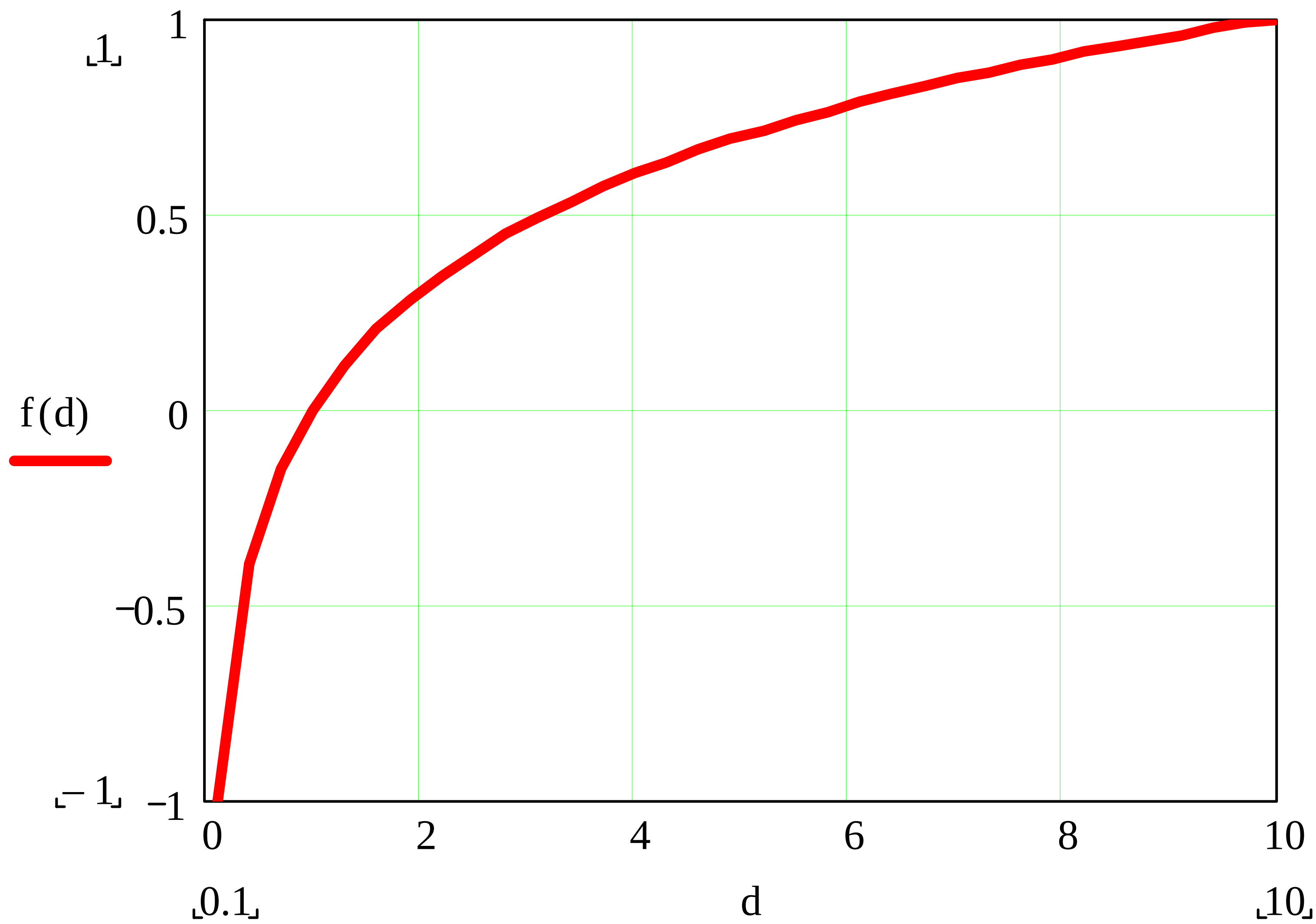
Chapter 4
Technical Information cont’d



The (decadic) logarithm of **0.1 = -1.**

Log**(1)= 0**; Log**(10) =1** ……

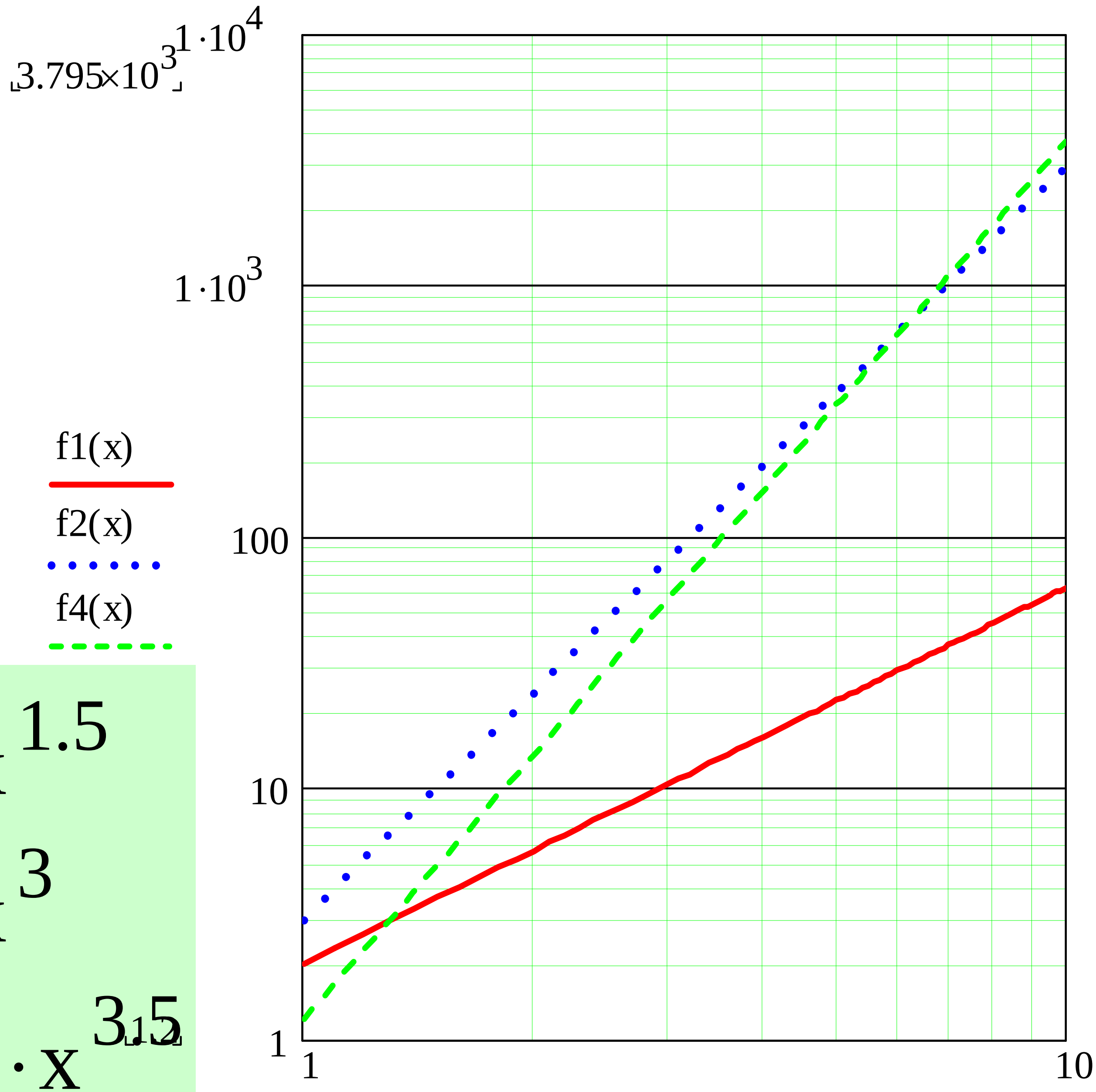
We can use logarithmic plots to test a data set for polynomial relationships. Look at these three polynomials:

$$f1(x) := 2 \cdot x^{1.5}$$

$$f2(x) := 3 \cdot x^{3}$$

$$f4(x) := 1.2 \cdot x^{3.5}$$

Now graph the three polynomials in log-log format:



$$f1(x) := 2 \cdot x^{1.5}$$

$$f2(x) := 3 \cdot x^{3}$$

$$f4(x) := 1.2 \cdot x^{3.5}$$

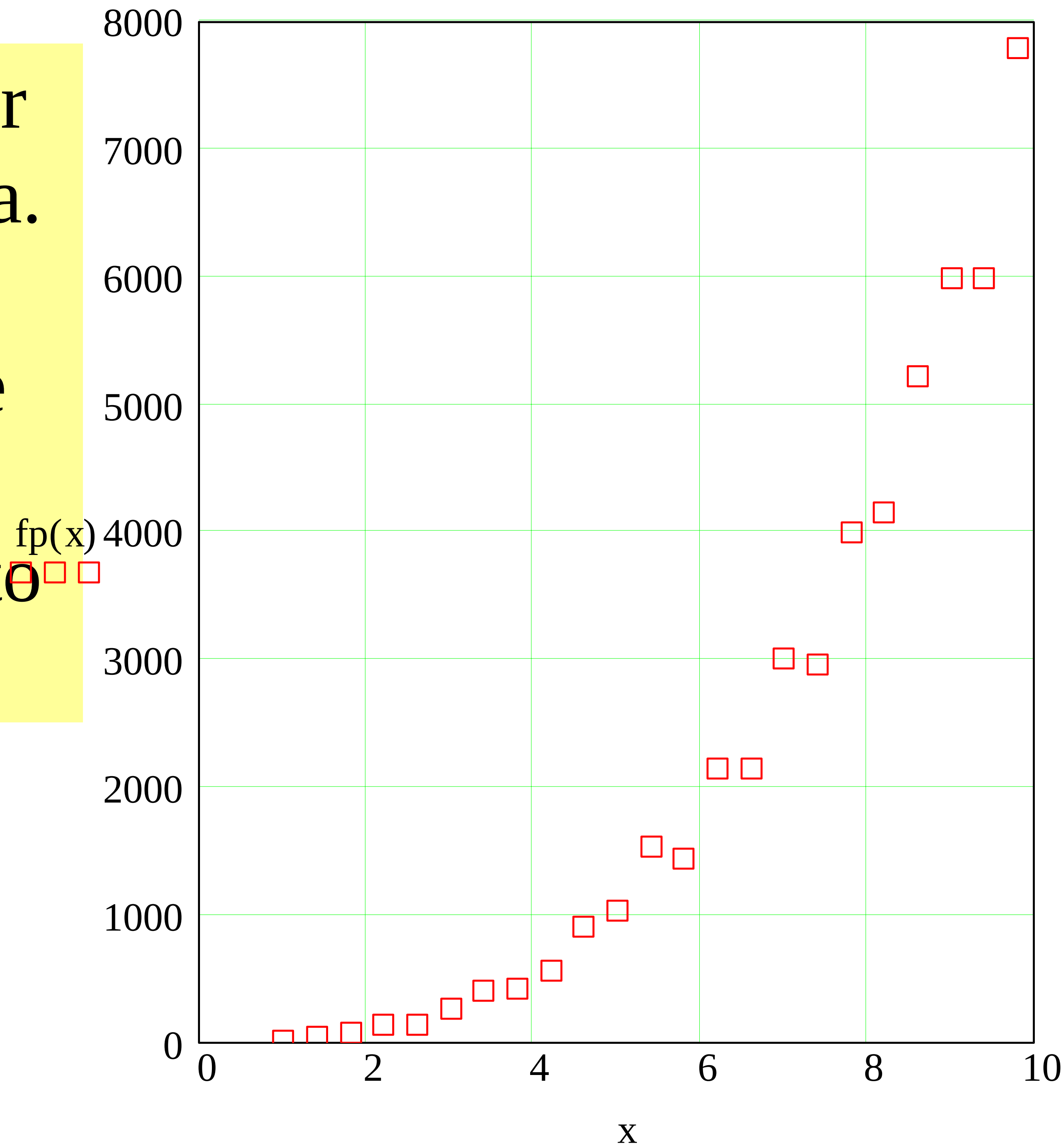
We can use log-log graphing to identify patterns.

Example:
Testing the data Set at right for Polynomial Properties.

$x =$	$fp(x) =$
1	20.085
1.4	30.624
1.8	73.481
2.2	94.966
2.6	222.621
3	269.297
3.4	298.011
3.8	514.174
4.2	612.635
4.6	833.211
5	$1.231 \cdot 10^3$
5.4	$1.532 \cdot 10^3$
5.8	$1.625 \cdot 10^3$
6.2	$2.186 \cdot 10^3$
6.6	$2.226 \cdot 10^3$
7	$2.821 \cdot 10^3$

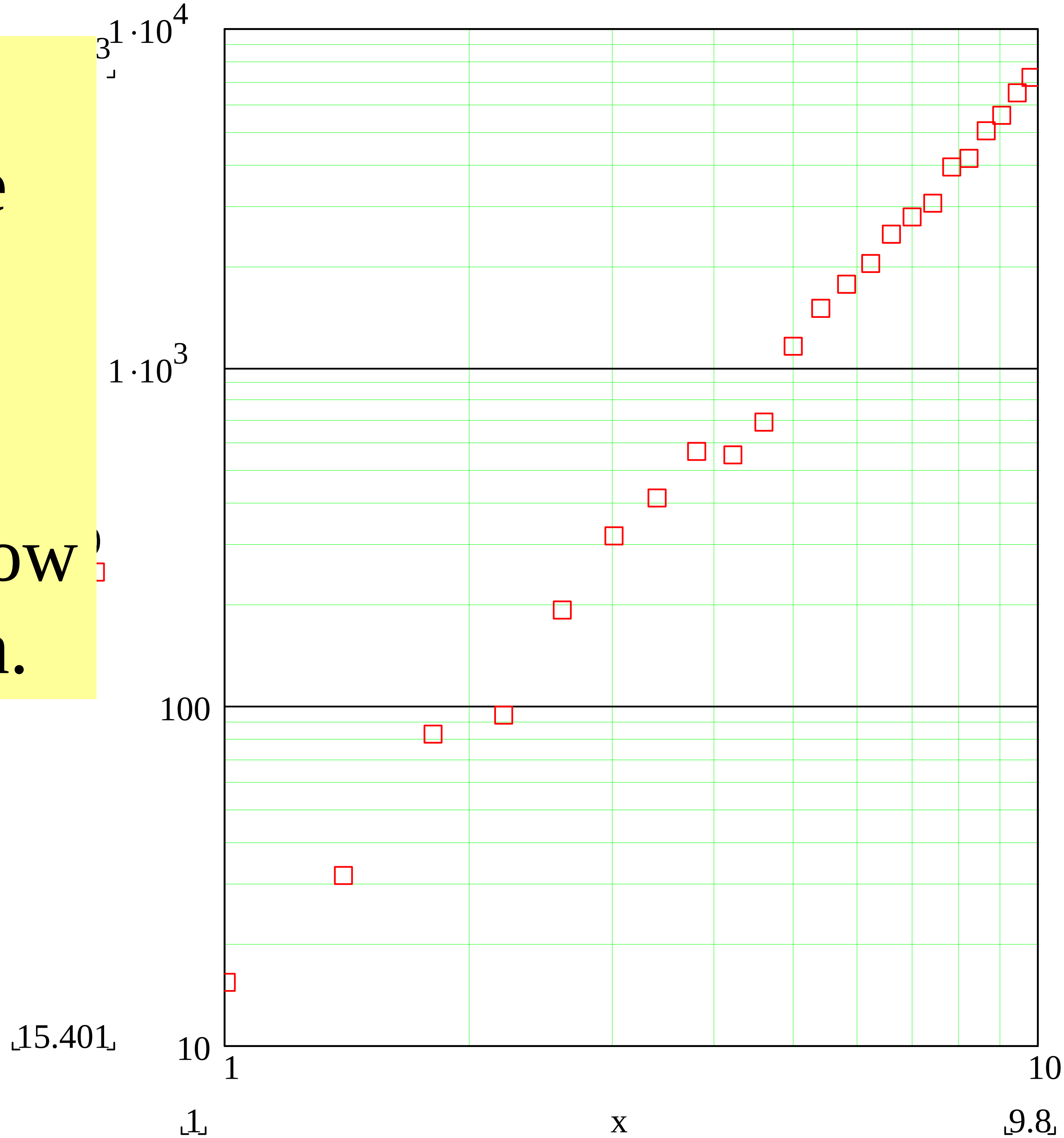
Here is a linear plot of the data.

The values are somewhat scattered due to sensor noise.

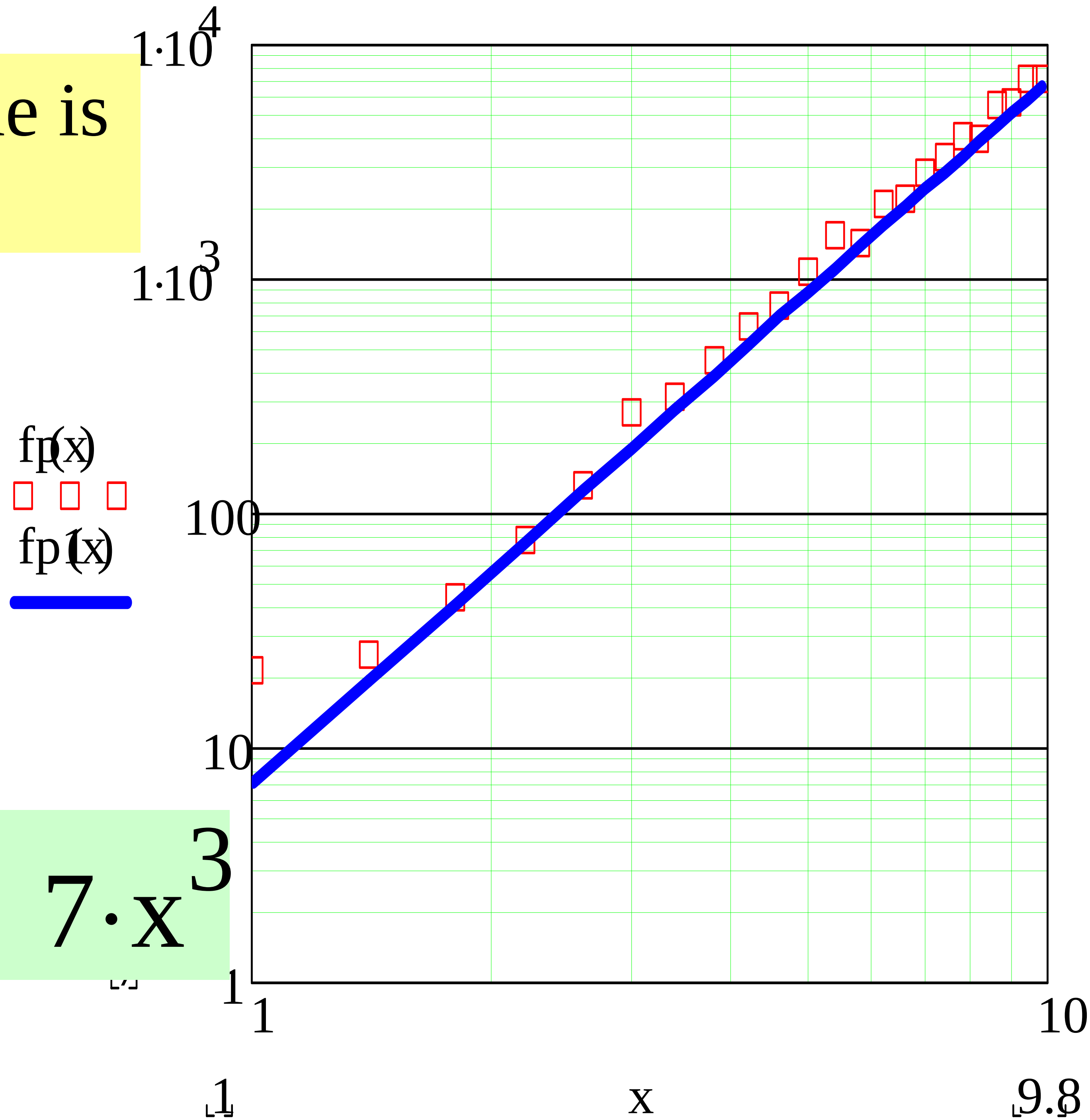


Here is a log-log plot of the same data.

The values appear to follow a straight path.

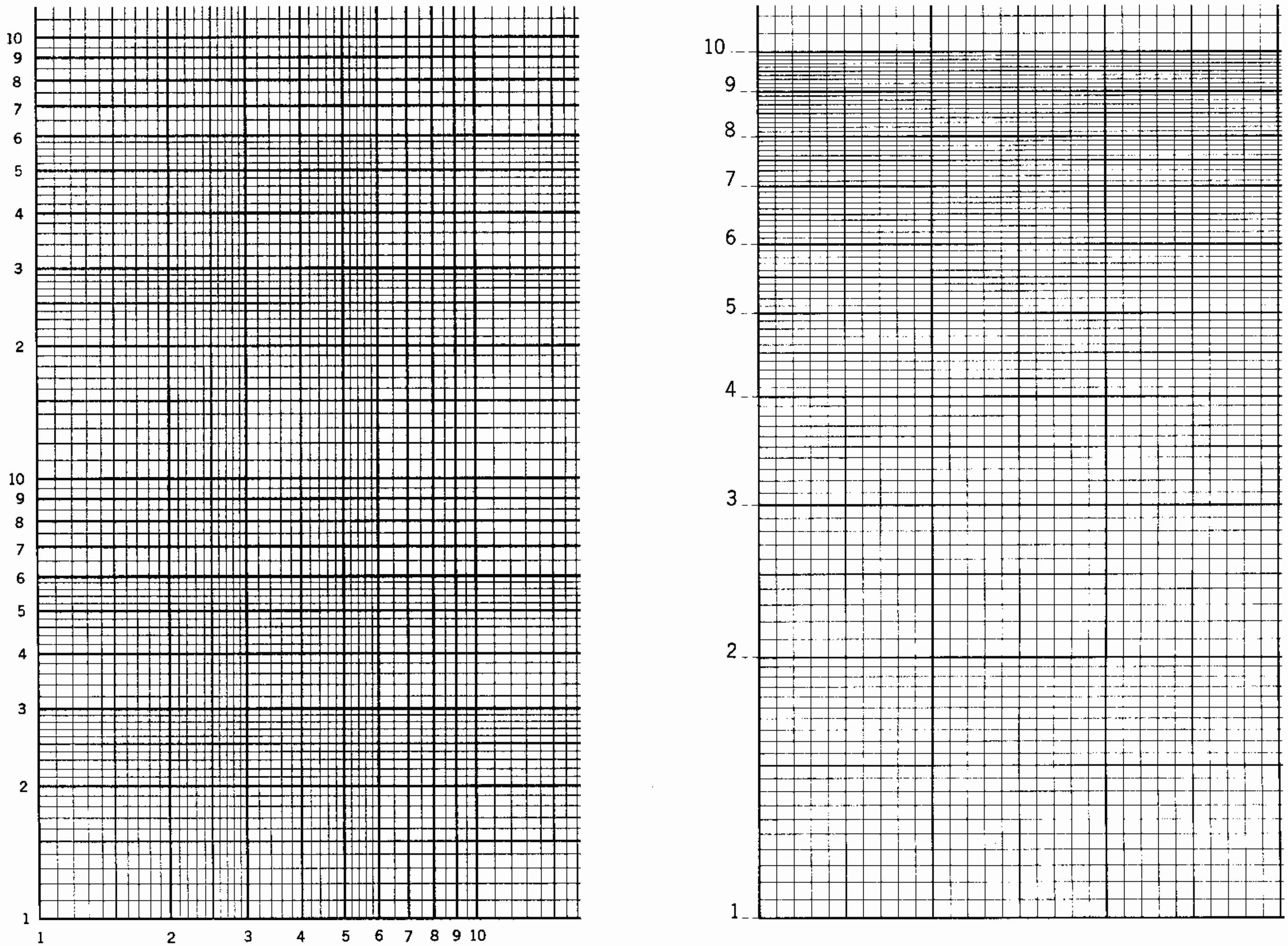


A best fit line is found as:



$$fp1(x) := 7 \cdot x^3$$

Figure 4.5



(*a*) Log-log

(*b*) Semilog

Commercial graph paper.

When using Log-scaled paper:

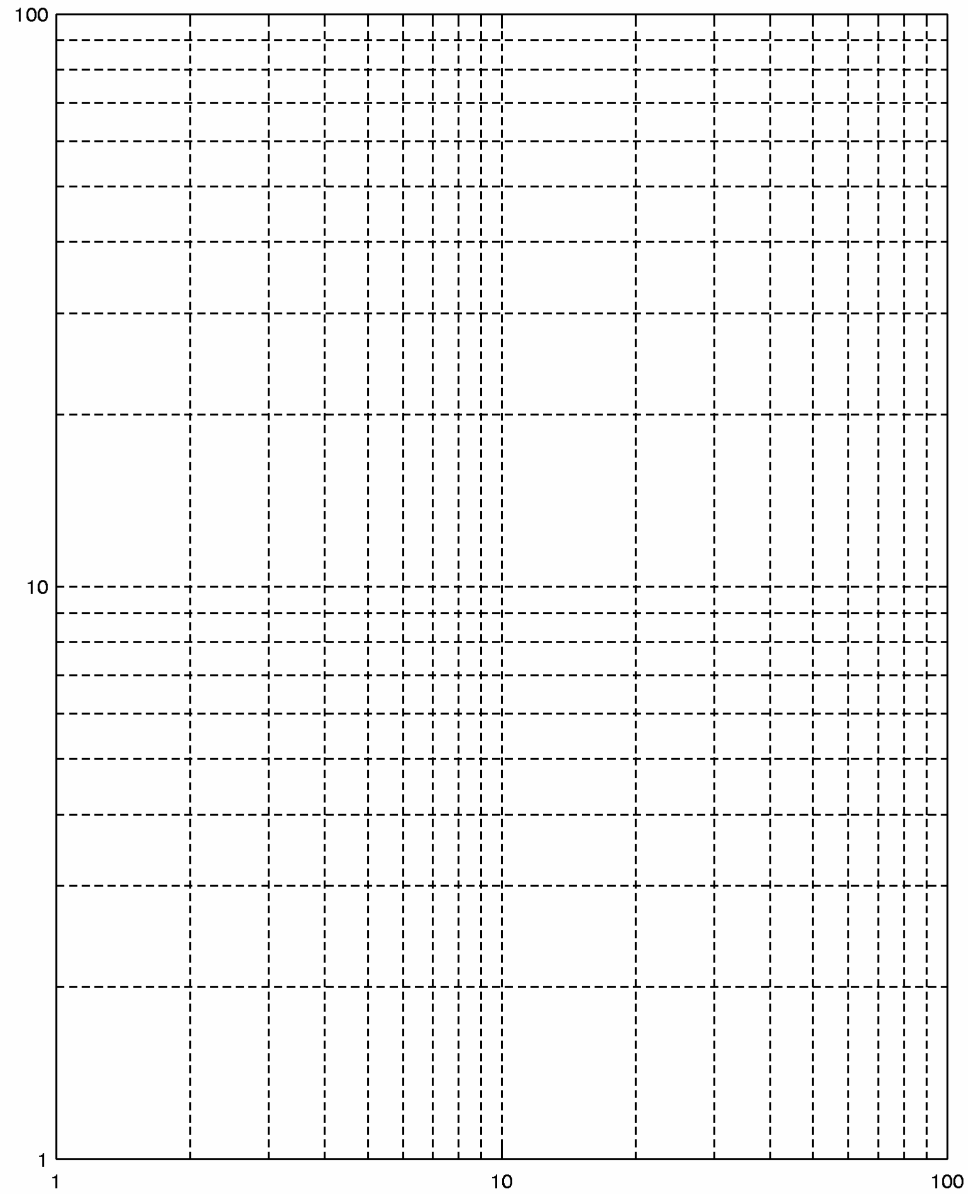
Scale and label the axes!,
e.g.

Example:

Log-log scaling

2 decades on each axis

See also Fig. 4.16 in book!



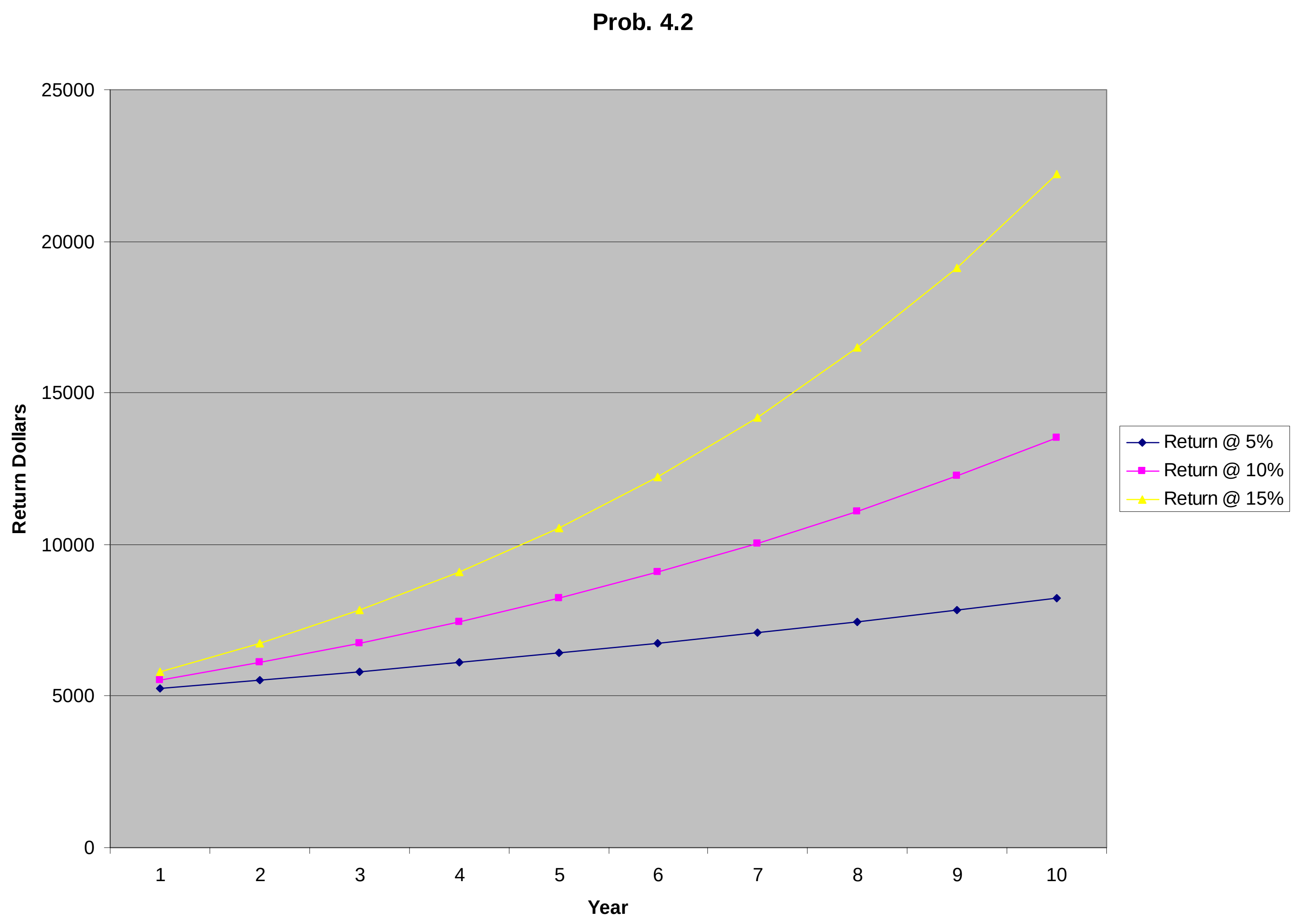
Some Remarks on Homework #10

(Graphing of data sets)

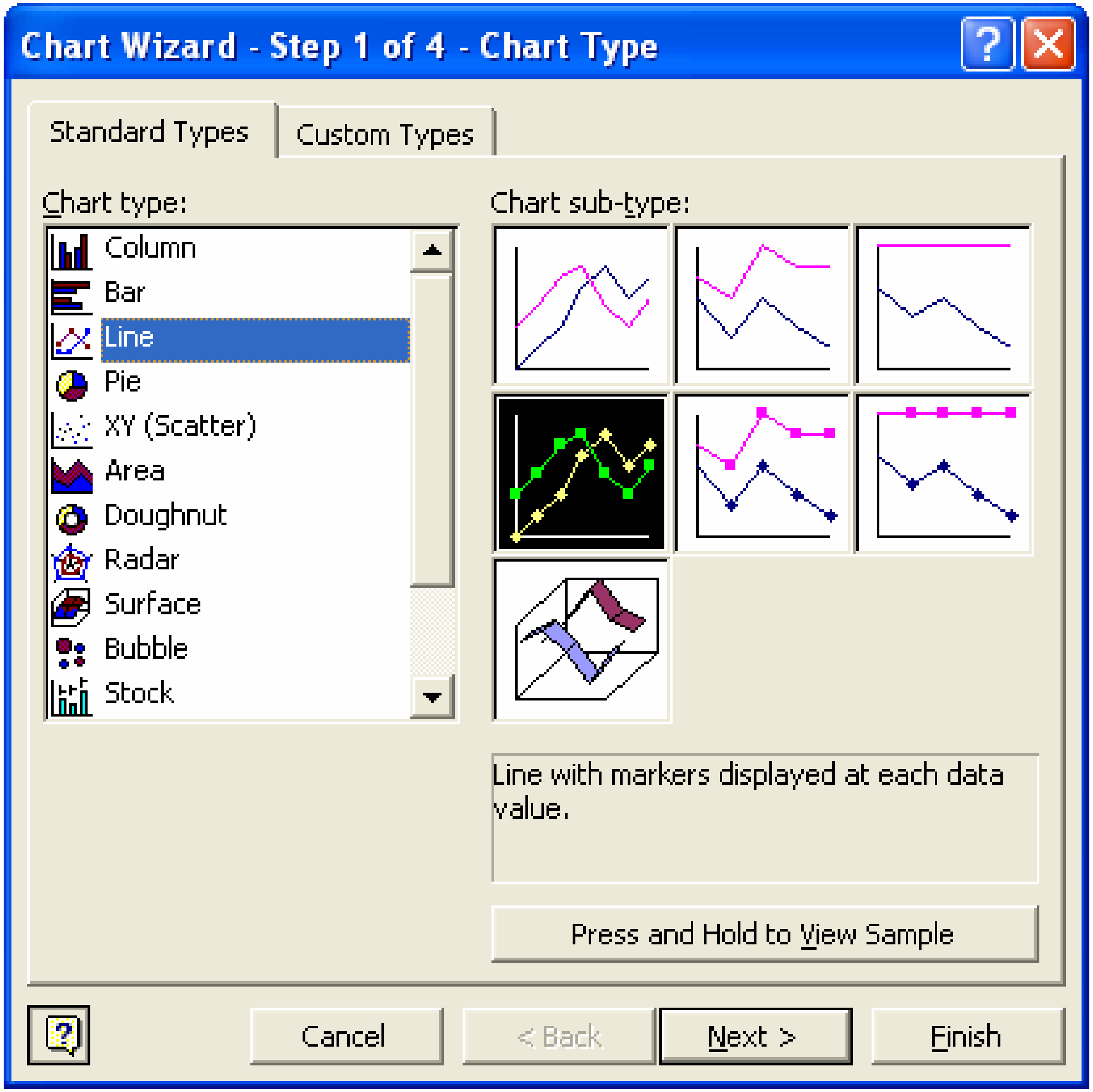
1. Please Follow Instructions precisely!

2. If you find working with the software difficult, don’t give up! Try one or all of the following:

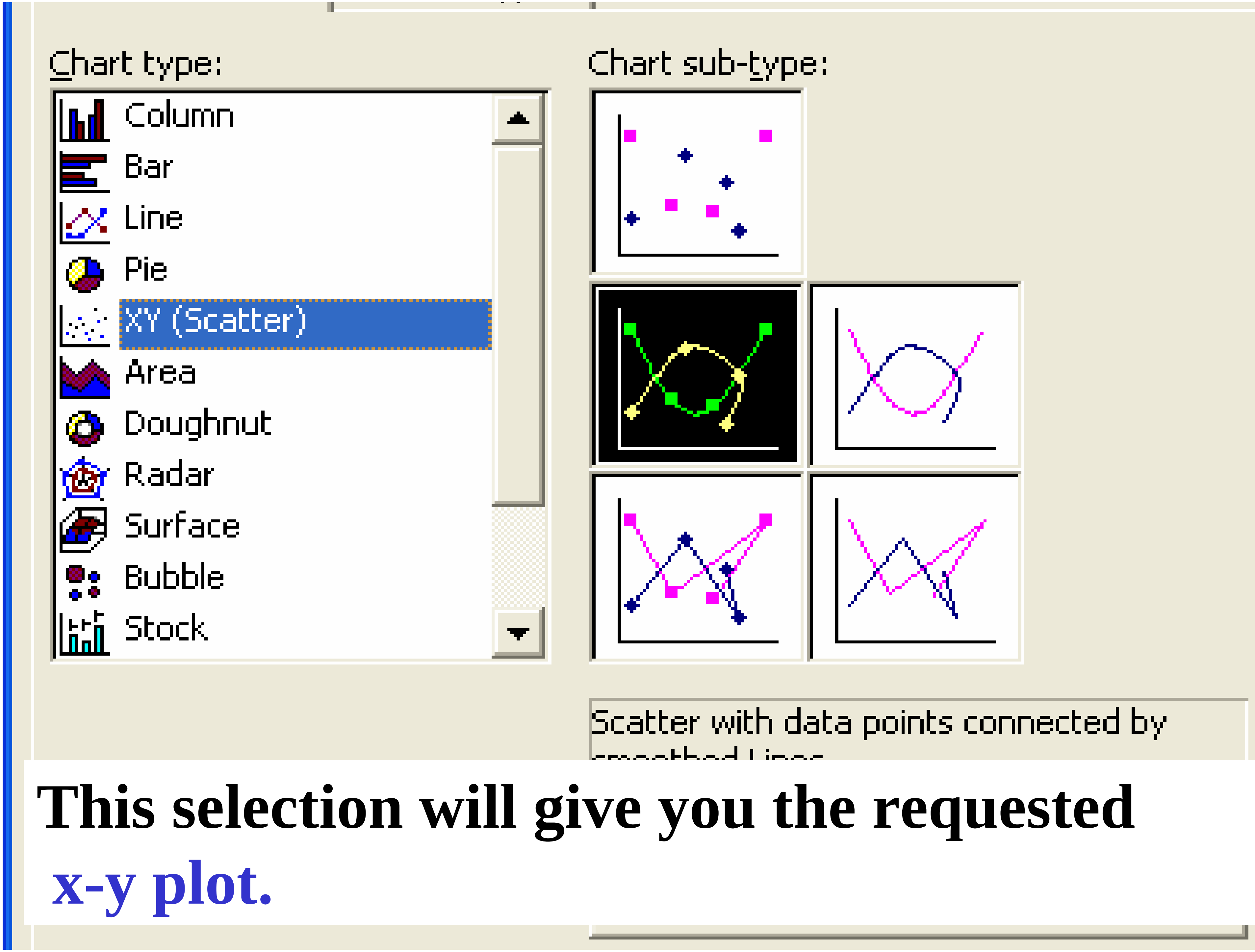
- The Help menu
- Ask someone with more experience
- Explore different Option menus



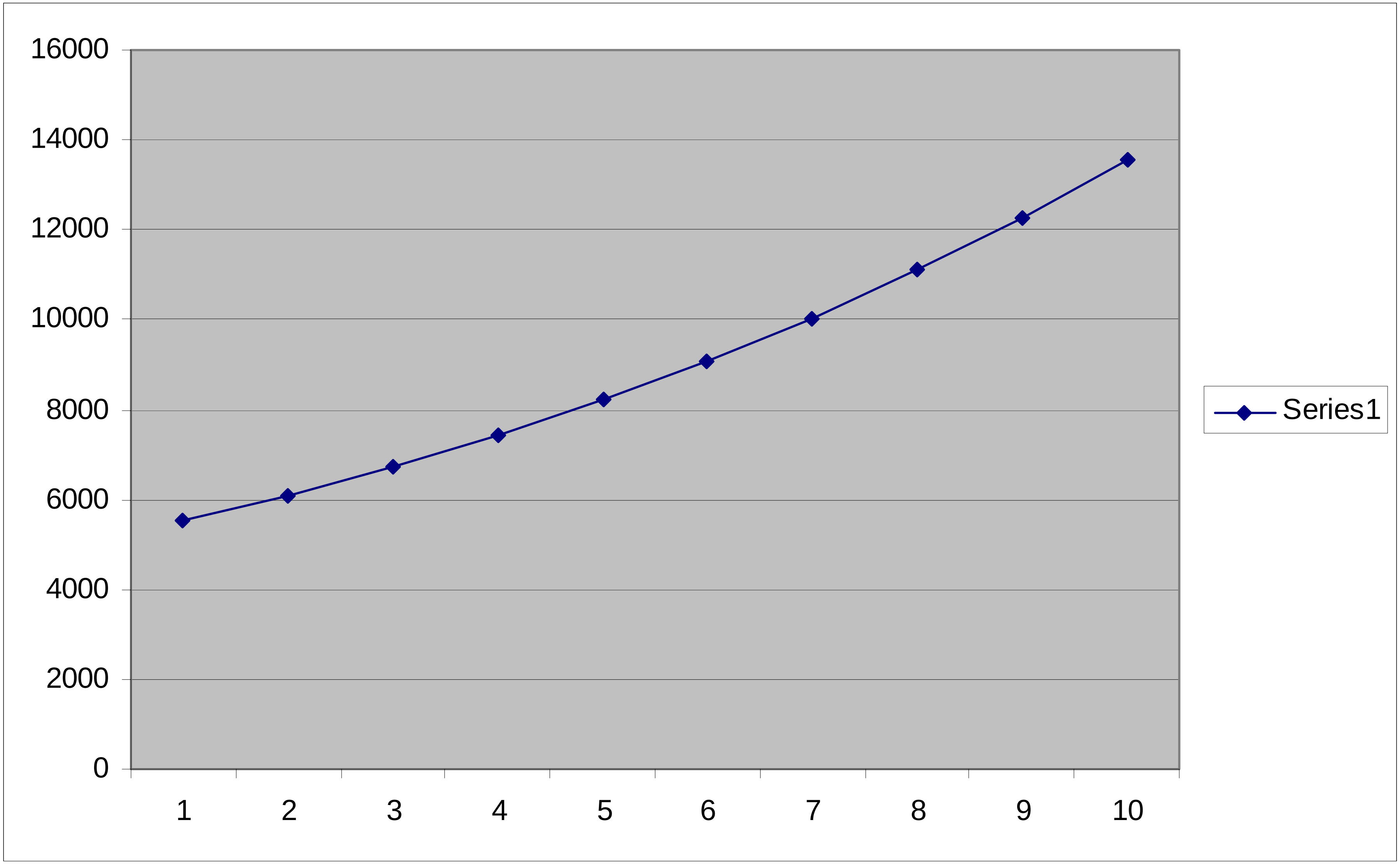
Correct Example (4.2): all graphs in the same plot. Both axes are labeled and scaled.



Incorrect Graphing (4.2): incorrect menu choice: NOT an x-y plot!



This selection will give you the requested x-y plot.

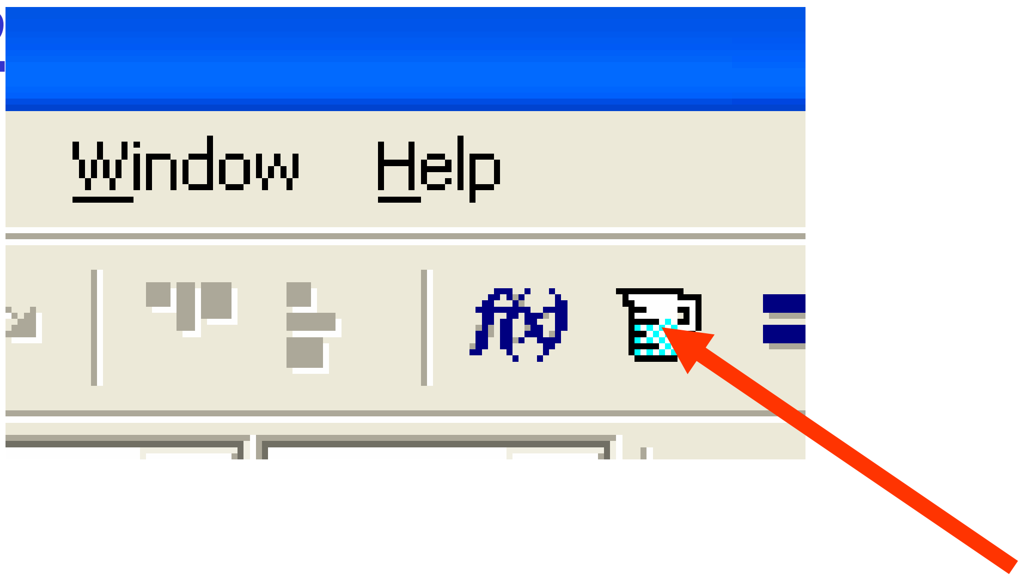


Incorrect Graphing (4.2): incorrect menu choice, only one vector, no labels or titles.

Advice for Homework #10 and 11 (Chapter 5)

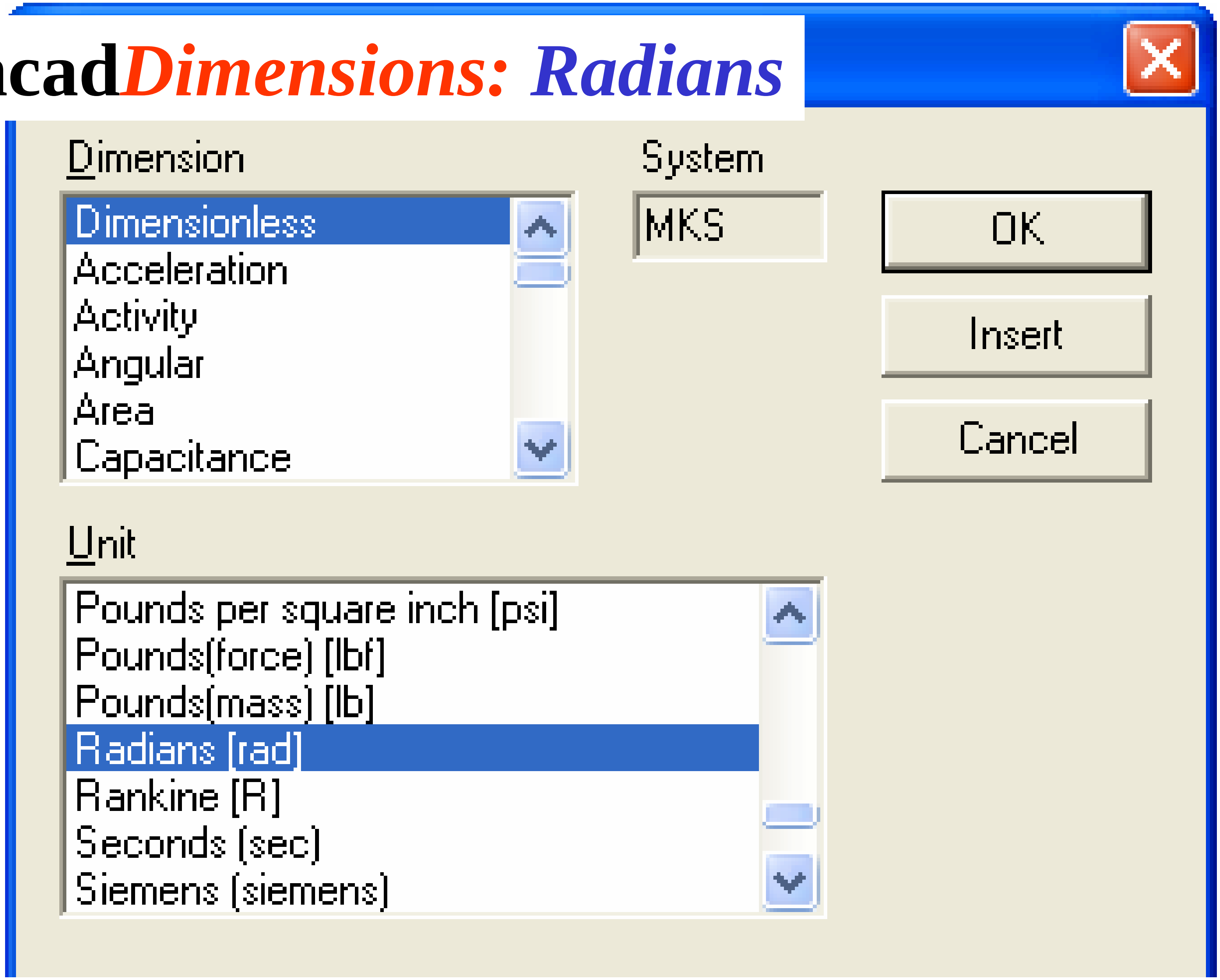
- **Please Use Mathcad, and dimensions as appropriate.**

Here is the *Dimensions* icon in Mathcad 2



Advice for Homework #11 (Chapter 5)

Mathcad *Dimensions: Radians*



Example Mathcad *Dimensions:*

Find thdot and accel at t = 2s. Given: Omega = 2.5 rad/s

blic Solution

Numbers $t := 2 \cdot sec \quad om := 2.5 \cdot \frac{rad}{sec}$

$om = 2.5\, sec^{-1}$

$$rddot(t) := -450 \cdot \cos(3 \cdot th(t)) \cdot \left(\frac{d}{dt} th(t)\right)^2$$

Angle $th := t \cdot om$

Centripetal Accel $rddot := -450 \cdot \cos(3 \cdot th) \cdot (om)^2$

$$rddot = 2.137 \times 10^3\, sec^{-2}$$

Chapter 5
Engineering Estimations and Approximations

Measurement

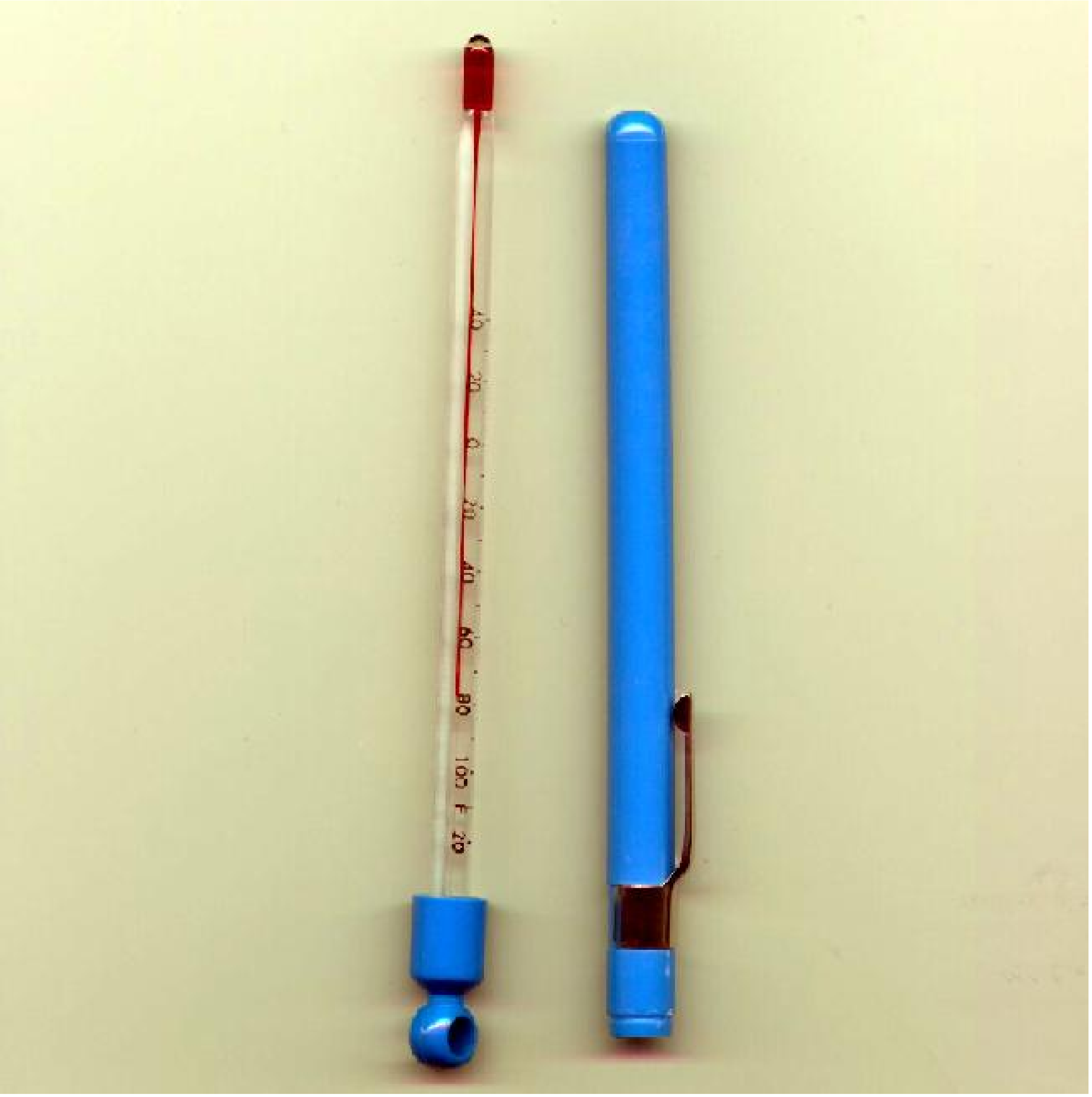
Definition:

Measurement is the Comparison with a standard.

How useful is it?

Who needs it?

Some examples follow.



Example: **Thermometer**

The Thermometer

At the start of the seventeenth century there was no way to quantify heat. In Aristotelian matter theory, heat and cold were fundamental qualities. Like dry and wet, heat and cold were qualities combined with "prima materia" to make up the elements, earth, water, air, and fire. Thus earth was dry and cold, fire dry and hot, etc.

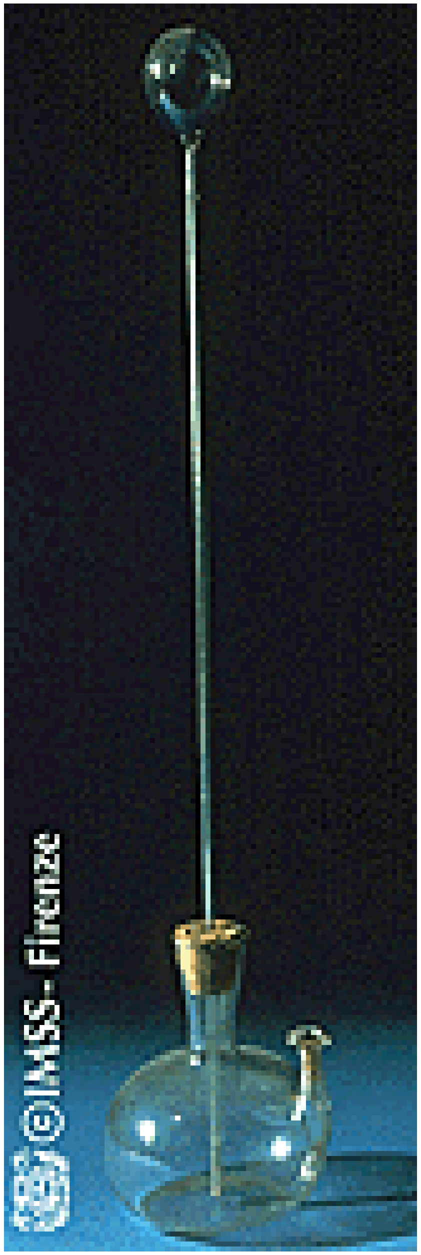
The Thermometer

Although one might speak of "degrees of heat or cold," there was no formal distinction between what we would call the extensive concept of heat and the intensive concept of temperature. Also these degrees were not measured, except perhaps in a very rough way as when a physician put his hand on a patient's forehead and diagnosed "fever heat."

Galileo around 1603: The Thermoscope

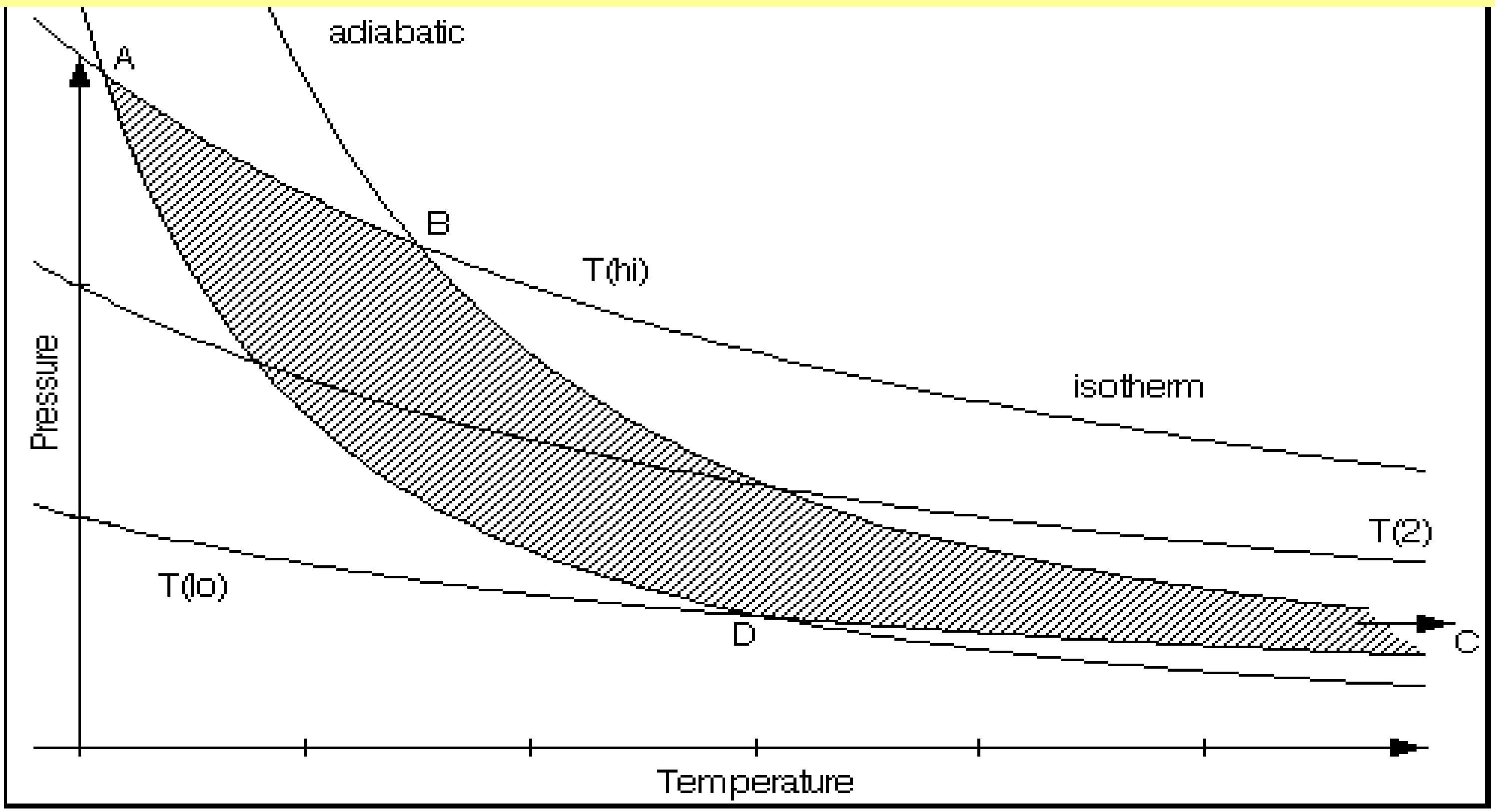
“He took a small glass flask, about as large as a small hen's egg, with a neck about two spans long [perhaps 16 inches] and as fine as a wheat straw, and warmed the flask well in his hands, then turned its mouth upside down into the a vessel placed underneath, in which there was a little water. When he took away the heat of his hands from the flask, the water at once began to rise in the neck, and mounted to more than a span above the level of the water in the vessel. The same Sig. Galileo had then made use of this effect in order to construct an instrument for examining the degrees of heat and cold. “

Benedetto Castelli



We use the Thermodynamic Temperature Scale (Carnot Process)

The Kelvin Temperature is equal to the Absolute Temperature as defined by the expansivity of an Ideal Gas



The Scientific Method

A simple premise: The scientist tries to get the correct answer to the particular problem at hand.

Now if the answer to the problem is correct there must be some way of knowing and proving that it is correct--the very meaning of truth implies the possibility of checking or **verification**.

This checking must be **exhaustive**: the truth of a general proposition may be disproved by a single exceptional case.

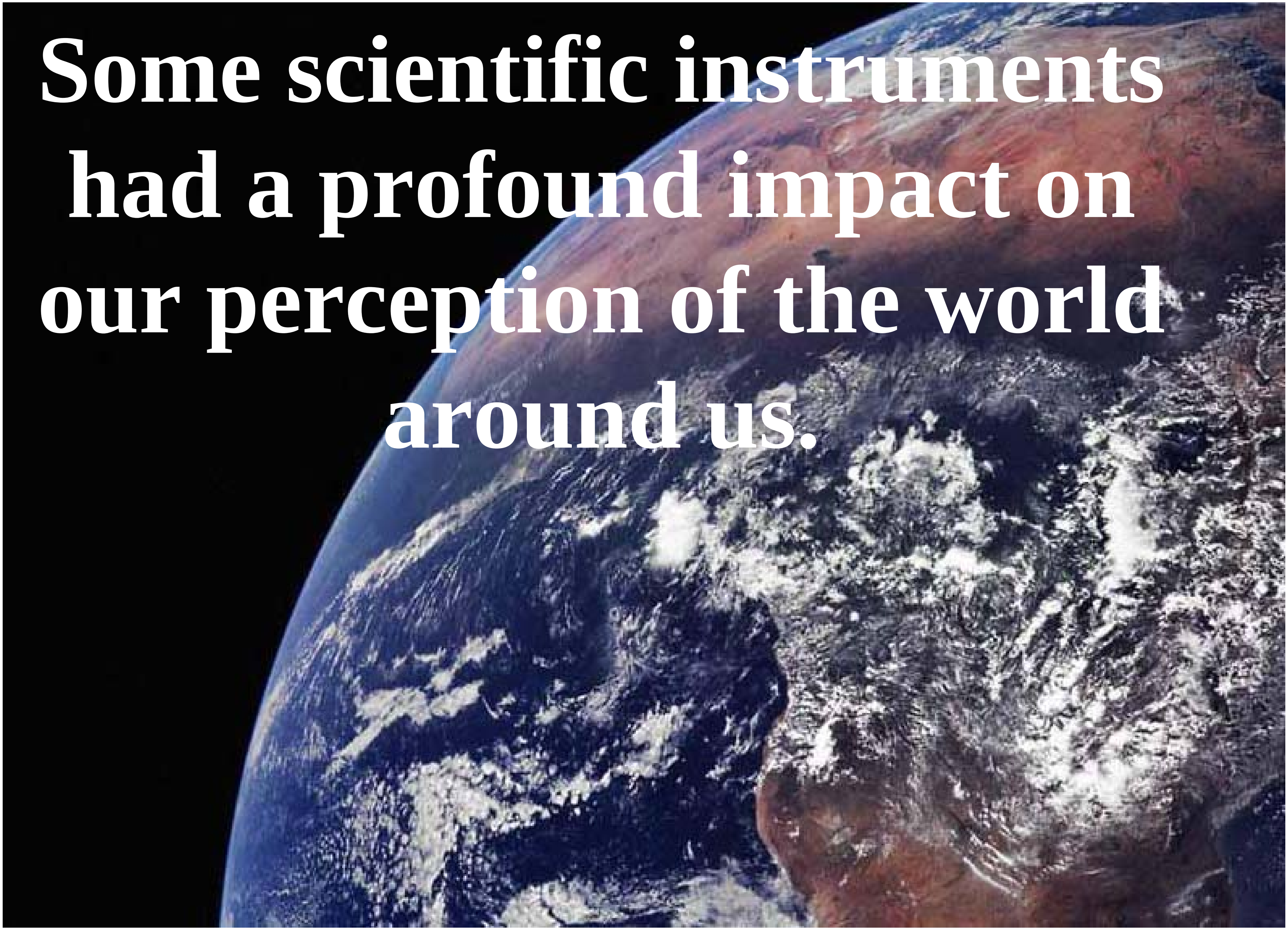
The Scientific Method

It is not sufficient to **trust** the word of his neighbor. Hence the scientist is the enemy of all authoritarianism. Furthermore, he finds that he often makes mistakes himself and he must learn how to guard against them. He cannot permit himself any preconception as to what sort of results he will get, nor must he allow himself to be influenced by wishful thinking or any personal bias.

Scientific instruments and uniform standards of measurement allow us to establish objectivity:

Everyone repeating an experiment under identical conditions should arrive at the same results.

Often, truth is fuzzy and uncertain. It is scientific practice to state degrees of uncertainty, e.g. by using statistical methods.


Some scientific instruments had a profound impact on our perception of the world around us.

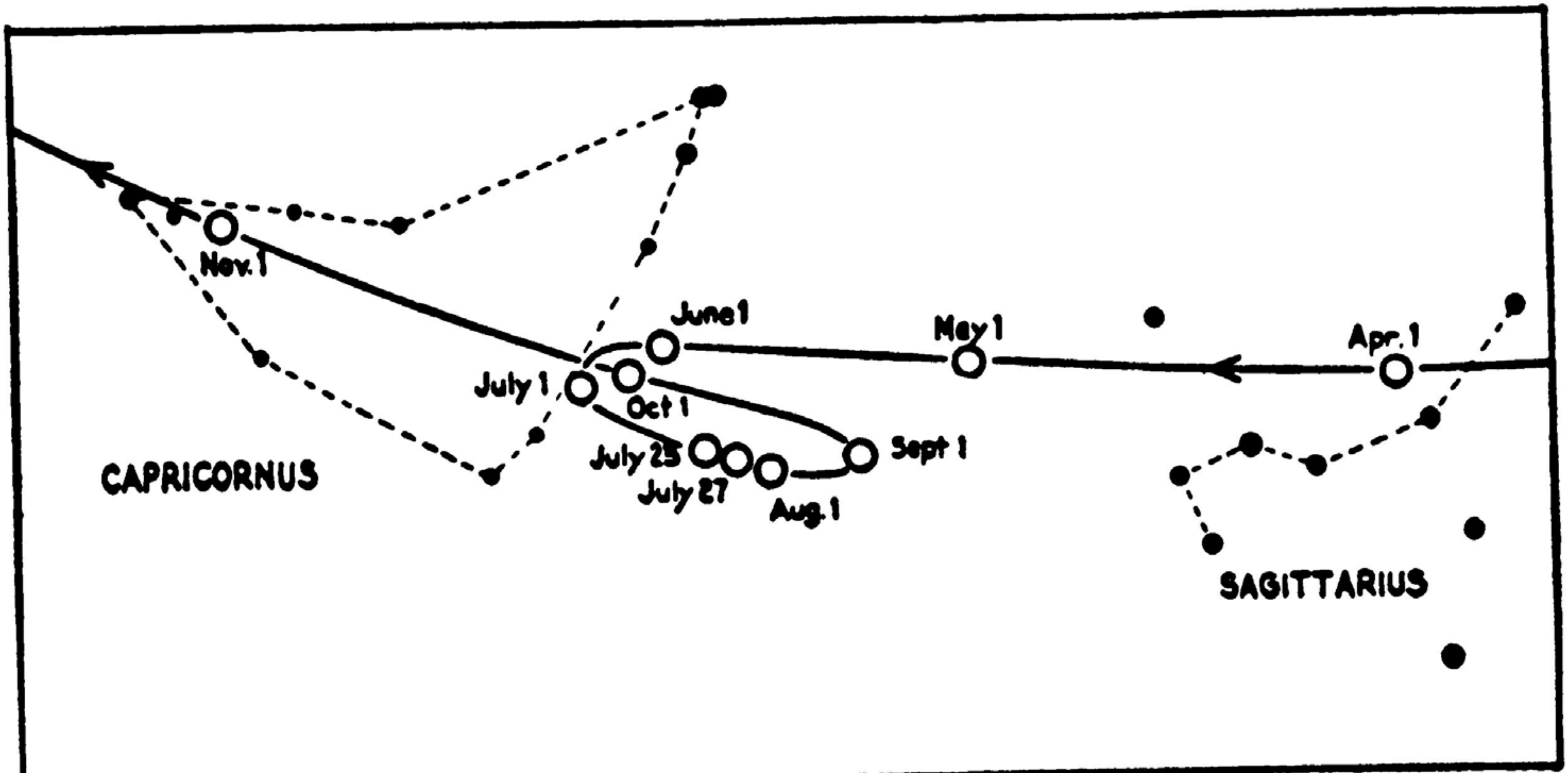
The Telescope

The telescope was seminal for the Scientific Revolution of the seventeenth century. It revealed hitherto unsuspected phenomena in the heavens and had a profound influence on the controversy between followers of the Ptolemaic astronomy and cosmology and those who favored the heliocentric system of Copernicus. It was the first extension of one of man's senses, and demonstrated that ordinary observers could see things that the great Aristotle had not dreamed of.

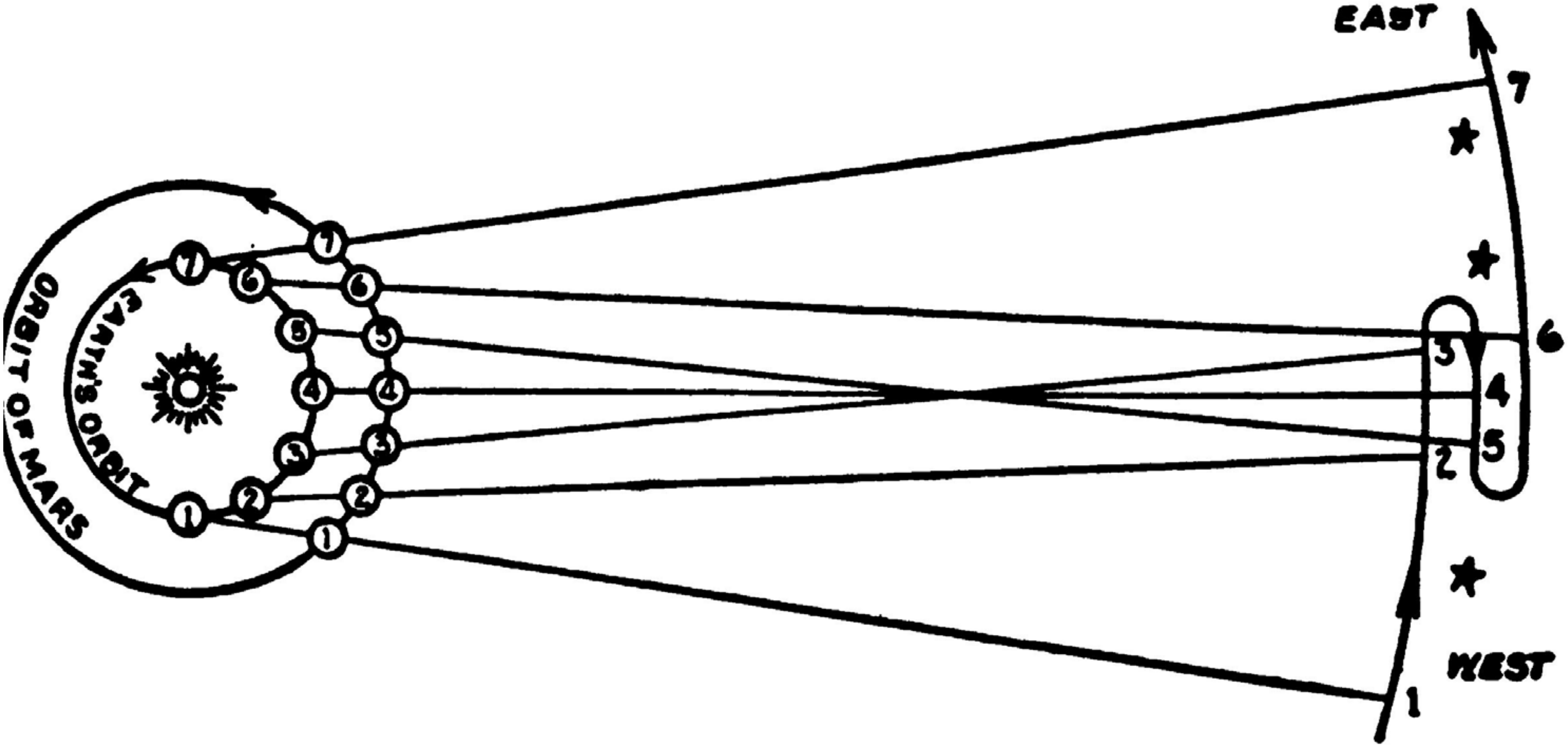
The telescope was unveiled in the Netherlands. In October 1608, the States General (the government) in The Hague discussed the patent applications on a device for "seeing faraway things as though nearby."

The Telescope

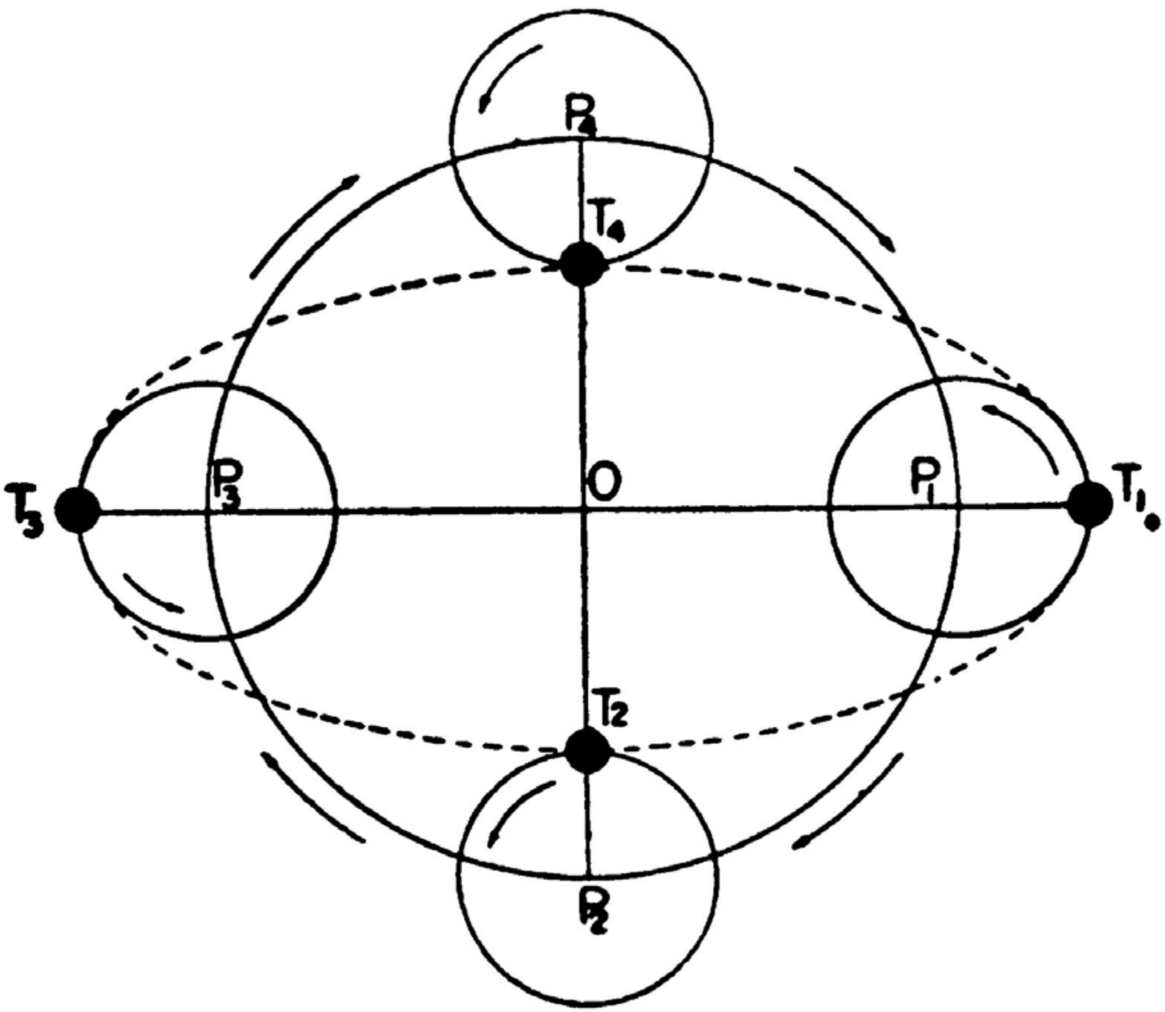
The telescope therefore helped shift authority in the observation of nature from **men** to **instruments**. In short, it was the prototype of modern scientific instruments. But the telescope was not the invention of scientists; rather, it was the product of craftsmen. For that reason, much of its origin is inaccessible to us since craftsmen were by and large illiterate and therefore historically often invisible.



The apparent movement of planet Mars in 1939, as seen from earth.



Heliocentric (Copernican) Interpretation



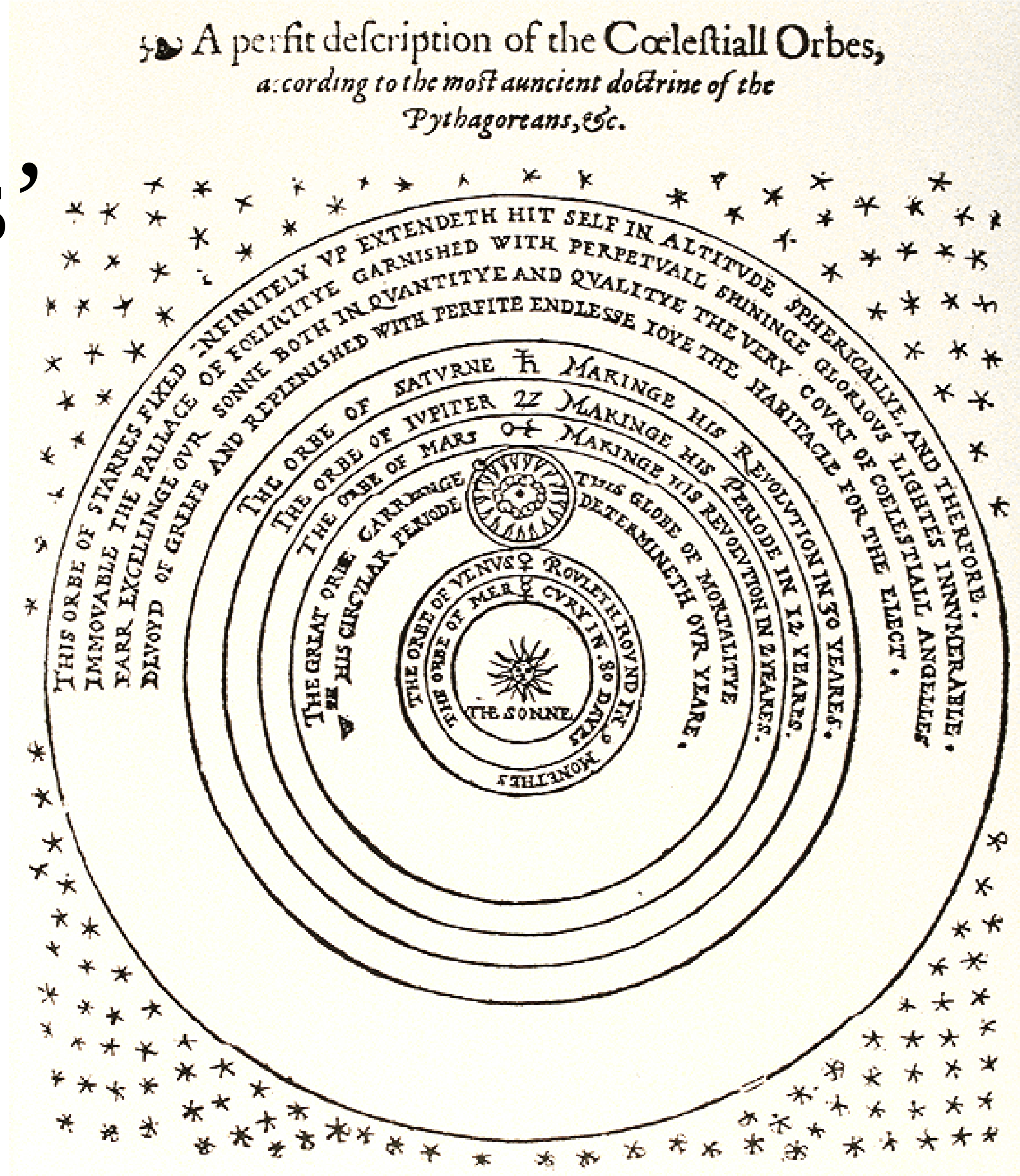
The equivalence of the epicycle motion of the sun with an elliptical path. (Reproduced by permission of the publisher from M. Cohen & I. E. Drabkin, "A Source Book in Greek Science," copyright 1948, McGraw-Hill Book Co., Inc.)

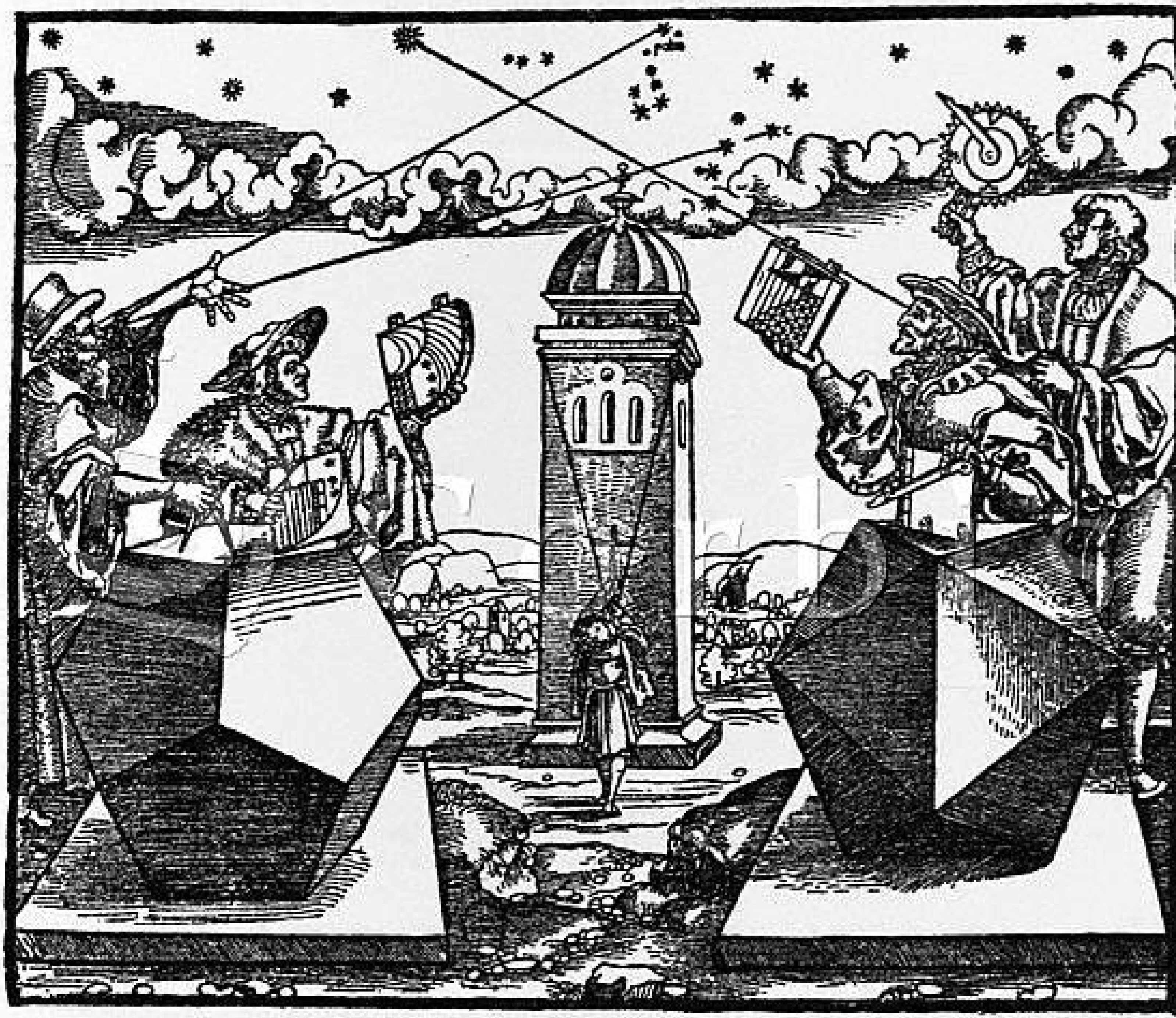
Contrast Copernicus with the Aristotelian (Ptolemaic) Cosmos

Schema huius præmissæ diuisionis Sphærarum.

The **Flat Earth**
is surrounded by seven spheres

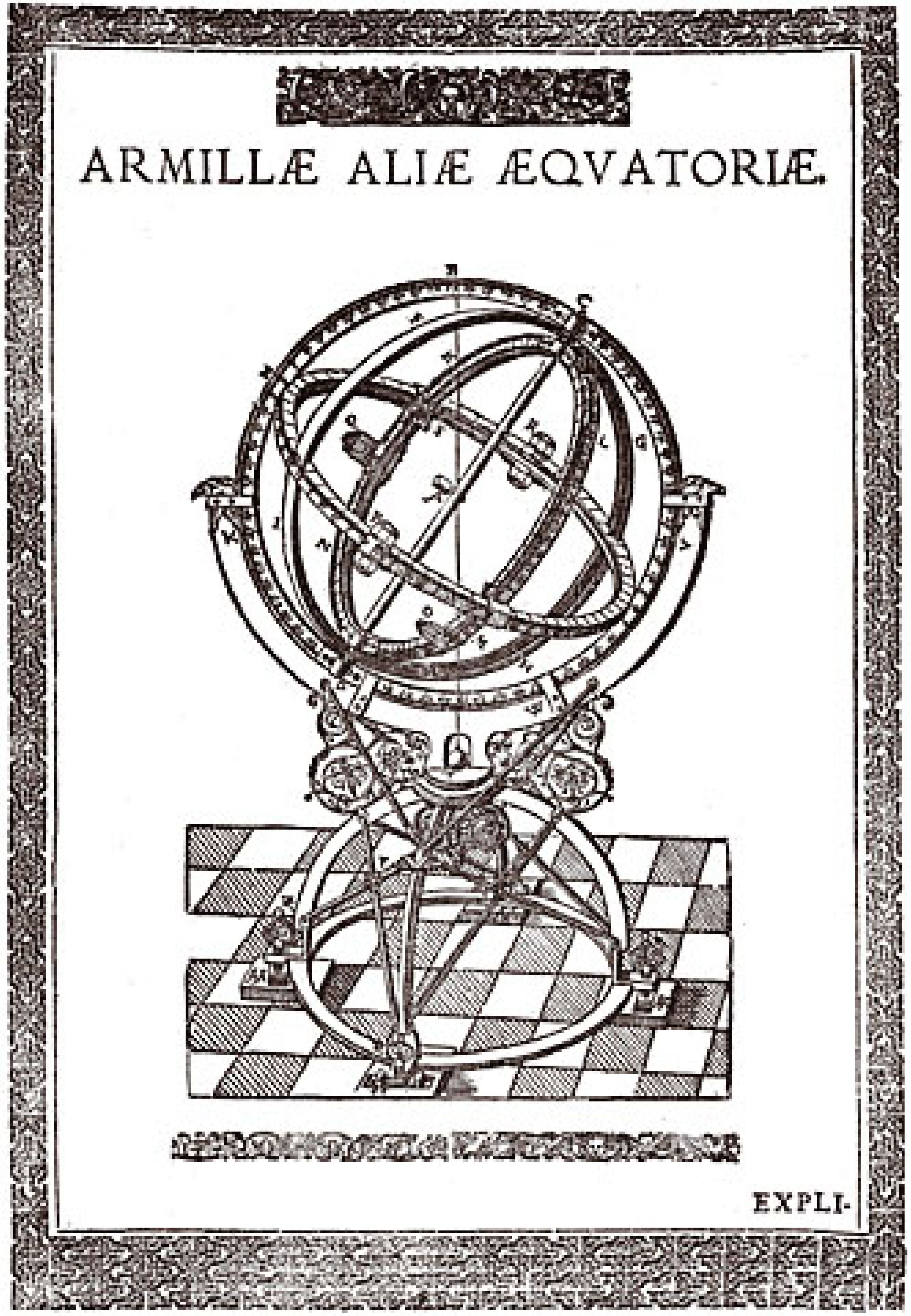
Copernicus' Universe





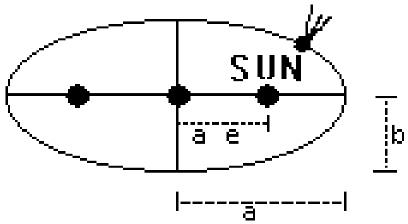
Tycho Brahe:

An equatorial armillary instrument from Tycho's observatory as illustrated in his Astronomiæ instauratæ mechanica (Wandesburg,1598)



An imagined scene in the life of the sixteenth-century Danish astronomer Tycho Brahe (1546-1601). painted in 1855

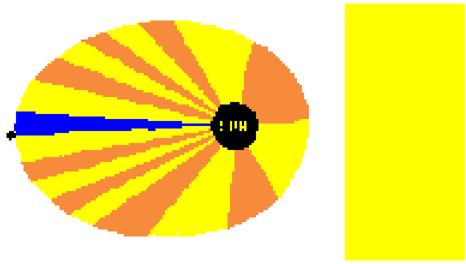
Kepler's LAW 1: The orbit of a planet/comet about the Sun is an ellipse with the Sun's center of mass at one focus



This is the equation for an ellipse:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

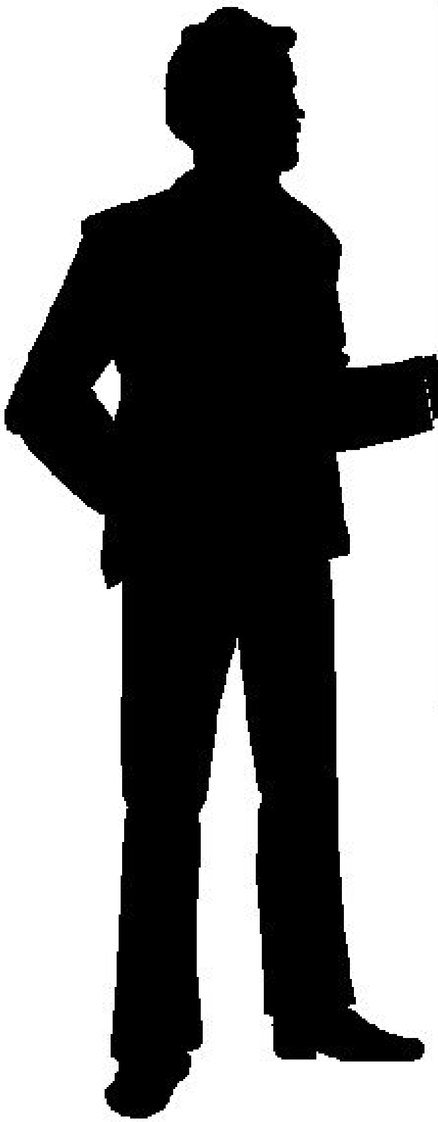
LAW 2: A line joining a planet/comet and the Sun sweeps out equal areas in equal intervals of time



Johannes Kepler

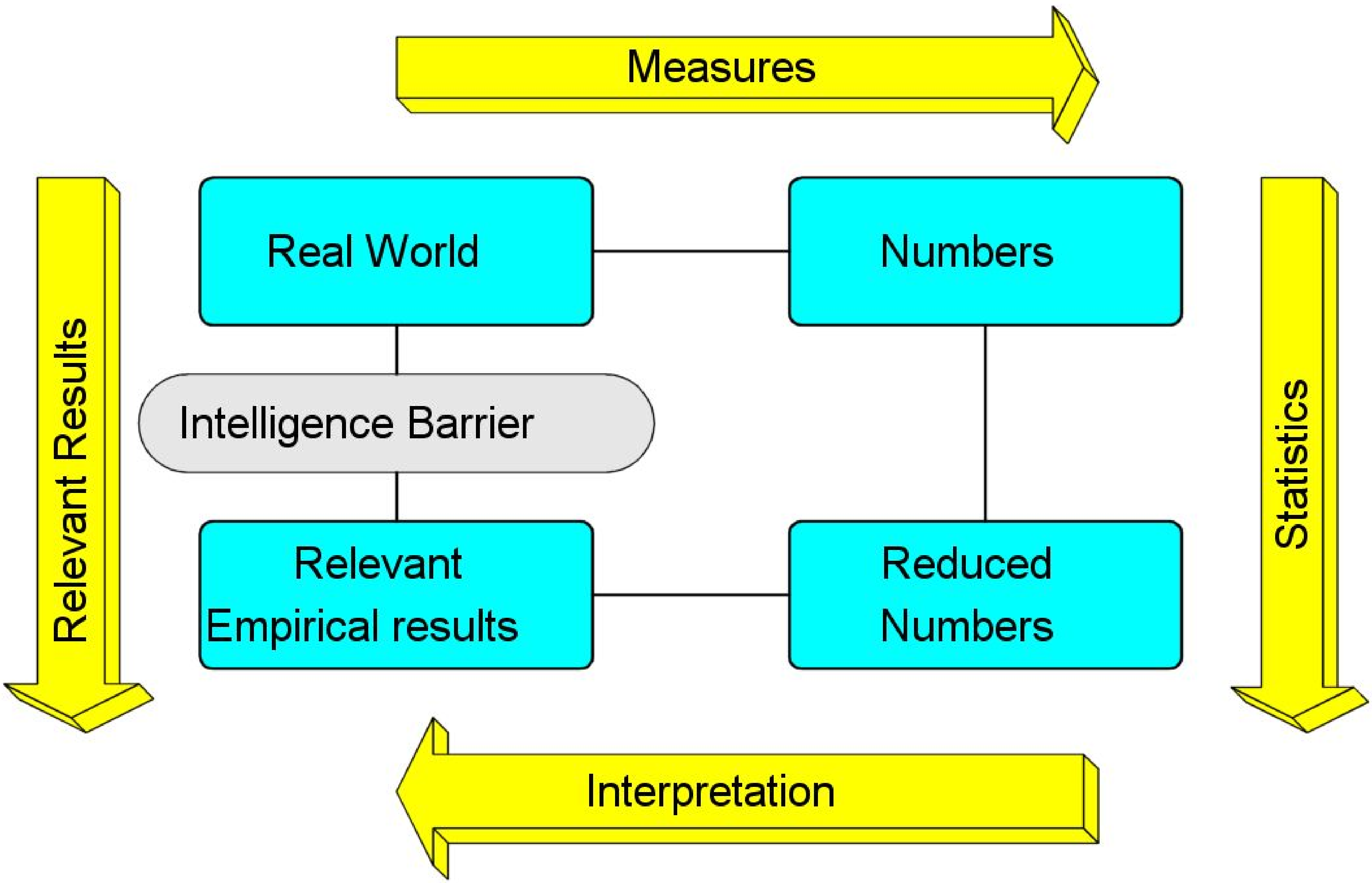
1572-1630

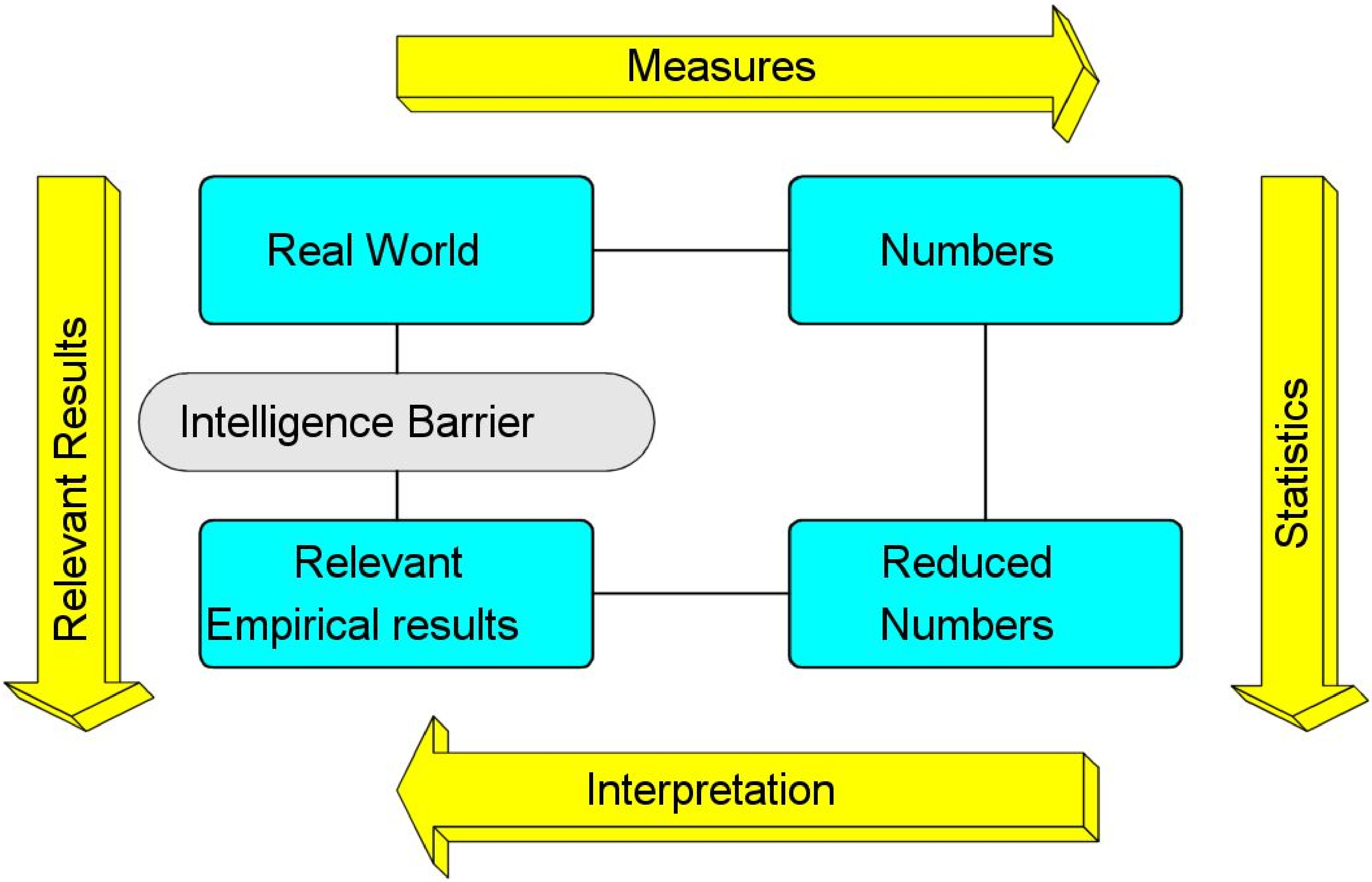
Measurement Theory



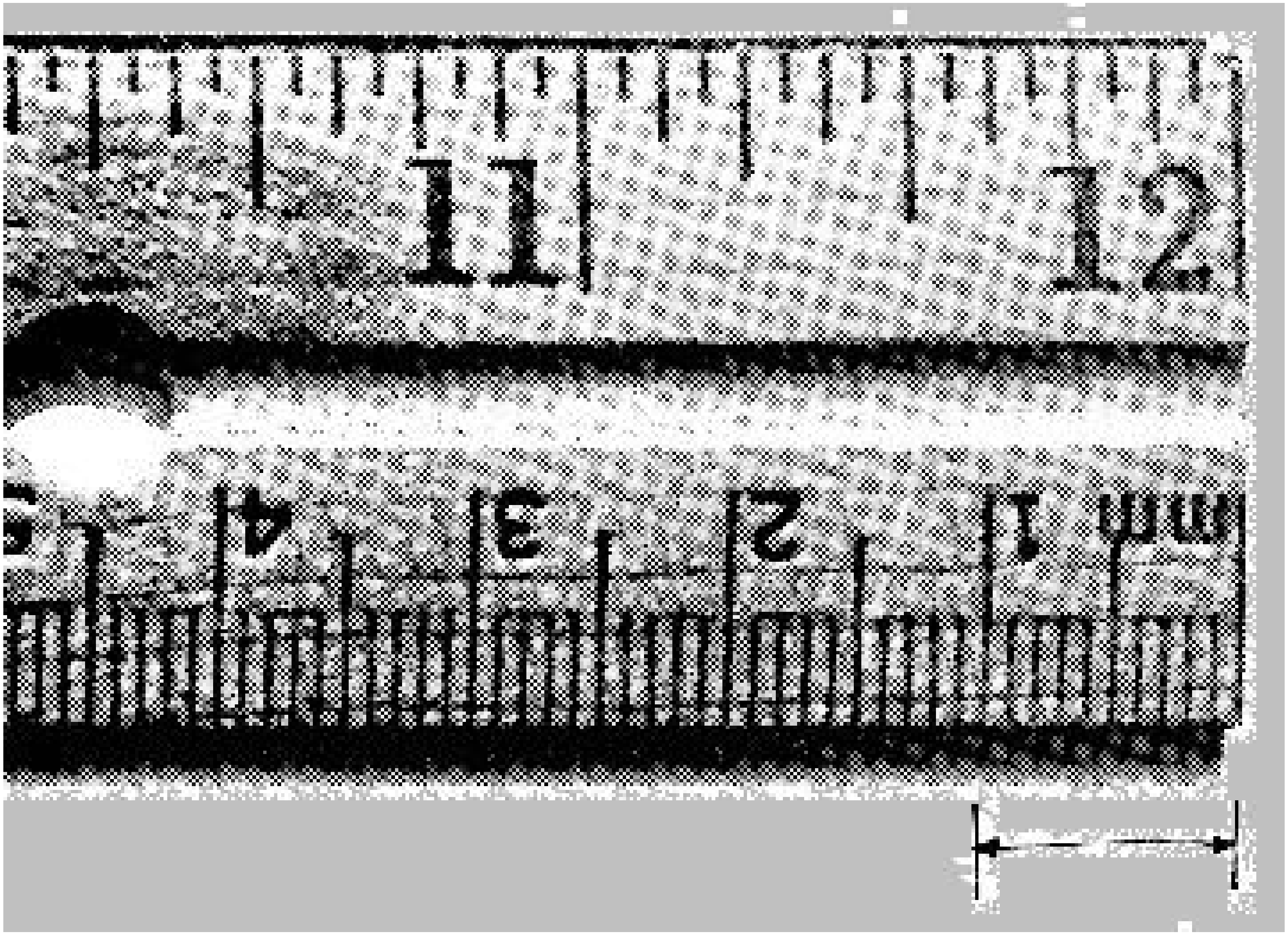
What is the empirical Interpretation of the Numbers?

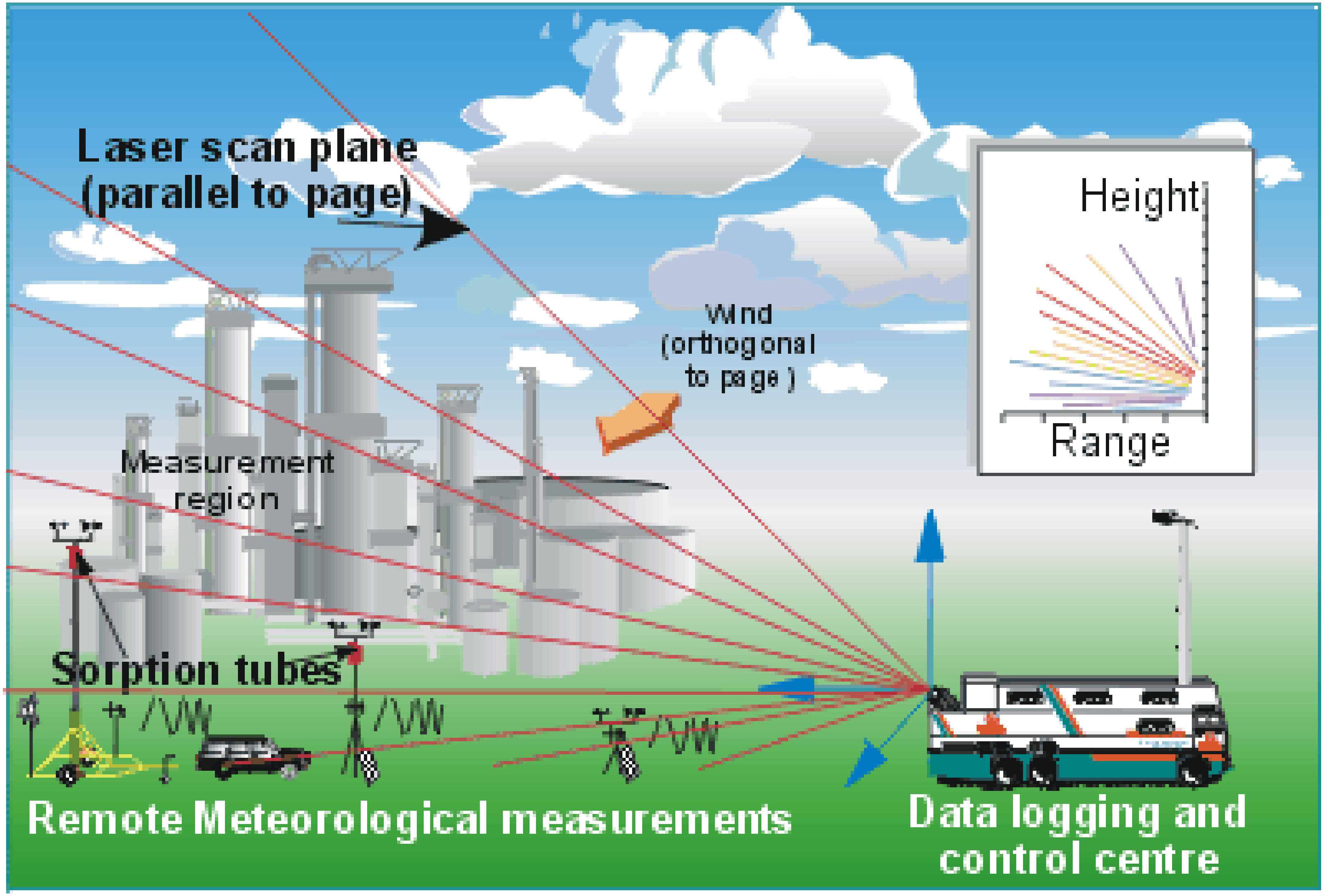
Measurement Theory



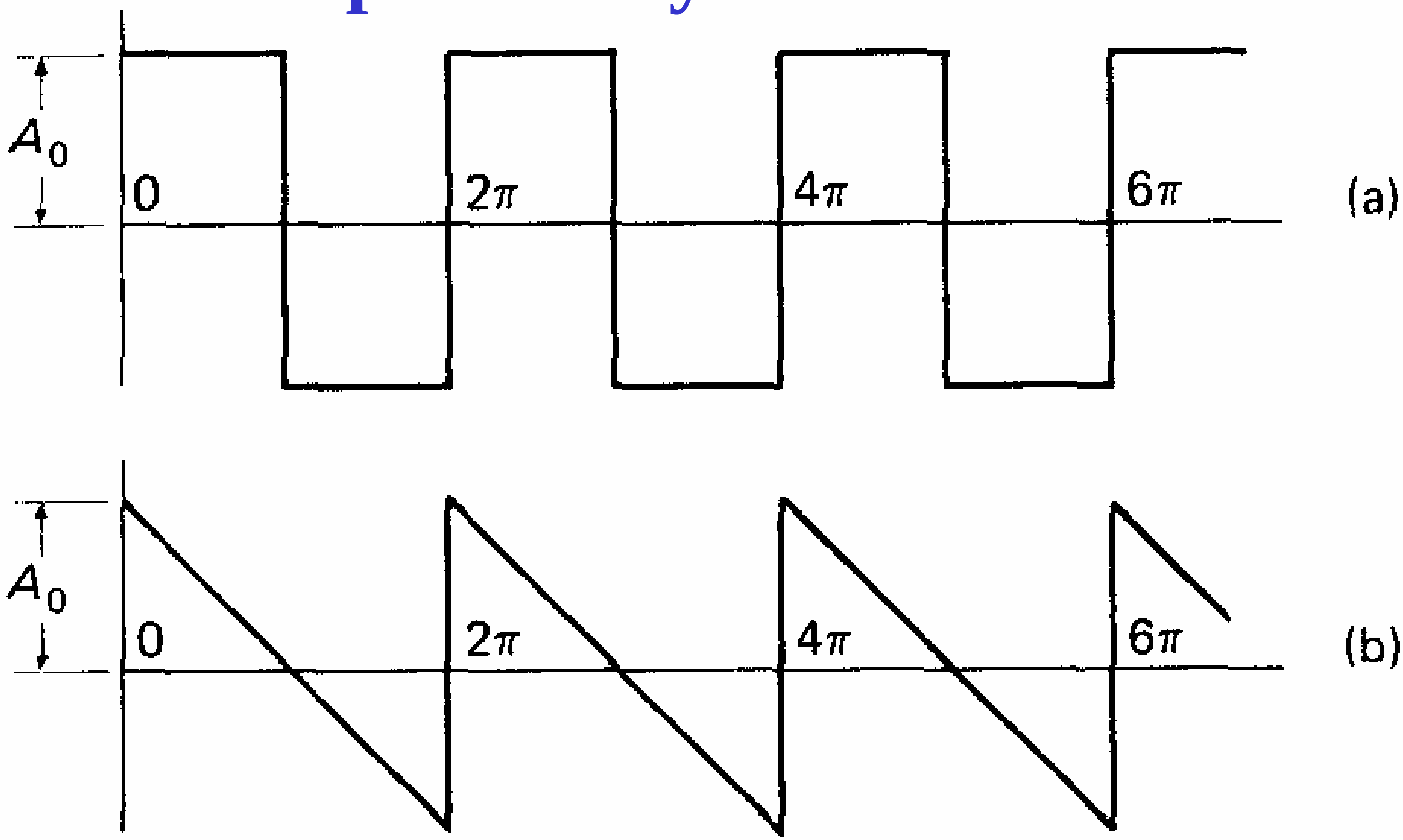


In complex situations, the human brain is not able to produce directly relevant empirical results.


11
12

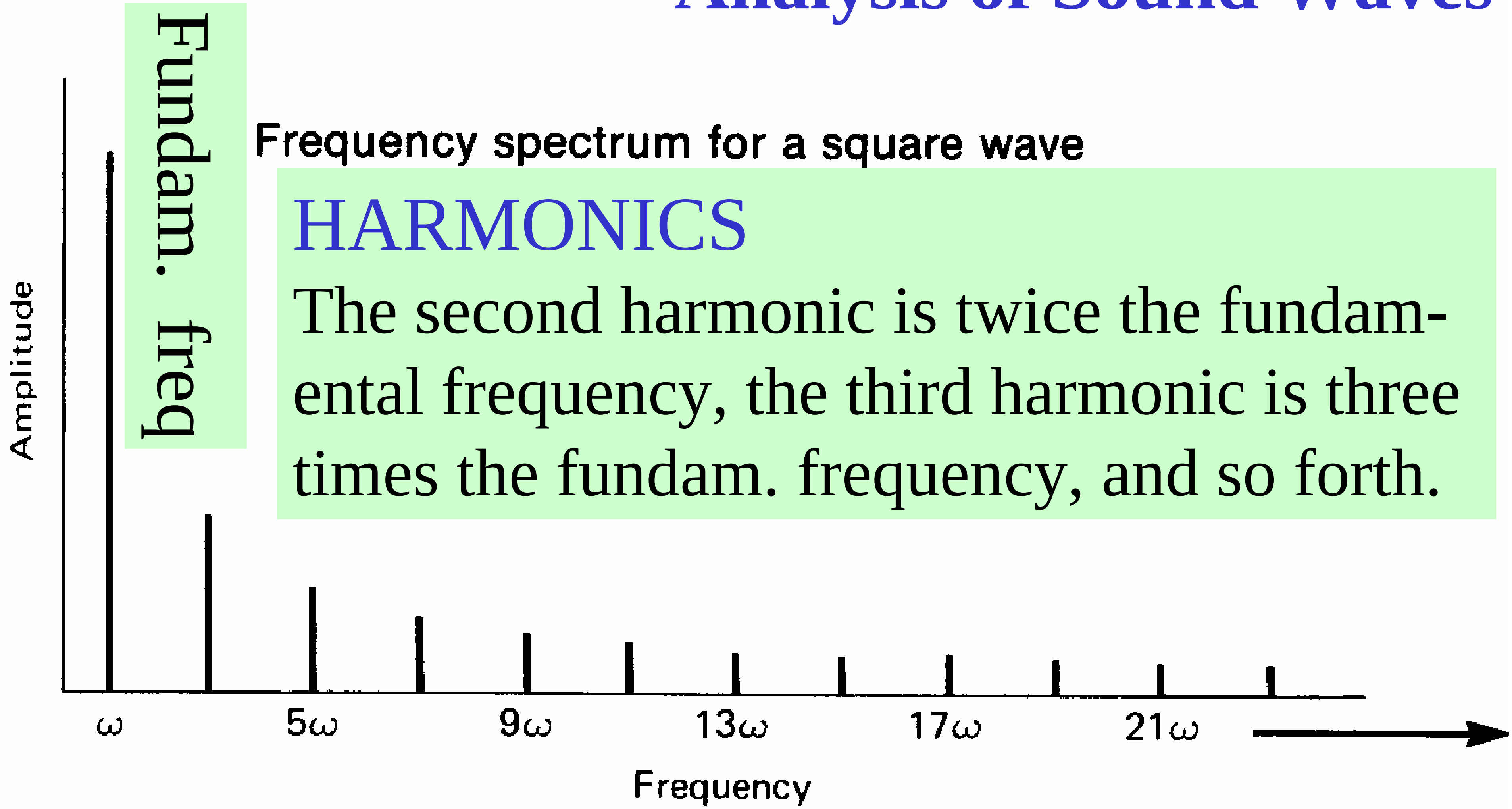

Laser scan plane
(parallel to page)
Wind
(orthogonal
to page)
Height
Range
Measurement
region
Sorption tubes
Remote Meteorological measurements
Data logging and
control centre

An Example: Analysis of Sound Waves



Time domain signals: **Square Wave and triangular wave.**

Analysis of Sound Waves



HARMONICS

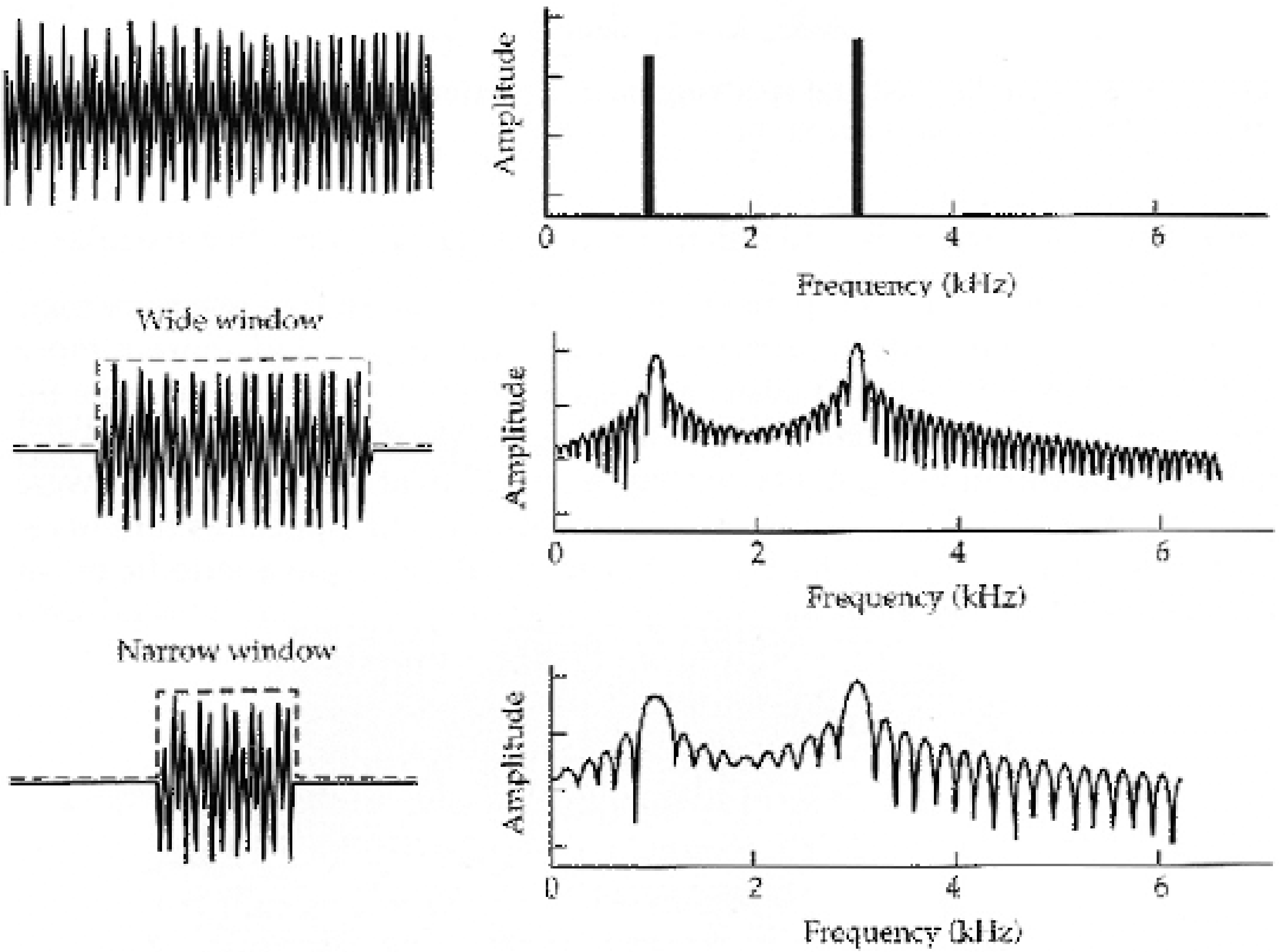
The second harmonic is twice the fundamental frequency, the third harmonic is three times the fundam. frequency, and so forth.

Time domain signal analysis:

Spectrum of Square Wave

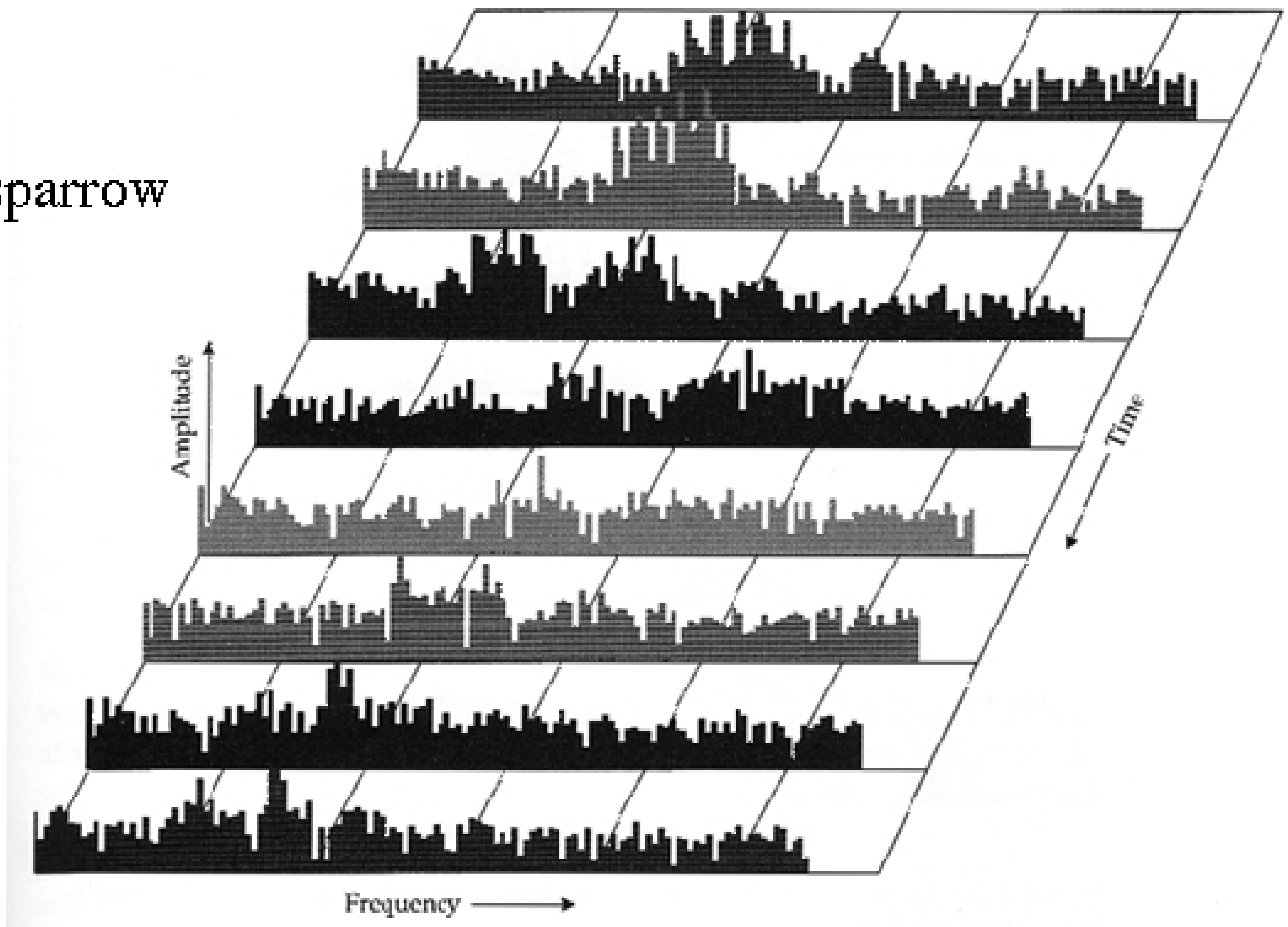
An Example: Analysis of Sound Waves

Finite sounds and Fourier 'lobes'

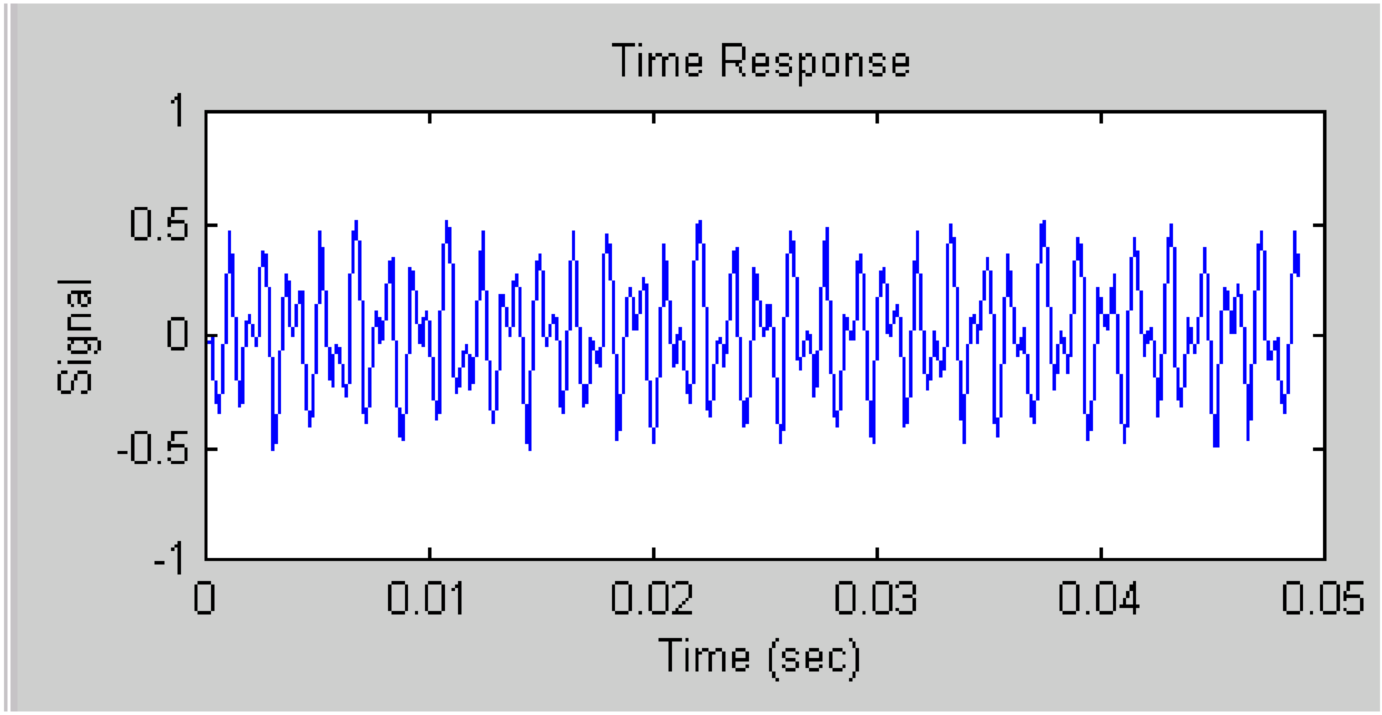


Sound spectrum "waterfall"

Song sparrow

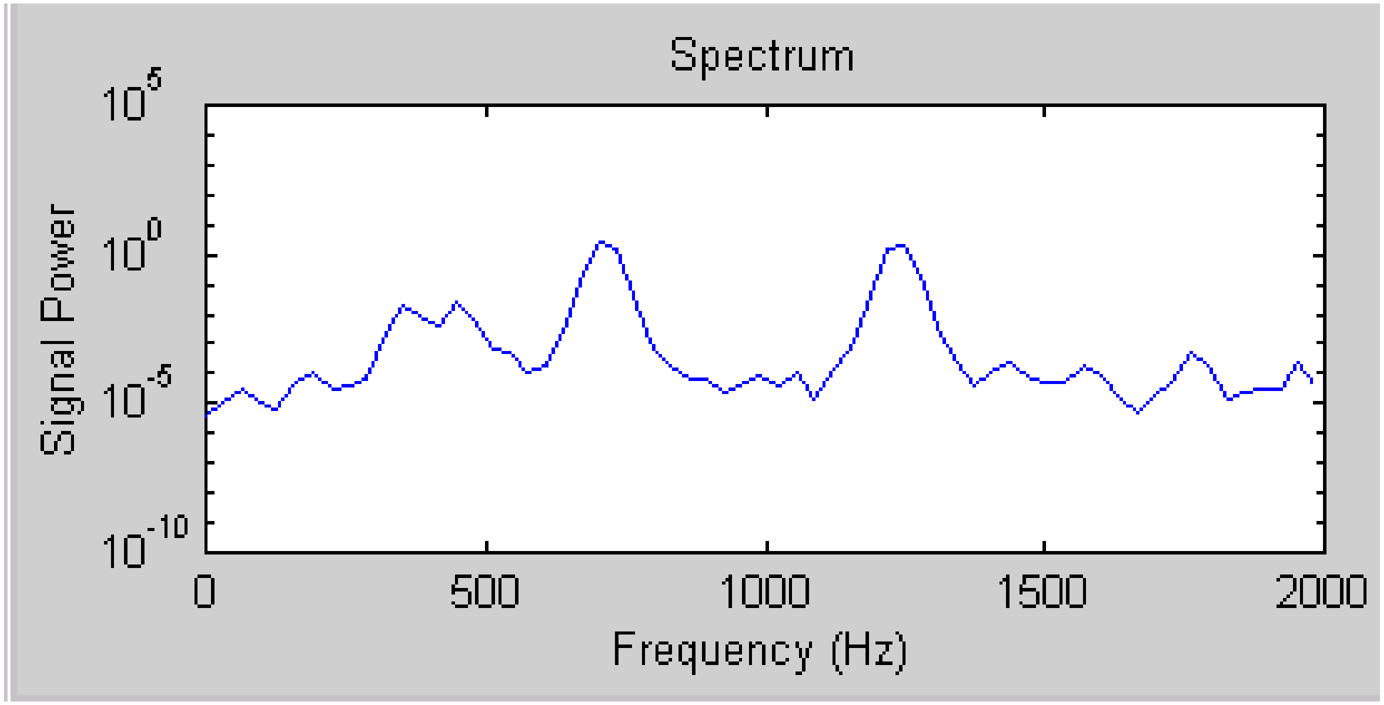


A
Sound
Wave



and
its

Spectrum



Question:

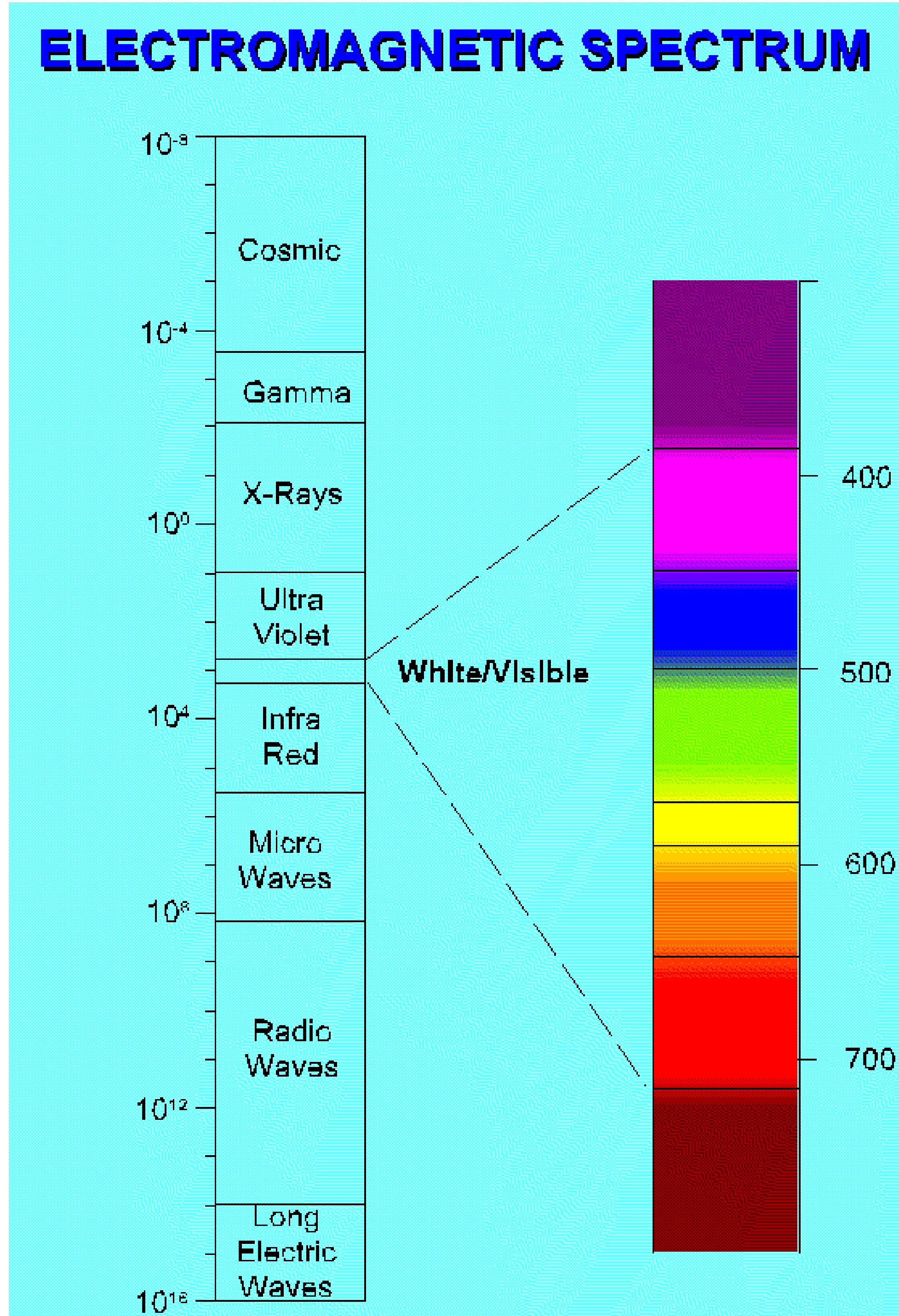
By which means do we recognize voices or musical instruments?

Answer:

Our brains perform a real time spectral analysis of the incoming sound signal. The spectrum, not the signal itself, informs us about the source.

Question:

How do we recognize color?



5.2 Significant Digits

See Fig. 5.1 in Book!

How do you decide?

Example: Your Voltmeter displays:
5.67889 Volts.
You know that its accuracy is +/- 1%.
How many digits should you report?

Multiplication or Division:

If the measurement reading (at accuracy +/- 1%) is converted to another unit:
e.g. (2.27m) * (3.048 ft/m)
the result remains just as inaccurate:
2.25 m = 6.91896 ft.

Rounding (p.187):

Increase the last digit retained by one if the first figure dropped is 5 or higher.

Analog and Digital

Analog: The signal varies continuously. Examples: Most speedometers in cars Pressure gages et al.

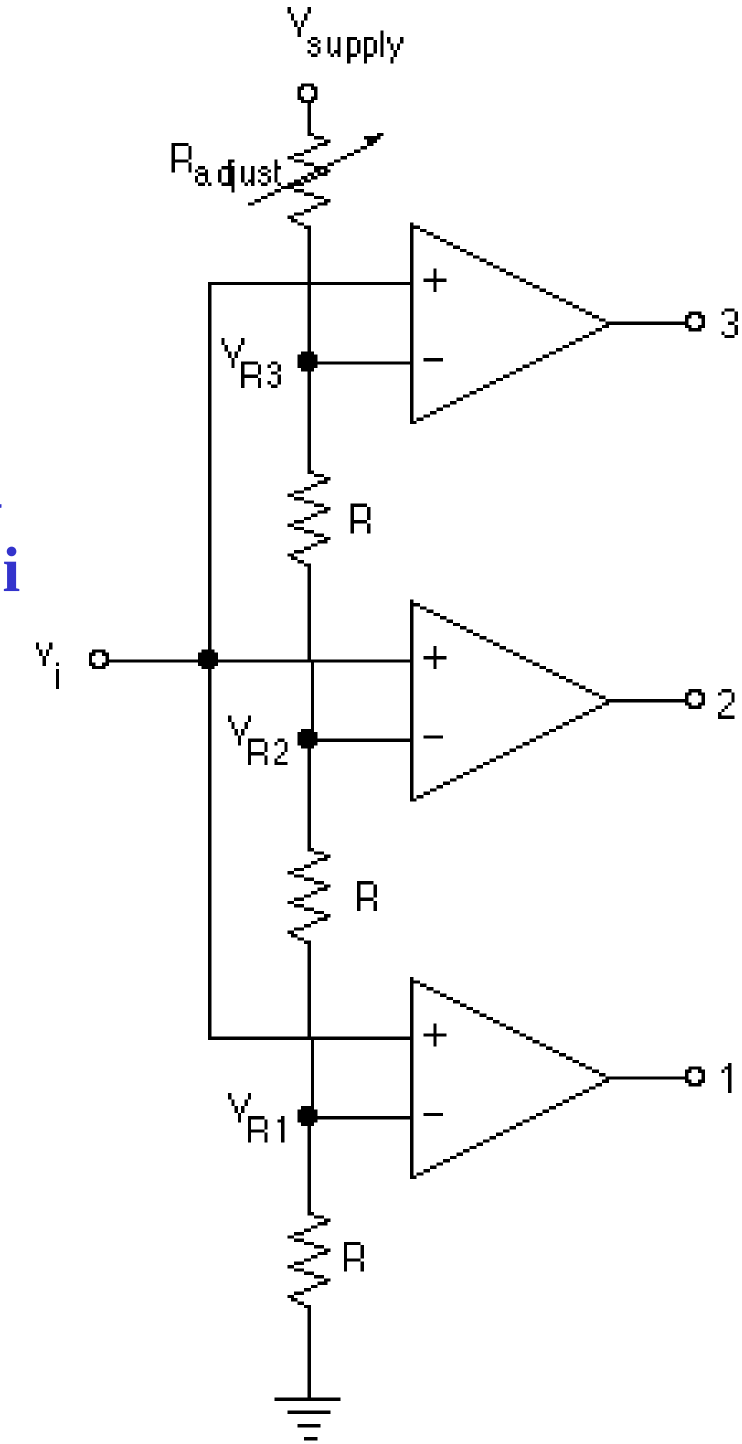
Characteristics:
The signal changes **continuously.**
Theoretically, you should be able to read **infinitesimally small** changes.

Digital

The signal is expressed as a **multiple** of some fundamental smallest unit.
A digital instrument cannot detect increments smaller than the smallest unit.

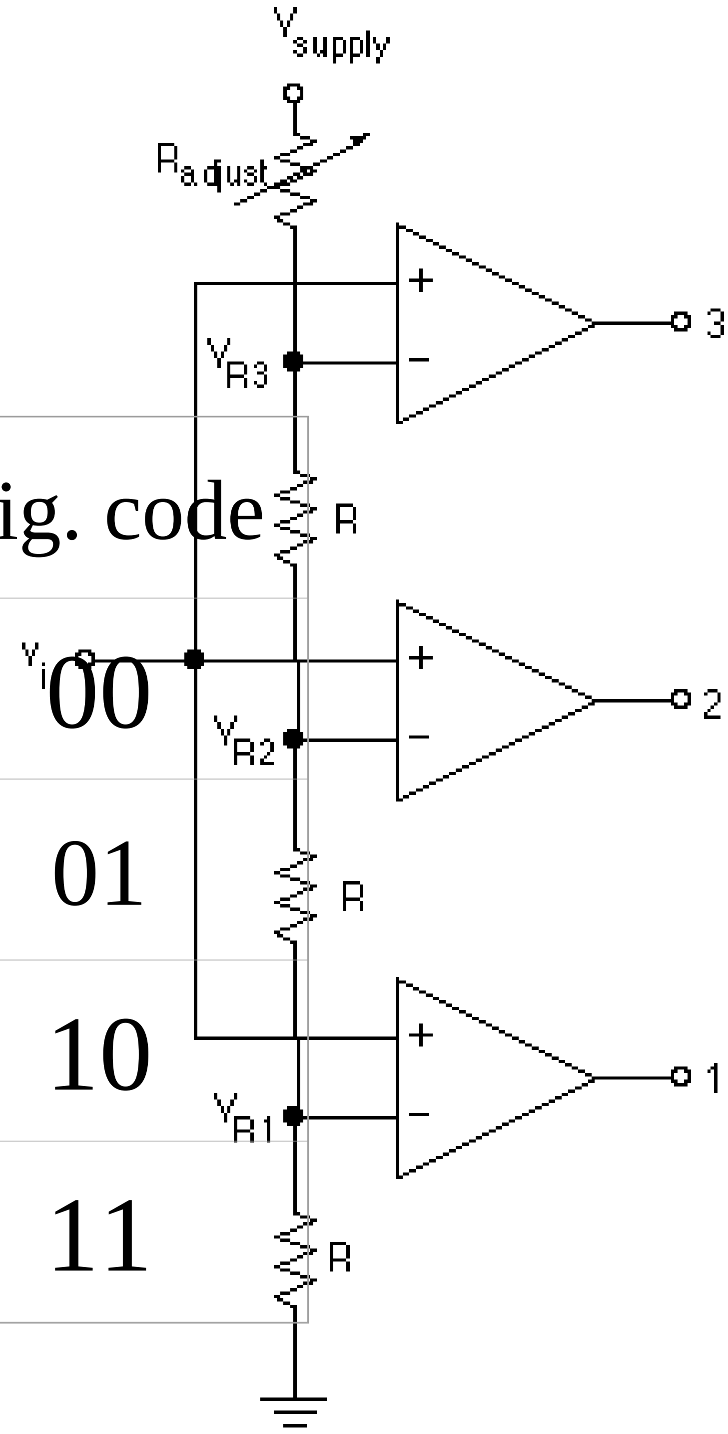
2-bit Electronic A→D Converter

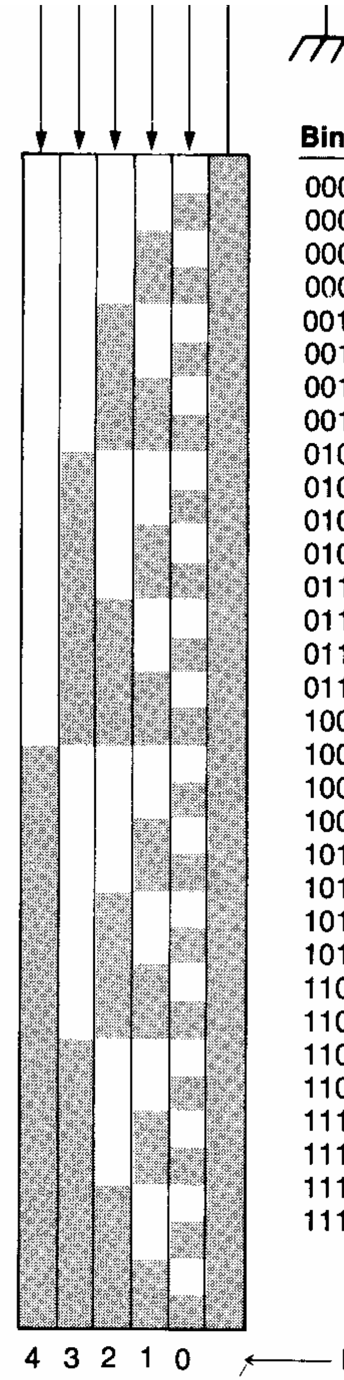
Input Voltage V_i



The supply voltage is divided into Voltages V_{R1}, V_{R2} and V_{R3} .Op. amps 1, 2, and 3 are '0' or '1' depending on the magnitude of V_{in}.

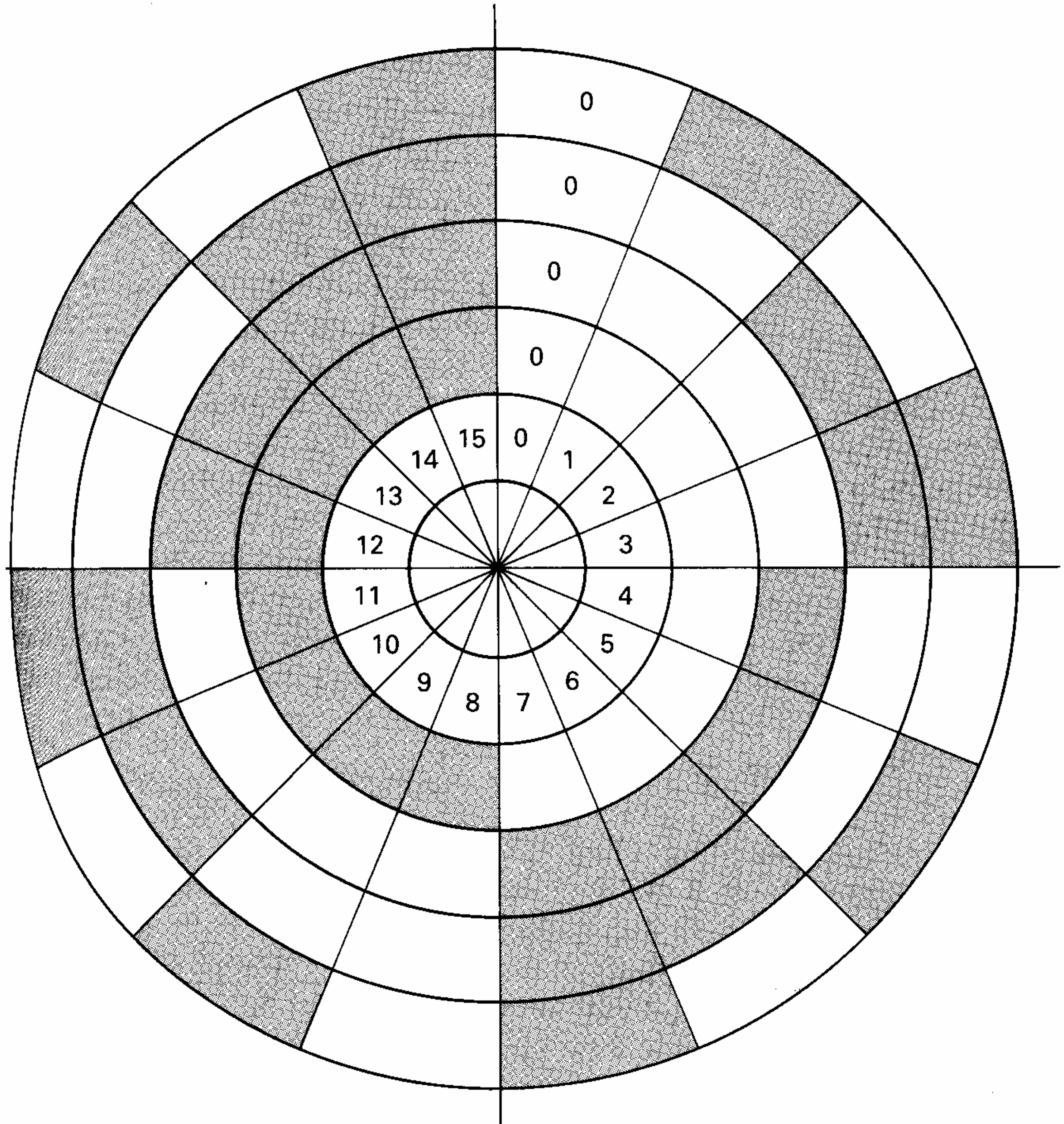
$\mathbf{v_{in}}$	1	2	3	Dig. code
$\mathbf{v_i < V_{R1}}$	low	low	low	00
$V_{R1} < v_i < V_{R2}$	high	low	low	01
$V_{R2} < v_i < V_{R3}$	high	high	low	10
$\mathbf{v_i > V_{R3}}$	high	high	high	11





Binary	Decimal
00000	0
00001	1
00010	2
00011	3
00100	4
00101	5
00110	6
00111	7
01000	8
01001	9
01010	10
01011	11
01100	12
01101	13
01110	14
01111	15
10000	16
10001	17
10010	18
10011	19
10100	20
10101	21
10110	22
10111	23
11000	24
11001	25
11010	26
11011	27
11100	28
11101	29
11110	30
11111	31

5-Bit Distance Encode



4-Bit Angle Encoder

5.3 Accuracy and Precision

Def.: Accuracy = Maximum error =

|Reading – TrueValue|

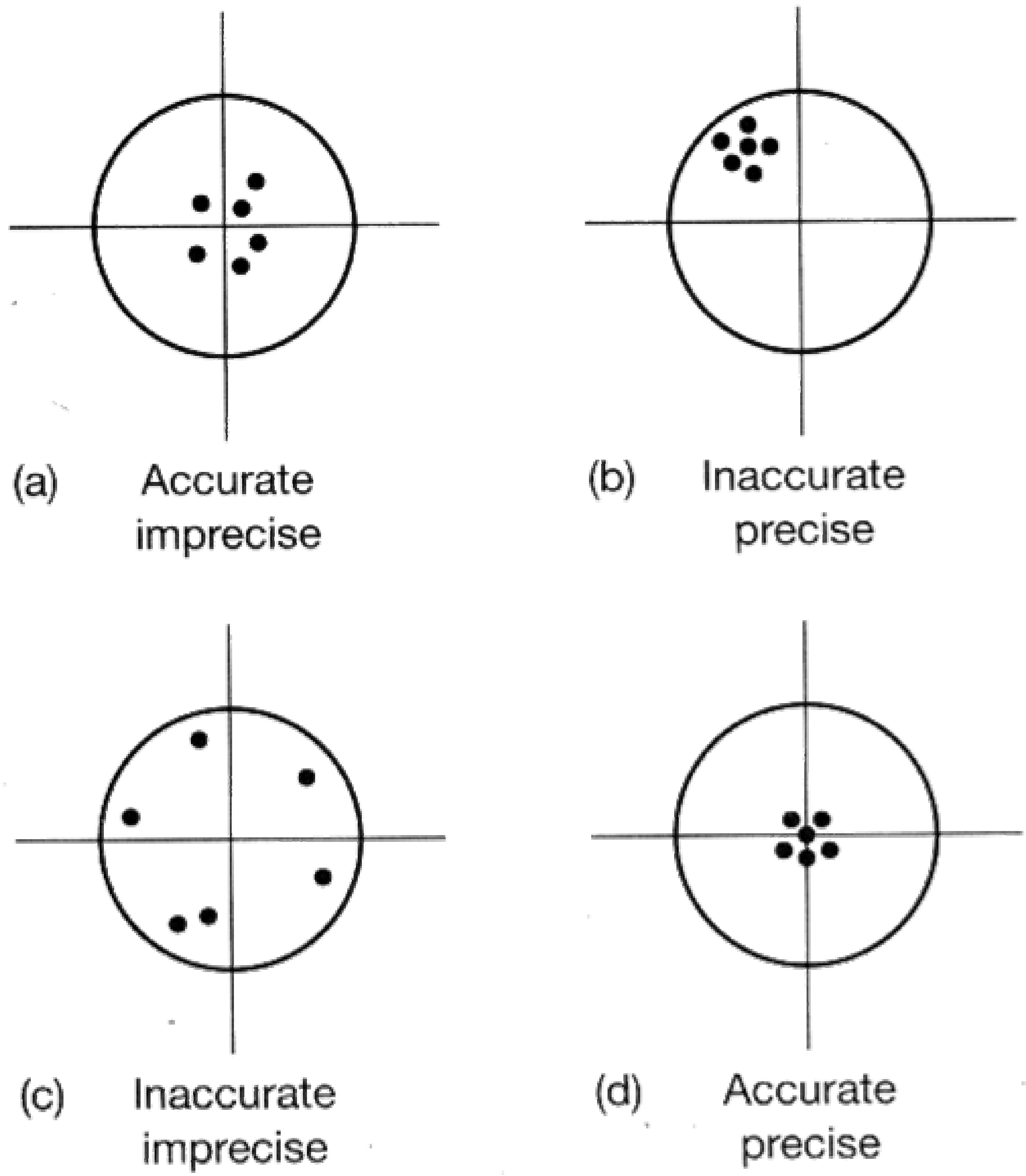
Accuracy is the closeness of an observation to its true value.

Def.: Precision = Ability to reproduce a reading with a given accuracy.

Or:

Precision is the similarity between repeat readings.

Accuracy
Vs.
Precision



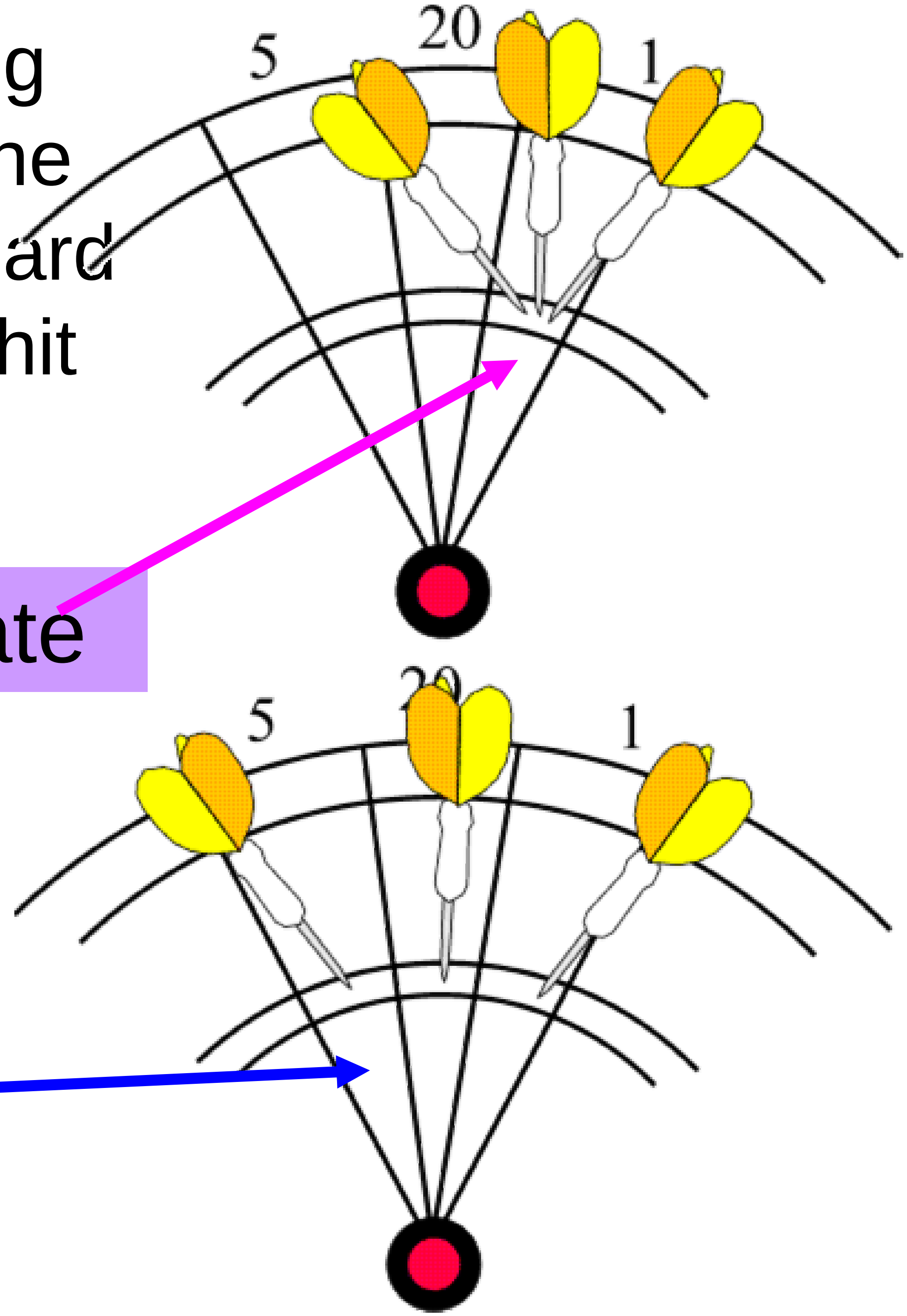
Accuracy (inverse of: *error*)

- agreement with (departure from) "reality"
- usu. expressed as a tolerance
- *bias*: systematic error
  - e.g. miscalibration, flipped axes, etc.
  - consistent: (relatively) easy to correct

Precision

- recorded level-of-detail
  - # decimal places
  - *resolution*: smallest feature recordable
- repeatability

Another way of explaining the difference between the two terms is by a dart board metaphor. The aim is to hit treble 20 three times.

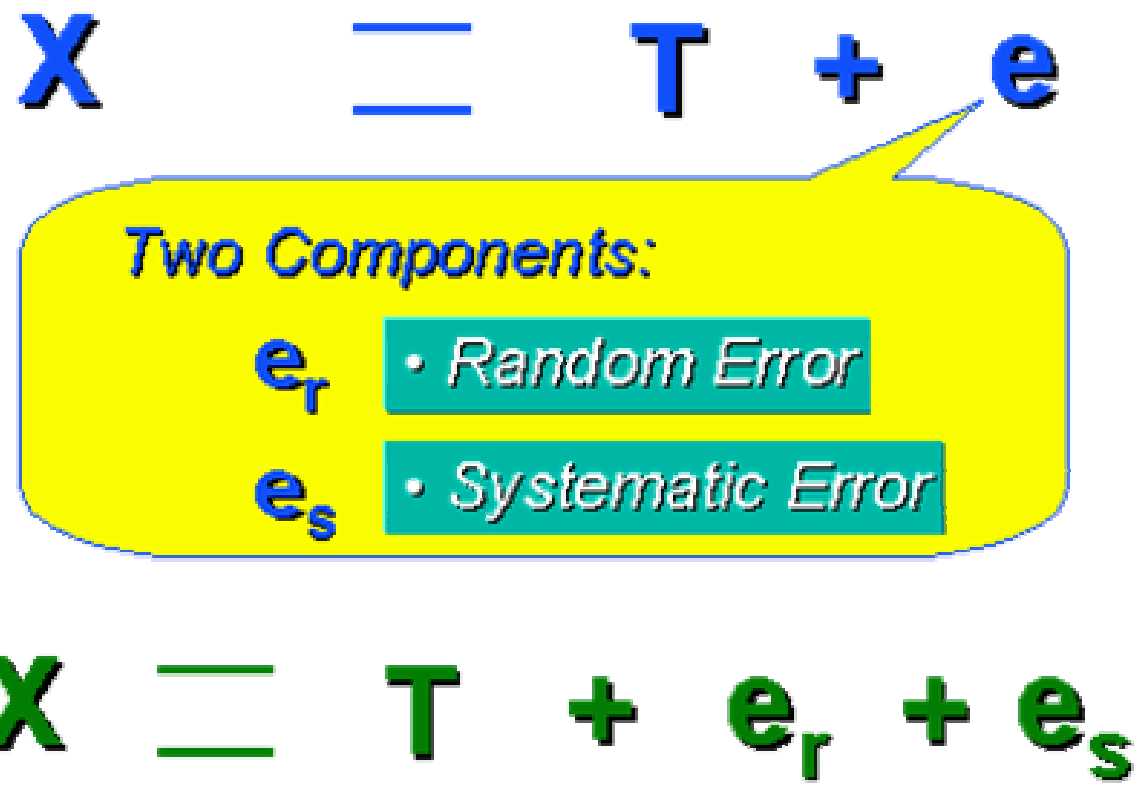


precise but inaccurate

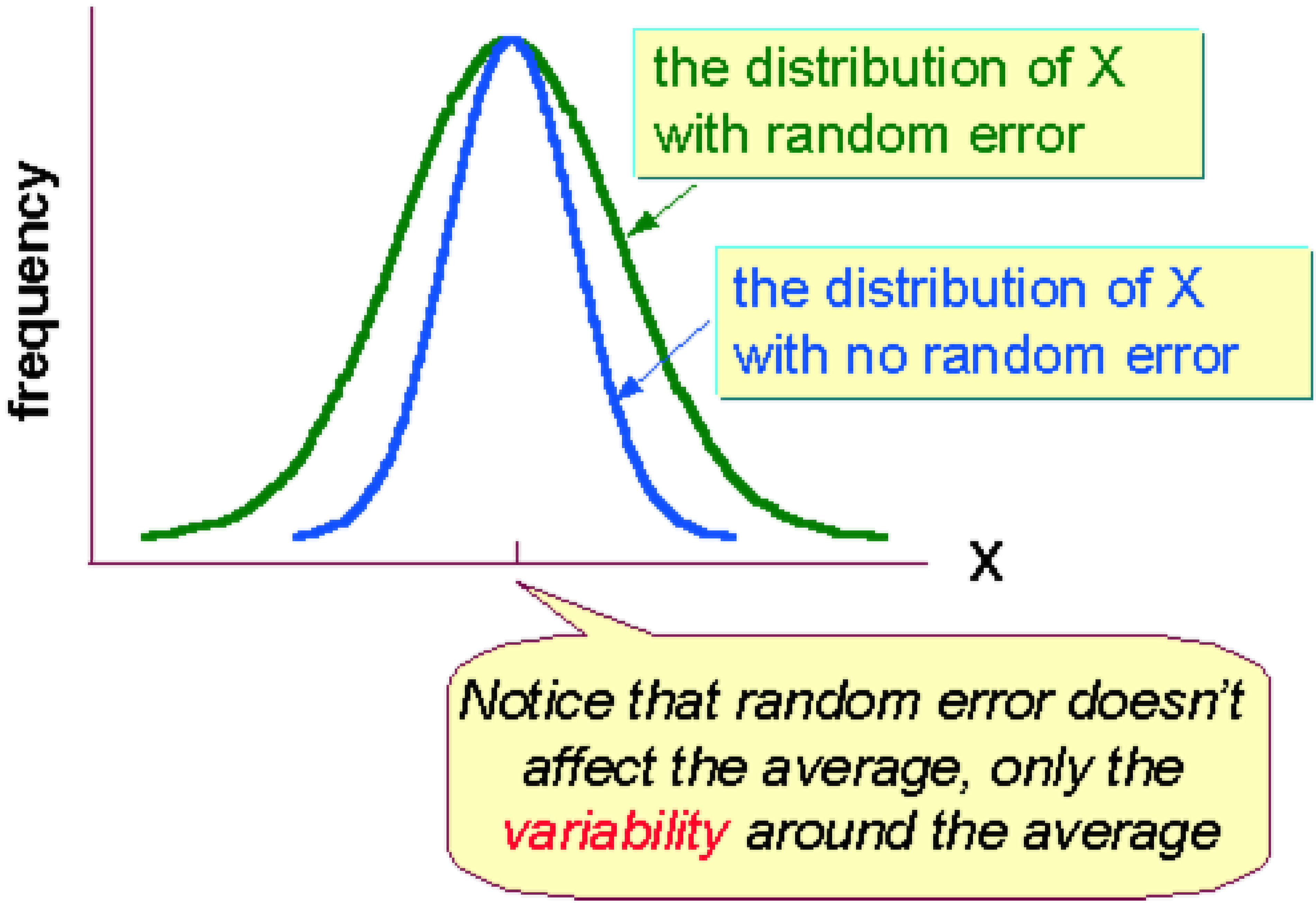
less precise but more accurate

5.4 Errors

An observation can be viewed as **True value + some (random or systematic) error** value.



Random error: uncontrolled factors affect measurement of the variable across the sample. The important property of random error is that it adds variability to the data but does not affect average performance for the group. Because of this, random error is sometimes considered ***noise***.

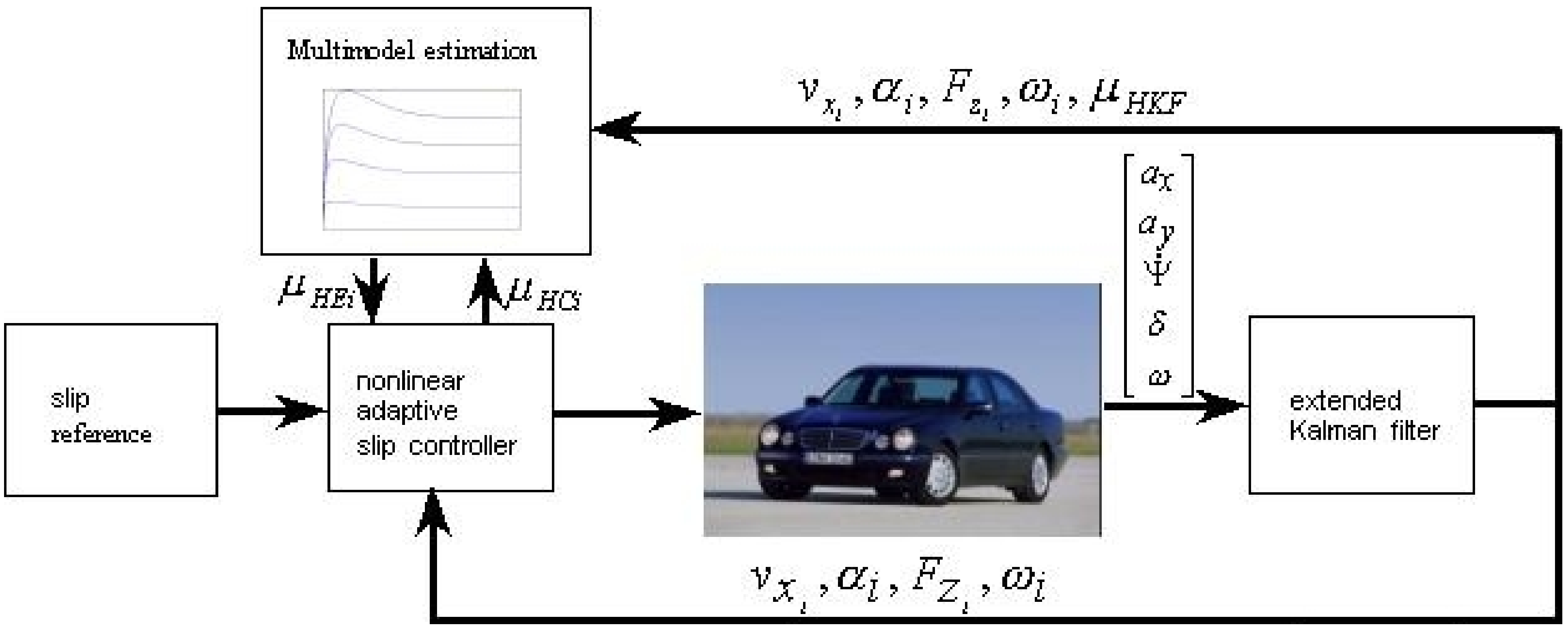

frequency
X
the distribution of X
with random error
the distribution of X
with no random error
Notice that random error doesn't affect the average, only the variability around the average

5.5 Approximations

Strategies for sifting through incomplete information.

- Judging what's relevant
- Minimizing cost and time requirements
- Focusing on Essentials

Read examples in Book!



The ABS brake controller estimates:

- Road Condition
- Vehicle dynamics
- Tire slip rate

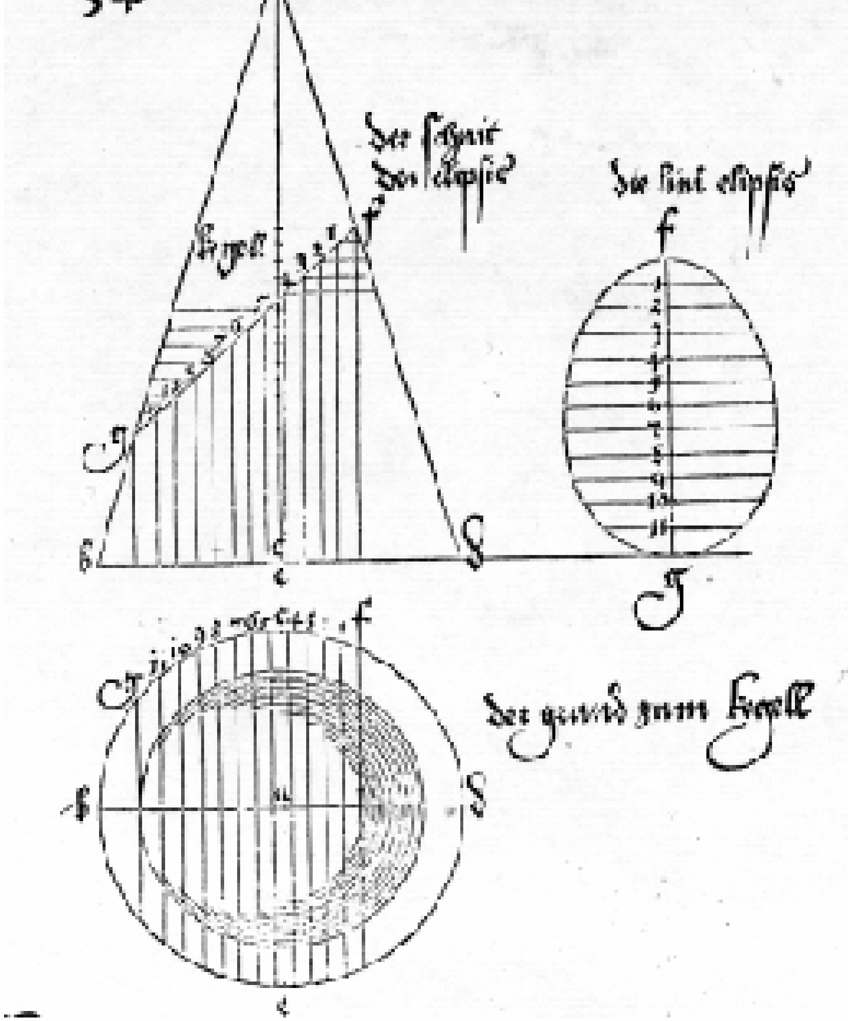
5.5 Approximations

Be careful!
Verify all results for plausibility and safety!

After all, your approximation must be approximately correct!
The ABS brake controller constantly verifies and corrects its estimates.

Measurements and Science

Historical Observations



"Die Elipsis will ich ein eyerlini nennen. Darumb das sie schyer einem ey gleich ist." (A. D., 1525 Unterweysung)

Isaac Newton (1642-1727)

1665 Trinity College, Cambridge: Bachelor's degree in mathematics. He was forced, the same year by the plague to return to his home village.
There (1665-1666) he worked out the fundamentals of all his most important future discoveries in mathematics and physics. He returned to Cambridge in 1667, and two years later took the chair of mathematics.

Isaac Newton (1642-1727)

Newton published one of the most important works in the history of science, the **Philosophiae naturalis principia mathematica (1st edn. 1687)**

Newton's studies provided the basis of **modern optics, infinitesimal calculus, cosmology and mechanics**

Isaac Newton

Francis Bacon (1561-1626)

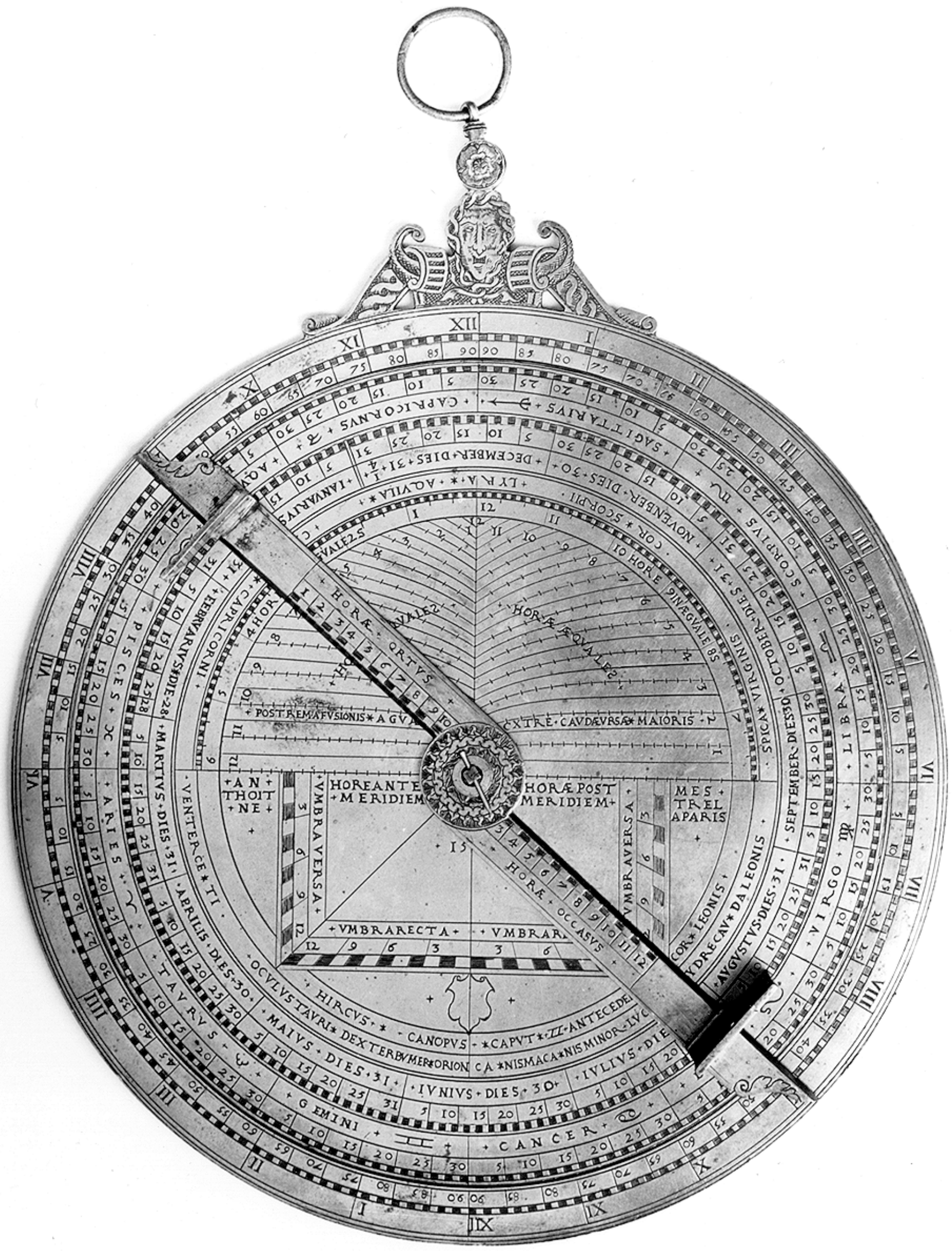
Bacon is often considered the first expounder of the "scientific" method of arriving at Truth--giving the method a legitimacy as an alternative to religious truth.

His approach was empirical--collecting bodies of actual observations or data and then bringing them under the careful study of a community of scholars. He led scholarship away from both the Aristotelian and Platonist schools that had long been prevalent in Europe. He proposed to work from the hard facts and let them suggest their own theoretical order--at the same time barraging such theories with doubts and constant testing to see at what point they might not hold. In this he was laying the foundations of empiricism--which would take a strong hold over the English scholarly mind.

Bacon was a bridge between the traditional religious worldview and the newly arising secularist worldview. He acknowledged the importance of both, proposing that science and theology were two separate enterprises because of two different systems of proof required by each: direct observation and divine revelation.

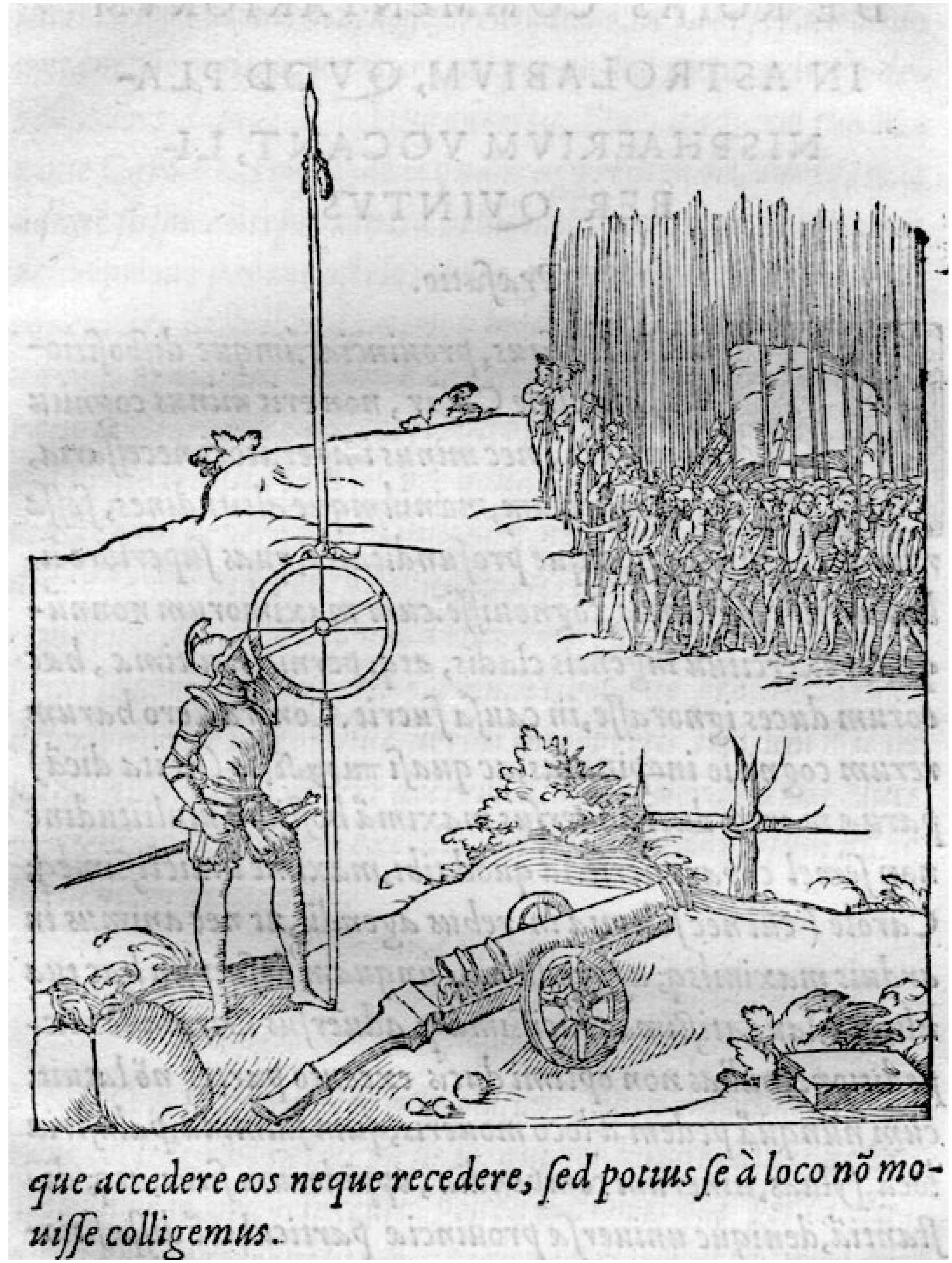
The Astrolabe

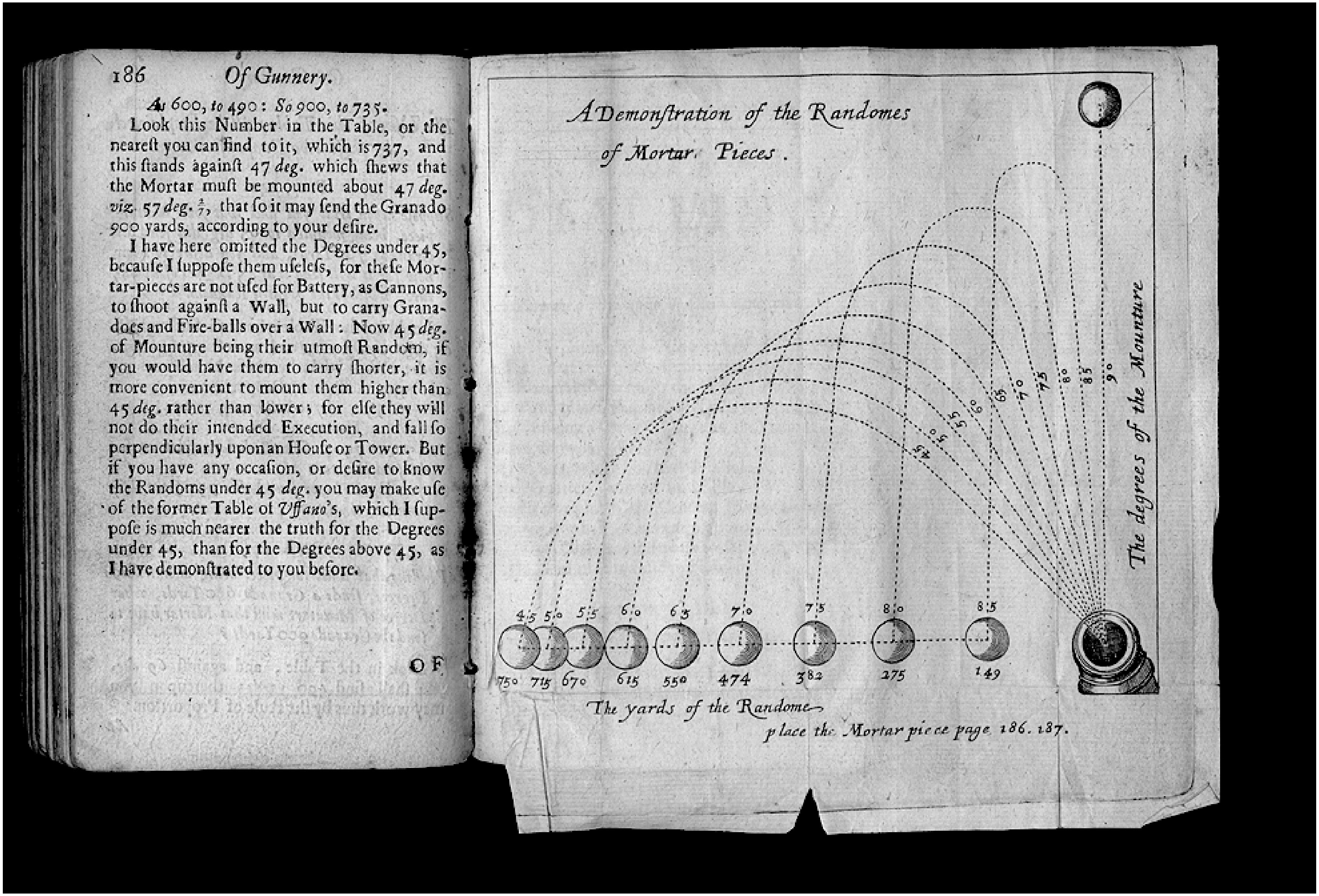
An instrument to measure the angles at which celestial objects appear.



An Astrolabe for the military

From: Juan de Rojas, Commentariorum in astrolabium (Paris, 1551)

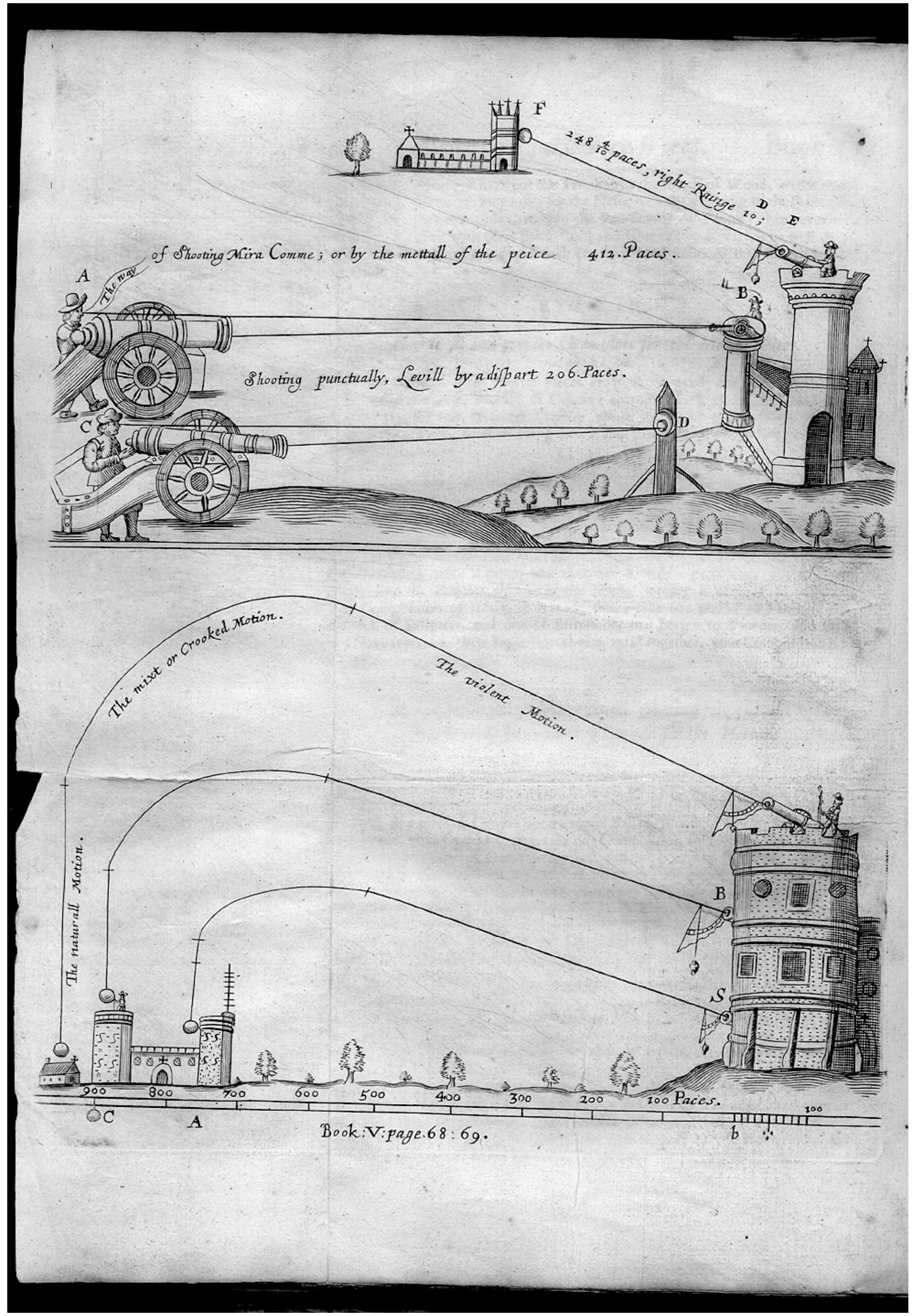




Gunnery: Finding the right angle.

Gunnery:

Before Newton, the flight of cannon balls was not well understood.



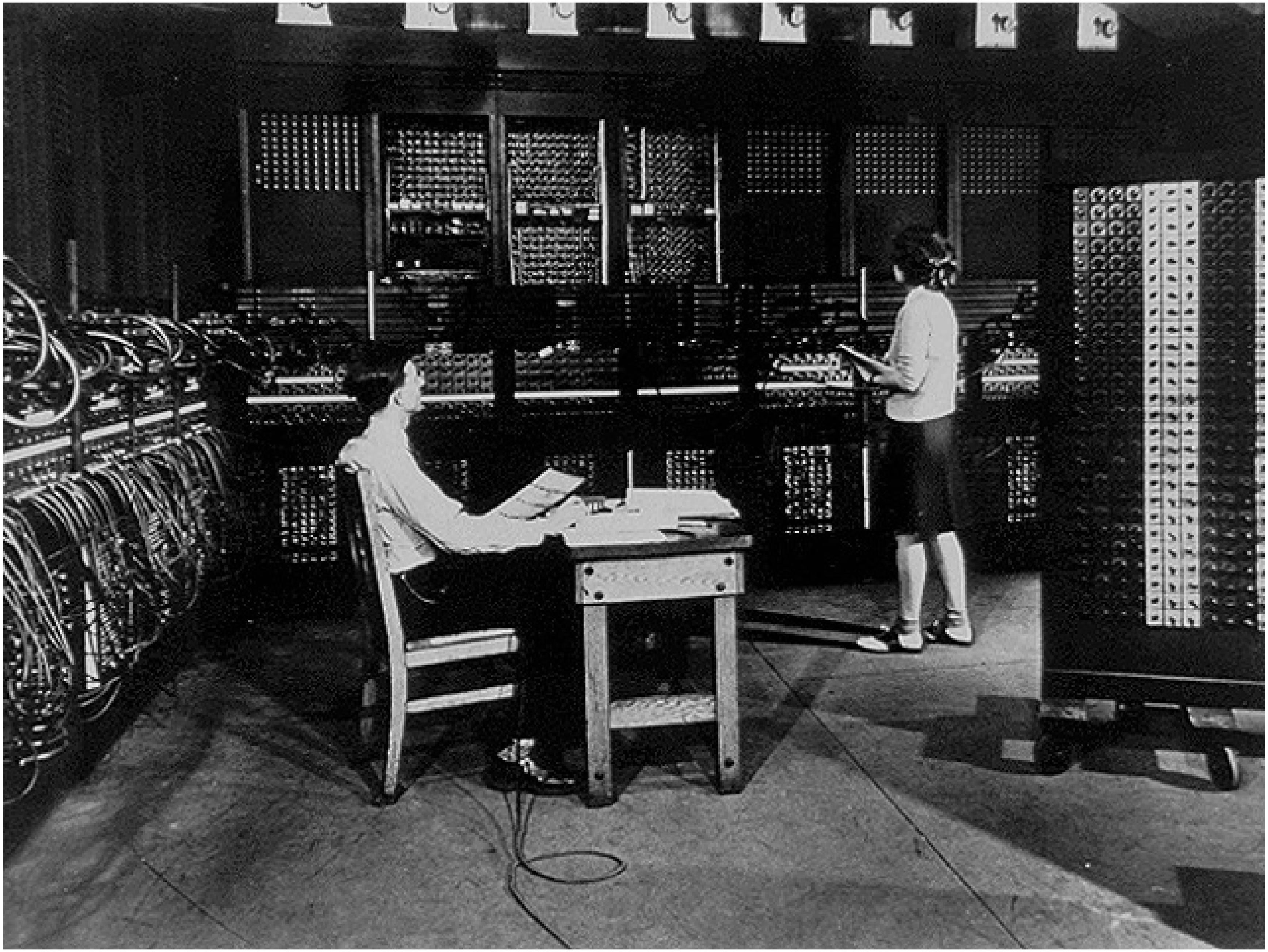
Gunnery:

During WWII, the US army still had enormous difficulties creating gunnery tables.

“Scores of "**computers**"--young women with mathematics degrees, supplemented by specially trained recruits from the U.S. Army's Women's Auxiliary Corps, were engaged in the ballistics computation work assigned to the University. The rate of change in artillery designs and the changing patterns of warfare created demands that exceeded their computational capacity.

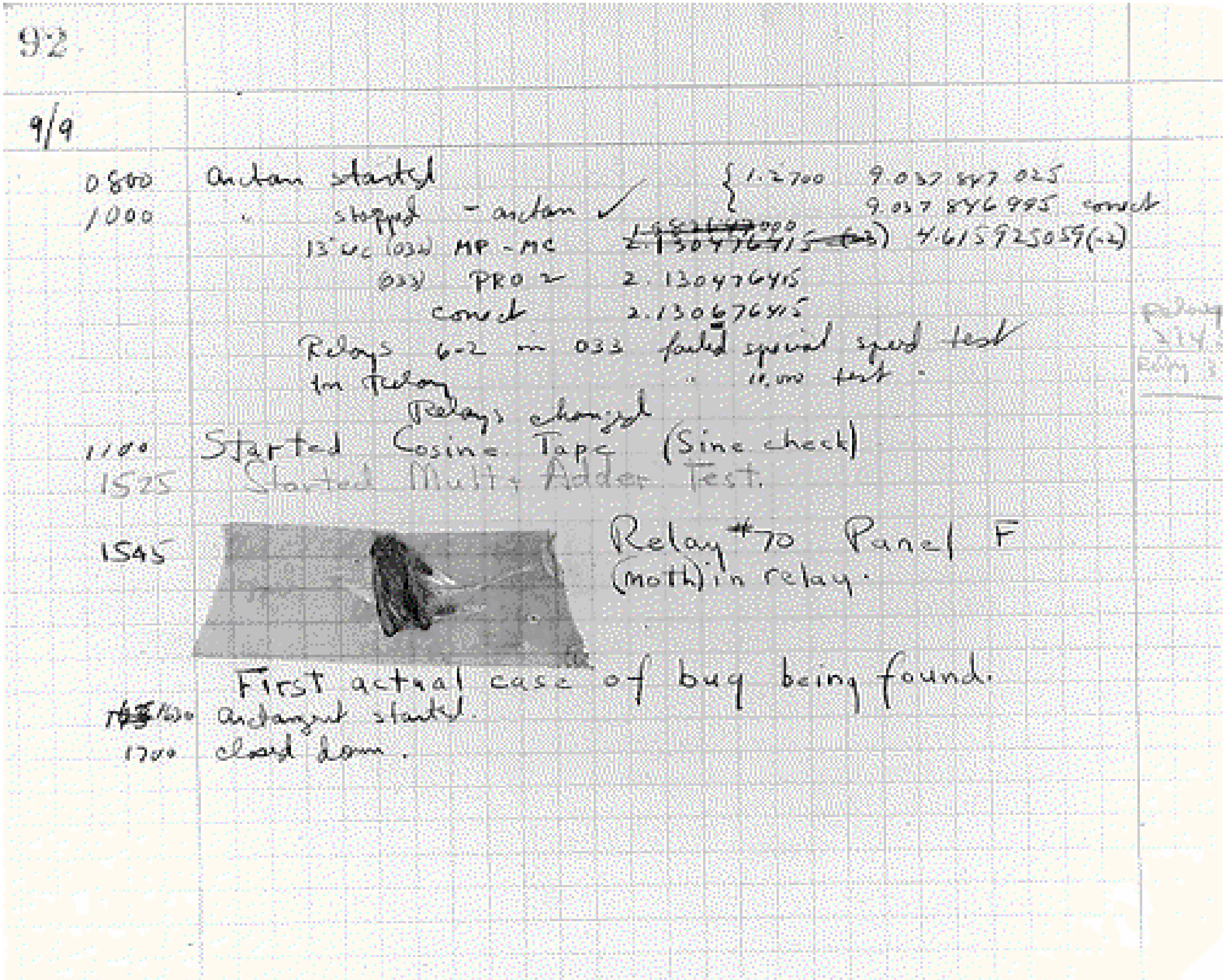
At any other time, the ideas worked out by John Mauchly and J. Presper Eckert--only 32 and 23 years old at the time that they met--would have been dismissed as impractical. Under other circumstances, their ideas would have been rejected for the simple reason that the ENIAC would cost too much to build. “

From: A Short History of the Second American Revolution
by Dilys Winegrad and Atsushi Akera



Eniac, 1946

The ENIAC was enormous. It occupied over 1,500 square feet, contained about 18,000 vacuum tubes, weighed more than 30 tons! and consumed about 180,000 watts of electrical power.



92

9/9

0800 Anctan started {1.2700 9.037 847 025
1000 " stopped - anctan ✓ 9.037 846 995 correct
13" UC (032) MP-MC 2.130476415 (-3) 4.615925059(-2)
(033) PRO 2 2.130476415
correct 2.130676415
Relays 6-2 in 033 failed special speed test
In Relay " " 10,000 test.
Relays changed
1100 Started Cosine Tape (Sine check)
1525 Started Mult+ Adder Test.
1545 Relay #70 Panel F
(moth) in relay.
First actual case of bug being found.
1630 antangent started.
1700 closed down.

First Computer Bug, found in 1945

First computer using RAM

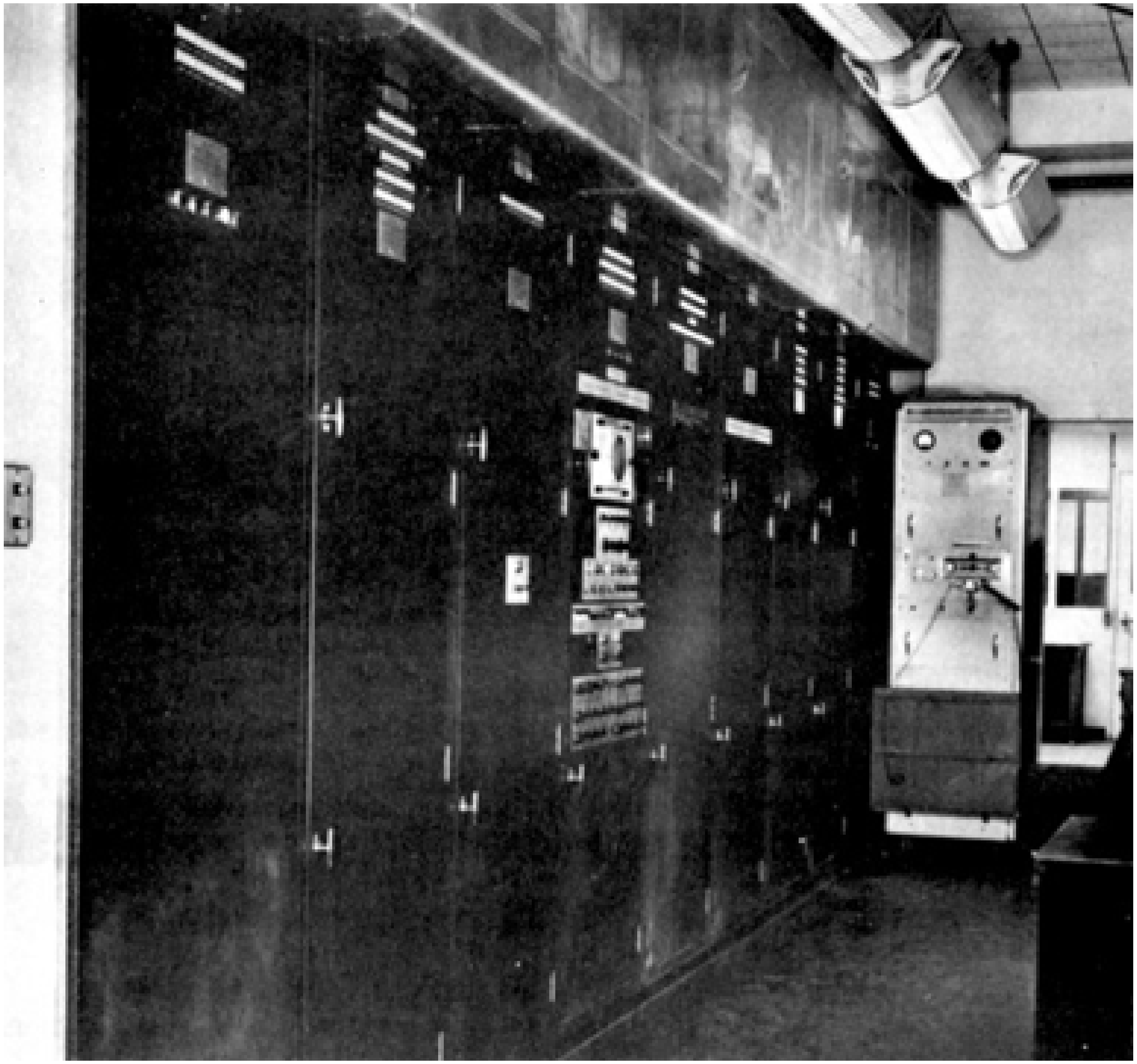
These machines had punched-card or punched-tape input and output devices and RAMs of **1,000-word**. Physically, they were much more compact than ENIAC: some were about the size of a grand piano and required 2,500 small electron tubes, far fewer than required by the earlier machines.

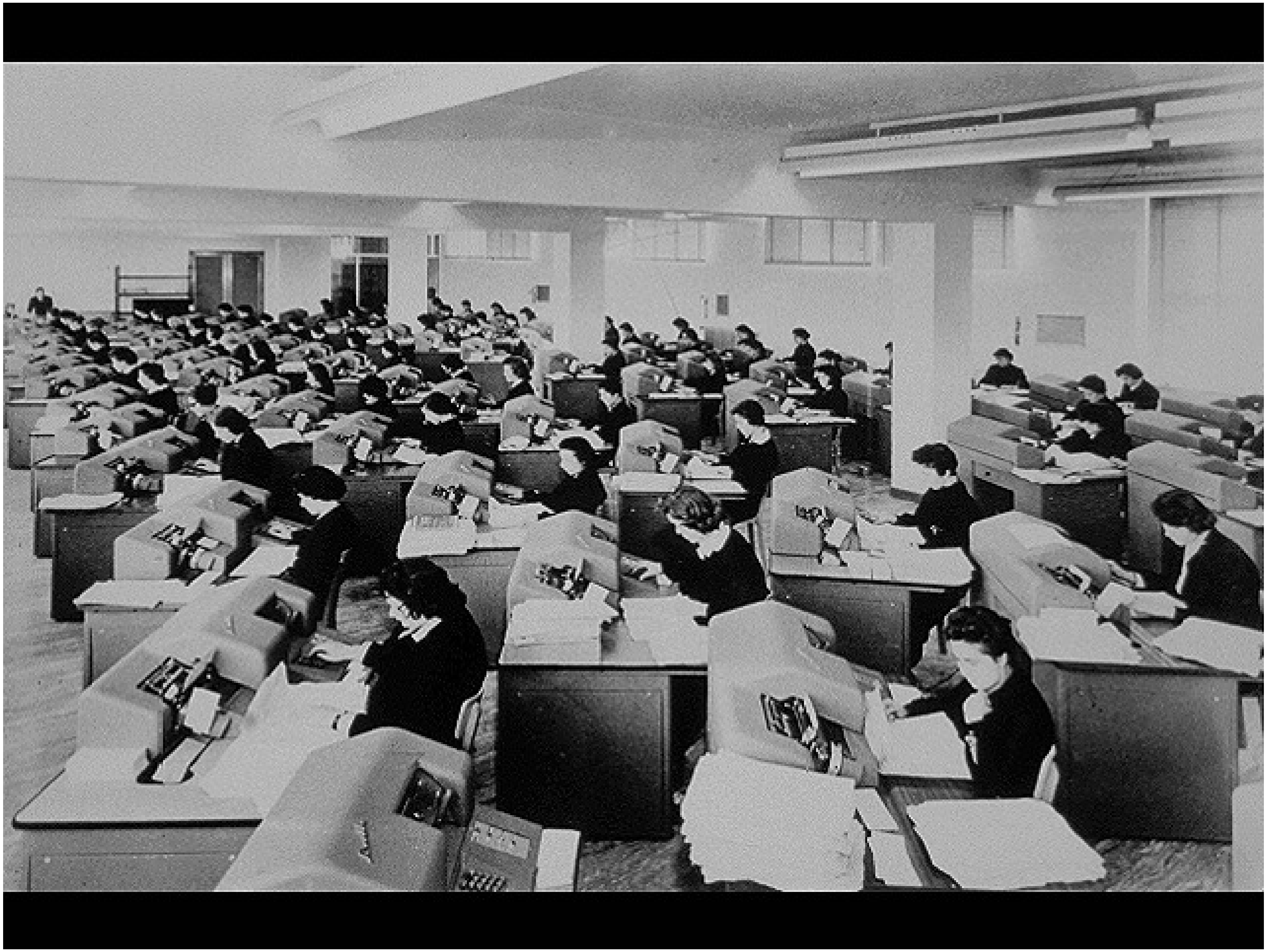
The first- generation stored-program computers required considerable maintenance, attained perhaps 70% to 80% reliable operation, and were used for 8 to 12 years. Typically, they were programmed directly in **machine language**, although by the mid-1950s progress had been made in several aspects of advanced programming.

The EDVAC

EDVAC (Electronic Discrete Variable Automatic Computer) was a vast improvement upon ENIAC. Mauchly and Eckert started working on it two years before ENIAC even went into operation. Their idea was to have the program for the computer stored inside the computer. This would be possible because EDVAC was going to have more internal memory than any other computing device to date. Memory was to be provided through the use of mercury delay lines. The idea being that given a tube of mercury, an electronic pulse could be bounced back and forth to be retrieved at will--another two state device for storing 0s and 1s. This on/off switchability for the memory was required because EDVAC was to use binary rather than decimal numbers, thus simplifying the construction of the arithmetic units.

The EDVAC





A Card Punching Room