Understanding the Cosmos

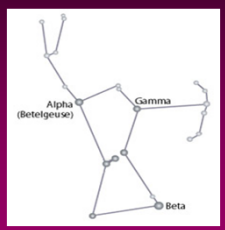
There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophies.

-- William Shakespeare, *Hamlet*

Why?

Mankind eventually made up stories to help them make sense of the world around them.

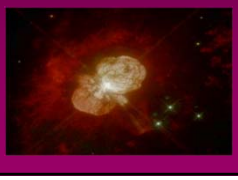
Orion



Most early civilizations had a well developed astronomy before they had a written language.

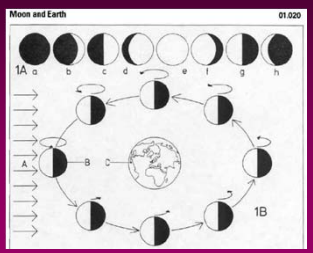
Stonehenge

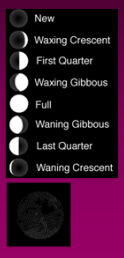
The night sky contains amazing vistas …



… along with order and predictability.

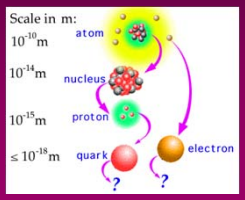
The Moon





Today, we still make up stories about the heavens. They tell us about things that no eye could ever see ...

Black Holes



Quarks

… and of distances to vast to imagine.

Hubble Deep Field

(*every point of light is a galaxy*)

The seeds of physics were planted back when astronomers first tried to unravel the mystery of planetary motion.

Johannes Kepler
(1571-1630)

It was the marriage of mathematics with astronomy that marked the dawn of classical physics.

In Ancient Times, Astronomy and Astrology were completely intertwined and inseparable.

Astrology

- the study of the positions and movements of astronomical bodies and how they impact events on earth

The belief was that the motion of the heavens impacted a persons life from birth to death.

Names = Star Arrangements (Constellations)

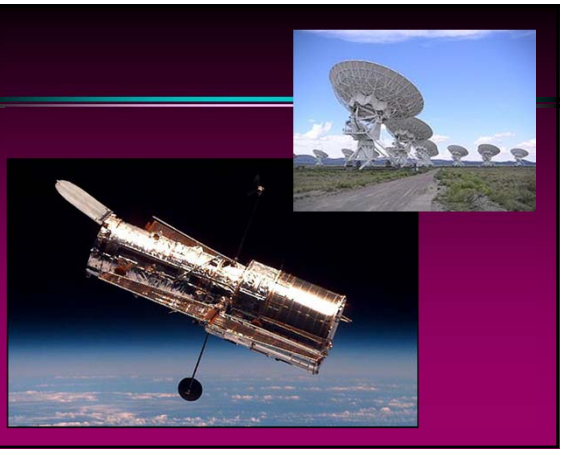
Planets, comets, meter showers… in or around one of these constellations was said to indicate some type of event in a persons life.

What the future holds…

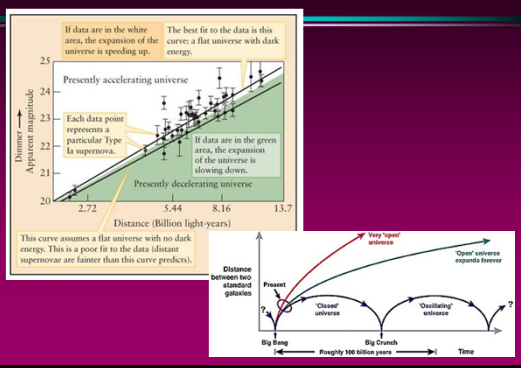
Astronomy

- The study of the positions, movements (evolution) and composition of astronomical bodies

This is done using very high precision instruments.



What the future holds …

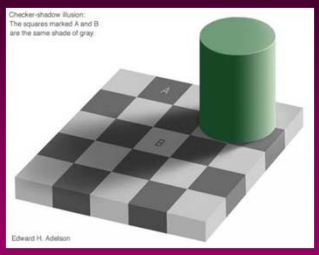


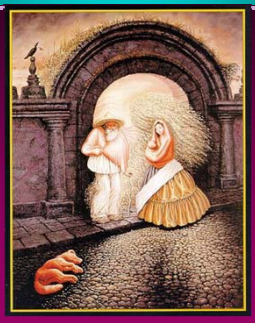
- Science rejects astrology for two reasons:
  - Influence of the planets/stars on a person is too small to measure and overshadowed by much closer objects
  - Doesn't work
    - Success rate is equivalent to that of random guessing (~10%)
  - In addition, astrologers don't have a unified system or approach!

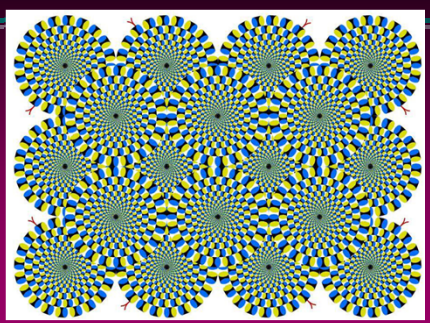
Ways of Knowing:

- Observation (Senses)
- Equipment (Direct Measurements)
- Inference (Logic)
  - The best approach is by equipment since it is indifferent to the outcome, followed by inference and then observation.
  - Observation is the easiest, but least trusted. Why?

The eyes can be deceived!







Physics is…

- A quantifiable & measureable 'philosophy'
  - Not based on logic or reason alone but,
    - Observation
    - Analysis
    - Modeling

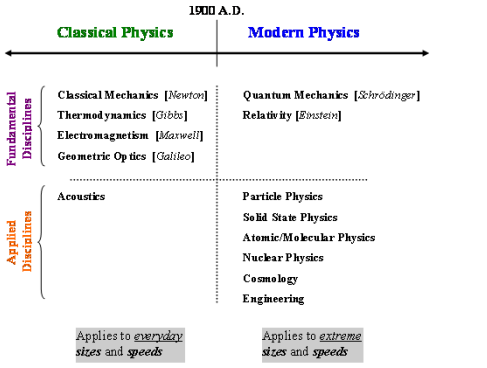
The word Physics comes from the Latin ***physica***, meaning 'knowledge of natural things'.

Physics – the study of matter and energy and the ***interactions*** that govern their behavior

** Physics is the discipline where man attempts to explain the **motion** and **behavior** of the physical universe as completely and accurately as possible, on scales that are very large (*universe, galaxies*…), very small (*atoms, quarks*…) and everywhere in between.

* Natural phenomena exists and has existed long before we observed them.
(*i.e. Newton did not discover gravity, he was the first to describe it quantitatively*)

Traditional & Modern Fields of Study



The Physics Process

- Observation
  - Information about our universe comes from experiments and observation.
- Analysis
  - Scientific experiments produce immense, confusing or even exciting data that must be carefully analyzed.
- Modeling
  - The physicists job is to produce a "story" or model that accurately represents the observed phenomena.

The Game of Physics

- Any number of individuals may play
- The object of the game is to discover the Rules of Nature
- The playing field is the entire universe
- Any device: physical, conceptual or computational may be used
- Players can score "Prestige" points while playing:
  - Points for Discovering a Rule of Nature
  - Points for the each phenomena a Rule correctly explains
  - Bonus points if the Rule predicts previously unobserved phenomena
- The game is never over
- Players can *never* win!

The Game of Physics, Cont.

- An untested candidate for a Rule of Nature is called a hypothesis
- When a hypothesis has successfully described many phenomena, it may achieve the status of theory
- Well tested theories that successfully explain a large number of events, by agreement of the players, may be awarded the exulted status of law.
- Any hypothesis, theory or law may be challenged by any player at any time
- All disputes will be settled by experiments as agreed upon by the players
- The decisions of Nature, as revealed through experiments, are final!

This part of the game is known as the Scientific Method

The Communication Problem

How can scientific information (or a scientific "story") be presented so that other people can understand it?

DEMO: What's in the bag?

ANSWER:
Analogies
Models

Requires *individuals to share some common reference points and a common language.*

The Solution

A. The standard reference problem is solved by using:
Measurements

B. The language problem is solved by using:
the "Symbolic" Language of Mathematics

** Whenever words, rather than math, must used to express a physical principle, the words used are very specific and well crafted to avoid any confusion or miss-understanding.*

Solution A – Common References

Every scientific measurement always consists of 2 parts:

a number (*which represents magnitude or size*)

a unit

Numbers in Physics are meaningless without units!

Units provide the reference point to which all **like** measurements are compared.

What are **like** measurements?

distance, time, mass, temperature…

Fundamental Properites

- Any physical property in the universe that can be measured can be described by using 1 of 4 fundamental physics properties or by some combination of the 4.

4 Fundamental Physics Properties:

Length (*a measure of the amount of space in a given direction*)

Mass (*a measure of the amount of matter an object contains*)

Time (*a measure of the interval between events*)

Charge

Examples

- What fundamental property would you use to describe the size of this room?

  Length ➔ area *or* volume

- What color is the sky?

  What fundamental property would you use to describe the color blue?

  Length or time ➔ wavelength *or* frequency

Different colors have different wavelengths or frequencies.

The unit associated with each fundamental property depends on the choice of measurement system.

- 2 Types of Measurement Systems
  - Imperial (English/British) System
    - ft-lb-s
  - SI or Metric System
    - mks*
      - Length – meter (m)
      - Mass – kilogram (kg)
      - Time – seconds (s)

      *standard
    - cgs

The metric system is based on powers of **10** for quick & easy conversions using **prefixes**

Ex.

10,000 meters = 10 kilometers

0.001 meter = 1 millimeter

When the magnitudes get too large or small, scientific notation is used

- Always use the base SI unit when adding a prefix
  - Exception: Mass (grams)

Units of Convenience

Fundamental units can be combined with themselves or other fundamental units to help describe or represent other physical phenomena. Units formed by a combination of the fundamental SI units are called units of convenience or derived units.

Ex.

Area (*length *length*) → m*m = m^2

Volume (*length *length *length*) → m*m*m = m^3

??? Density (ρ) (*??? / Volume*)

mass density (ρ=m/V) → kg/m^3

- **Importance of Units**

  Units are extremely important because they will always be associated with a unique property or concept.

- **Unit Conversions**

  At times, it may become necessary to switch between measurement systems.

  Ex. Length

  English System — *feet*

  mks — *meter*

  But $1\ ft \neq 1\ m$

  ➔

  $1\ ft = .3048\ m$ or $1\ m = 3.281\ ft$

- What is 34 *m* in *ft* ?
  - Write down what you start w/ followed by a set of big parenthesis w/ a line in them

    $34\ m \left(\quad \right)$

  - Place the number 1 & the current unit on bottom & the destination unit on top

    $34\ m \left(\frac{ft}{1\ m} \right)$

  - Insert the appropriate conversion factor on top & then multiply

    $34\ m \left(\frac{3.281\ ft}{1\ m} \right) = 111.554\ ft$

What is 100 *km/hr* in *ft/s*?

$100\ km/hr \left(\quad \right)$

$100\ km/hr \left(\frac{ft/s}{1\ km/hr} \right)$

$100\ km/hr \left(\frac{0.911\ ft/s}{1\ km/hr} \right) = 91.1\ ft/s$

The Dangers of Incorrect Measurements or Conversions

- [Magnitude]
  Ex. Prescription Drugs
  How much of a cancer curing pill would you take if more than 750 *mg* was fatal?
  100.0 *mg*
  1000 *mg*
  Magnitudes are important!

- [Units]
  Ex. Salary
  Suppose you are to be paid 100,000 a month. Would you rather be paid:
  100,000 *cents*
  100,000 *dollars*
  Missing units create confusion!

Solution B – The Common Language

Why Mathematics?

Mathematics is very precise.

Mathematics and mathematical symbols can be used as shorthand ways of representing physical quantities.

Mathematical equations can convey relationships, theories, data, concepts… quickly and efficiently.

Mathematics is Universal.

Symbols

Symbols stand for or represent a very specific property or concept

Ex.
π - the ratio of the circumference of a circle to its diameter
θ - refers to an angle

Subscripts on symbols or letters can also be used to help identify or label a particular quantity

Ex. Time
t = time
t_i = (*i*)nitial time
t_f = (*f*)inal time

Identifiable Symbols




π

$

Average vs. Instantaneous Values

Average **[Big Picture]**

Average ??? – total quantity divided by the total elapsed time

** Average values tell us ***nothing*** about fluctuations or values at specific points in time (*unless the value was constant the whole time*)

Ex. Class Test Grades

The class test average tells how the class did as a whole, but does not indicate how any one individual did on the test.

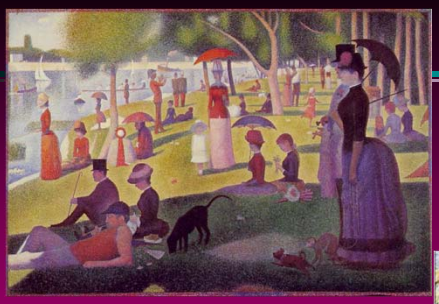
Instantaneous **[Snap Shot]**

Instantaneous ??? – value of a quantity at a specific instant in time

** Instantaneous values tell us ***nothing*** about general trends or the total process over time (*unless the value was constant the whole time*)

Ex. Individual Test Grades

An individual test grade tells how a student did on the test, but does not indicate how they did compared to the rest of the class.



Georges Seurat's *A Sunday Afternoon on the Island of La Grande Jatte*

Dangers of interchanging Avg. and Inst. Values

When information from one type of time measurement is extended to gain information about the other, chances are it will be wrong!

Ex.

The average daily temp. in Hawaii is 84°

➔ Today it will be 84° in Hawaii

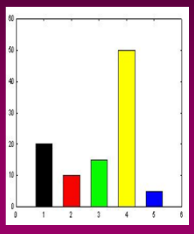
One bag of 100 M&M's has 70 reds

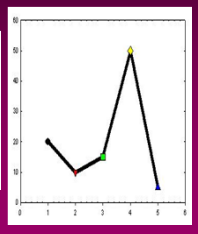
➔ The average # of red M&M's per bag is 70

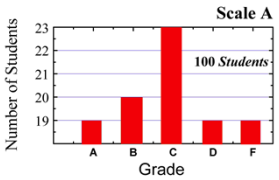
Graphing

Graphs are a visual representation of the relationships between quantities

Graphs can come in many different forms:







Graphs are one of the quickest and easiest methods to convey information, ***but*** they can also be one of the most deceptive!

How many students got A's using Scale A?
How many students got C's using Scale A?

Tables

Another quick method to display data is to use ***tables***.

Table 24. Acid-Base Indicators

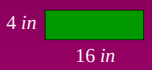
Indicator	pH Range	pKa	Colors*
Cresol red			R-Y
Thymol blue	1.2 to 2.8	1.65	R-Y
Methyl yellow	2.9 to 4.0	3.3	R-Y
Methyl orange	3.1 to 4.4	3.4	R-O
Bromophenol blue	3.0 to 4.6	3.85	Y-B
Bromocresol green	4.0 to 5.6	4.7	Y-B
Methyl red	4.4 to 6.2	4.95	R-Y
p-Nitrophenol	5.3 to 7.6	7.2	C-Y
Phenol red	6.4 to 8.0	7.9	Y-R
Thymol blue	8.0 to 9.6	8.9	Y-B
Phenolphthalein	8.0 to 10.0	9.4	C-R
Alizarin yellow R	10.0 to 12.0	11.2	Y-V

*B = blue, C = colorless, O = orange, R = red, V = violet, Y = yellow

*Correct labeling of graphs and tables is **critical** if any useful information is to be learned or derived from them.*

Examples of Mathematical Efficiency

- Which would you rather use? Why?
  - A: The length of a football field is one hundred yards
  - B: *l* = 100 *yds*
  - A: 32,738
  - B: Thirty Two Thousand, Seven Hundred Thirty Eight
- What does this mean?



A = 64 in^2

Information can be transmitted without using any words at all!

What if you can't speak the language?

You will **NOT** be able to understand the thoughts or information being presented, which will likely cause confusion and/or frustration.

Ex. Spanish

El chocolate es regalo del Dios a la humanidad

** With a common reference system and language, it is much easier to develop analogies or models that others can understand.

Summary

- **Stories** were used by ancient civilizations to explain the workings of the natural world.
- **Physics** is the discipline where man attempts to explain the motion and interactions of the physical universe as completely and accurately as possible.
- Scientists communicate to others with **models** using the language of mathematics and a reference system built around a set of established **units**.

In the beginning you laid the foundations of the earth, and the heavens are the work of your hands.

Psalms 102:25