Scientific Methodology

Scientific methods

- Definition and purpose
- The natural world
- Hypotheses
- Theories

The metric system

Science

The process by which scientists, collectively and over time, endeavor to construct an accurate (that is, reliable, consistent and non-arbitrary) representation of the world.

Yielding the same or compatible results in different clinical experiments or statistical trials.

Being in agreement with itself

not subject to individual determination

http://teacher.nsrl.rochester.edu/phy_labs/AppendixE/AppendixE.html

Purpose of Science

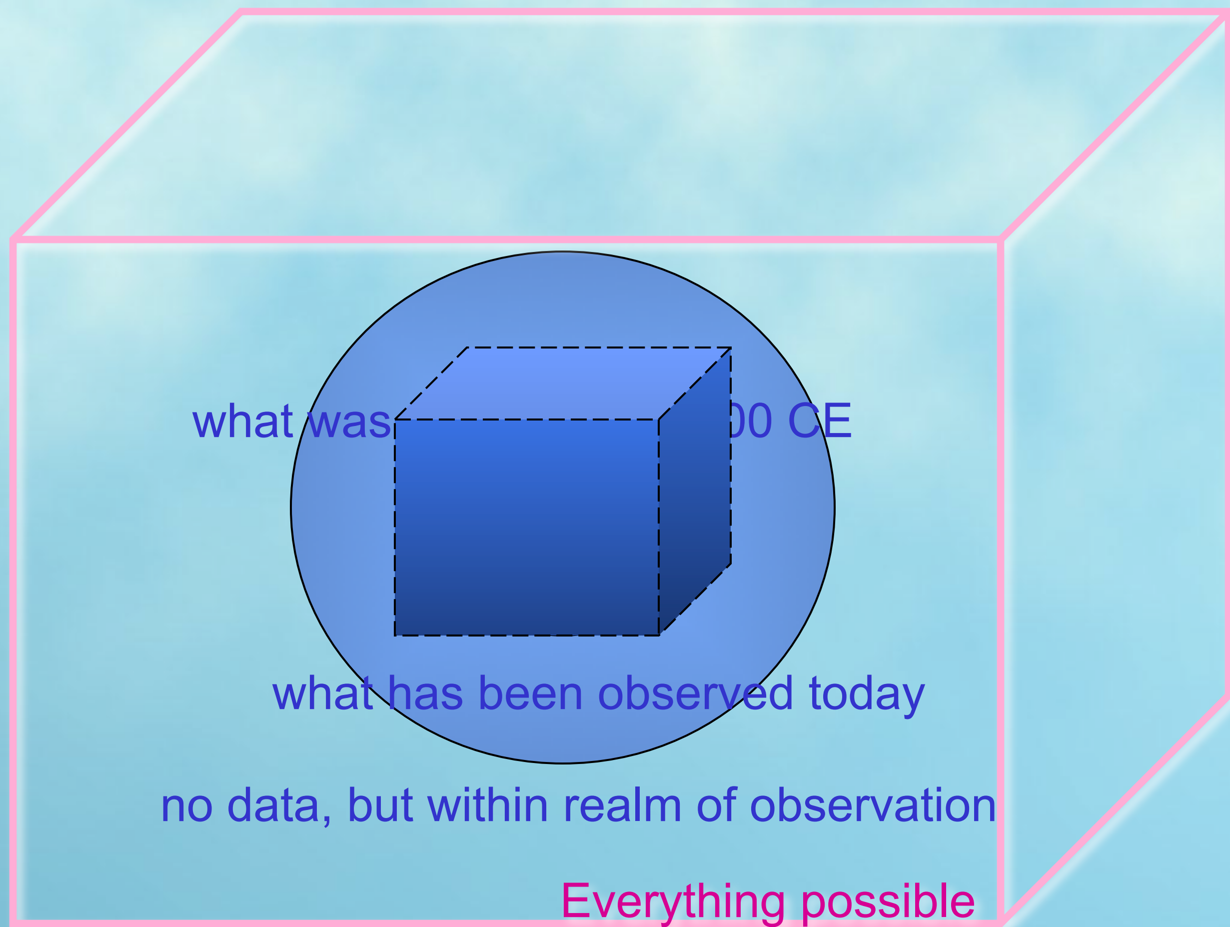
"To discover the underlying patterns in the natural world and then use this knowledge to predict what will or will not happen, give certain facts or circumstances."

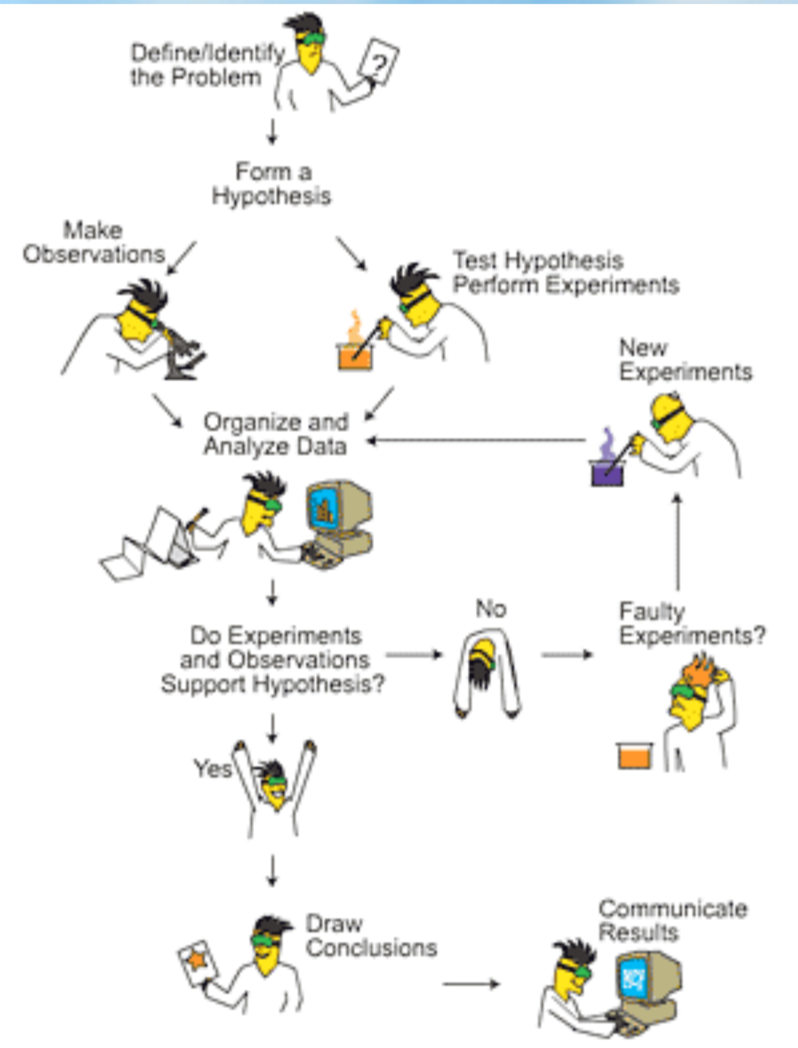
Tarbucks and Lutgens 2000

The Natural World

- Observable phenomena - including both the unaided and technologically aided senses.
- Repeatable phenomena - methodology usually fails with completely unique phenomena
- No supernatural causation - methodology can not address phenomena caused by anything except natural phenomena.

The Natural World





The "scientific method" requires the scientist to formulate hypotheses to explain natural phenomena.

These hypotheses are then tested using experimentation. Hypotheses that fail testing are discarded. New hypotheses must be formulated.

If an experiment confirms the predictions of a hypothesis, the hypothesis is provisionally accepted, pending further testing.

“Scientific Method”

hypotheses

Frequently described as a “guess.”

“preliminary, untested explanation” for an observed phenomenon, incorporating previous observations and theories.

“Educated guess”

Constructing Hypotheses

Designing a scientific experiment requires a series of predictions about what might happen:

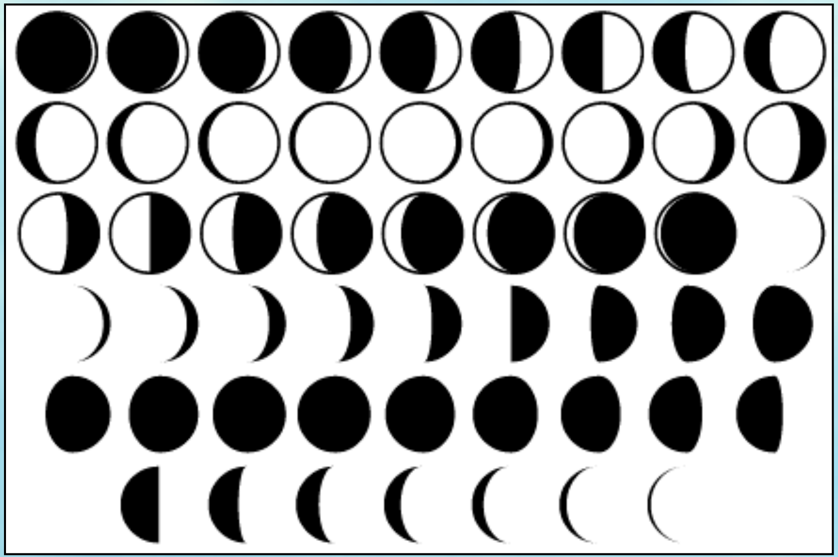
- The null hypothesis (H_o) is the expected result if there is no effect
- Hypotheses for testing (H_1, H_2, etc.) are predictions of what will happen if the hypothesized effect occurs.

A testing hypotheses must:

Include specific observations you *expect to make* if the hypothesis is true.

Be testable with the data you *intend to collect*.

Phases of the Moon Experiment



A group of students intends to observe the phases of the moon for a period of 49 days (7 weeks). Based on previous observations, they expect the Moon phases to change in predictable way, and that moonrise will occur later every day/night of observations.

Phases of the Moon Experiment

Data Collected: Students collected data about moonrise times from the internet. They also observed the phase of the Moon directly two times a week.

Phases of the Moon Experiment

- **H_0** - Over the 49 days of data collecting, we will not observe the Moon go through its complete cycle of phases in order 1.7 times.

- **H_1** - Over the 49 days of data collecting, we will observe the Moon go through its cycle of phases in order 1.7 times.

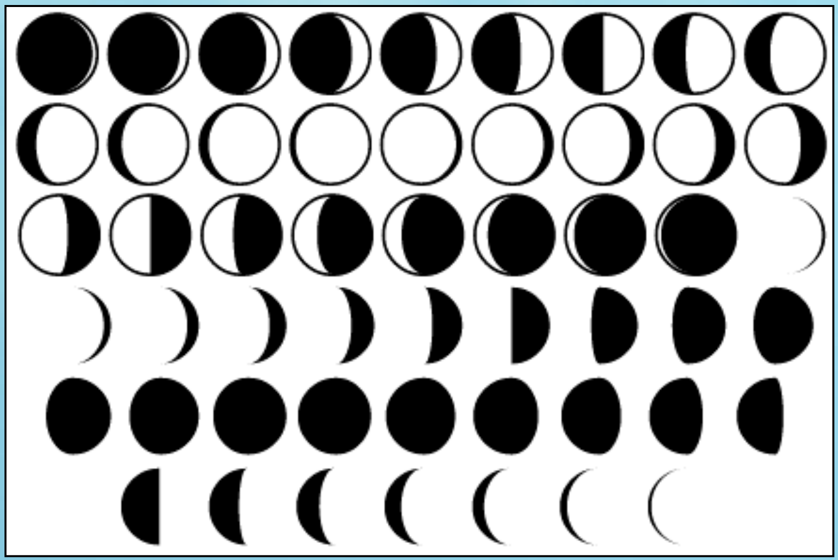
Phases of the Moon Experiment

- **H_0** - During a seven week period, the Moon will not rise approximately one hour later every day/night as it cycles through its phases.
- **H_1** - During a seven week period, the Moon will rise approximately one hour later every day/night as it cycles through its phases.

Phases of the Moon Experiment

The Null Hypothesis - the result if there is no experimental effect. The hypothesis must be both possible (potentially true), and related to the observations being made

"There is no scientific reason why the Moon changes phase."



Phases of the Moon Experiment

Bad hypotheses

Not expected result for 7 weeks

H_1 - The Moon will complete two cycles in the next three months.

Not observation period!

H_1 - The Moon will complete one and a half revolutions around the Earth.

Not directly observable from Earth

H_1 - The Moon will behave as I predict 80% of the time.

Does not include specific observations. Why would Moon misbehave 20% of the time?

Scientific Method

Terminology

Hypothesis - limited statement regarding cause and effect in specific situations; e.g., your car will not start. You may say, "My car does not start because the battery is low." This is your first hypothesis.

Scientific theory or law - an hypothesis, or a group of related hypotheses, which has been confirmed through repeated experimental tests.

The validity that we attach to scientific theories as representing realities of the physical world is to be contrasted with the facile invalidation implied by the expression, "It's only a theory." For example, it is unlikely that a person will step off a tall building on the assumption that they will not fall, because "Gravity is only a theory."

http://teacher.nsrl.rochester.edu/phy_labs/AppendixE/AppendixE.html

Scientific Method

Terminology

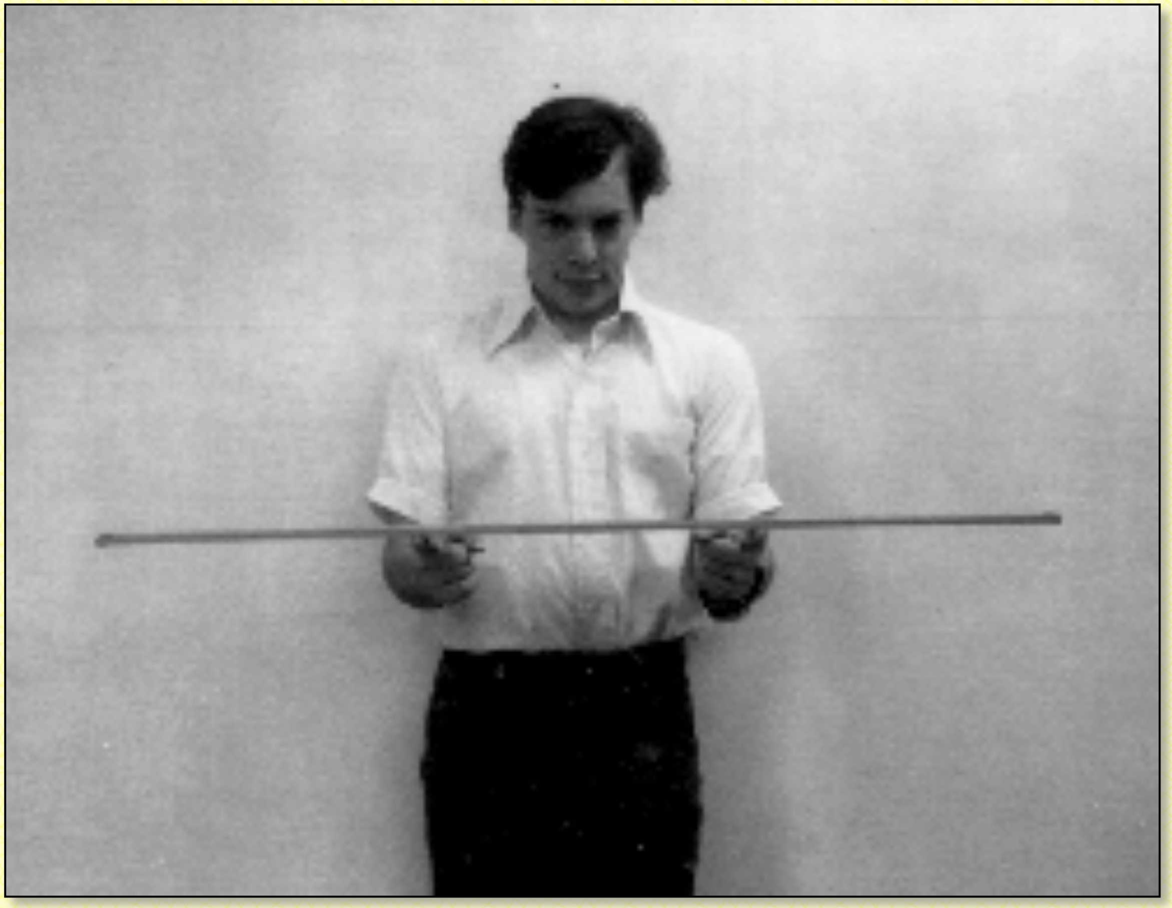
Some theories are so well supported by the available evidence that they take on an even more exalted title – "Accepted Theory."

Examples of Accepted Theories:

- Quantum theory (physics)
- Theory of evolution (biology)
- Theory of plate tectonics (geology)
- Germ theory of infection (medicine)
- Atomic theory of matter (chemistry)

All of these theories are supported by so many diverse lines of evidence that rejecting any of them would require a complete restructuring of our understanding of the natural world.

The Metric System



1791 French Academy of Sciences: meter intended to equal 10^{-7} (1 ten-millionth) of the length of the line of longitude through Paris from pole to equator. First prototype short by 0.2 millimeters because researchers miscalculated the flattening of the Earth at poles (the Earth is not a perfect sphere).

1827: meter more precisely defined as the distance between axes of the two central lines marked on a bar of platinum-iridium (subject to standard atmospheric pressure at 0°C; supported on two cylinders (>1 cm diameter) symmetrically placed in the same horizontal plane 57.1 cm from each other)

1889: new international prototype made of platinum-iridium alloy

1960: new definition based upon a wavelength of krypton-86 radiation

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

http://web.northnet.org/training/Instructions.htm

Metric Prefixes

HUGE VALUES

10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M

10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
1		
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m

tiny values

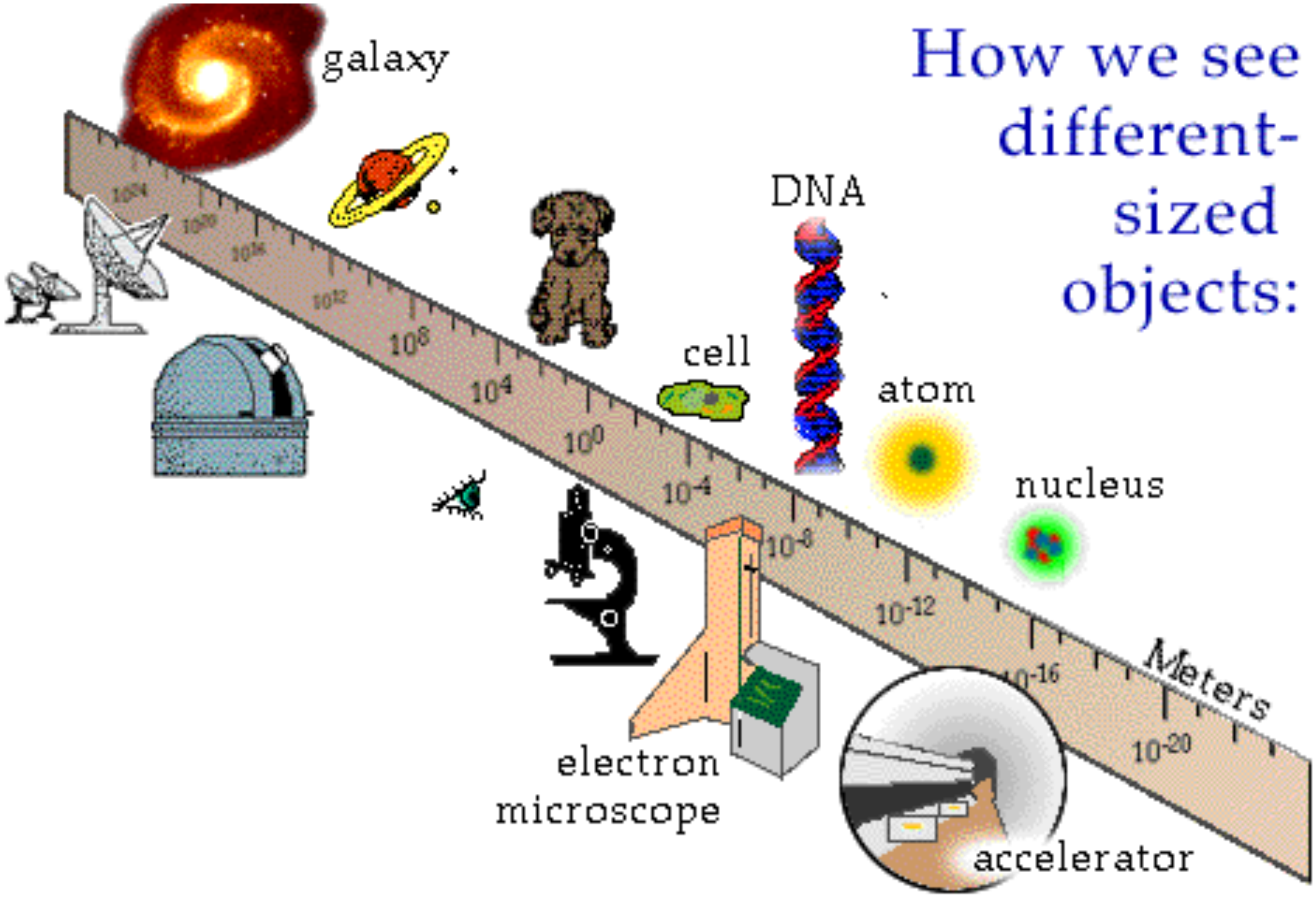
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

1 millionth of a fish = 1 microfiche
1 trillion pins = 1 terrapin
10 rations = 1 decoration

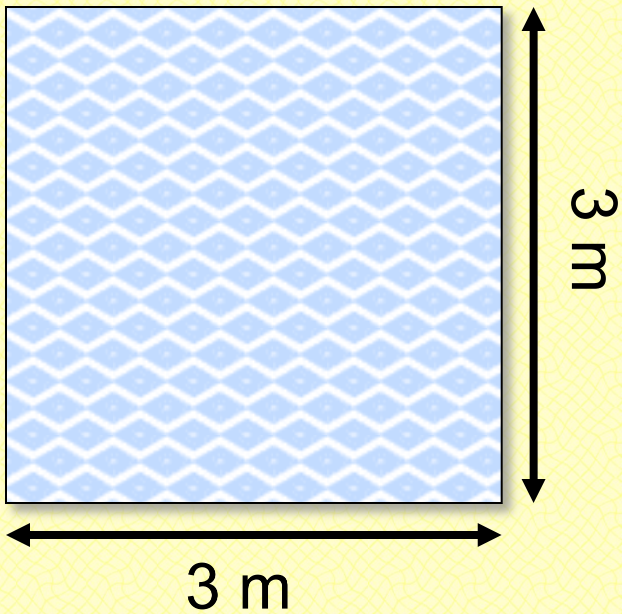
1 trillion microphones = 1 megaphone
2000 mockingbirds = two kilomockingbirds
10 cards = 1 decacards

100 rations = 1 C-ration
10 millipedes = 1 centipede
3 1/3 tridents = 1 decadent

How we see different-sized objects:



Area



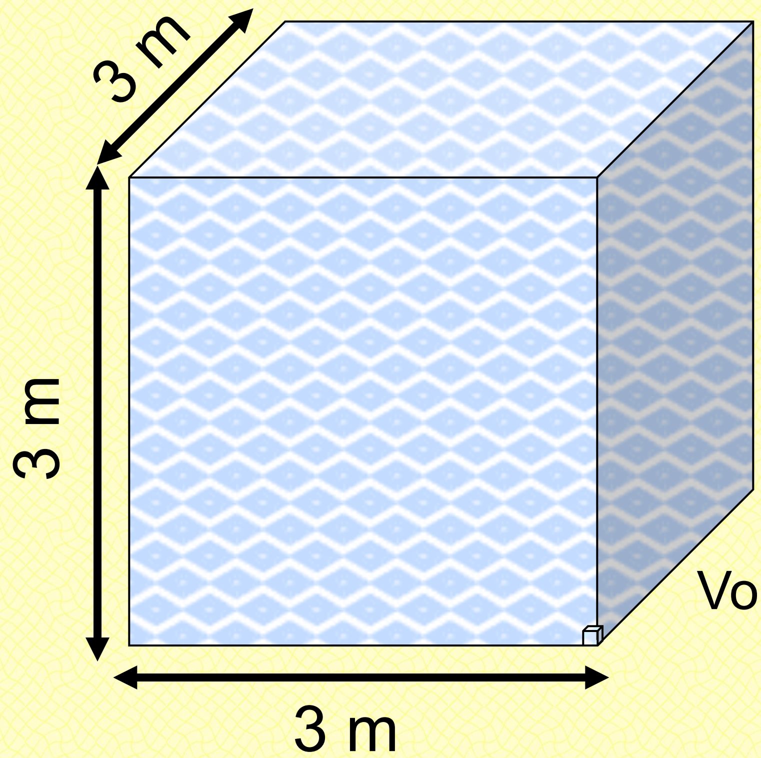
Area = (length)(width)

Area = (3 m)(3 m) = 9 m^2

Area = ? cm^2

1 m^2 = (1 m)(1 m) = (100 cm)(100 cm) = 10,000 cm^2

Area = 90,000 cm^2



Volume

Volume = (length)(width)(height)

Volume = (3 m)(3 m)(3 m) = 27 m^3

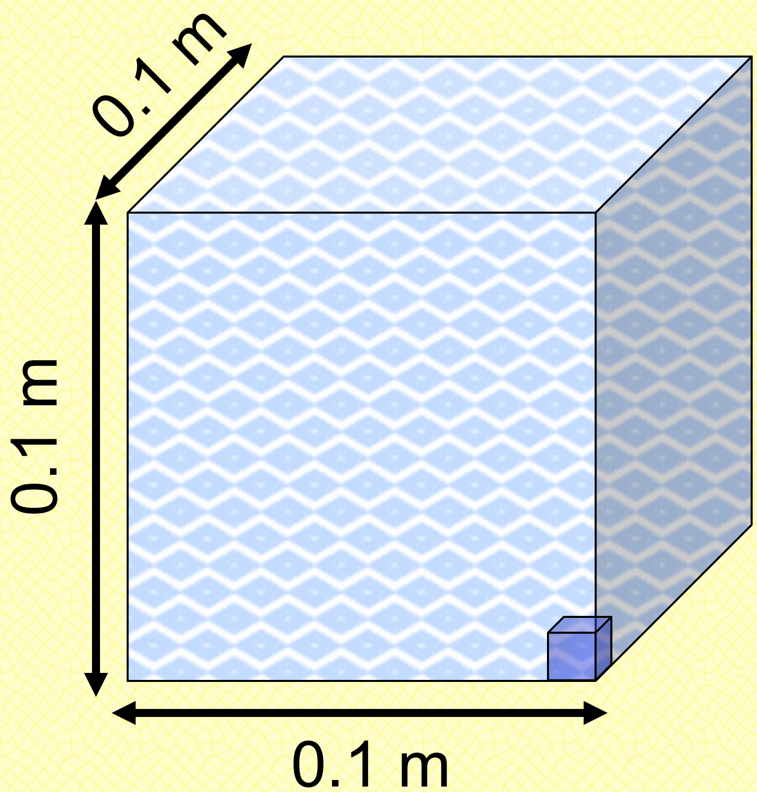
Volume = ? cm^3

1 m^3 = (1 m)(1 m)(1 m)

= (100 cm)(100 cm)(100 cm)

= 1,000,000 cm^3

Volume = 27,000,000 cm^3



Volume: The Liter

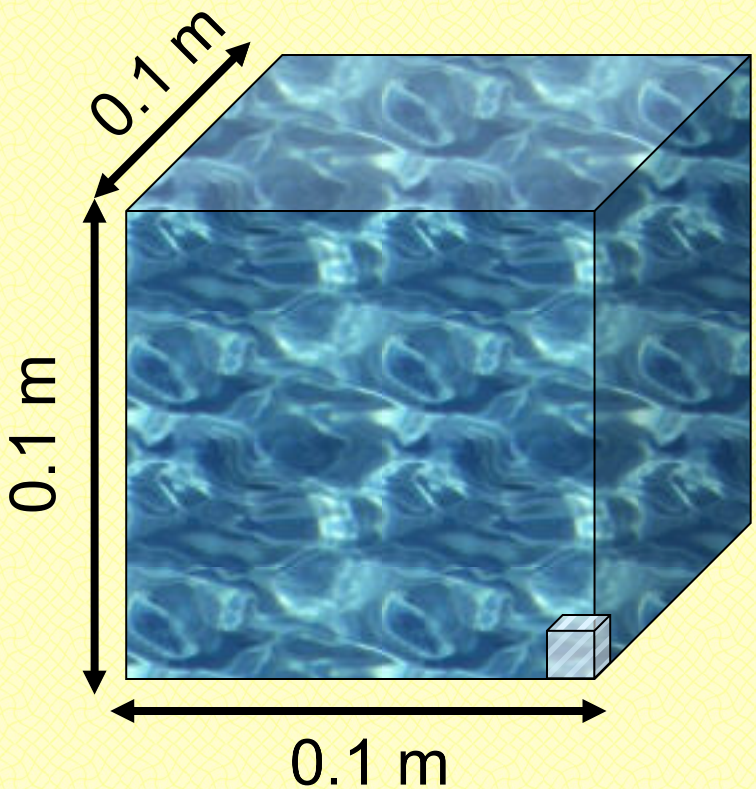
Definition: volume of 1 decimeter cubed (dm^3)

1 Liter = ? cm^3

$$1\ L = (1\ dm)(1\ dm)(1\ dm)$$
$$= (10\ cm)(10\ cm)(10\ cm)$$
$$= 1{,}000\ cm^3$$

1 cm^3 = 1 milliliter

Mass: The Kilogram

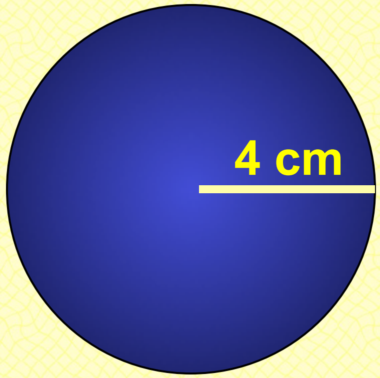


Definition: mass of 1 liter of water at standard conditions

How many kg of water in a cm^3 ?

1 cm^3 water = 1 milliliter water has a mass of 1/1,000 kg = 1 gm

1 cm^3 of water has a mass of 1 g



5 kg

Density

Definition: mass of a volume of material

In the metric system, *water* has a density of :

1 kg/L

$1\ g/ml = 1\ g/cm^3$

Volume of Sphere $= (4/3)\ \pi\ r^3 = (4/3)(3.14.59)(4\ cm)^3 = 268\ cm^3$

Density $= mass/volume = (5\ kg) / (268\ cm^3) = .0185\ kg/cm^3$

$1\ kg = 1000\ g$ $\qquad$ $1\ cm^3 = 1\ ml = 1/1000\ L$

$0.0185\ kg/cm^3 = (1000\ g/kg)(0.0185\ kg/cm^3) = \mathbf{18.5\ g/cm^3}$

$0.0185\ kg/cm^3 = (0.0185\ kg/(1/1000\ L/cm^3)cm^3) = \mathbf{18.5\ kg/L}$