Physics 50
Introduction to Mechanics
Physics Background, Units, Dimension

Lana Sheridan

De Anza College

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Last time

- course info
- science, science terms, and the scientific method

Overview

- physics
- scientific terms
- definitions of the base units
- dimensional analysis

What is Physics?

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Physicists (and others who use physics) want to predict accurately how an object or collection of objects will behave when interacting.

Why?

- to better understand the universe
- to build new kinds of technology (engines, electronics, imaging devices, mass manufacturing, energy sources)
- to build safer and more efficient infrastructure
- to go new places and explore
- to prepare for the future

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How?

Amazingly, relatively simple mathematics can represent interacting physical objects.

The results of calculations give accurate predictions, provided the mathematical model is a good one.

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eg. a pool table. The system might include the balls, the sides of the table, but maybe not the whole Earth. And certainly not the Andromeda galaxy.

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Hypothesis

An educated guess about a relationship between measurable quantities. It must be *falsifiable* by observations or experiments.

The Scientific Hypotheses

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Near the surface of the Earth, if two objects are dropped from the same height at the same time in a vacuum they will strike the ground at the same time, regardless of their masses.

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- and <u>not</u> the behavior of electrons in atoms.

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Valid when

- $v << c$,
- gravitational fields are not too strong,
- distances are much bigger than ℓ_p (Planck length), etc.

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eg. $\vec{\mathbf{F}}_{\text{net}} = m\,\vec{\mathbf{a}}$

("If I push this shopping cart twice as hard, it will accelerate twice as fast.")

Question

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(A) an educated guess.
(B) less than a fact.
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Quantities, Units, Measurement

If we want to make precise *quantitative* statements we need to agree on measurements: standard reference units.

We will mostly use SI (Système International) units:

Length	meter, m
Mass	kilogram, kg
Time	second, s

and many more!

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In all your numerical answers, make sure you include the appropriate units!

Defining Units

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Physicists now strive to chose definitions for units that are based on **fundamental physical phenomena** - things anyone, anywhere could in principle observe consistently.

Units: Length

The *meter*, m, is the SI unit of length. It is about 3.28 feet.

Originally (in 1793) the meter was defined so that the distance from the North Pole to the equator would be 10 million meters.

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The current definition of the meter (since 1983) is more precise and more convenient for experiments:

meter

One meter is the distance light travels in 1/299,792,458-ths of a second.

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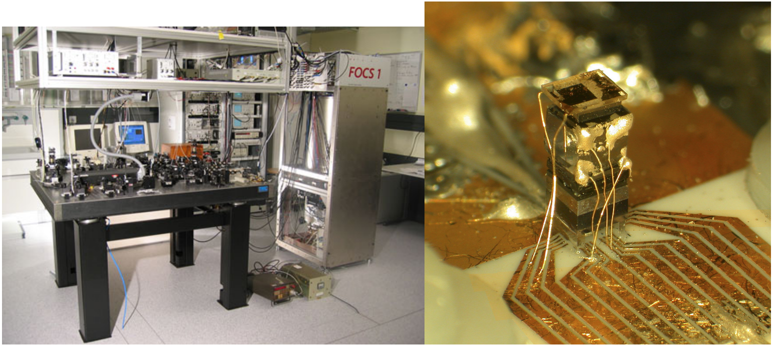
Devices used to measure time this way are called *atomic clocks*. They are accurate to 1 second in 100 million years.



[1]Atomic clock FOCS-1, METAS, Bern, Switzerland; Chip photo, NIST.

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→ The atomic clocks at the National Institute for Standards and Technology (NIST) are principle references for International Atomic Time.

second

One second is the time for the radiation corresponding to the transition between the two hyperfine energy levels of the ground state of the caesium-133 atom to complete 9,192,631,770 oscillations.

Units: Mass

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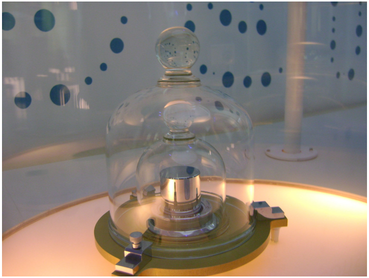
Before May 20th, the official 1-kilogram sample, the *international prototype kilogram* was a cylinder of platinum and iridium stored near Paris.



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Units: Mass

1 kilogram is 1,000 grams.

Originally, the gram was defined to be the mass of one cubic centimeter of water at the melting point of water.

The international prototype kilogram was designed to follow this definition.

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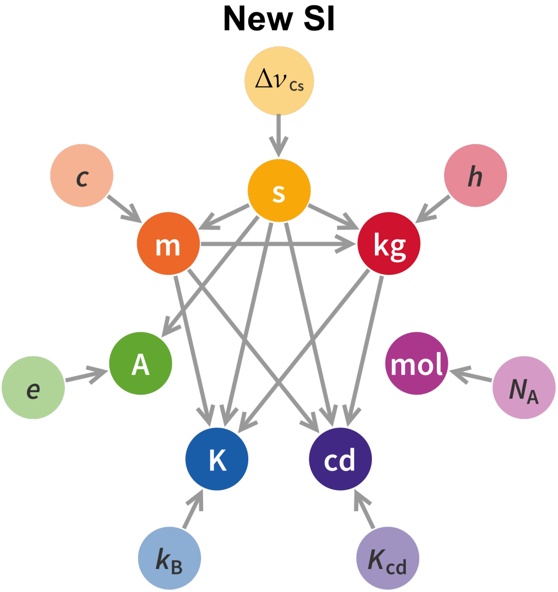
The Kibble balance measures mass by way of current and voltage measurements. Both current and voltage in this device are *quantized*, meaning they have a **smallest unit** and cannot take any value. The smallest units depend on a fundamental constant of nature, Planck's constant, h.

Thus, the kilogram is defined so that Planck's constant is exactly:

$$h = 6.626\,070\,15 \times 10^{-34} \text{ kg m}^2/\text{s}.$$

SI Units Definition Summary



[1]Figure by Emilio Pisanty.

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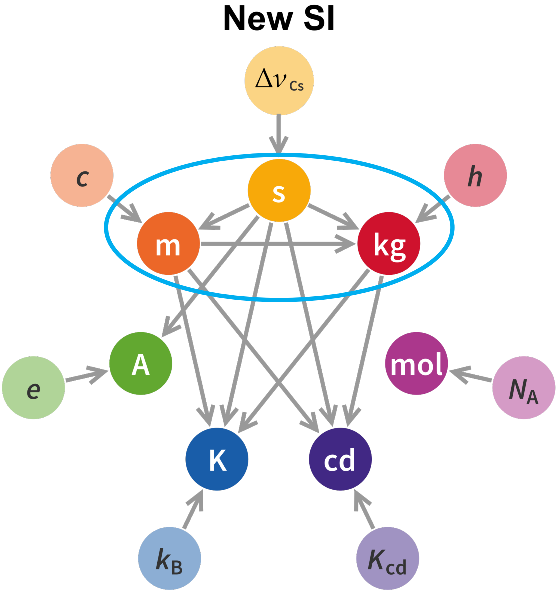

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Dimensional Analysis

All measurement values have associated units.

Equations relating measurable physical values also relate units.

This means units on each side of the equals sign must be equal.

Dimensional analysis allows us to:

- check our equation is correct
- check our calculation
- figure out the final units of an answer if we can't remember what they should be

This is very important!

Dimensional Analysis Examples

$$\text{distance traveled} = \text{speed} \times \text{time}$$

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$$x = vt$$

Distance is a length. In the textbook, a value with units length is written [L]. Time units would be [T].

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So,

$$[\mathrm{L}] = [\mathrm{L}] \quad \checkmark$$

Dimensional Analysis Examples

Another one,

$$v^2 = v_0^2 + 2ax$$

a is an acceleration, a rate of change of speed.
Units: $[\mathrm{L}]/[\mathrm{T}]/[\mathrm{T}] = [\mathrm{L}]/[\mathrm{T}^2]$

2 is a constant and has no units.

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Units for each term are the same.

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$$[\mathrm{m^2/s^2}] = [\mathrm{m^2/s^2}] + [\mathrm{m^2/s^2}] \quad \checkmark$$

Summary

- physics
- hypotheses and theories
- definitions of the base units
- dimensional analysis

Quiz Monday, in class.

Homework (not handed in, but do it)

- Get the textbook, James S. Walker, “Physics”
- Read chapter 1
- Ch 1, onward from page 14. Questions: 1; Problems: 5, 7, 9, 11, 12*, 41, 51 (compare the answers to 12 and 51)

*Ans for 12: $[M]/[T^2]$