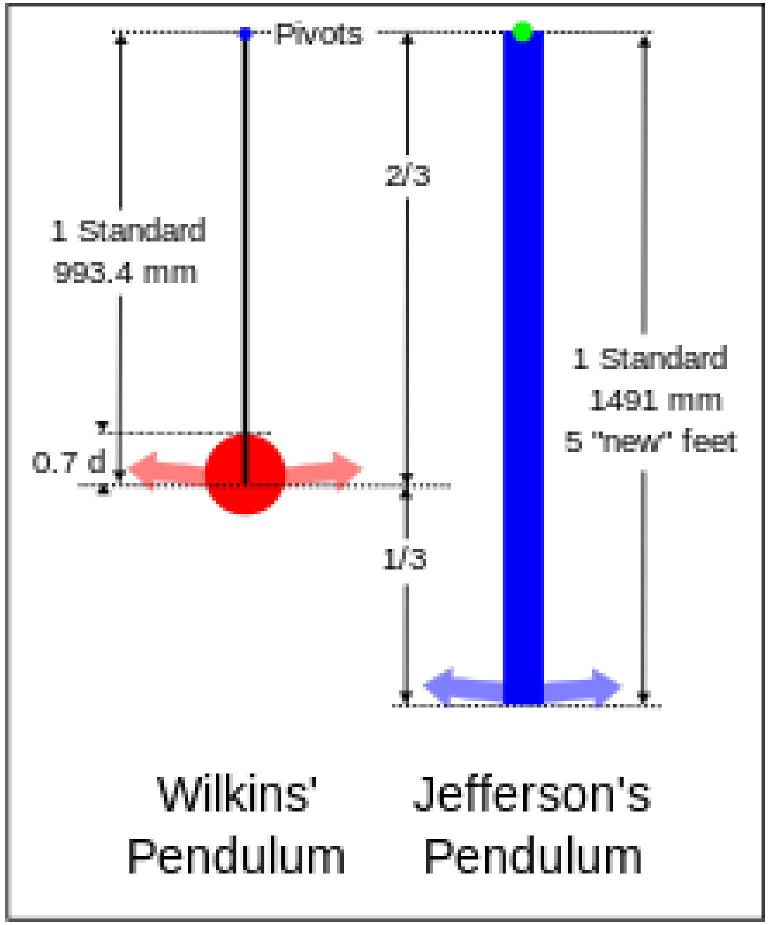
Current definition: 1984



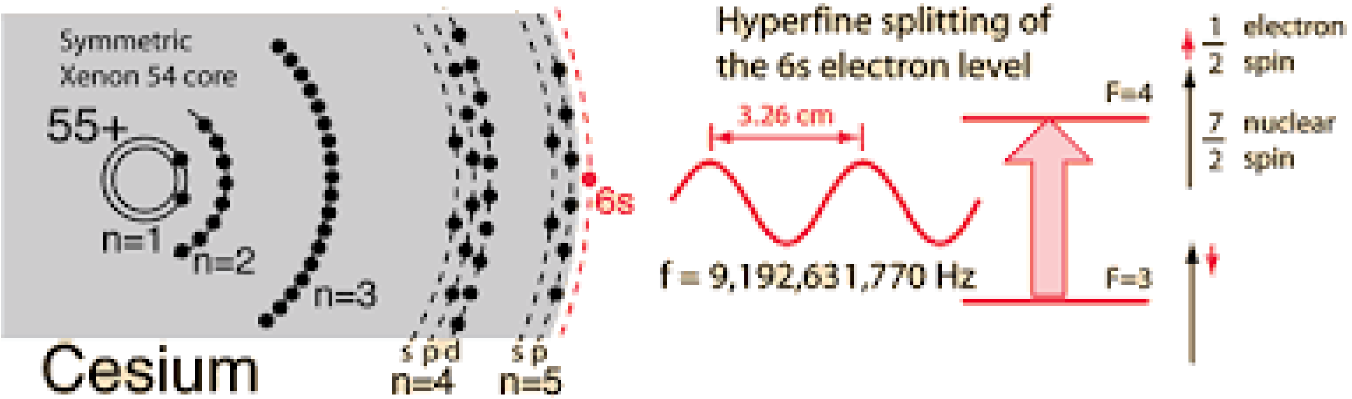
Time (s)

1/86 400
of “mean solar day”



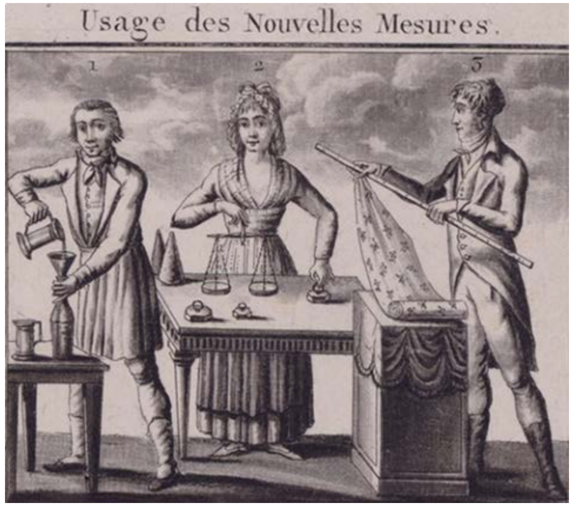


1967
^{133}Kr

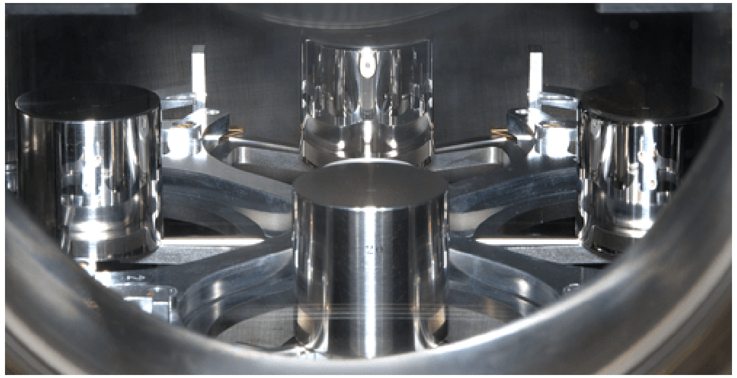


Mass (kg)

Gram=mass of 1 cm^3 of water at 4 °C.



1890



Future Standard?

^{28}Si

Other Fundamental Units

TABLE 1.4 • SI Base Units

Physical Quantity		Name of Unit	Abbreviation
Mass		Kilogram	kg
Length	MKS or SI	Meter	m
Time		Second	s or sec
Temperature		Kelvin	K
Amount of substance		Mole	mol
Electric current		Ampere	A or amp
Luminous intensity		Candela	cd

TABLE 1.5 • Prefixes Used in the Metric System and with SI Units

Prefix	Abbreviation	Meaning	Example
Peta	P	10^{15}	1 petawatt (PW) $= 1 \times 10^{15}$ watts[a]
Tera	T	10^{12}	1 terawatt (TW) $= 1 \times 10^{12}$ watts
Giga	G	10^{9}	1 gigawatt (GW) $= 1 \times 10^{9}$ watts
Mega	M	10^{6}	1 megawatt (MW) $= 1 \times 10^{6}$ watts
Kilo	k	10^{3}	1 kilowatt (kW) $= 1 \times 10^{3}$ watts
Deci	d	10^{-1}	1 deciwatt (dW) $= 1 \times 10^{-1}$ watt
Centi	c	10^{-2}	1 centiwatt (cW) $= 1 \times 10^{-2}$ watt
Milli	m	10^{-3}	1 milliwatt (mW) $= 1 \times 10^{-3}$ watt
Micro	μ[b]	10^{-6}	1 microwatt (μW) $= 1 \times 10^{-6}$ watt
Nano	n	10^{-9}	1 nanowatt (nW) $= 1 \times 10^{-9}$ watt
Pico	p	10^{-12}	1 picowatt (pW) $= 1 \times 10^{-12}$ watt
Femto	f	10^{-15}	1 femtowatt (fW) $= 1 \times 10^{-15}$ watt
Atto	a	10^{-18}	1 attowatt (aW) $= 1 \times 10^{-18}$ watt
Zepto	z	10^{-21}	1 zeptowatt (zW) $= 1 \times 10^{-21}$ watt

Scientific Notation

In scientific notation all numbers are written in the form:

mantissa *Order of magnitude*

$$m \times 10^{n}$$

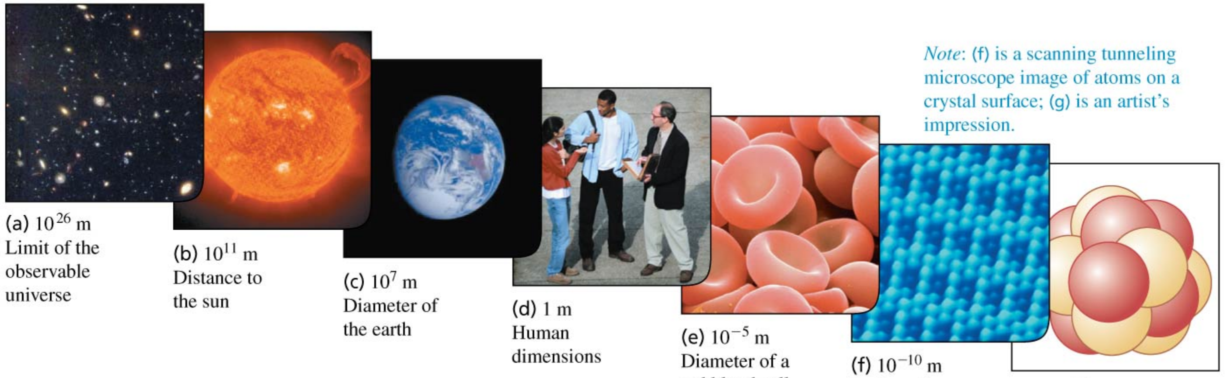
Here *m* satisfies

$$1 \leq m < 10$$

Any physical quantity must be accompanied by units:

$$\text{Mass of the sun} = 1.99 \times 10^{30}\,\text{kg}$$

This mantissa contains 3 significant figures.



(a) 10^{26} m Limit of the observable universe

(b) 10^{11} m Distance to the sun

(c) 10^{7} m Diameter of the earth

(d) 1 m Human dimensions

(e) 10^{-5} m Diameter of a red blood cell

(f) 10^{-10} m Radius of an atom

(g) 10^{-14} m Radius of an atomic nucleus

Note: (f) is a scanning tunneling microscope image of atoms on a crystal surface; (g) is an artist's impression.

TABLE 1–1 • Orders of Magnitude for Length

Parameter	Length (m)	Parameter	Length (m)
Proton	10^{-15}	Earth–Moon distance	10^{9}
Hydrogen atom	10^{-10}	Earth–Sun distance	10^{11}
Flu virus	10^{-7}	Diameter of solar system	10^{13}
One bit on a DVD	10^{-6}	Distance to nearest star (Proxima Centauri)	10^{17}
Raindrop	10^{-3}	Diameter of our galaxy (Milky Way)	10^{21}
Height of person	10^{0}	Distance to nearest galaxy	10^{22}
One mile	10^{3}	Distance to edge of observable universe	10^{26}
Diameter of Earth	10^{7}		

TABLE 1–2 • Orders of Magnitude for Time

Parameter	Time (s)	Parameter	Time (s)
Time for light to cross proton	10^{-23}	Class lecture	10^{3}
Time for light to cross atom	10^{-19}	One Earth day	10^{5}
Period of visible light wave	10^{-15}	One Earth year	10^{7}
Period of vibration for standard cesium clock	10^{-10}	Age of Greek antiquities	10^{11}
Time required for one operation in a personal computer	10^{-9}	Age of first humanoids	10^{14}
Half-life of muon	10^{-6}	Age of Earth	10^{17}
Period of highest audible sound	10^{-4}	Age of universe	10^{18}
Period of human heartbeat	10^{0}		

TABLE 1–3 • Orders of Magnitude for Mass

Parameter	Mass (kg)	Parameter	Mass (kg)
Electron	10^{-30}	Battleship	10^{8}
Hydrogen atom	10^{-27}	Moon	10^{23}
Uranium atom	10^{-24}	Earth	10^{25}
Dust particle	10^{-13}	Sun	10^{30}
Raindrop	10^{-6}	Our galaxy (Milky Way)	10^{41}
Piece of paper	10^{-2}	Observable universe	10^{52}
Human	10^{2}		

Uncertainty in Measurements

Good accuracy
Good precision

Poor accuracy
Good precision

Poor accuracy
Poor precision

It is understood that the last digit is always the result of approximation:
7.61011

Identifying Significant Figures

- Any non zero digit is significant.
- Zeros:
  - Zeros *between* significant figures all zeros are **always** significant:

    10.05 m has four significant figures
  - Zeros *at the beginning* are **never** significant:

    0.025 kg has two significant figures.
  - Zeros *at the end* are significant if the number has a decimal point:

    0.70 s has two significant figures
  - Problem: Zeros at the end without decimal point is ambiguous:

    4200 cm could have two or four figures.

    To avoid this ambiguity use scientific notation.

    4.2×10^3 cm two significant figures

    4.20×10^3 cm three significant figures

    4.200×10^3 cm four significant figures

Significant Figures in Calculations

Addition and subtraction.

$$20.42 + 1.322 + 83.1$$

$$\begin{array}{r} 20.42 \\ 1.322 \\ +\ 83.1 \\ \hline 104.842 \\ \hline 104.8 \end{array}$$

The result has the same number of decimal places as the measurement with the fewest decimal places.

Multiplication and division

$$6.221 \times 5.2$$

$$\begin{array}{r} 6.221 \\ \times\ 5.2 \\ \hline 12442 \\ +\ 31105 \\ \hline 32.3492 \\ 32. \end{array}$$

The result contains the same number of significant figures as the measurement with the fewest significant figures.

Q1.1

The density of a material is equal to its mass divided by its volume. What is the density in kg/m^3 of a rock of mass 1.80 kg and volume 6.0×10^{-4} m^3?

A. 3×10^3 kg/m^3

B. 3.0×10^3 kg/m^3

C. 3.00×10^3 kg/m^3

D. 3.000×10^3 kg/m^3

E. Any of these — all of these answers are mathematically equivalent.

A1.1

The density of a material is equal to its mass divided by its volume. What is the density in kg/m^3 of a rock of mass 1.80 kg and volume 6.0×10^{-4} m^3?

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Some SI Derived Units

Area is measured in: m^2 → $[A] = [L^2]$

Volume is measured in: m^3 → $[V] = [L^3]$

Density is measured in: $\frac{\text{kg}}{\text{m}^3}$ → $[\rho] = \left[\frac{M}{L^3}\right] = [ML^{-3}]$

Speed is measured in: $\frac{\text{m}}{\text{s}}$ → $[v] = \left[\frac{L}{T}\right] = [LT^{-1}]$

Acceleration is measured in: $\frac{\text{m}}{\text{s}^2}$ → $[a] = \left[\frac{L}{T^2}\right] = [LT^{-2}]$

Energy is measured in Joules: $\text{J}=\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$ → $[E] = \left[\frac{ML^2}{T^2}\right] = [ML^2T^{-2}]$

Power is measured in Watts: $\text{W}=\frac{\text{kg}\cdot\text{m}^2}{\text{s}^3}$ → $[P] = \left[\frac{ML^2}{T^3}\right] = [ML^2T^{-3}]$

Dimensional Analysis

- The dimensions of one side of the equation must be the same as those on the other side of the equation:

For example:

$$a\,h = \frac{v^2}{2}$$

$[h] = [L\ ]$

$[a] = [LT^{-2}]$

$[ah] = [L^2T^{-2}]$

The dimensions are the same.

Numbers are dimensionless

$[v] = [LT^{-1}]$

$[v^2] = [L^2T^{-2}]$

You can not add or substract different units, but you can multiply them or divide them.

Conversion Factors

- Suppose we needed to change a speed in "US units" of 55 mph, to SI units (m/s).
- We know the following relations:

1 mi = 1.609 km

1 km = 1000 m

1 hour = 60 min

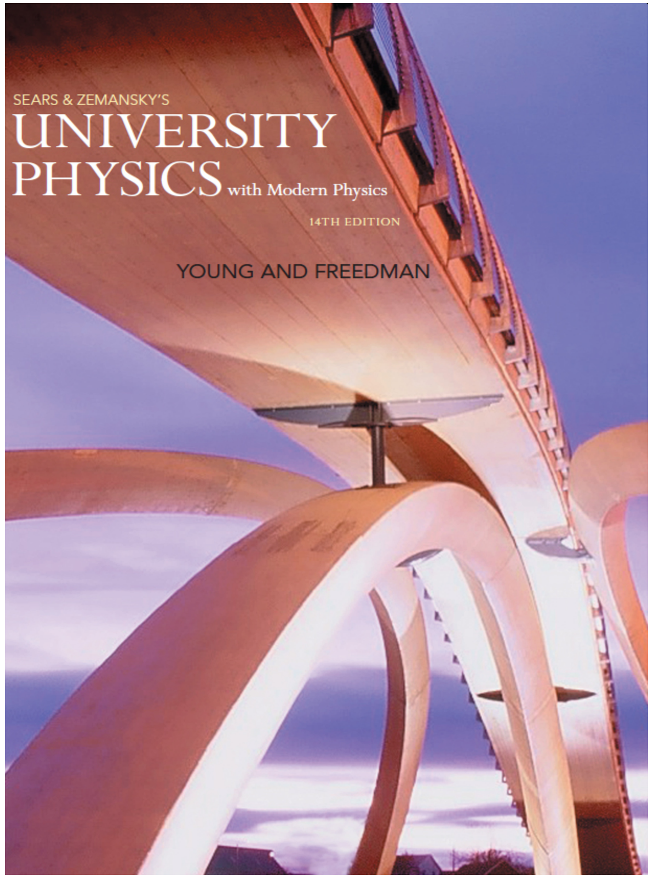
1 min = 6 s

- We multiply by expressions that are equal to 1

$$55\left(\frac{\mathrm{mi}}{\mathrm{hr}}\right) = 55\left(\frac{\cancel{\mathrm{mi}}}{\cancel{\mathrm{hr}}}\right)\left(\frac{1.609\cancel{\mathrm{km}}}{1\,\cancel{\mathrm{mi}}}\right)\left(\frac{1000\mathrm{m}}{1\cancel{\mathrm{km}}}\right)\left(\frac{1\cancel{\mathrm{hr}}}{60\cancel{\mathrm{min}}}\right)\left(\frac{1\cancel{\mathrm{min}}}{60\mathrm{s}}\right)$$

$$25\left(\frac{\mathrm{m}}{\mathrm{s}}\right)$$

Solving Problems in Physics



- All of the **Problem-Solving Strategies** and **Examples** in the textbook will follow these four steps:
- **Identify** the relevant concepts, target variables, and known quantities, as stated or implied in the problem.
- **Set Up** the problem: Choose the equations that you'll use to solve the problem, and draw a sketch of the situation.
- **Execute** the solution: This is where you "do the math."
- **Evaluate** your answer: Compare your answer with your estimates, and reconsider things if there's a discrepancy.

Estimation
“Back of the Envelope Calculations”

- ***Estimate*** the average area available to each person
  - in the USA.
  - In the World.
- IDENTIFY:
  - We need:
    - Approximate number of people in the USA
    - Approximate number of people in the World
    - Approximate area of the USA
    - Approximate area of the world.
  - Execute:
    - We only care about the orders of magnitude.