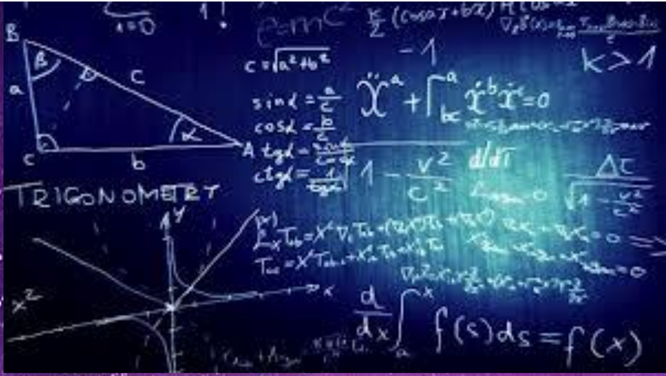

Physics Lab -1

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2019-2020

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Evaluation

%20 Reports + %30 Visa Exam + %50 Final Exam

For details please visit !
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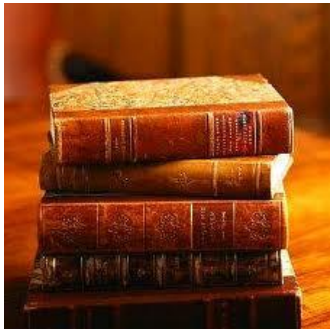
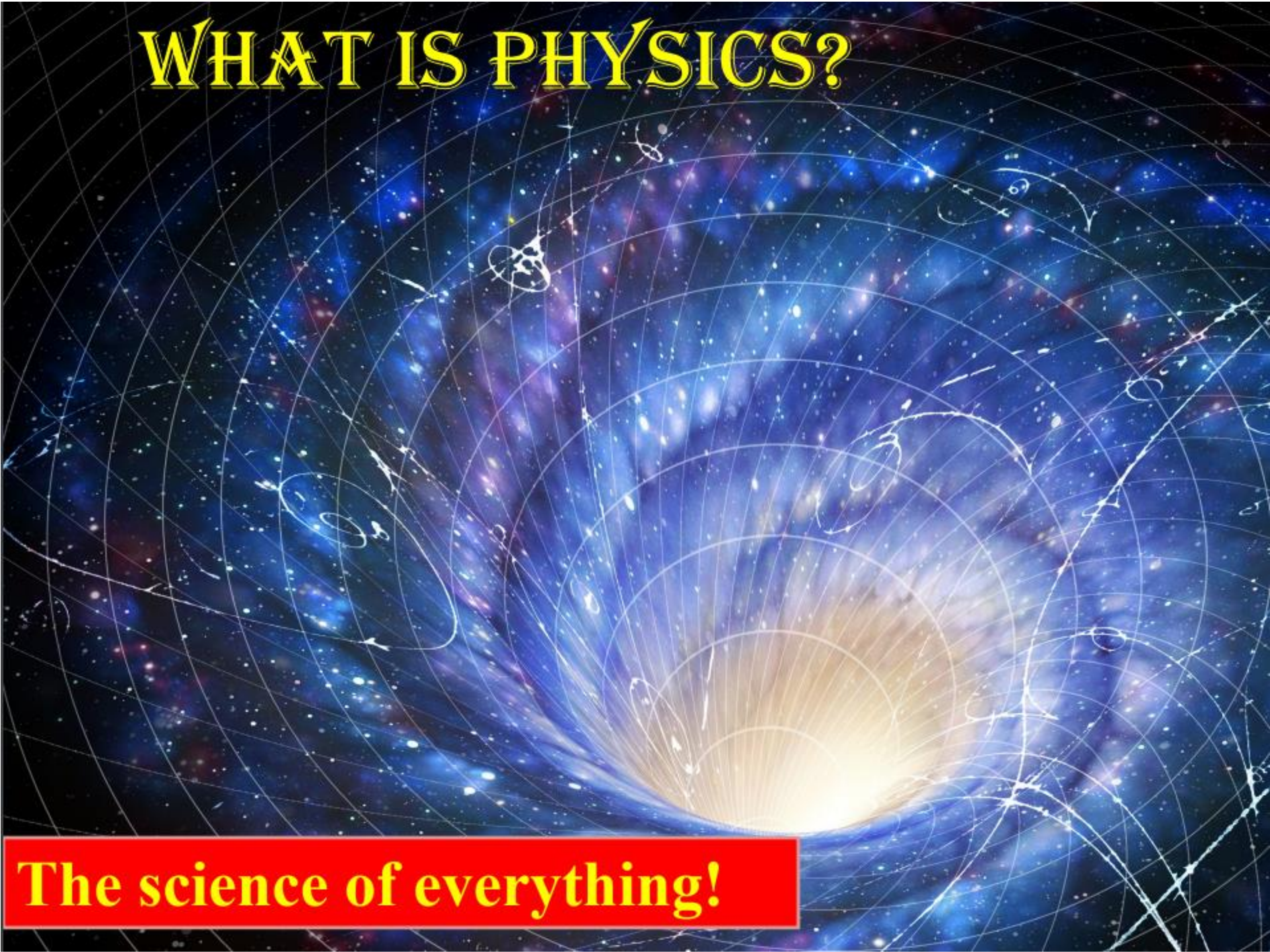
Resources



- Fundamentals of Physics by David Halliday, Robert Resnick and Jearl Walker
- Physics for Scientist and Engineers (Serway) Physics I, Frederick J.Keller, W.Edward Gettys, Malcolm J. Skove.
- Fen Bilimcileri ve Mühendisler için Fizik, Giancoli, Akademi Yayın, 2009
- Sears ve Zemansky University Physics, Cilt 1, 12. Baskı, Pearson Education Yayıncılık, 2009


WHAT IS PHYSICS?
The science of everything!

What is PHYSICS?

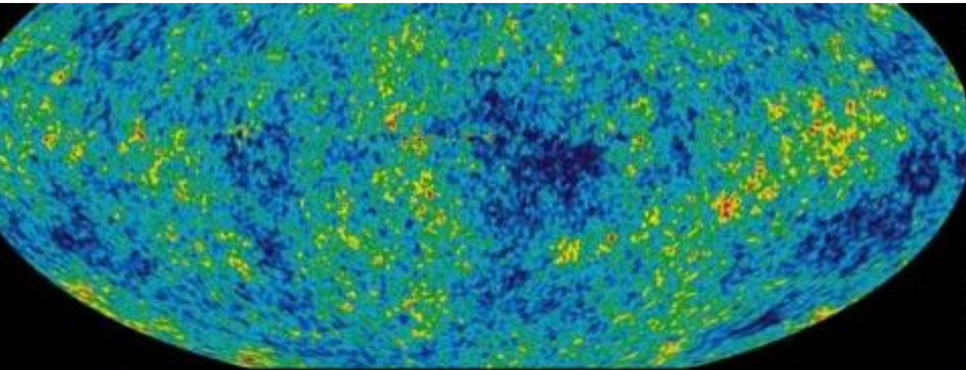
Physicists ask really big questions like:

- How did the universe begin?
- How will the universe change in the future?
- How does the Sun keep on shining?
- What are the basic building blocks of matter?
- ....
- ....
- ....

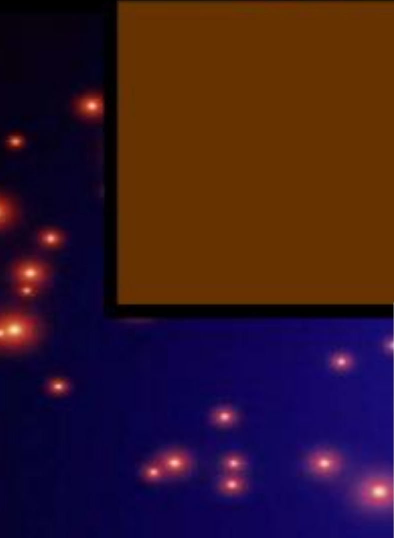
What is Physics?

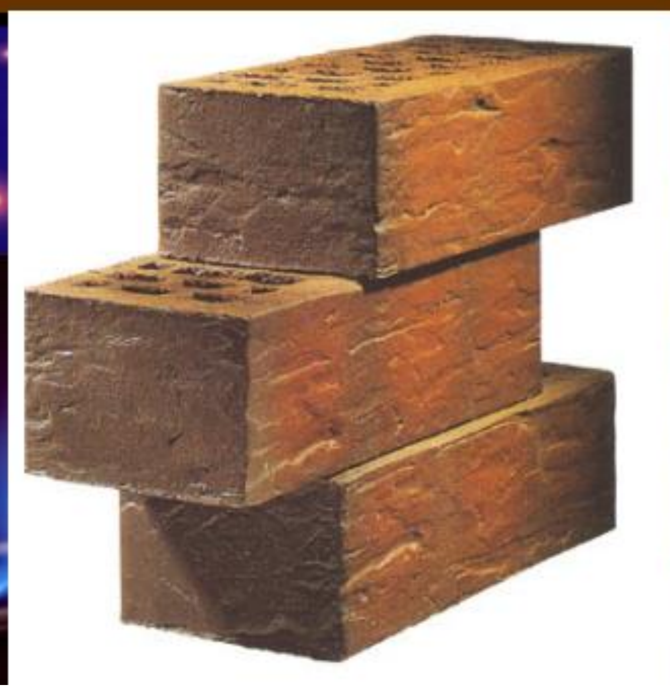
Two Complementary Questions:

How does the world work?	Why does it work that way?
• Observe the universe	• Look for patterns
• Careful measurements	• Mathematical models
• Is it reproducible?	• Unified descriptions
(Experimental physics)	(Theoretical physics)



Matter

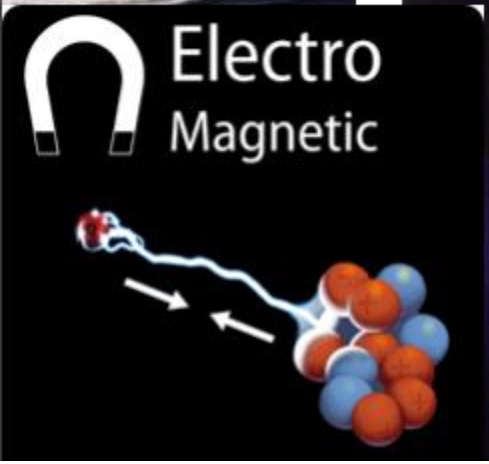




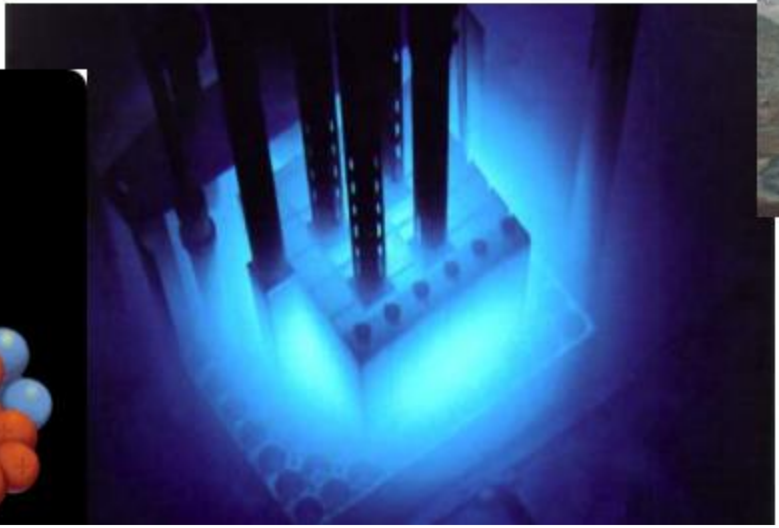
Weak

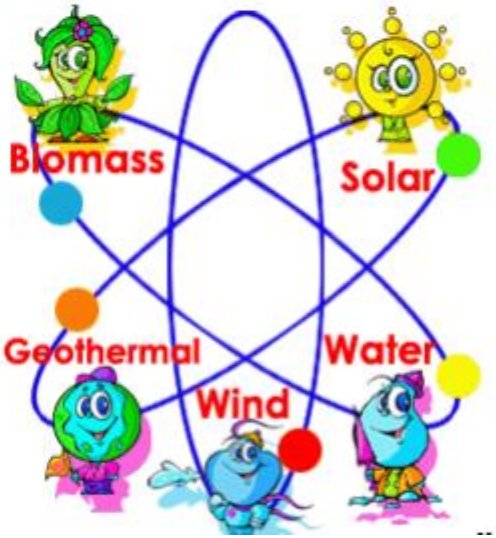
Gravity

ENERGY



Electro
Magnetic





Biomass
Solar
Geothermal
Water
Wind



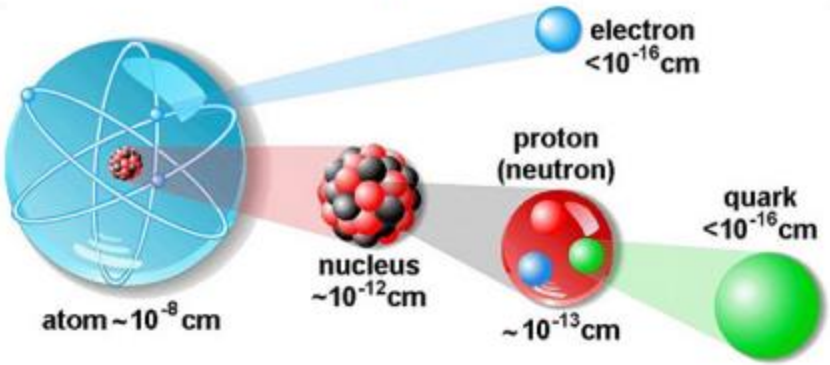


Space

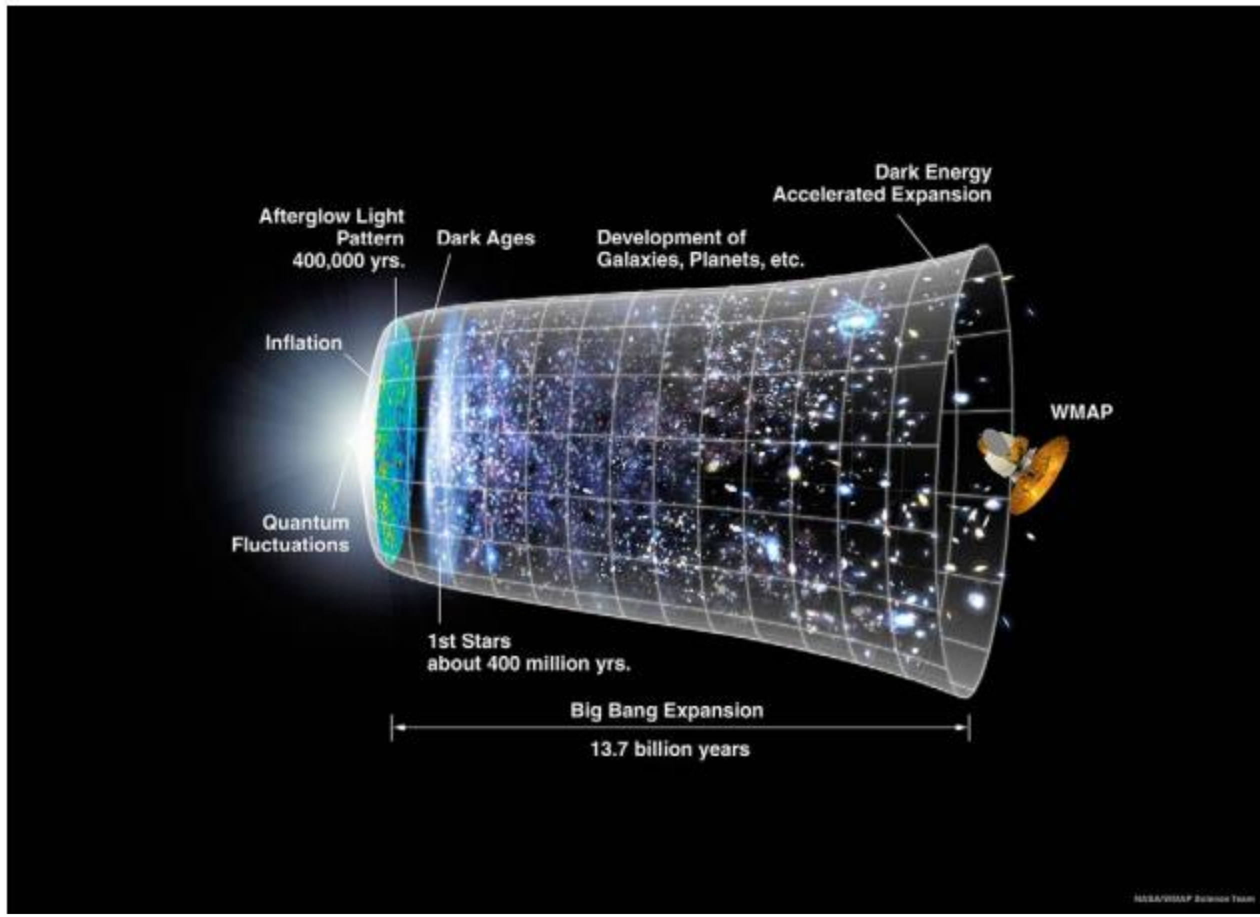




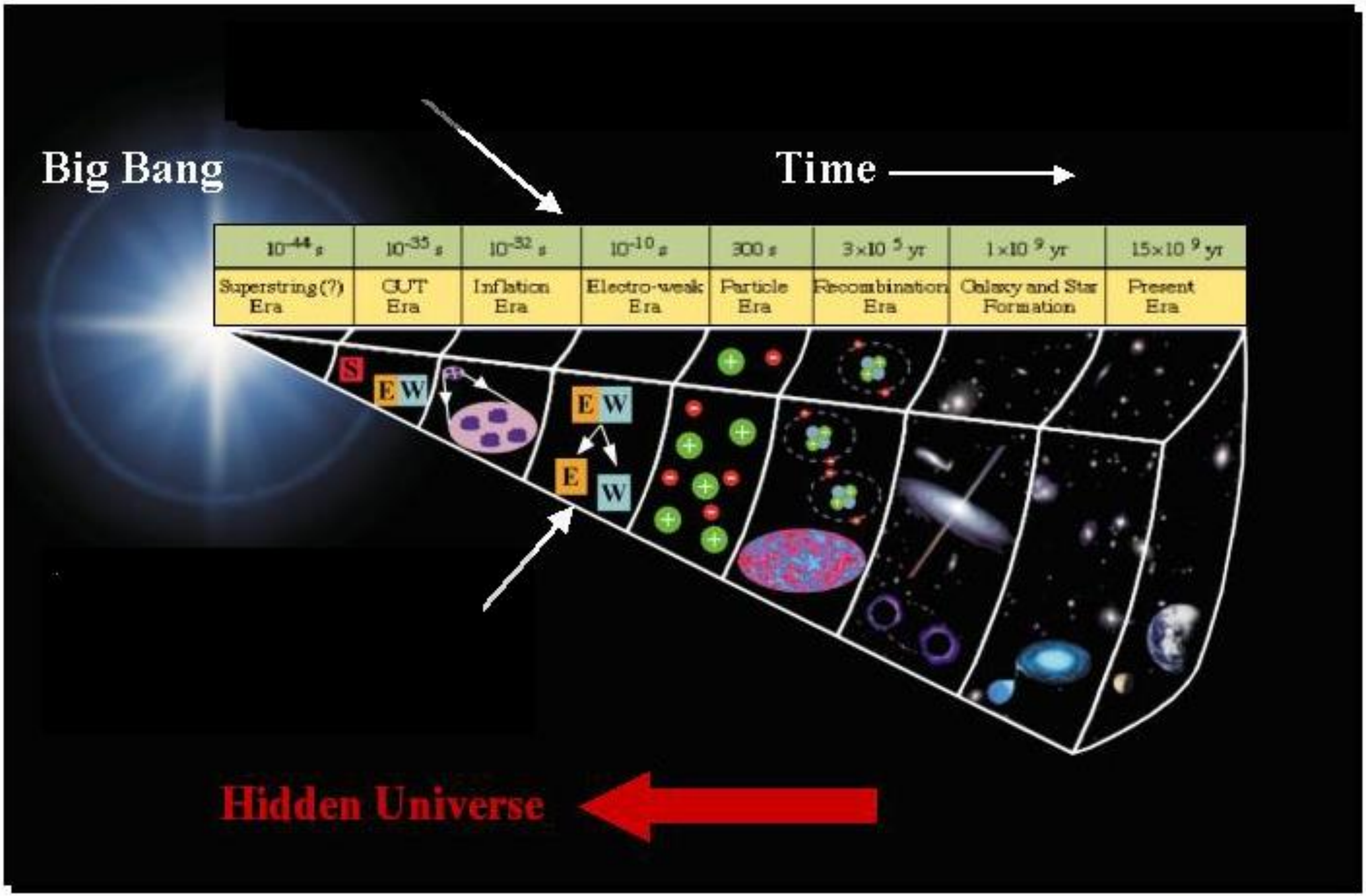
Particle Physics



Astrophysics & Cosmology



History (Big Picture)



History (people oriented)

$13\ 10^9$ BCE	Universe started
$5\ 10^9$ BCE	Solar system & Earth formed
10^5 BCE	*Homo Sapiens* with BIG brains
10^4 BCE	Writing (for business)
1000 BCE	Bible written down
400 BCE -400	Greeks, Romans … ideas … many wrong
1400-1650	DaVinci, Brahe, Copernicus, Galileo
1650-1900	Newton, … -- Classical Mechanics
1750-1900	Franklin,…Maxwell --Electricity&Mag
1900-	"Modern" Physics

Table 1.1 Some physicists from different countries of the world and their major contributions

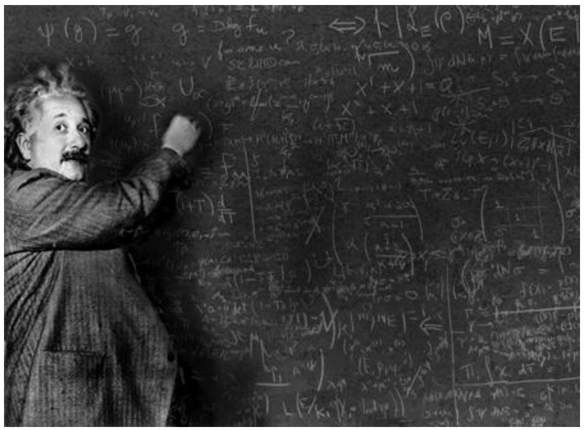
Name	Major contribution/discovery	Country of Origin
Archimedes	Principle of buoyancy; Principle of the lever	Greece
Galileo Galilei	Law of inertia	Italy
Christiaan Huygens	Wave theory of light	Holland
Isaac Newton	Universal law of gravitation; Laws of motion; Reflecting telescope	U.K.
Michael Faraday	Laws of electromagnetic induction	U.K.
James Clerk Maxwell	Electromagnetic theory; Light-an electromagnetic wave	U.K.
Heinrich Rudolf Hertz	Generation of electromagnetic waves	Germany
J.C. Bose	Ultra short radio waves	India
W.K. Roentgen	X-rays	Germany
J.J. Thomson	Electron	U.K.
Marie Sklodowska Curie	Discovery of radium and polonium; Studies on natural radioactivity	Poland
Albert Einstein	Explanation of photoelectric effect; Theory of relativity	Germany

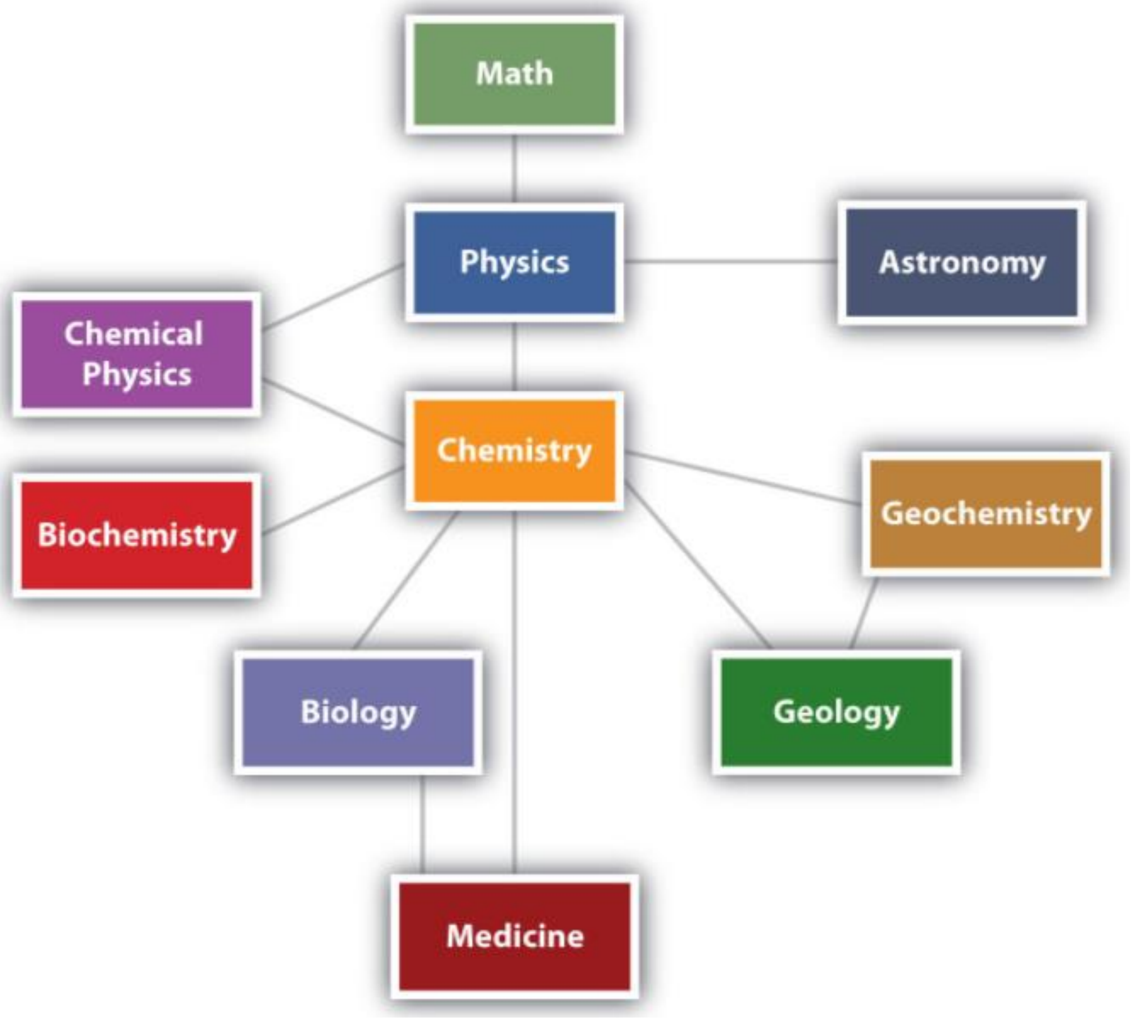
Name	Major contribution/discovery	Country of Origin
Victor Francis Hess	Cosmic radiation	Austria
R.A. Millikan	Measurement of electronic charge	U.S.A.
Ernest Rutherford	Nuclear model of atom	New Zealand
Niels Bohr	Quantum model of hydrogen atom	Denmark
C.V. Raman	Inelastic scattering of light by molecules	India
Louis Victor de Borglie	Wave nature of matter	France
M.N. Saha	Thermal ionisation	India
S.N. Bose	Quantum statistics	India
Wolfgang Pauli	Exclusion principle	Austria
Enrico Fermi	Controlled nuclear fission	Italy
Werner Heisenberg	Quantum mechanics; Uncertainty principle	Germany
Paul Dirac	Relativistic theory of electron; Quantum statistics	U.K.
Edwin Hubble	Expanding universe	U.S.A.
Ernest Orlando Lawrence	Cyclotron	U.S.A.
James Chadwick	Neutron	U.K.
Hideki Yukawa	Theory of nuclear forces	Japan
Homi Jehangir Bhabha	Cascade process of cosmic radiation	India
Lev Davidovich Landau	Theory of condensed matter; Liquid helium	Russia
S. Chandrasekhar	Chandrasekhar limit, structure and evolution of stars	India
John Bardeen	Transistors; Theory of super conductivity	U.S.A.
C.H. Townes	Maser; Laser	U.S.A.
Abdus Salam	Unification of weak and electromagnetic interactions	Pakistan

Table 1.2 **Link between technology and physics**

Technology	Scientific principle(s)
Steam engine	Laws of thermodynamics
Nuclear reactor	Controlled nuclear fission
Radio and Television	Generation, propagation and detection of electromagnetic waves
Computers	Digital logic
Lasers	Light amplification by stimulated emission of radiation
Production of ultra high magnetic fields	Superconductivity
Rocket propulsion	Newton's laws of motion
Electric generator	Faraday's laws of electromagnetic induction
Hydroelectric power	Conversion of gravitational potential energy into electrical energy
Aeroplane	Bernoulli's principle in fluid dynamics
Particle accelerators	Motion of charged particles in electromagnetic fields
Sonar	Reflection of ultrasonic waves
Optical fibres	Total internal reflection of light
Non-reflecting coatings	Thin film optical interference
Electron microscope	Wave nature of electrons
Photocell	Photoelectric effect
Fusion test reactor (Tokamak)	Magnetic confinement of plasma
Giant Metrewave Radio Telescope (GMRT)	Detection of cosmic radio waves
Bose-Einstein condensate	Trapping and cooling of atoms by laser beams and magnetic fields.

Physics and Other Sciences





Physics Branches

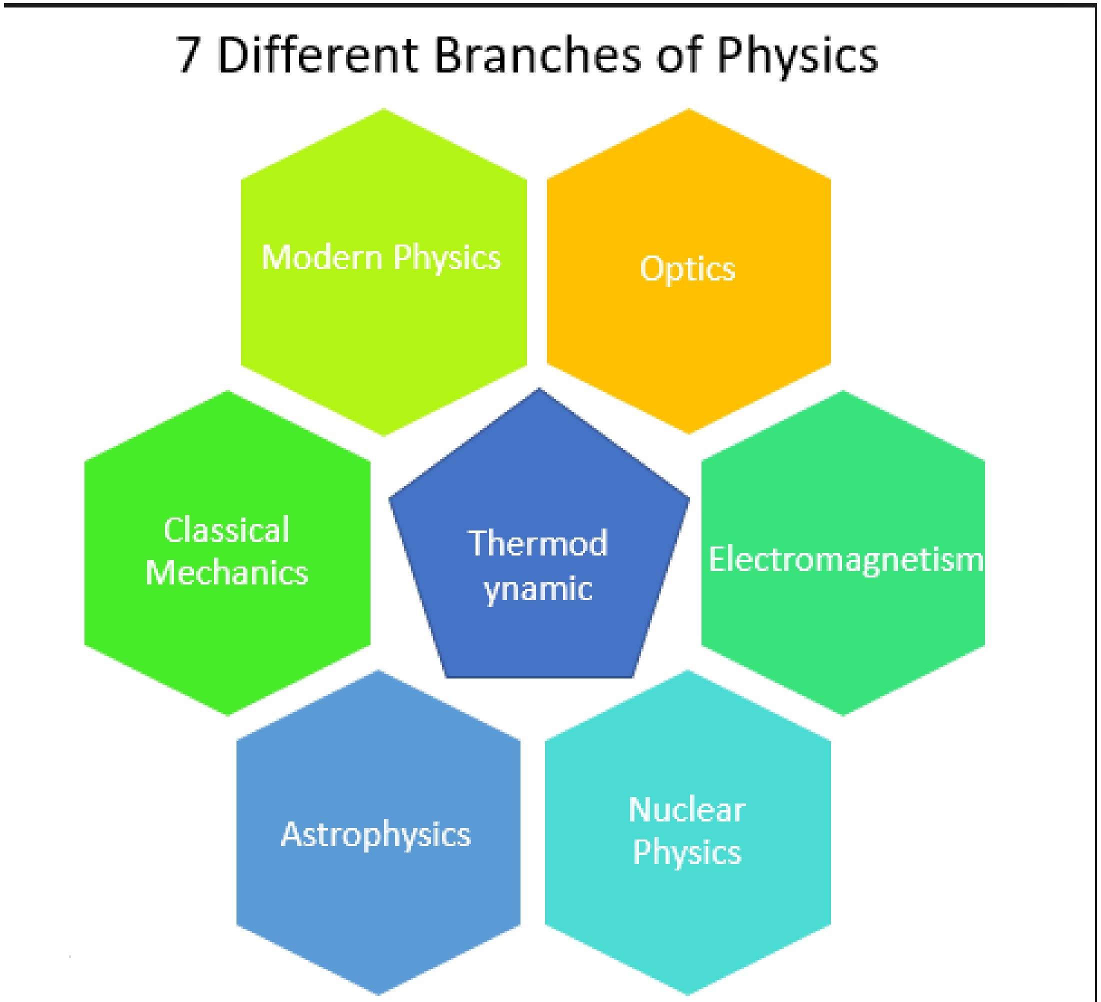


Table 1-1 Areas within physics

Name	Subjects	Examples
Mechanics	motion and its causes	falling objects, friction, weight, spinning objects
Thermodynamics	heat and temperature	melting and freezing processes, engines, refrigerators
Vibrations and wave phenomena	specific types of repetitive motions	springs, pendulums, sound
Optics	light	mirrors, lenses, color, astronomy
Electromagnetism	electricity, magnetism, and light	electrical charge, circuitry, permanent magnets, electromagnets
Relativity	particles moving at any speed, including very high speeds	particle collisions, particle accelerators, nuclear energy
Quantum mechanics	behavior of submicroscopic particles	the atom and its parts

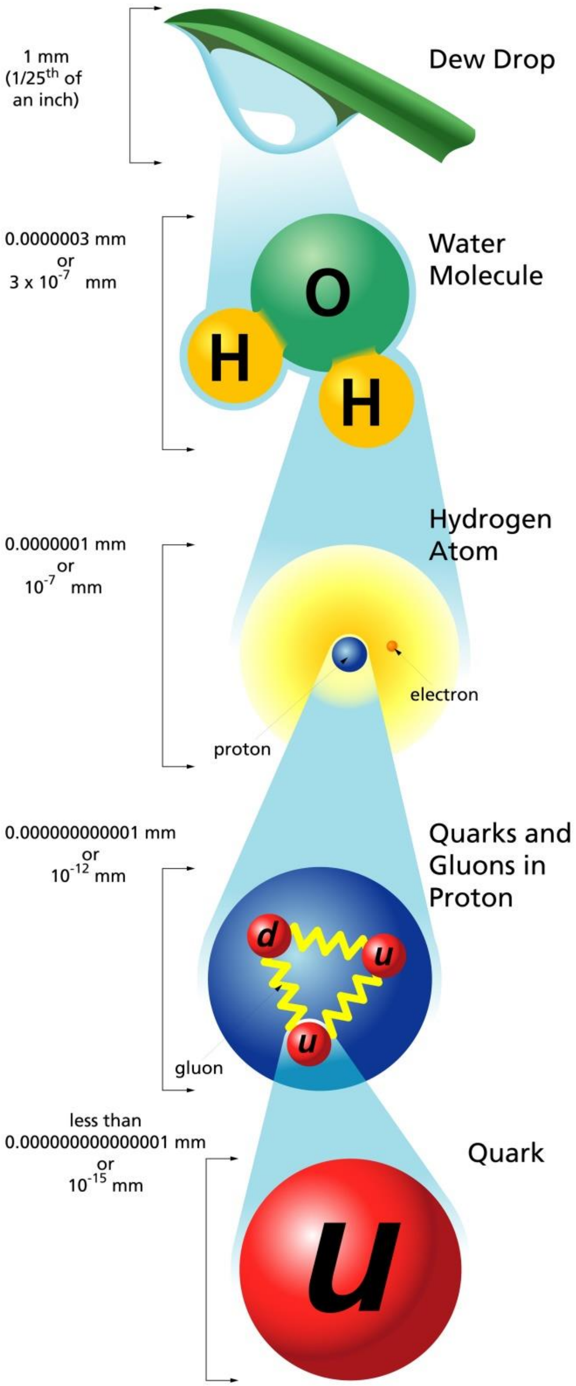
We have always been curious about the world around us.

Classical Physics – It constructs the concepts Galileo (1564-1642) and Newton's space and time. It includes mechanics (rotation), light, heat (James Joule, Sadi Carnot), sound, electricity and magnetism (James Maxwell)

Modern Physics – The application of special relativity, and particularly quantum theory, to such microscopic systems as atoms, molecules, and nuclei, which has led to a detailed understanding of solids, liquids, and gases, is often referred to as modern physics.

Physics explains things that are very, very large.

Physics explains things that are very, very small.



The Scale of the Universe

- [Video]
- https://www.youtube.com/watch?v=i93Z7zljQ7I
- http://htwins.net/scale2/

What Questions does this field address ?

Want to know the basic laws of nature

- Can we unify all the forces with one equation or one theory ?

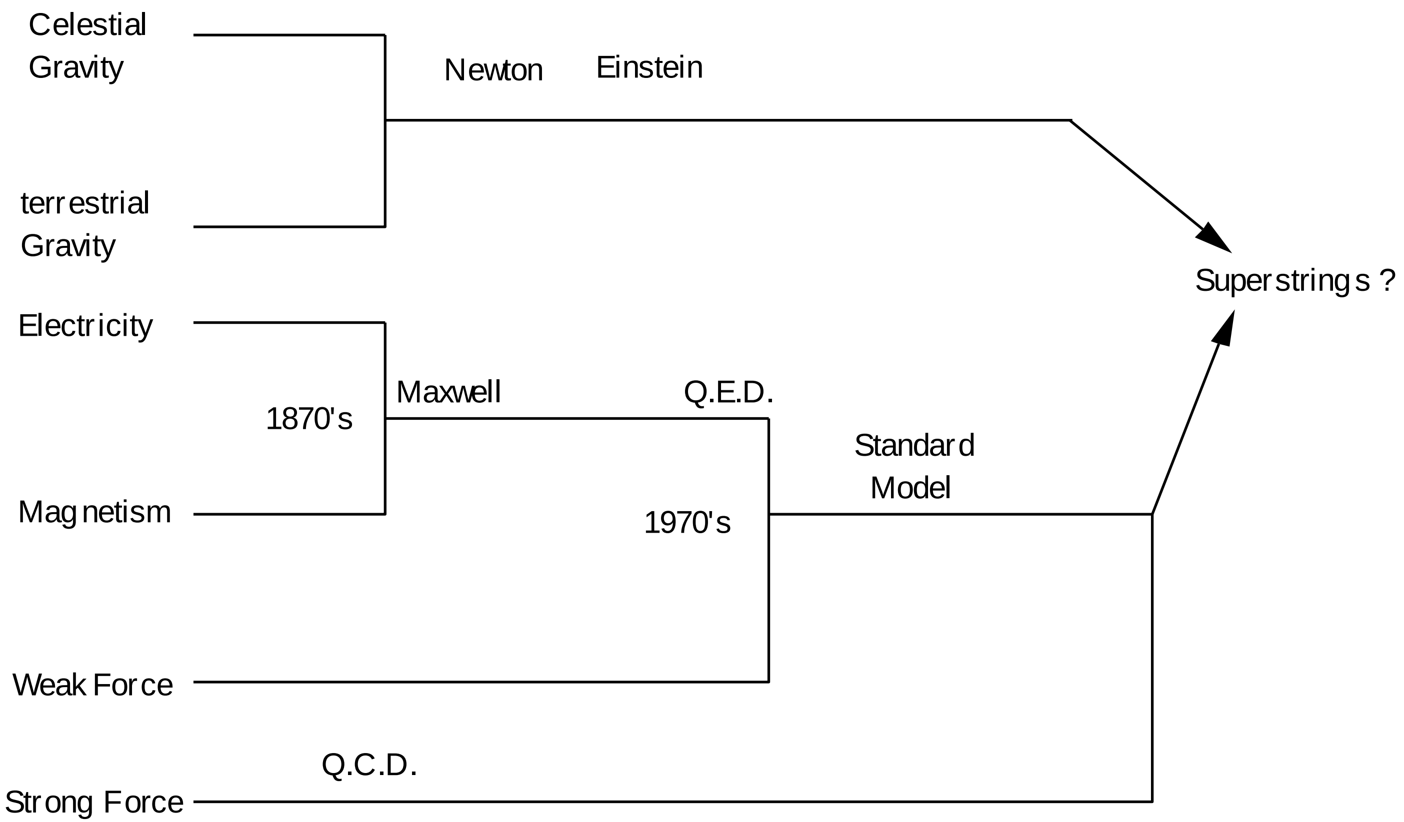
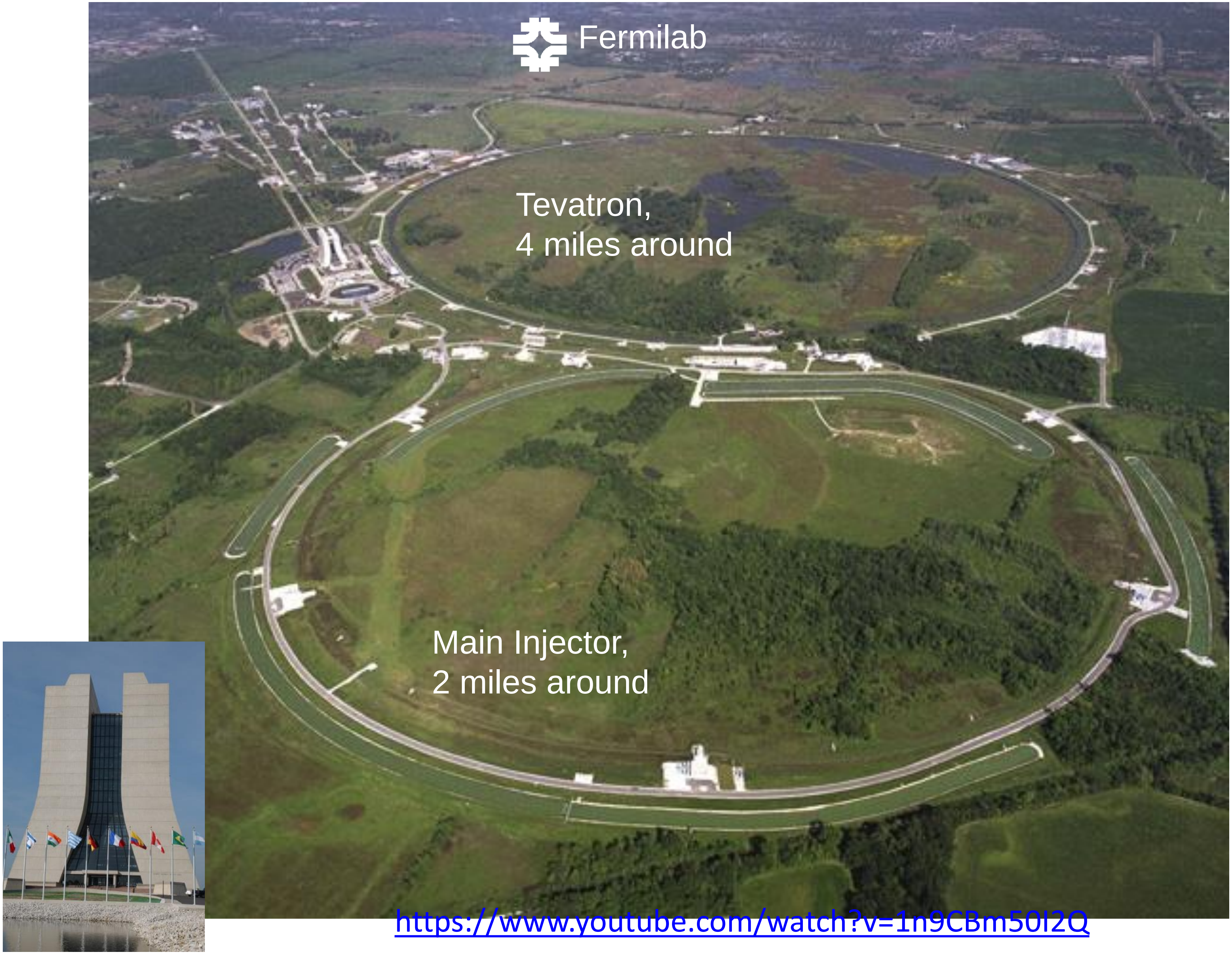


Table 1.3 Fundamental forces of nature

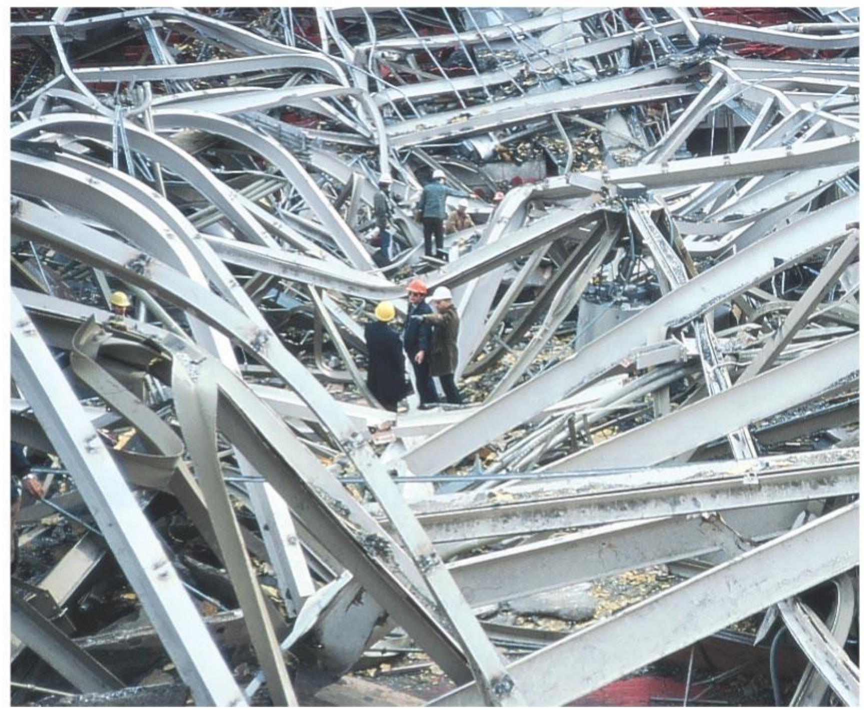
Name	Relative strength	Range	Operates among
Gravitational force	10^{-39}	Infinite	All objects in the universe
Weak nuclear force	10^{-13}	Very short, Sub-nuclear size ($\sim 10^{-16}$m)	Some elementary particles, particularly electron and neutrino
Electromagnetic force	10^{-2}	Infinite	Charged particles
Strong nuclear force	1	Short, nuclear size ($\sim 10^{-15}$m)	Nucleons, heavier elementary particles



https://www.youtube.com/watch?v=1n9CBm50I2Q

The Nature of Science

The principles of physics are used in many practical applications, including construction. **Communication** between architects and engineers is essential if disaster is to be avoided.



Models, Theories, and Laws

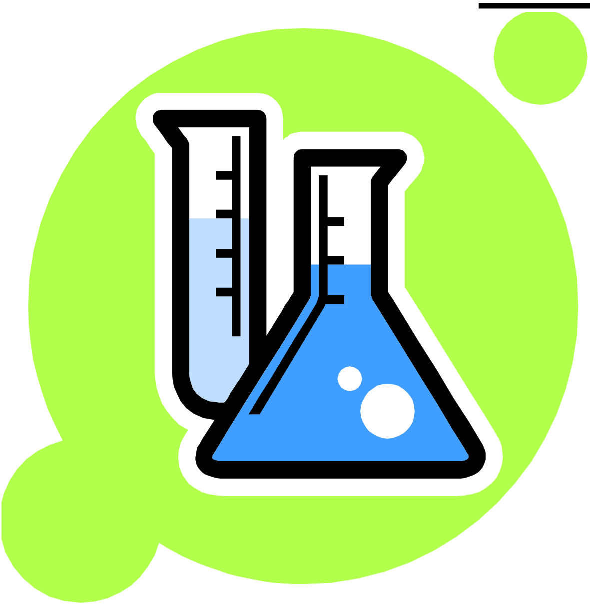
- A **law** is a brief description of how nature behaves in a broad set of circumstances.
- *Ex: Hooke's Law for simple harmonic oscillators*
- A **principle** is similar to a law, but applies to a narrower range of phenomena.
    - *Ex: Principle of Hydrostatic Equilibrium*

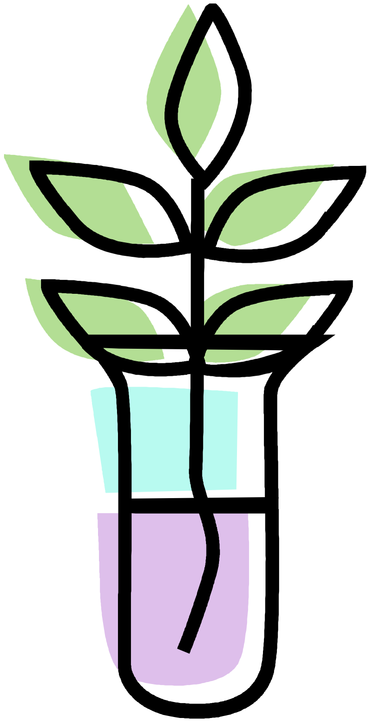
Physics

- Mechanics
  - Kinematics (motion)
  - Statics, Dynamics (forces)
- Electricity
- Magnetism
- Waves
- Optics (geometric optics)
- Nuclear Physics (Modern Physics)

What is Science?

- The knowledge obtained by **observing** natural events and conditions in order to discover **facts** and formulate **laws** or principles that can be verified or **tested**.





What is the Scientific Method?

- Step-by-step way in which scientists answer questions.
- 1. Ask a **question**.
- 2. **Research** the topic.
- 3. Form a **hypothesis.**
- 4. **Test** the Hypothesis.
- 5. Gather **Data**.
- 6. Analyze **Results.**
- 7. Draw **Conclusions.**
- 8. Communicate **Results.**

Scientific Method

- Recognize a problem
- Hypothesis- educated guess, testable
  – When tested and confirmed becomes a law
- Observation -measurement, data collection (experiment)
- Theory – information including tested hypothesis
- Conclusion

State the Problem/Questions

- The problem identifies what you want to find out.
- Develop a **<u>clear</u>** statement defining the problem
- Make sure your problem is narrowed/**<u>specific</u>** enough
- State the problem in the form of a question:
- How does ____________ affect ________?
- What is the effect of ________ on _________?

Research

- Write down all information you already **know**
- Do research in books on the **topic** you are investigating
- Ask **experts** on the subject you are researching
- If you find an **answer** to your problem/question you do not need to move on

What is a hypothesis?

- An **<u>explanation</u>** that is based on prior scientific research or observations and that can be tested.
- "**<u>Educated</u>** Guess" (your high school teacher may not like this definition)
- "If… then… because" Statement

How do you test a hypothesis?

- Develop a **test** to support or not support your hypothesis. (This is your experiment).
  - Must be run **multiple** times
  - Must have only **1** independent **variable** (the factor being tested
  - Must include 2 setups
    - **Experimental setup**
    - **Control setup**

How do you test a hypothesis?

- Use a Controlled Experiment
  - An experiment that tests only **one** factor at a time by using a comparison of a control group and an experimental group.
- Control Group
  - The group that the scientist changes **nothing** in. The Control group is used for comparison.
- Experimental Group
  - The group that the scientist has changed something. It is the **variable** in the experiment where you want to see how this condition affects something.

What is a variable?

- A variable is something that can change, either naturally or on purpose. ***
- In an experiment it is a factor that is **<u>different</u>** from one group to another.
- Independent variable
  - The factor that the scientist **<u>has</u>** changed in order to test the hypothesis (on purpose). It is the cause
- Dependent Variable
  - The **<u>result</u>** of what the scientist changed. It is the effect of what happened in the experiment.

What are constants?

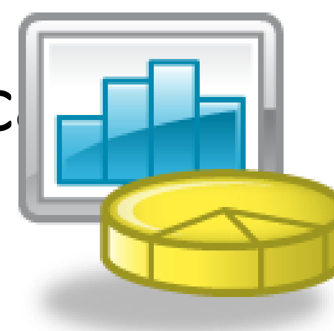
- They are what the scientist kept the **same** in both the control group and the experimental group.

How can you gather data?

- Make **Observations.**
  - Any use of the senses to gather information.
- **Qualitative** Observations
  - Anything that you see, smell, touch, taste, or hear.
  - Ex. Blue, bitter, fizzing sound.
- **Quantitative** Observations
  - Any observation that can be measured.
  - Must include a number.
  - Ex. 5 centimeters long

How can you analyze results to determine patterns?

- Record Data
  - Write observations and measurements
  - Be consistent when you are checking your experiments and recording the results
  - Create tables or charts (Data Tables and Pie Charts)
- Create graphs from collected Data (Line Graphs, Bar Graphs)
  - Complete all necessary mathematic calculations



How can you draw conclusions?

- Answer the following questions in paragraph form (Always explain in detail using scientific vocabulary.):
  - Do your results/data support your hypothesis? Why or why not?
  - What are ways you can improve your data?
  - What would you do differently if you were to repeat the experiment?

What is in a conclusion?

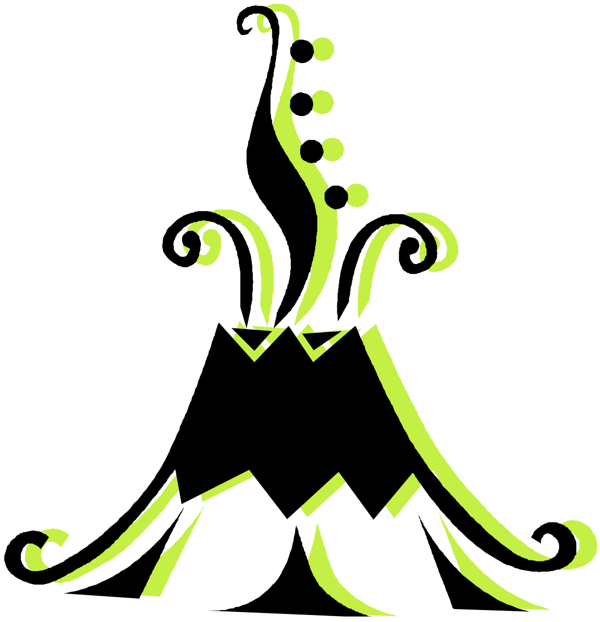
- You restate the purpose of your experiment
- You indicate what the results were. Use numbers!!!!! Example: “On average after 3 trials, …….”
- You explain why those results were given. Here you think about what you found out in your research.
- You consider any improvements to your procedure. This is error analysis.
- You ask a new question – what do you want to do next?
- s

How would you communicate results?

- Share data and information with others, such as scientists.
- Publish your findings in a book, magazine, journal, the internet.

What are scientific models?

- Model
  - A representation of an <u>**object**</u> or system.
    - Physical Models
    - Mathematical Models
    - Conceptual Models



What is the difference between a scientific theory and a scientific law?

- Theory
  - An explanation that **ties** together many hypotheses and observations.
  - Supported by **repeated** trials.
  - May help with further predictions.
  - Tells **why** it happens.
- Law
  - A s**ummary** of many experimental results and observations.
  - Tells **how** things work
  - Only tells what happens, it does **not** explain why.

Science and Technology

- Science → Pure
- Technology → Applied

Lets Think !

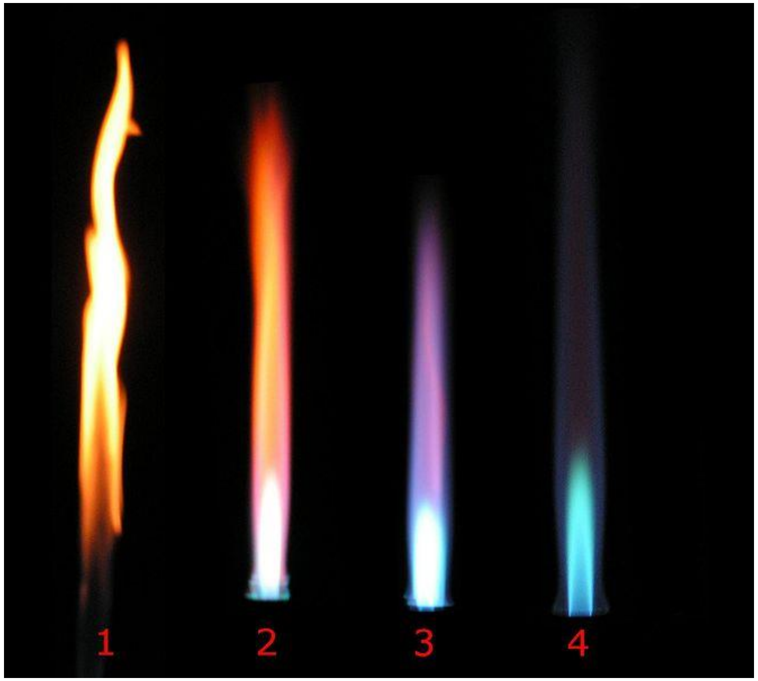
- What is fire?

What is fire?

- Rapid oxidation (loss of electrons)
- Very exothermic combustion reaction
- Combustion: Fuel + O2 = CO2 + H2O + Heat
- Gives off heat and light
- Sometimes considered a plasma, but not all of the flame is ionized gas

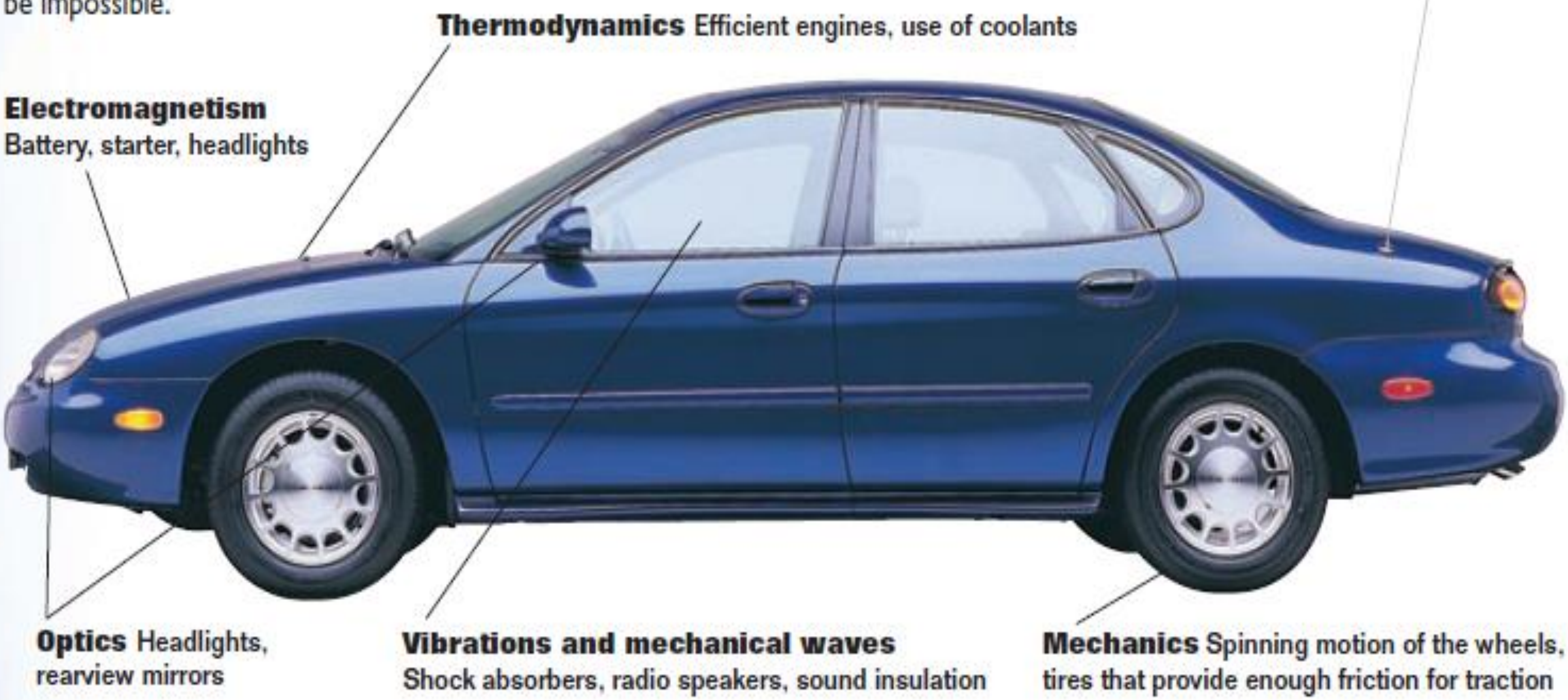
Flame Types

- Premixed: oxygen and fuel are already added together
- Diffusion: oxygen is added to fuel during the burning



Physics is everywhere !

Figure 1-1
Without knowledge of many of the areas of physics, making cars would be impossible.



Physical Quantities

Quantitative versus qualitative

- Most observation in physics are quantitative
- Descriptive observations (or qualitative) are usually impre

<u>Qualitative Observations</u>

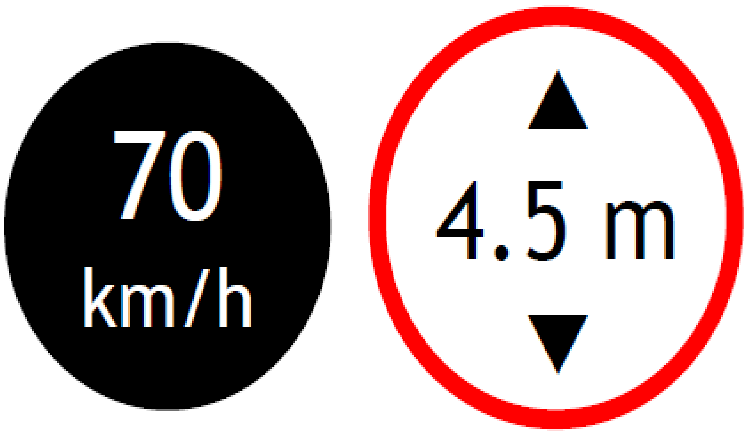
How do you measure artistic beauty?

<u>Quantitative Observations</u>

What can be measured with t instruments on an aeroplane

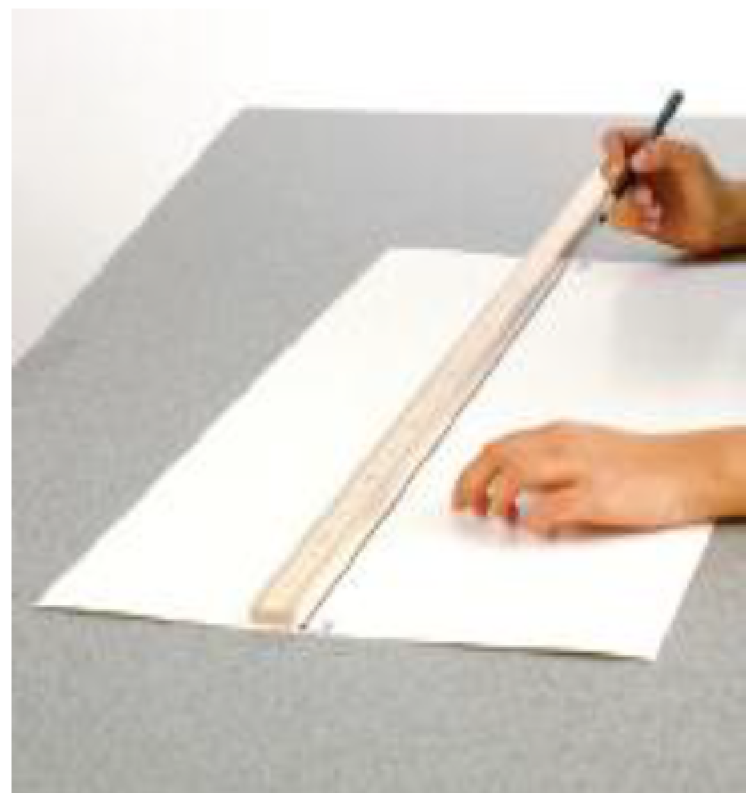
Physical Quantities

- A physical quantity is one that can be measured and consists of a magnitude and unit.



SI units are used in Scientific works

Measuring length



What is Measurement?

Meauserement

- The basis of science and technology is meauserement.
- Scientiests and technicians must be able to measure **physical objects and events.**
- Measurement is especially important in the laboratory. Experiments involve measuring **mass, length, time, temperature, pressure**, or other **quantities**.

Meauserement

Spring balance

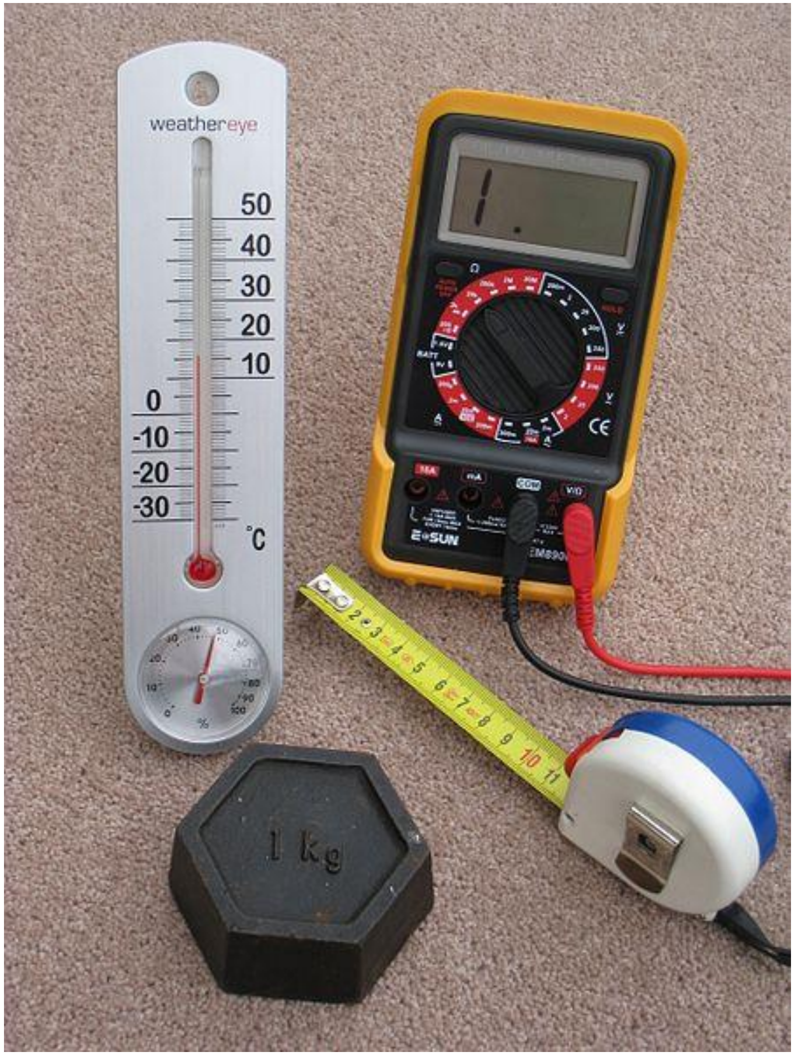
stopwatch

Vernier calipers

What is Measurement?

- **Measurement** (from Old French, *mesurement*) is the assignment of numbers to objects or events.
- It is a cornerstone of most natural sciences, technology, economics, and quantitative research in other social sciences.
- A measurement is **made by comparing** a quantity with a **standard unit**.

What is Measurement ?



- Scientific measurement has been defined as **“rules for assigning numbers to objects in such a way as to represent quantities of attributes”**.

Measurement and Uncertainty; Significant Figures

No measurement is exact; there is always some **uncertainty** due to limited instrument accuracy and difficulty reading results.

The photograph to the left illustrates this – it would be difficult to measure the width of this board more accurately than **± 1 mm**.

1-3 Measurement and Uncertainty; Significant Figures

•**Estimated uncertainty** written "$\pm$"

ex. 8.8 ± 0.1 cm.

•**Percent uncertainty**: ratio of uncertainty to measured value, multiplied by 100:

$$\frac{0.1}{8.8} \times 100\% \approx 1\%.$$

1-3 Measurement and Uncertainty; Significant Figures

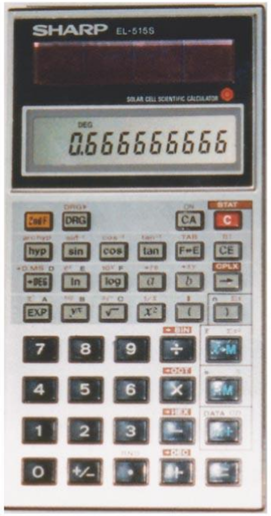
Number of significant figures = number of "reliably known digits" in a number.

- Often possible to tell # of significant figures by the way the number is written:
- 23.21 cm = four significant figures.
- 0.062 cm = two significant figures (initial zeroes don't count).
- 80 km is ambiguous—it could have one or two sig figs. If it has three, it should be written 80.0 km.

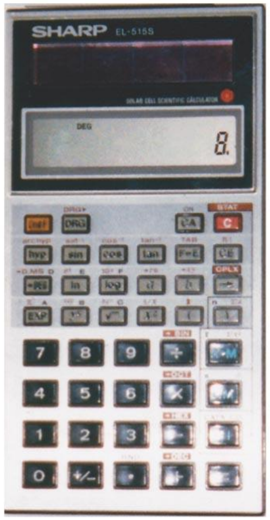
1-3 Measurement and Uncertainty; Significant Figures

- When **multiplying** or **dividing** numbers, or using functions, result has as many sig figs as term with **fewest.**
    - ex: 11.3 cm x 6.8 cm = 77 cm.
- When **adding** or **subtracting**, answer is no more precise than **least** precise number used.
- ex: 1.213 + 2 = 3, not 3.213!

1-3 Measurement and Uncertainty; Significant Figures



- **Calculators** will not give right # of sig figs; usually give too **many** but sometimes give too **few** (especially if there are trailing zeroes after a decimal point).

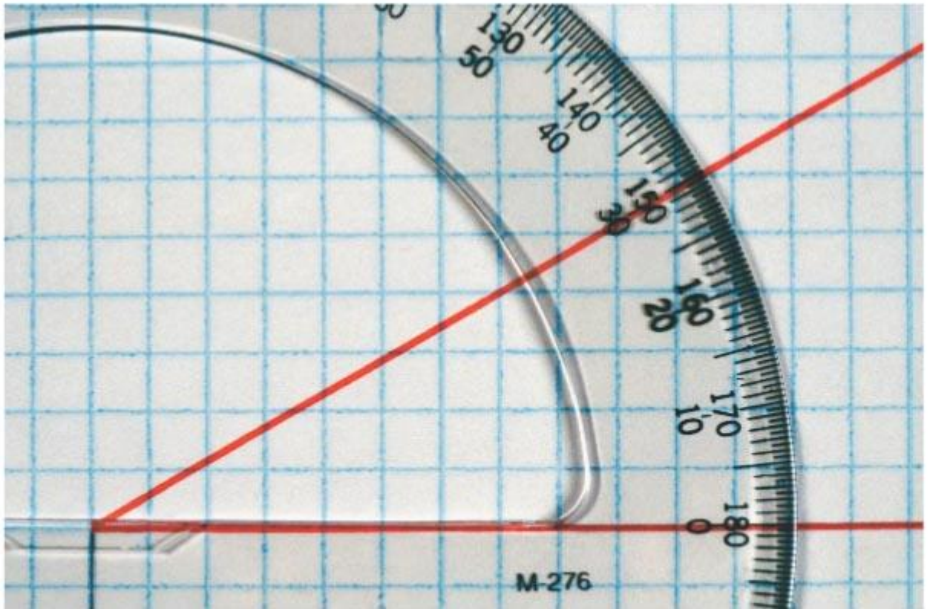


- top image: result of 2.0/3.0.
- bottom image: result of 2.5 x 3.2.

1-3 Measurement and Uncertainty; Significant Figures

Conceptual Example 1-1: Significant figures.

Using a protractor, you measure an angle to be 30°. (a) How many **significant figures** should you quote in this measurement? (b) Use a calculator to find the cosine of the angle you measured.



1-3 Measurement and Uncertainty; Significant Figures

Scientific notation is commonly used in physics; it allows the number of **significant figures** to be clearly shown.

For example, we cannot tell how many significant figures the number 36,900 has. However, if we write 3.69×10^4, we know it has **three**; if we write 3.690×10^4, it has **four**.

Much of physics involves **approximations**; these can affect the precision of a measurement also.

1-3 Accuracy vs. Precision

Accuracy is how **close** a measurement comes to the true value.

ex. Acceleration of Earth's gravity = 9.81 m/sec^2
Your experiment produces 10 ± 1m/sec^2

You were accurate, but not super "precise"

Precision is the **repeatability** of the measurement using the same instrument.

ex. Your experiment produces 8.334 m/sec^2
You were precise, but not very accurate!

1-5 Converting Units

Unit conversions involve a **conversion factor**.

Example: 1 in. = 2.54 cm.

Equivalent to: 1 = 2.54 cm/in.

Measured length = 21.5 inches, converted to centimeters?

$$21.5\text{ inches} = (21.5\ \cancel{\text{in.}}) \times \left(2.54\,\frac{\text{cm}}{\cancel{\text{in.}}}\right) = 54.6\text{ cm.}$$

How many sig figs are appropriate here?

1-5 Converting Units

Example 1-2: The 8000-m peaks.

The 14 tallest peaks in the world are referred to as "eight-thousanders," meaning their summits are over 8000 m above sea level.

What is the elevation, in feet, of an elevation of 8000 m?

1-5 Converting Units

- 1 m = 3.281 feet
- 8000 m = 2.6248 E04 or 26,248 feet.
- “8000 m” has only 1 significant digit!
- Round the answer up to 30,000 ft!
- Rather rough!
    - 30,000 – 26,248 = 3,752
    - 3,752/26,248 = 14.3% high!

1-6 Order of Magnitude: Rapid Estimating

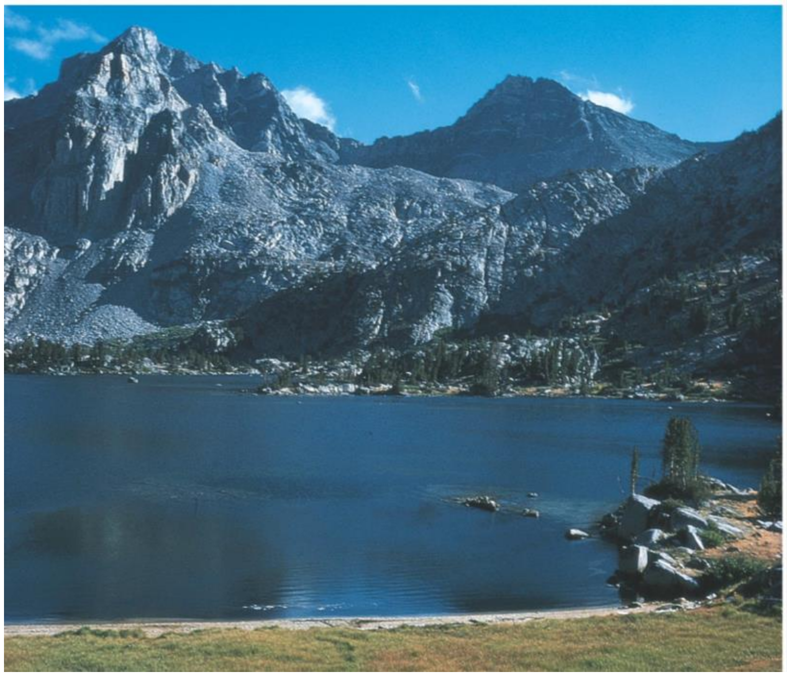
Quick way to **estimate** calculated quantity:

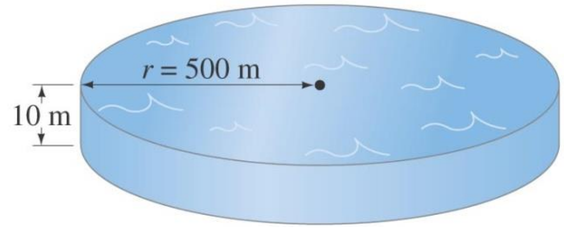
- round off all numbers to **one** significant figure and then calculate.

- result should be right **order of magnitude**; expressed by rounding off to nearest power of 10.

1-6 Order of Magnitude: Rapid Estimating

Example 1-5: Volume of a lake.



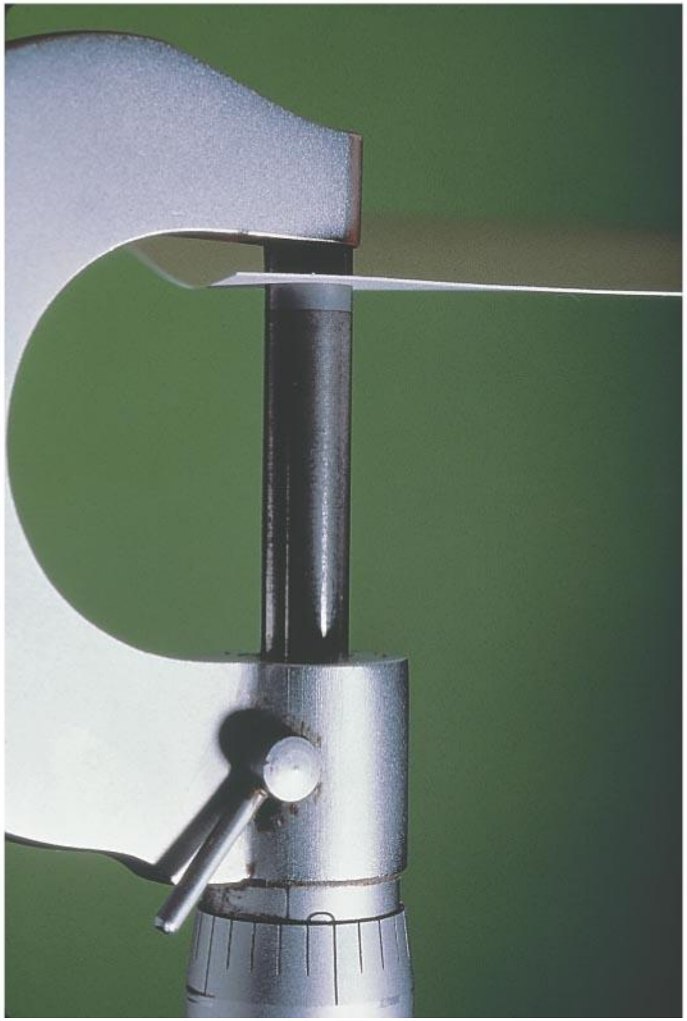


Estimate how much water there is in a particular lake, which is roughly circular, about 1 km across, and you guess it has an average depth of about 10 m.

1-6 Order of Magnitude: Rapid Estimating

Example 1-6: Thickness of a page.

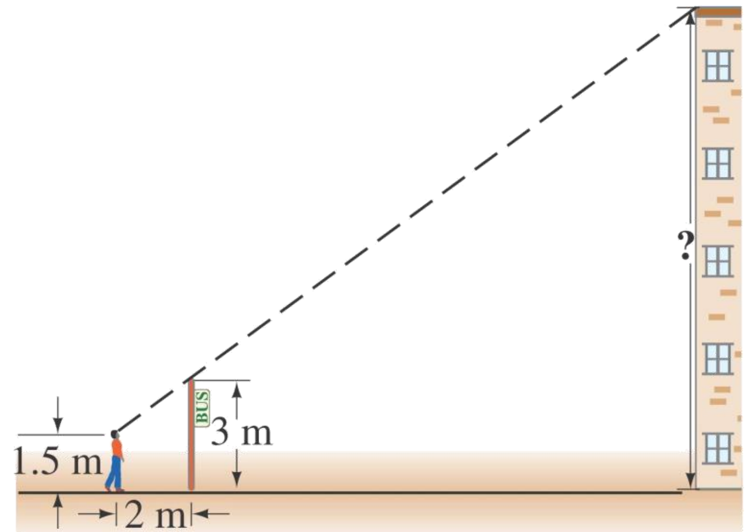
Estimate the thickness of a page of your textbook. (Hint: you don't need one of these!)

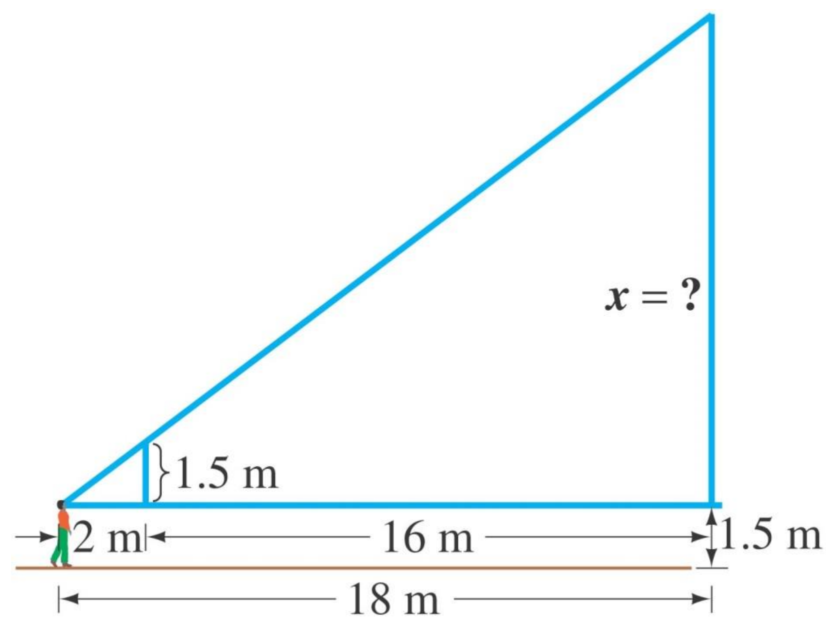


1-6 Order of Magnitude: Rapid Estimating

Example 1-7: Height by triangulation.

Estimate the height of the building shown by "triangulation," with the help of a bus-stop pole and a friend. (See how useful the diagram is!)





Units of Measurement

- The results are useless, however, unless standart units of measurement are used. One system of standart units is the **SI**.
- The **kilogram (kg), the meter (m), and the second (s)** are basic **SI units.**

Quantity	SI	cgs	Dimension
Length	m	cm	L
Mass	kg	g	M
Time	s	s	T

Physical Quantities

Are classified into two types:

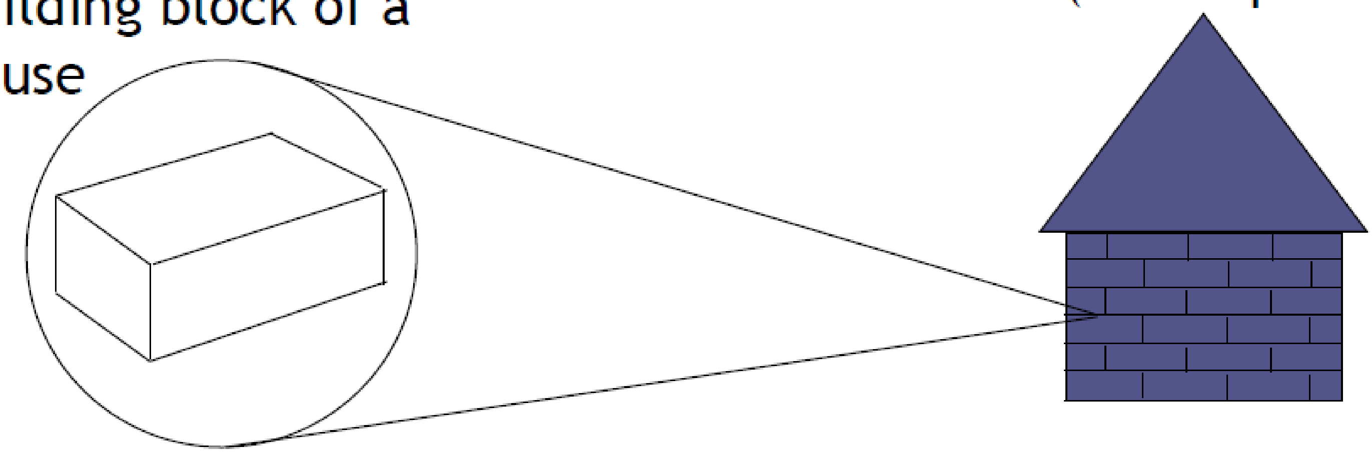
- Base quantities
- Derived quantities

Base quantity

For example : is like the brick - the basic building block of a house

Derived quantity

For example : is like the house that was build up from a collection of bricks (basic quantity)



Definitions :-

- Base quantities are the quantities on the basis of which other quantities are expressed.

- The quantities that are expressed in terms of base quantities are called derived quantities

Derived quantity & equations

- A derived quantity has an equation which links to other quantities.
- It enables us to express a derived unit in terms of base-unit equivalent.

Example: $F = ma$; Newton = $kg\ m\ s^{-2}$

$P = F/A$; Pascal = $kg\ m\ s^{-2}/m^2 = kg\ m^{-1}\ s^{-2}$

Some derived units

Derived quantity	Base equivalent units	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s or $m\ s^{-1}$
acceleration	meter per second squared	$m/s/s$ or $m\ s^{-2}$
density	kilogram per cubic meter	$kg\ m^{-3}$
amount concentration	mole per cubic meter	$mol\ m^{-3}$
force	$kg\ m\ s^{-2}$	Newton
work/energy	$kg\ m^2\ s^{-2}$	Joule
power	$kg\ m^2\ s^{-3}$	Watt
pressure	$kg\ m^{-1}\ s^{-2}$	Pascal
frequency	s^{-1}	Hertz

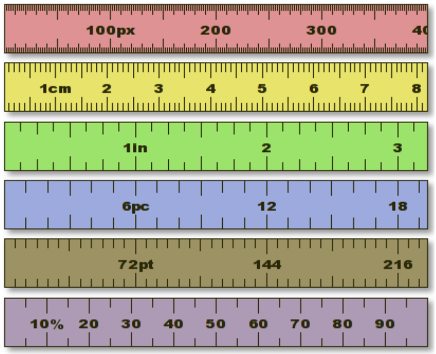
Table 2.2 Dimensions of Some Common Mechanical Quantities

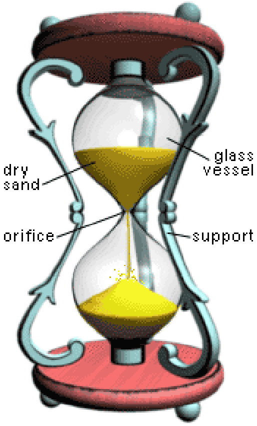
$M \equiv \text{mass}$, $L \equiv \text{length}$, $T \equiv \text{time}$

Quantity	Dimension	MKS unit
Angle	dimensionless	Dimensionless = radian
Solid Angle	dimensionless	Dimensionless = sterradian
Area	L^2	m^2
Volume	L^3	m^3
Frequency	T^{-1}	s^{-1} = hertz = Hz
Velocity	$L \cdot T^{-1}$	$m \cdot s^{-1}$
Acceleration	$L \cdot T^{-2}$	$m \cdot s^{-2}$
Angular Velocity	T^{-1}	$rad \cdot s^{-1}$
Angular Acceleration	T^{-2}	$rad \cdot s^{-2}$
Density	$M \cdot L^{-3}$	$kg \cdot m^{-3}$
Momentum	$M \cdot L \cdot T^{-1}$	$kg \cdot m \cdot s^{-1}$
Angular Momentum	$M \cdot L^2 \cdot T^{-1}$	$kg \cdot m^2 \cdot s^{-1}$
Force	$M \cdot L \cdot T^{-2}$	$kg \cdot m \cdot s^{-2}$ = newton = N
Work, Energy	$M \cdot L^2 \cdot T^{-2}$	$kg \cdot m^2 \cdot s^{-2}$ = joule = J
Torque	$M \cdot L^2 \cdot T^{-2}$	$kg \cdot m^2 \cdot s^{-2}$
Power	$M \cdot L^2 \cdot T^{-3}$	$kg \cdot m^2 \cdot s^{-3}$ = watt = W
Pressure	$M \cdot L^{-1} \cdot T^{-2}$	$kg \cdot m^{-1} \cdot s^{-2}$ = pascal = Pa

SI Unit for 3 Basic Quantities

- Many possible choices for units of **Length, Mass, Time**
- In 1960, standards bodies control and define Système Internationale (SI) unit as,
  - LENGTH: Meter
  - MASS: Kilogram
  - TIME: Second





Fundamental Quantities and SI Units

Length	**meter**	**m**
Mass	**kilogram**	**kg**
Time	**second**	**s**
Electric Current	**ampere**	**A**
Thermodynamic Temperature	**kelvin**	**K**
Luminous Intensity	**candela**	**cd**
Amount of Substance	**mole**	**mol**

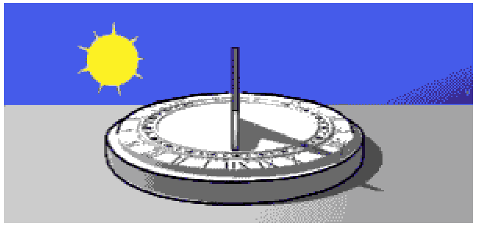
Why should we care about SI units?
Mars Climate Orbiter: http://mars.jpl.nasa.gov/msp98/orbiter

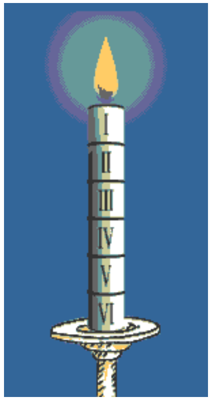
SI Length Unit: Meter

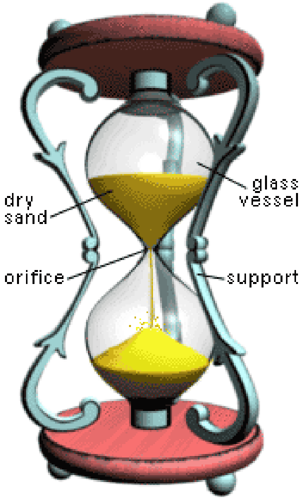
- French Revolution Definition, 1792
- 1 Meter = XY/10,000,000
- 1 Meter = about 3.28 ft
- 1 km = 1000 m, 1 cm = 1/100 m, 1 mm = 1/1000 m
- **Current Definition of 1 Meter**: the distance traveled by light in vacuum during a time of 1/299,792,458 second.

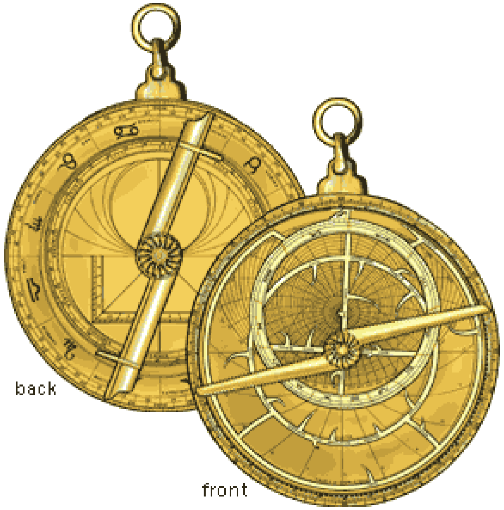
SI Time Unit: Second

- 1 Second is defined as "atomic clock"– time taken 9,192,631,700 oscillations of the light emitted by a ^{133}Cs atom.
- Defining unit precisely is a science (important for, for example, GPS):
  - This clock will neither gain nor lose a second in 20 million years.



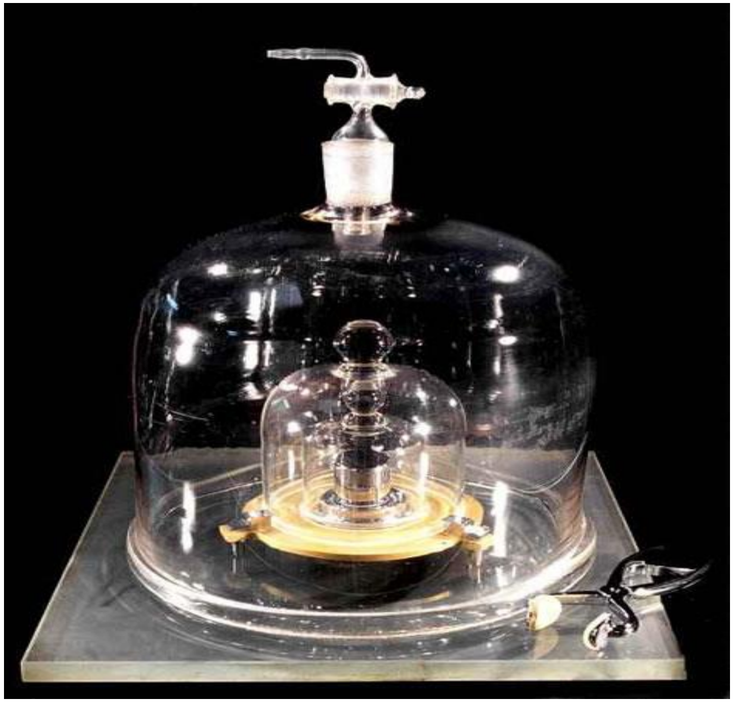






SI Mass Unit: Kilogram

- 1 Kilogram – the mass of a specific platinum-iridium alloy kept at International Bureau of Weights and Measures near Paris.
- Copies are kept in all other countries.



Derived Quantities and Units

- Multiply and divide units just like numbers
- Derived quantities: area, speed, volume, density ……
  - Area = Length × Length SI unit for area = m^2
  - Volume = Length × Length × Length SI unit for volume = m^3
  - Speed = Length / time SI unit for speed = m/s
  - Density = Mass / Volume SI unit for density = kg/m^3

- In 2008 Olympic Game, Usain Bolt sets world record at 9.69 s in Men's 100 m Final. What is his average speed in km/h?

Measurement and Uncertainty

- Physics is a quantitative, experimental science. To do physics, *one has to make measurements.*
- Every measurement has an uncertainty; no measuring instrument is perfect.
- Uncertainty may be written explicitly, e.g., height of a table = $72.3 \pm 0.1\,\mathrm{cm}$

These calipers have a precision of 0.001 in.

A tape measure has a precision of about 1 mm.

Other Unit System

- **U.S. customary system**: foot, slug, second
- **Cgs system**: cm, gram, second
- We will use SI units in this course, but it is useful to know conversions between systems.
  - 1 mile = 1609 m = 1.609 km 1 ft = 0.3048 m = 30.48 cm
  - 1 m = 39.37 in. = 3.281 ft 1 in. = 0.0254 m = 2.54 cm
  - 1 lb = 0.465 kg 1 oz = 28.35 , 1 slug = 14.59 kg
  - 1 day = 24 hours = 24 * 60 minutes = 24 * 60 * 60 seconds

Some Prefixes for Power of Ten

Power	Prefix	Abbreviation
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	*nano*	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

Table 1-3
Some prefixes for powers of 10 used with metric units

Power	Prefix	Abbreviation	Power	Prefix	Abbreviation
10^{-18}	atto-	a	10^{-1}	deci-	d
10^{-15}	femto-	f	10^{1}	deka-	da
10^{-12}	pico-	p	10^{3}	kilo-	k
10^{-9}	nano-	n	10^{6}	mega-	M
10^{-6}	micro-	μ (Greek letter *mu*)	10^{9}	giga-	G
			10^{12}	tera-	T
10^{-3}	milli-	m	10^{15}	peta-	P
10^{-2}	centi-	c	10^{18}	exa-	E

Figure 1-7
The mass of this mosquito can be expressed several different ways: 1×10^{-5} kg, 0.01 g, or 10 mg.

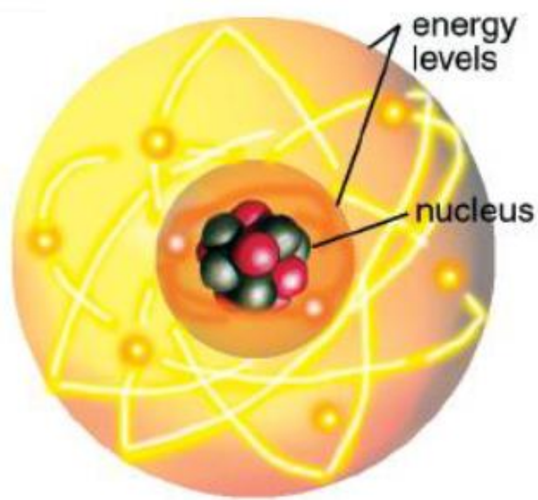
Prefixes

- For very large or very small numbers, we can use standard prefixes with the base units.
- The main prefixes that you need to know are shown in the table. (next slide)

Prefixes

- Alternative writing method
- Using standard form
- $N \times 10^n$ where $1 \leq N < 10$ and n is an integer

This galaxy is about 2.5×10^6 light years from the Earth.



The diameter of this atom is about 1×10^{-10} m.

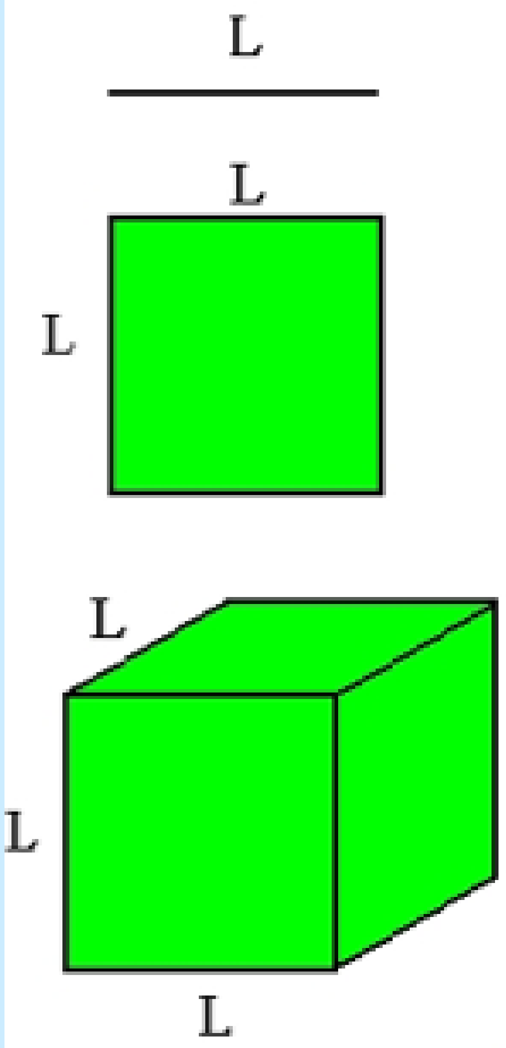
Dimensional Analysis

- Physical laws must be **independent** of arbitrarily chosen units of measure. **Nature does not care if we measure lengths in centimeters or inches or light-years or …**
- Check your units! **All natural/physical relations must be dimensionally correct.**

Dimensional Analysis

Dimensional Analysis refers to the physical nature of the quantity and the type of unit (**Dimension**) used to specify it.

- Distance has dimension L.
- Area has dimension L^2.
- Volume has dimension L^3.
- Time has dimension T.
- Speed has dimension L/T



Dimensions, Units and Equations

- Quantities have dimensions:
- **[Length]: L, [Mass] : M, [Time]: T**
- Quantities have units: Length: m, Mass: kg, Time: s

Quantity	Area	Volume	Speed	Acceleration
Dimension	$[A] = L^2$	$[V] = L^3$	$[v] = L/T$	$[a] = L/T^2$
SI Units	m^2	m^3	m/s	m/s^2

Dimensions and Units

Length	**L**
Mass	**M**
Time	**T**

Table 1-2 Dimensions of Physical Quantities

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 (F/A)	p	M/LT^2
Density (M/V)	ρ	M/L^3
Energy	E	ML^2/T^2
Power (E/T)	P	ML^2/T^3

Dimensional Analysis

- **Necessary either to derive a math expression, or equation or to check its correctness.**
- **Quantities can be added/subtracted only if they have the same dimensions.**
- **The terms of both sides of an equation must have the same dimensions.**

  - a, b, and c have units of meters, $s = a$, what is $[s]$?
  - a, b, and c have units of meters, $s = a + b$, what is $[s]$?
  - a, b, and c have units of meters, $s = (2a + b)b$, what is $[s]$?
  - a, b, and c have units of meters, $s = (a + b)^3/c$, what is $[s]$?
  - a, b, and c have units of meters, $s = (3a + 4b)^{1/2}/9c^2$, what is $[s]$?

Dimensions of Some Common Physical Quantities

[x], Length : L

[m], Mass : M

[t], Time : T

[v], Velocity : LT^{-1}

[a], Acceleration : LT^{-2}

[F], Force : MLT^{-2}

[ρ], Mass Density : ML^{-3}

[P], Pressure : $ML^{-1}T^{-2}$

[E], Energy : $ML^{2}T^{-2}$

[I], Electric Current : QT^{-1}

[q], Electric Change : Q

[E], Electric Field : $MLQT^{-2}$

All are powers of the fundamental dimensions:

[Any Physical Quantity] = $M^{a}L^{b}T^{c}Q^{d}$

Dimensional Analysis (1)

Any valid physical equation must be dimensionally consistent – each side must have the same dimensions.

TABLE 1–5 Dimensions of Some Common Physical Quantities

Quantity	Dimension
Distance	[L]
Area	$[L^2]$
Volume	$[L^3]$
Velocity	[L]/[T]
Acceleration	$[L]/[T^2]$
Energy	$[M][L^2]/[T^2]$

From the Table:

Distance = velocity × time

Velocity = acceleration × time

Energy = mass × (velocity)^2

Dimensional Analysis (2)

Example:

The period P (T) of a swinging pendulum depends only on the length of the pendulum d (L) and the acceleration of gravity g (L/T^2).

Which of the following formulas for P ***could*** be correct ?

(a) $P = 2\pi (dg)^2$ (b) $P = 2\pi \dfrac{d}{g}$ (c) $P = 2\pi \sqrt{\dfrac{d}{g}}$

Dimensional Analysis (3)

Remember that P is in units of time (T), d is length (L) and g is acceleration (L/T^2).

The both sides must have the *same* units

Try equation (a). Try equation (b). Try equation (c).

$$\cancel{\left(L\cdot\frac{L}{T^2}\right)^2=\frac{L^4}{T^4}\neq T}$$

$$\cancel{\frac{L}{\frac{L}{T^2}}=T^2\neq T}$$

$$\sqrt{\frac{L}{\frac{L}{T^2}}}=\sqrt{T^2}=T \quad \checkmark$$

(a) $\boxed{P=2\pi(dg)^2}$ (b) $\boxed{P=2\pi\dfrac{d}{g}}$ (c) $\boxed{P=2\pi\sqrt{\dfrac{d}{g}}}$

Dimensional Analysis

- **The force (F) to keep an object moving in a circle can be described in terms of:**
  - **velocity (v, dimension L / T) of the object**
  - **mass (m, dimension M)**
  - **radius of the circle (R, dimension L)**

Which of the following formulas for *F* *could* be correct ?

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

(a) $F = mvR$

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

(c) $F = \frac{mv^2}{R}$

Dimensional Analysis

Which of the following formulas for *F* *could* be correct ?

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

A. → $F = mvR$

B. → $F = m\left(\frac{v}{R}\right)^2$

$F = \frac{mv^2}{R}$

C. →

Velocity (v, dimension L / T)

Mass (m, dimension M)

Radius of the circle (R, dimension L)

Summary

- The three fundamental physical quantities of mechanics are length, mass and time, which in the SI system have the units meter (m), kilogram (kg), and second (s), respectively
- The method of **dimensional analysis** is very powerful in solving physics problems.
- Units in physics equations must always be consistent. Converting units is a matter of multiplying the given quantity by a fraction, with one unit in the numerator and its equivalent in the other units in the denominator, arrange so the unwanted units in the given quantity are cancelled out in favor of the desired units.