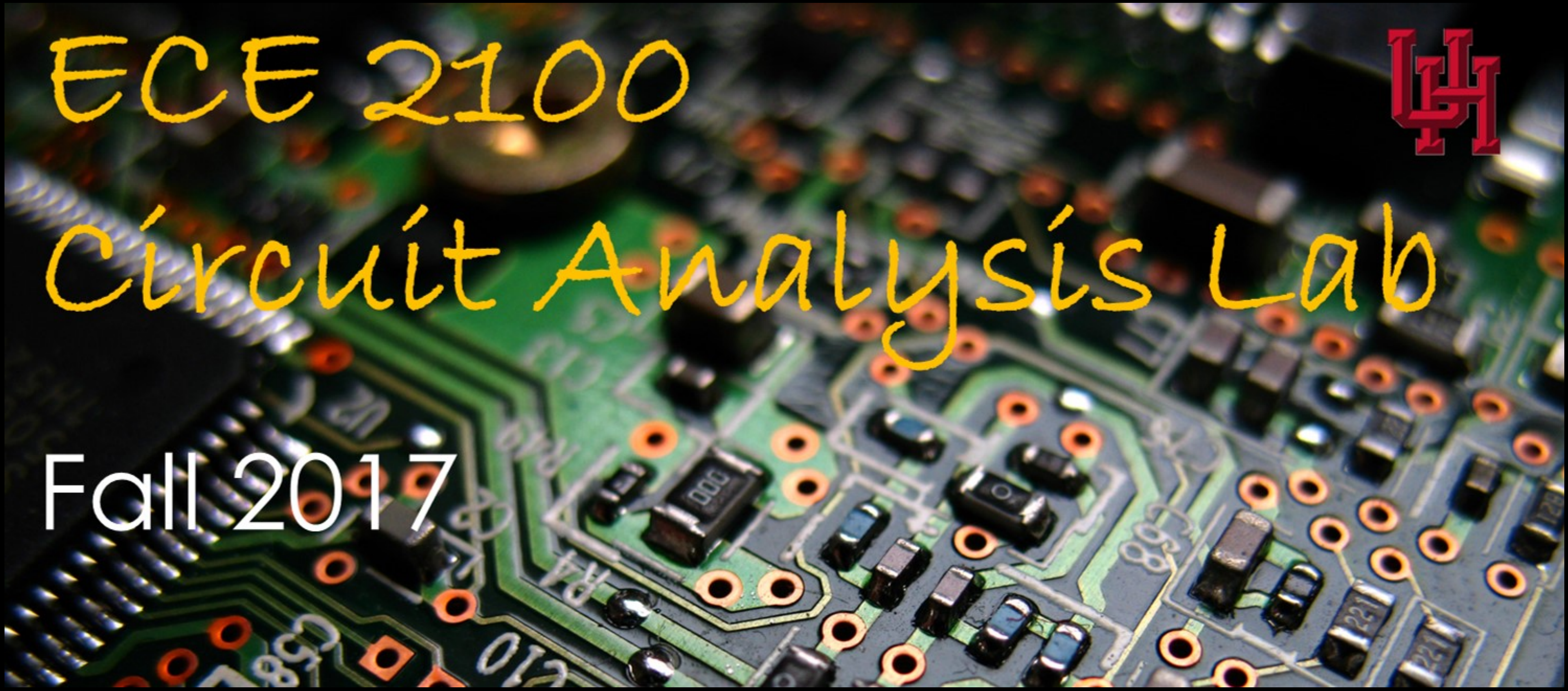
ECE 2100

Circuit Analysis Lab

Fall 2017



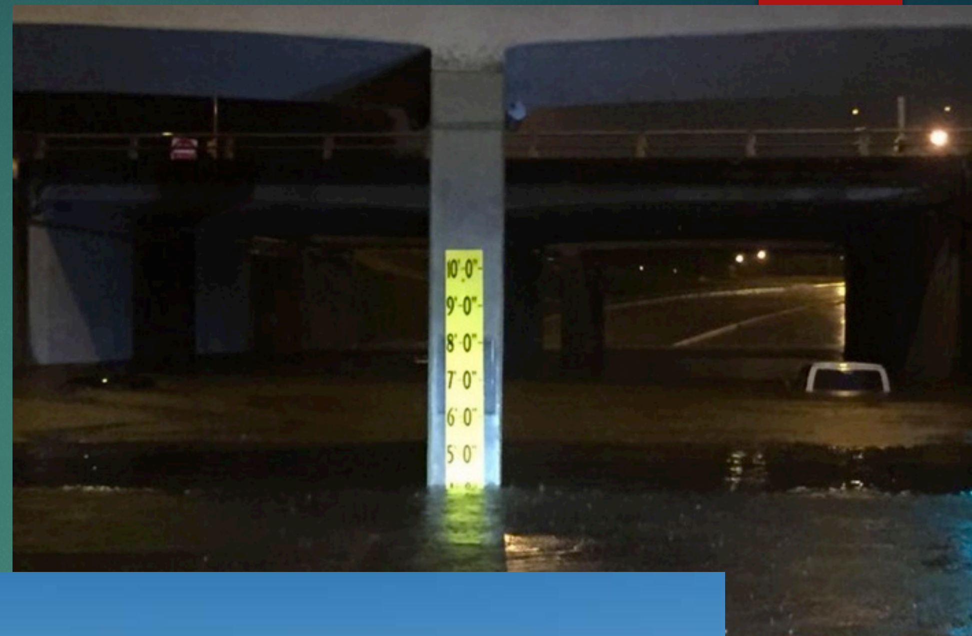
ECE 2100

Measurements basics

PROF. HAN Q. LE

what is the temperature?

How deep is the water here?

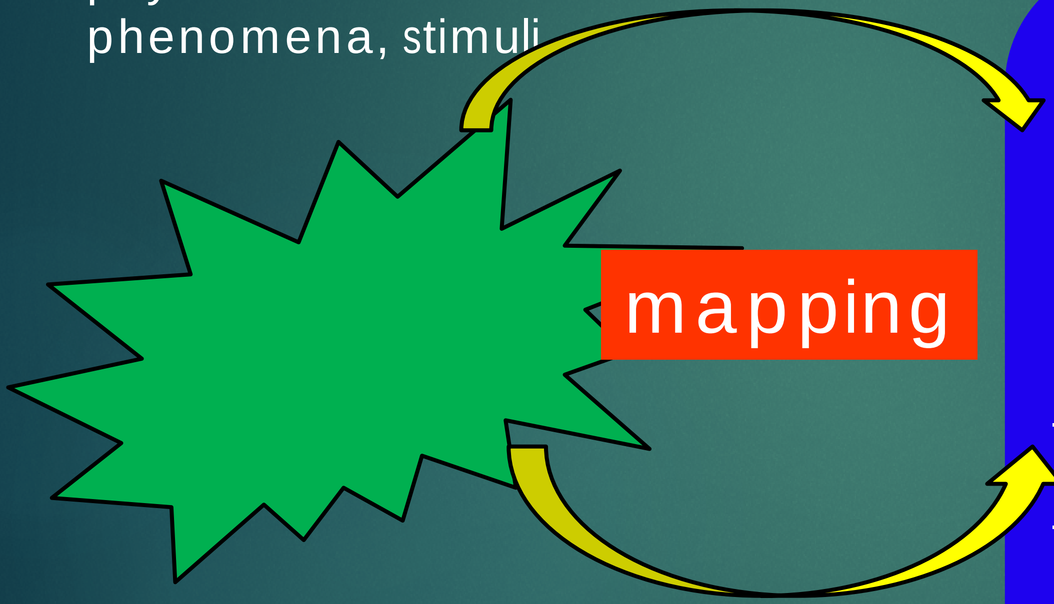


and here?

How strong is the wind?

What is measurement?

physical
phenomena, stimuli



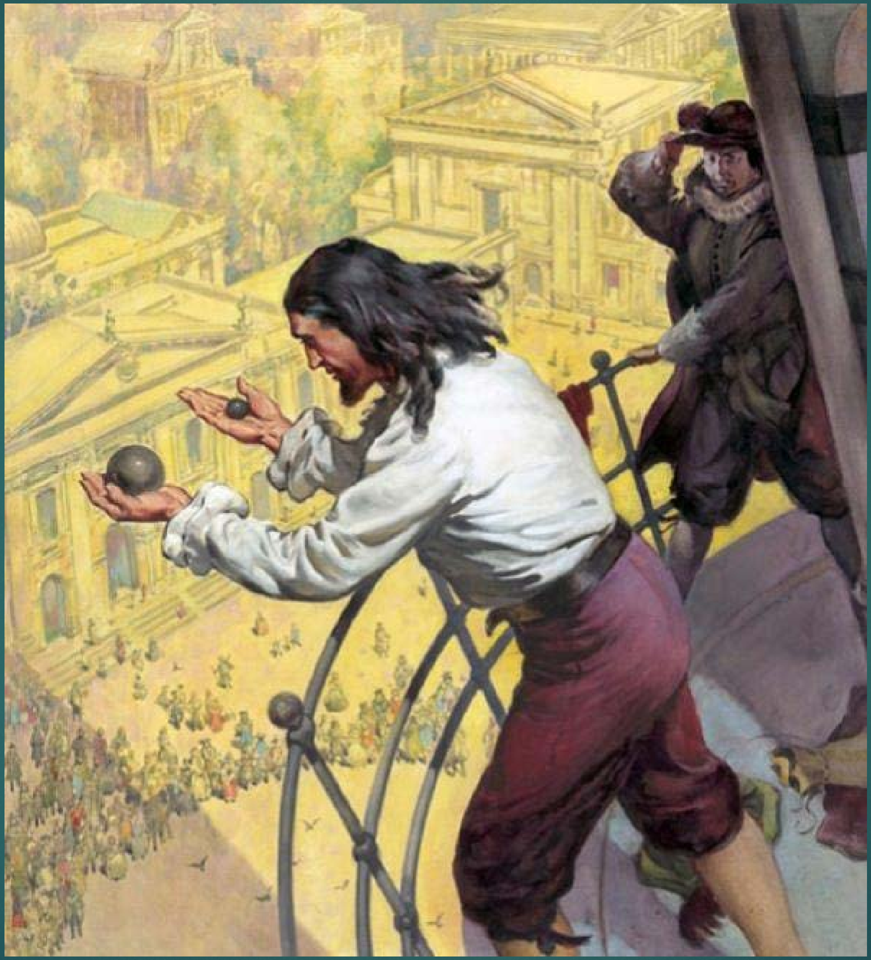
information

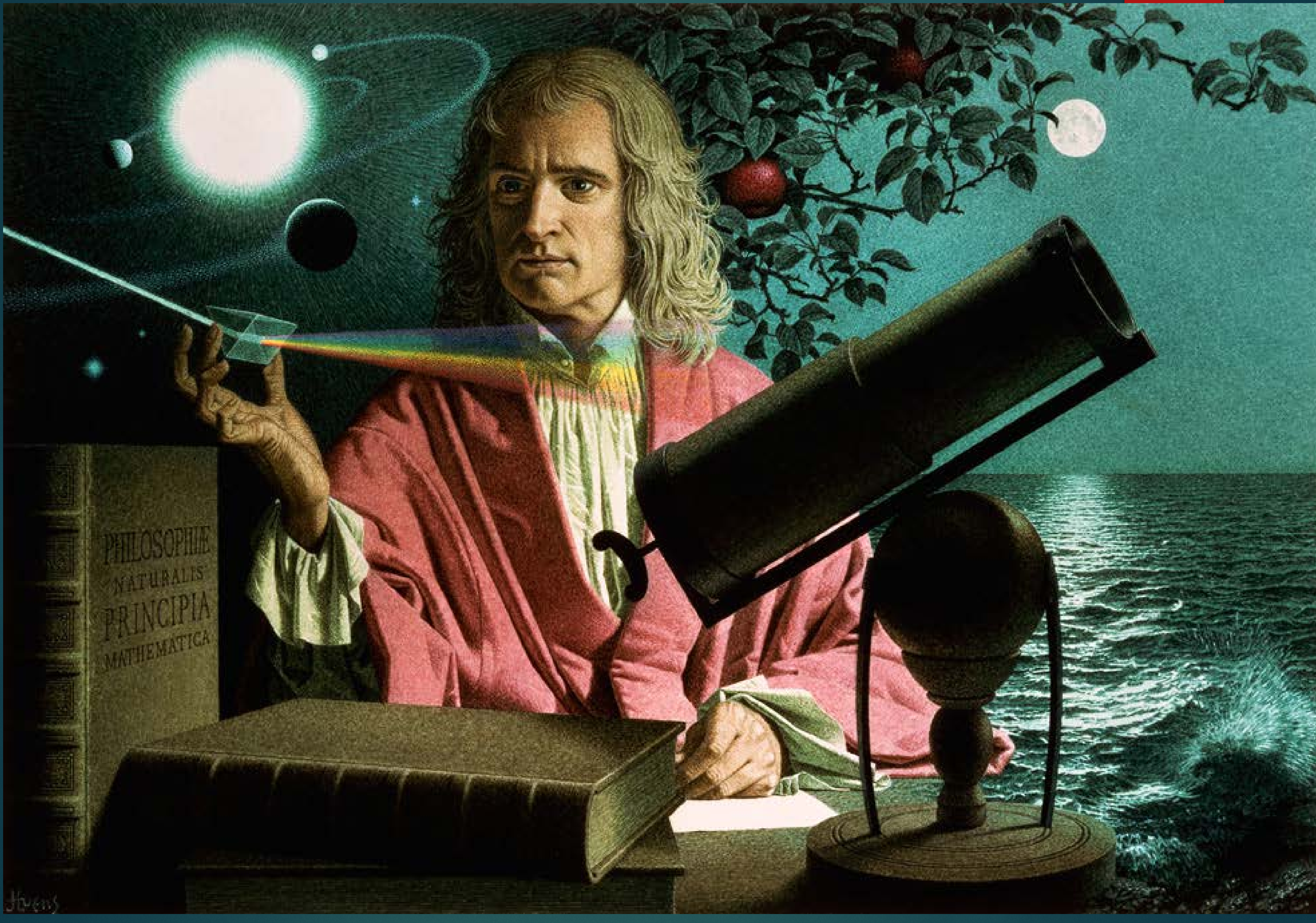
how hot? 108 F
how deep is the water? 6’5”
how strong is the wind? 120 m/hr
… and so on

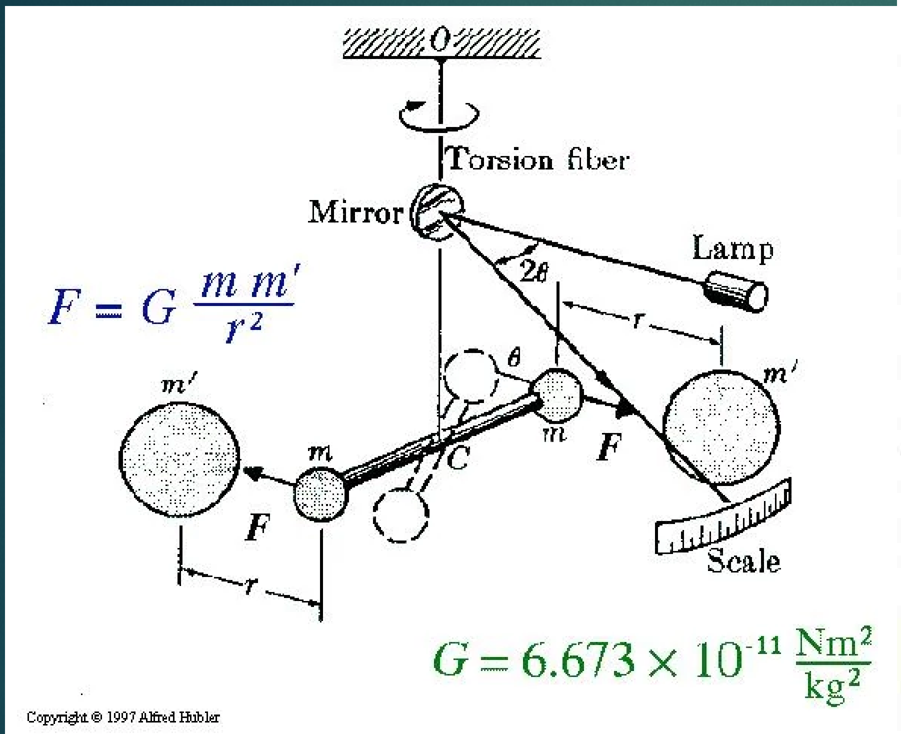
In this class:

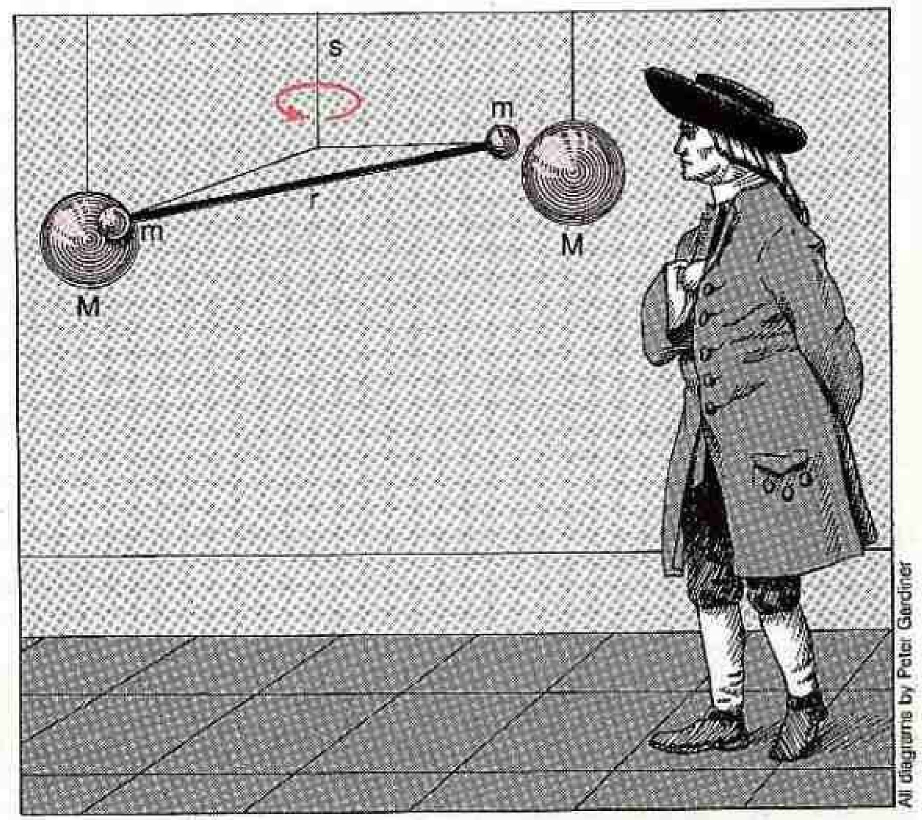
- how much is the voltage?
- how much is the current?
- how much is the frequency? or time characteristic of exponential decay
- …

Why measurement?

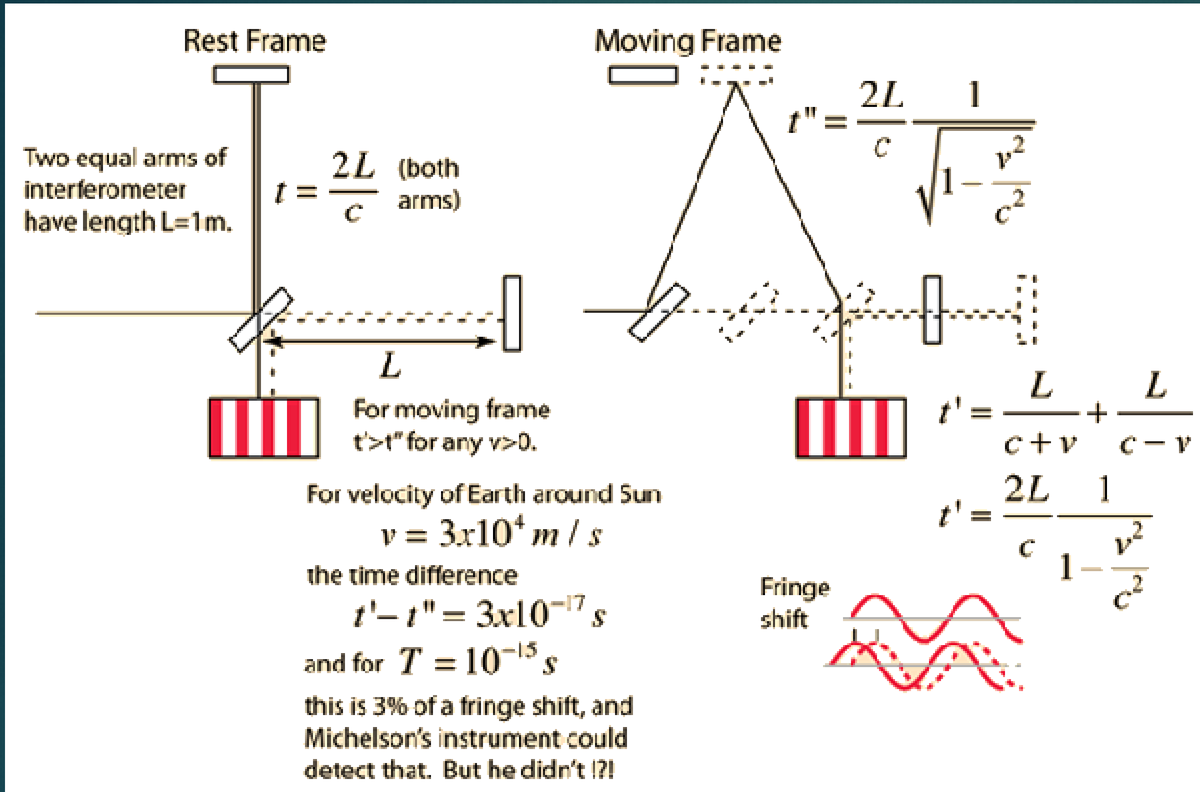


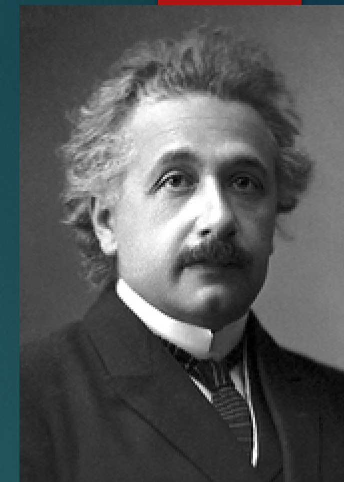

PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

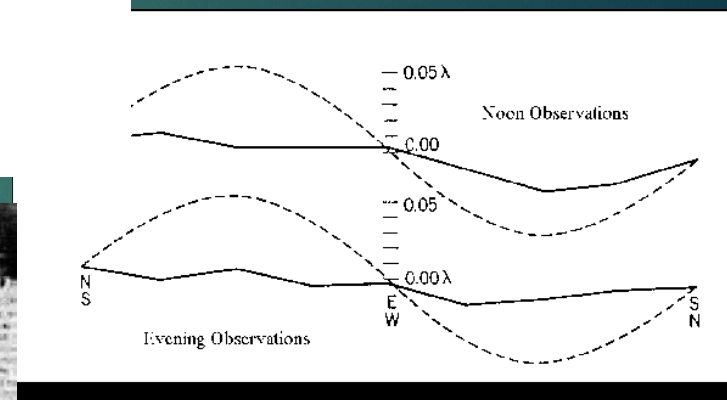


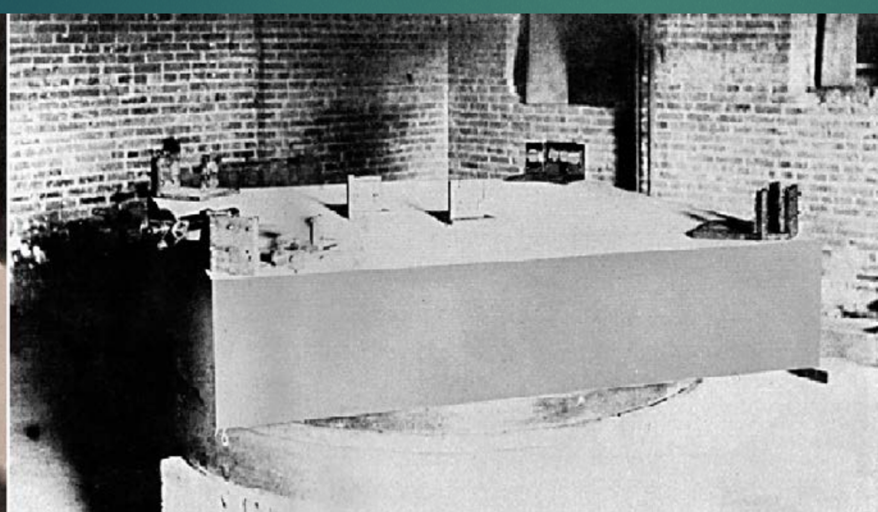


Henry Cavendish with the famous torsion balance experiment that determined the gravitational constant G and demonstrated Newton's inverse-square law of gravitation. Large lead spheres placed close to small ones caused angular deflections


Rest Frame
Moving Frame
Two equal arms of interferometer have length L=1m.
$t = \frac{2L}{c}$ (both arms)
$t'' = \frac{2L}{c}\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$
L
For moving frame t'>t'' for any v>0.
$t' = \frac{L}{c+v} + \frac{L}{c-v}$
$t' = \frac{2L}{c}\frac{1}{1-\frac{v^2}{c^2}}$
For velocity of Earth around Sun
$v = 3x10^4 \, m/s$
the time difference
$t' - t'' = 3x10^{-17} s$
and for $T = 10^{-15} s$
this is 3% of a fringe shift, and Michelson's instrument could detect that. But he didn't !?!
Fringe shift



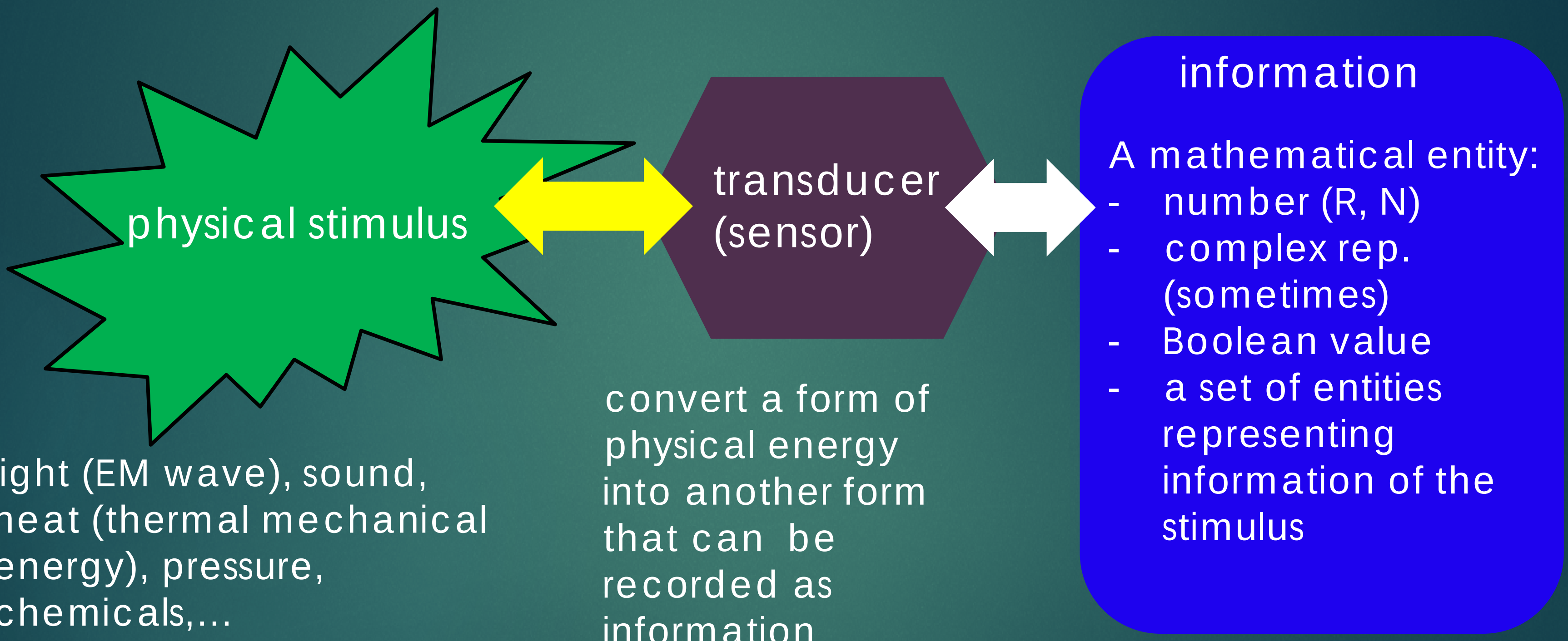

0.05 λ
Noon Observations
0.00
0.05
0.00 λ
N S
E W
S N
Evening Observations



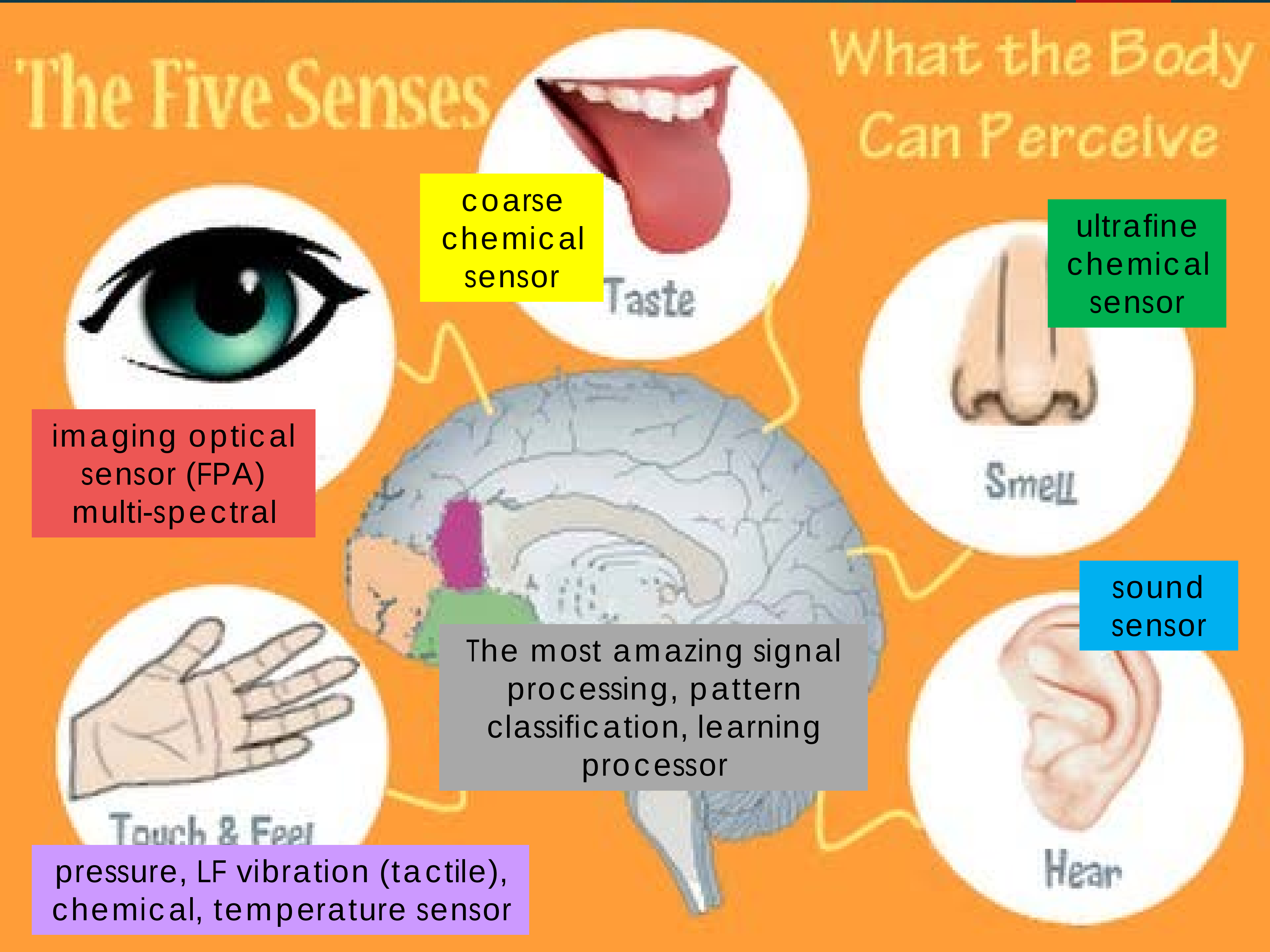
without measurement, we would not have science

Methodical measurement is the foundation of empiricism

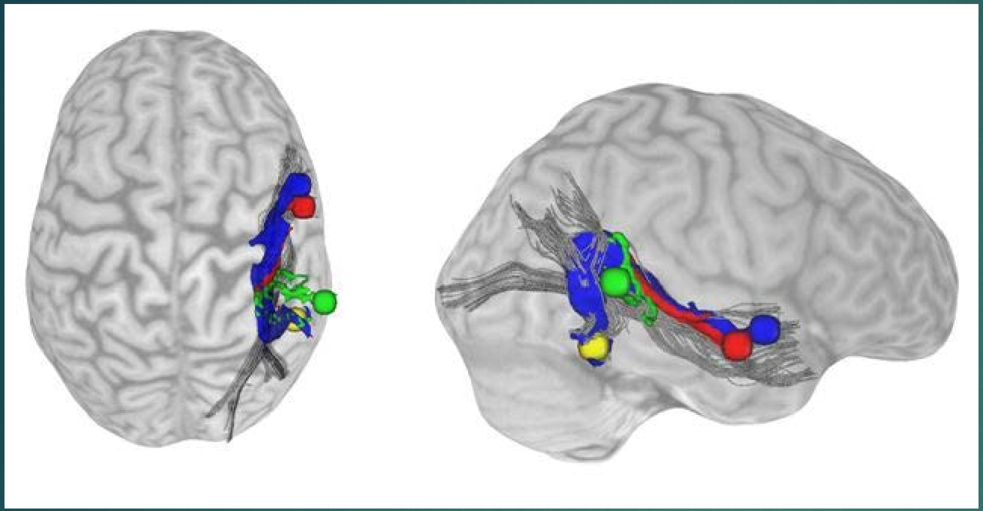
How to do measurement?



Some lab demonstration

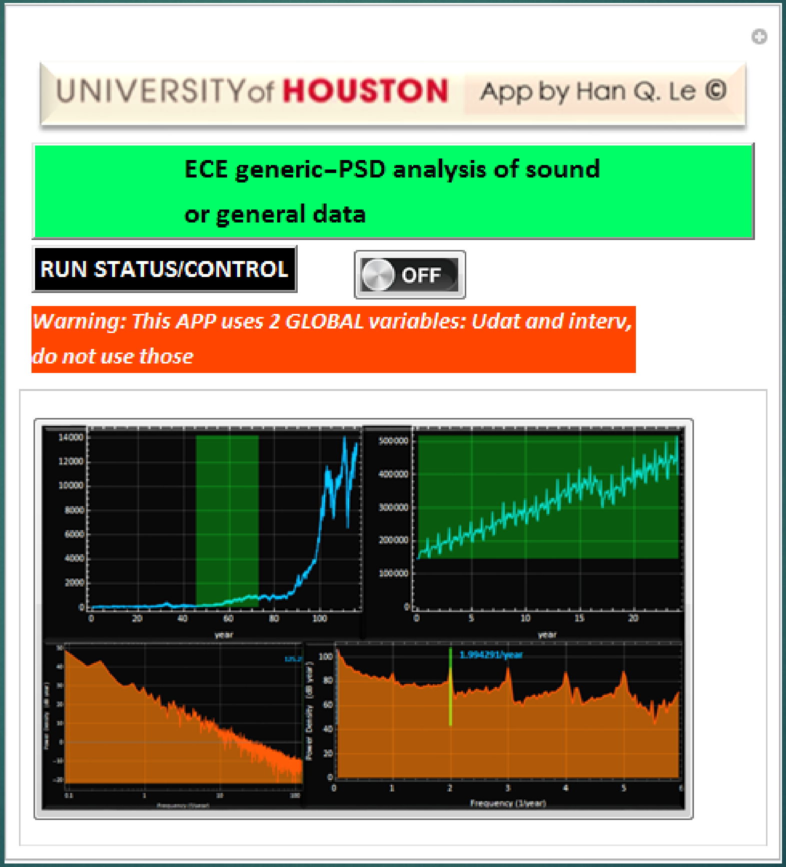

The Five Senses
What the Body Can Perceive
coarse chemical sensor
Taste
ultrafine chemical sensor
Smell
imaging optical sensor (FPA) multi-spectral
sound sensor
The most amazing signal processing, pattern classification, learning processor
Touch & Feel
Hear
pressure, LF vibration (tactile), chemical, temperature sensor

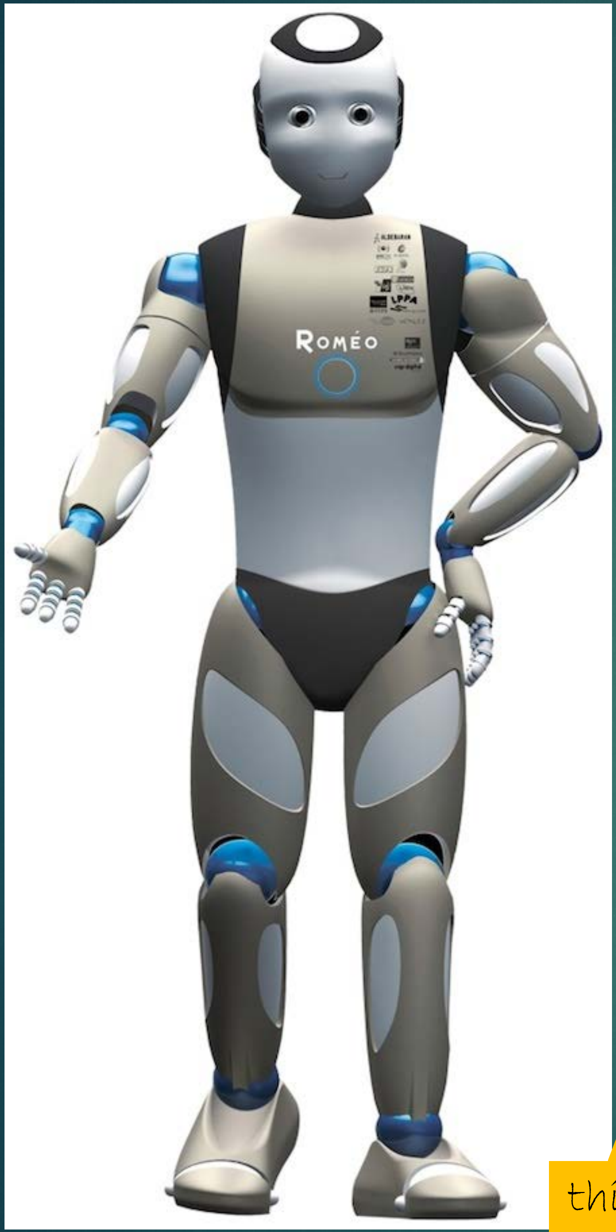
Have we met before? Direct connections between brain areas responsible for voice, face recognition



Human brain facial recognition (measurement: mapping optical sensing information into category: a classification) is so effortless compared to computation algorithm.

Demo with sound





Humanoid robots employ state of the art electronics and microprocessors and even cloud computing AI just to mimic some very basic human capabilities

this is what ECE 2100 for in the long run

- Measuring/sensing in itself is not the ultimate objective
- The ultimate objective is information
- More precisely, information with consequence

More demo of far simpler and common measurements

Yes, you do measurements all the time: taking picture is a measurement

Here is what you measure when taking a selfie or a picture

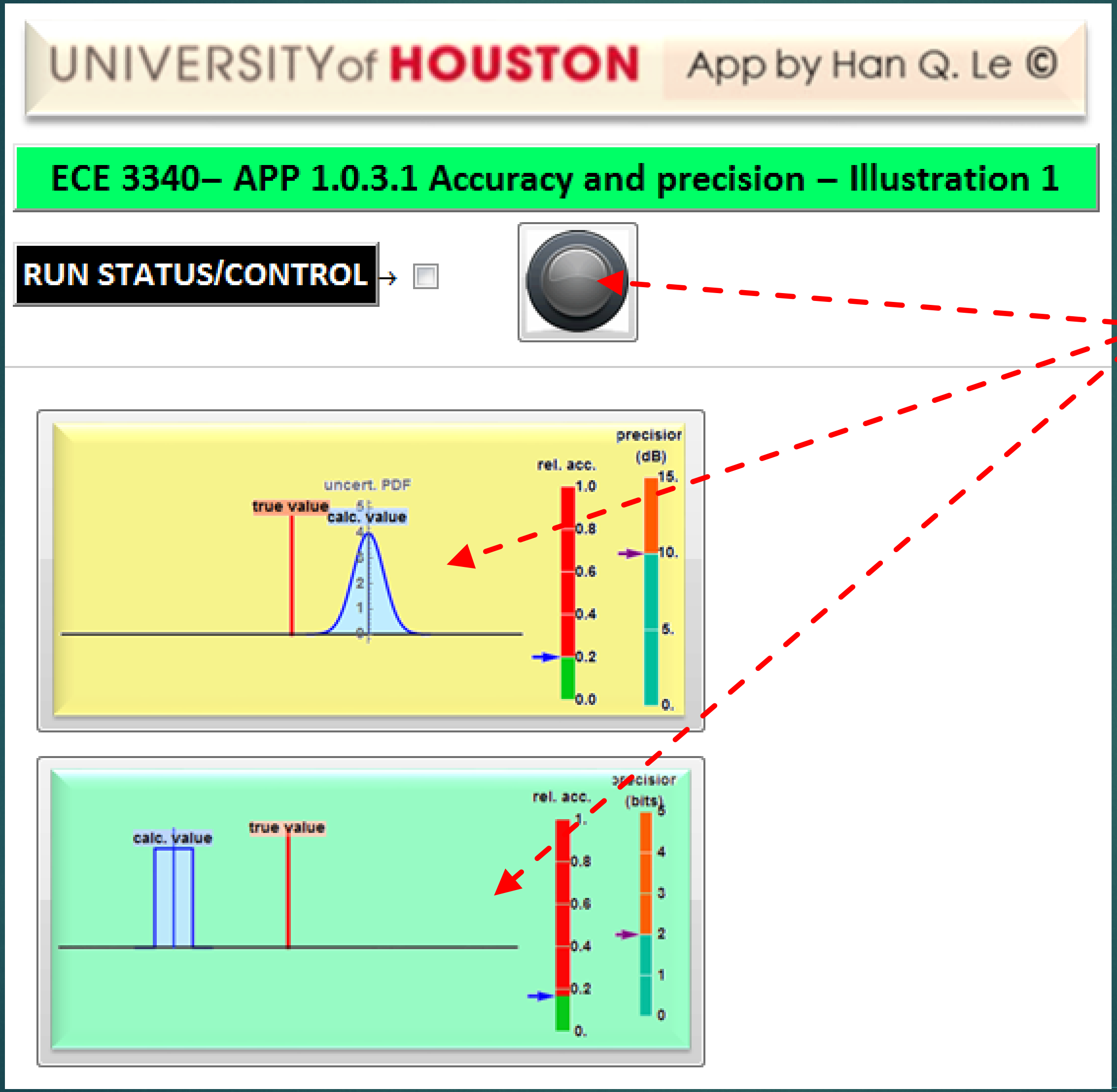
Accuracy and precision

Imagine you go to a showroom and step on these scales for sale. All are **precise** down to 0.1 lb. But they give readings differing by 10's lbs as above! What can you say?

At least 3, if not all are wrong. This means they are **precise**, but terribly **inaccurate**. (Well, may be the first one is the correct one?)

Inaccuracy in instruments – especially high precision, are usually caused by erroneous calibration or some incorrectly adjusted bias.

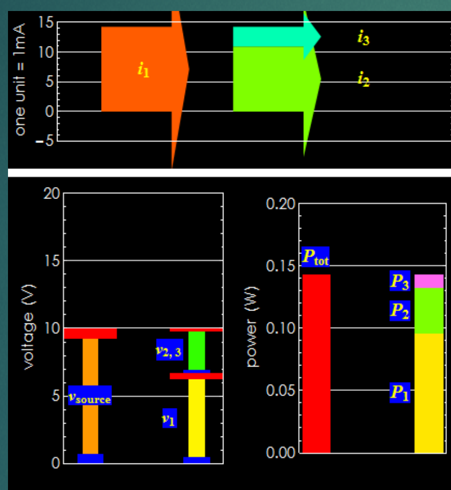
In empirical science, **accuracy** is defined as the degree that a measurement is close to the true value relative to uncertainty. Similarly in computing, **accuracy** is determined by the magnitude of error: the discrepancy between a calculation and the known correct value (via analytical knowledge).

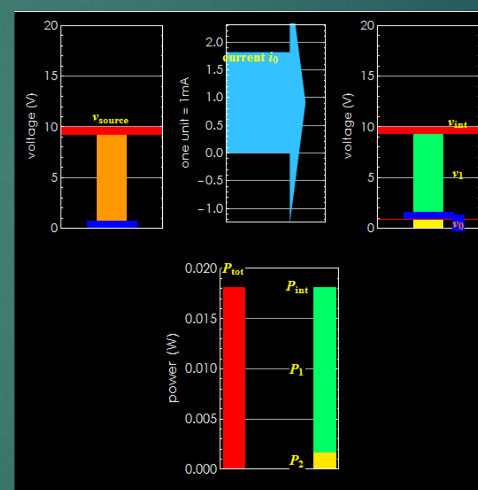


Click open this APP for demo

The most common and simplest type of measurements is to map a physical entity of interest into a real number (*is it real or rational – we'll see later on this*).

- for example, the voltage is 2.21 Volt, the current is 10 mA…



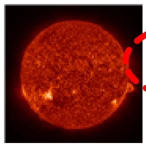
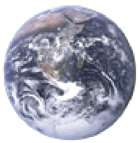
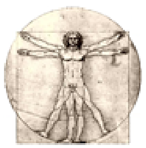
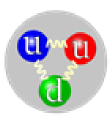
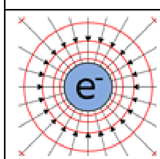
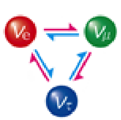


When measurement is to obtain a number, it is essential to understand how a number is represented

Mantissa and Exponent

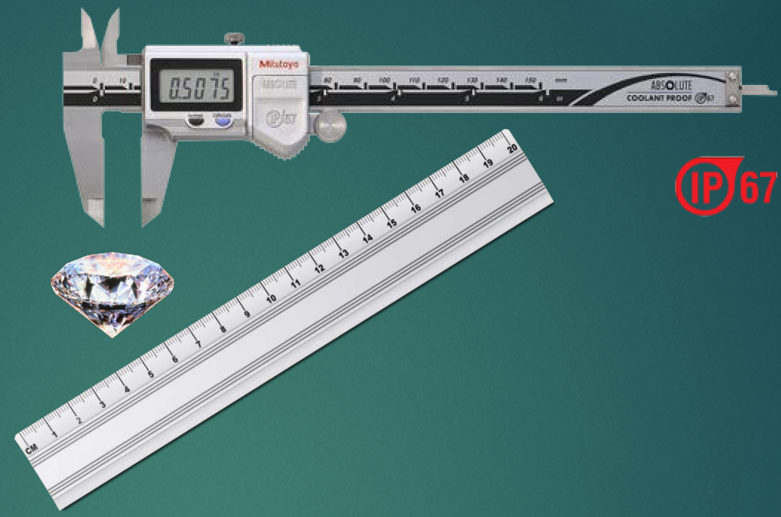
SCIENTIFIC REPRESENTATION OF NUMBERS

mantissa exponent save the hassle of all these zeros

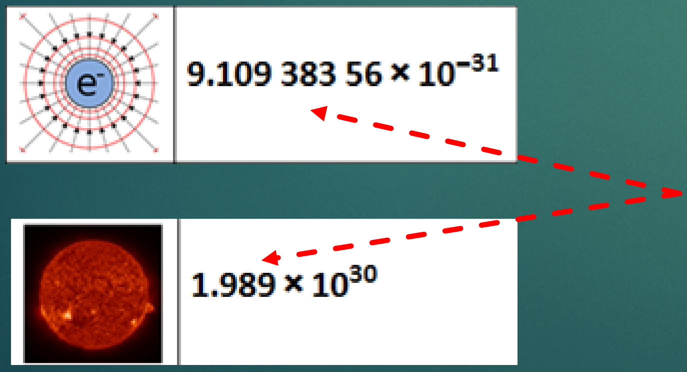
	mass (kg)	mass (kg)
	1.989×10^{30}	1,989000,000000,000000,000000,000000.
	5.972×10^{24}	5,972000,000000,000000,000000.
	65.	65.
	$1.672\ 621\ 9 \times 10^{-27}$	0.000000 000000 000000 000000 001672 6219
	$9.109\ 383\ 56 \times 10^{-31}$	0.000000 000000 000000 000000 000000 910938 356
	5.7×10^{-37}	0.000000 000000 000000 000000 000000 000000 57

electron mass and sun mass are 60 orders of magnitude different. But relatively speaking, which mass do we know "better" or more **precise**?

which tool would we want to use to measure this diamond?

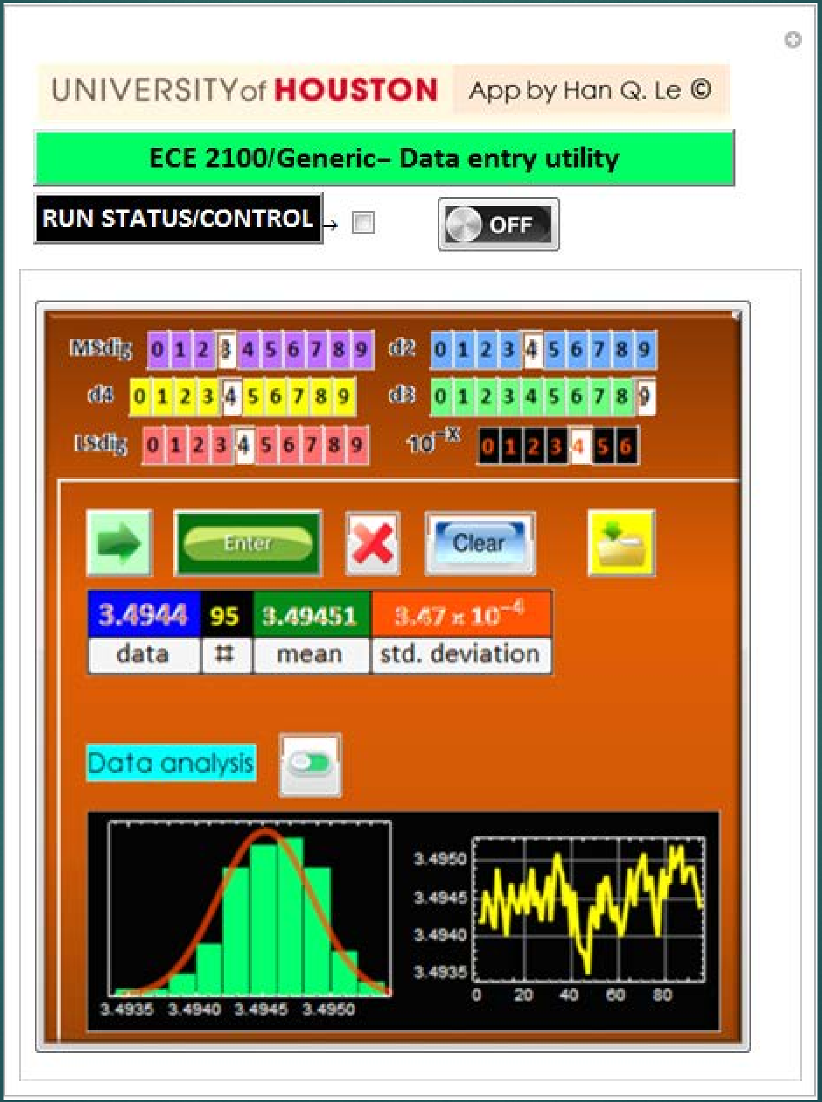


The caliper has higher precision, as it can give us a finer, or more-digit reading of the size: precision means the ability to give high resolution, more significant digit reading.



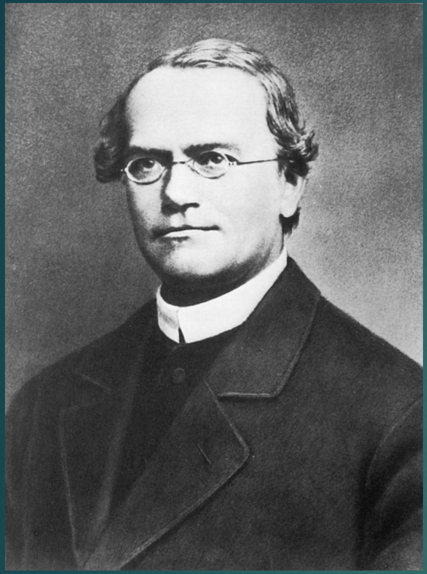
We know the electron mass with more **precision** than the Sun mass: The number of significant digits (with respect of measurement uncertainty) of the **mantissa** is the determinant of **precision**. The exponent is not relevant.

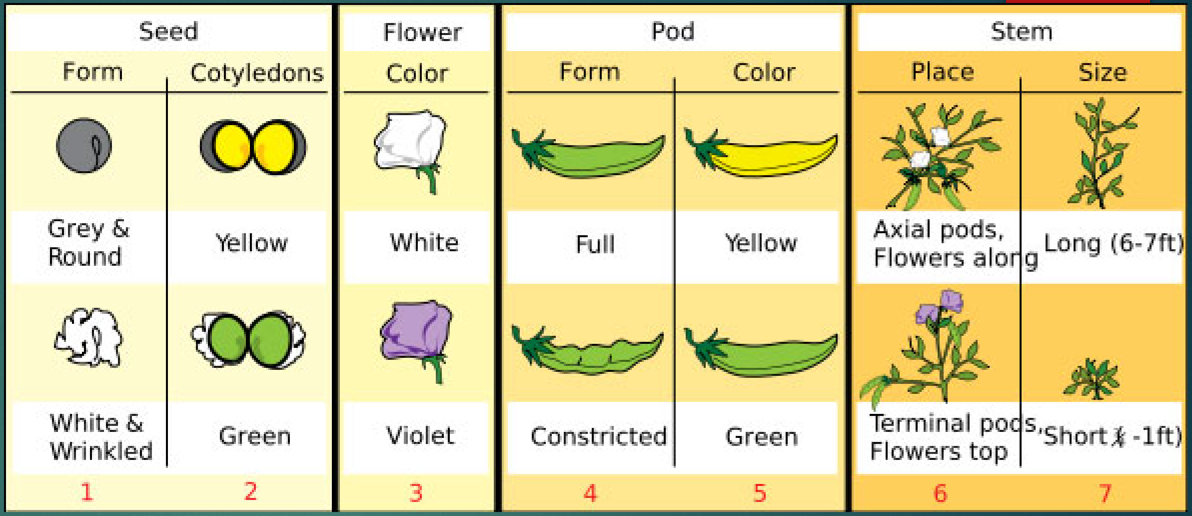
Example of an APP to record information



- Fluctuation and uncertainty are fundamental to nature
- Quantum fluctuation, quantum noise for example, are intrinsic.
- Many are due to uncontrollable factors that affect the measurement
- Many are just due to fundamental statistical and random fluctuation

The lack of statistical fluctuation in a measurement is a BIG red flag on the data



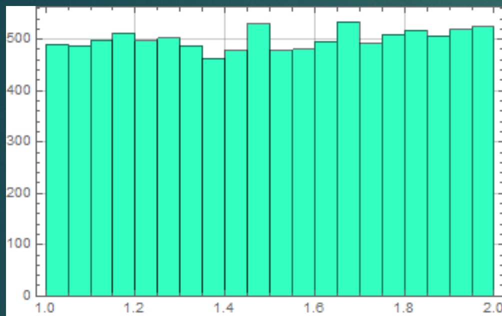


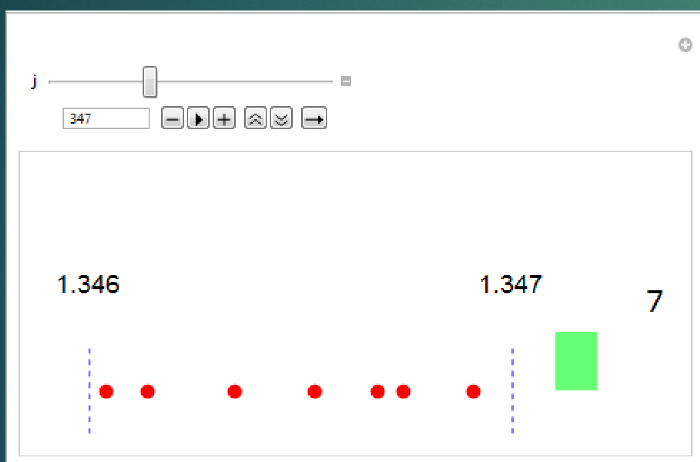
Mendelian Paradox, a paradox that remains unsolved to this very day. Thus, on the one hand, Mendel's reported data are, statistically speaking, too good to be true; on the other, "everything we know about Mendel suggests that he was unlikely to engage in either deliberate fraud or in unconscious adjustment of his observations."[53] A number of writers have attempted to resolve this paradox.
One attempted explanation invokes confirmation bias.[54] Fisher accused Mendel's experiments as "biased strongly in the direction of agreement with expectation... to give the theory the benefit of doubt".[47]

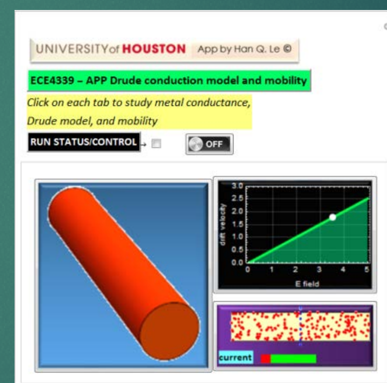
In his 2004, J.W. Porteous concluded that Mendel's observations were indeed implausible.[55] However, reproduction of the experiments has demonstrated that there is no real bias towards Mendel's data.[56]

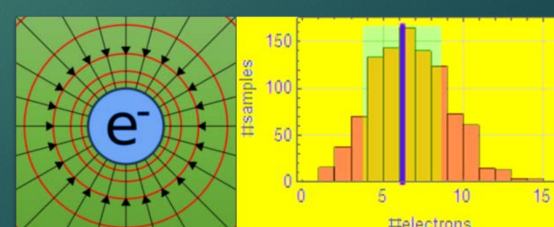
https://en.wikipedia.org/wiki/Gregor_Mendel#The_Mendelian_Paradox

Demo of electron Poisson statistics and current shot noise





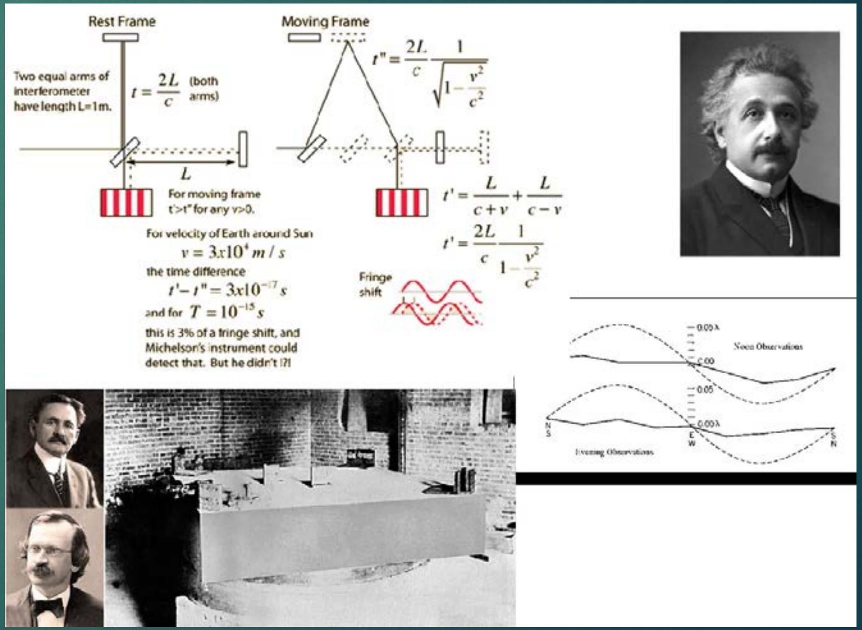




- Measurement “error” is NOT the same as “wrong”.
- Measurement error can be thought of as “deviation from expectation”.
- Greatest scientific discoveries were often made when deviation is discovered from the expectation of the prevalent theory (that’s how a new theory is discovered).

Remember this?

- Hence, **nothing wrong with deviation** as long as your method, techniques, instruments and execution are all correct.



just do it right. Let the chips fall where it may. The learning is greatest and most fun when you discover discrepancy and find out why!

You learn far more with Murphy law than when everything is smooth sailing

A class-wide project to study statistical deviation

- every one shall choose 10 resistors from your kit, all with the same error band 5% (gold band)
- for each resistor, measure the deviation:

$$\frac{\text{Actual resistor value } R - \text{nominal resistor value } R_0}{R_0}$$

Example, a nominal 100 Ohm resistor is measured to be 102.5 Ohm, the relative deviation is 0.025 or 2.5%

- file a report
- with 31 students, we'll have 310 data points
- we will plot a histogram, find the mean, standard deviation, and determine what distribution best describes the statistical deviation

have fun