Conceptual Physics

Lana Sheridan

De Anza College

July 3, 2017

Overview of the Course

Topics

- What is science? What is physics?
- How is it done?
- What is its history?

Overview of the Course

Topics

- What is science? What is physics?
- How is it done?
- What is its history?
- What is it useful for? How does it affect my life?
- What do scientists do? How do they think?

Overview of the Course

Topics

- What is science? What is physics?
- How is it done?
- What is its history?
- What is it useful for? How does it affect my life?
- What do scientists do? How do they think?
- Rational thinking / understanding science articles.
- Interpreting graphs and data.
- Basic physics ideas and theories.
- Applying knowledge to physics problems.

Overview of the Course

Physics Theory Topics

- Mechanics and kinematics; Newton's laws; momentum
- Properties of matter; phases of matter
- Heat
- Electricity and Magnetism; circuits and current
- Light; waves; color

Overview of the Course

Should I take this course?

You should if:

- You enjoy physics and other technical subjects.
- You are curious about how nature works.
- You are willing to use some math.
- You will be able to attend all or almost all class sessions.

Overview of the Course

Book

- Conceptual Physics, 11th Edition, Hewitt
- You may want another book as well.

Assignments

- Presentation (end of the course).
- 2 Essays.
- Some collected homework worksheets.
- Uncollected homework problems from the textbook. (You still need to do them.)
- Read the textbook.
- Other reading.

Overview of the Course

Evaluation

Quizzes & Incidental HW	25%
Class participation	10%
Essay questions	10%
Midterm	20%
Presentation	10%
Final	25%

Projected Grading Scheme

$$
\begin{aligned}
88\% \rightarrow 100\% &= A \\
75\% \rightarrow 87\% &= B \\
60\% \rightarrow 74\% &= C \\
50\% \rightarrow 59\% &= D \\
0\% \rightarrow 49\% &= F
\end{aligned}
$$

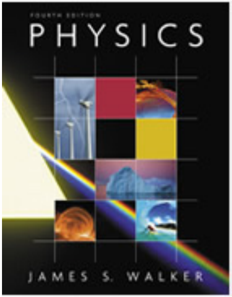
Overview of the Course

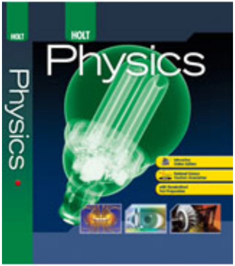
Official Book

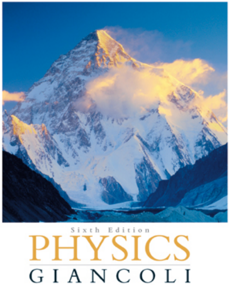
- Conceptual Physics, 11th Edition, Hewitt

Other suggested books

- James S. Walker, “Physics”
- Holt, “Physics”, any edition.
- Giancoli, “Physics: Principles with Applications”, any edition.







Overview of the Course

Note about presentation of calculations

- Underline, box, highlight, or unambiguously emphasize the answer.
- For each problem make sure your method is clear.
- If there is an equation or principle you are using, write it out at the start of your solution.
- If the reasoning is not clear, the answer is not correct.

Science

Science is a process for reasoning about the natural world and making predictions for its behavior.

Science

Science is a process for reasoning about the natural world and making predictions for its behavior.

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

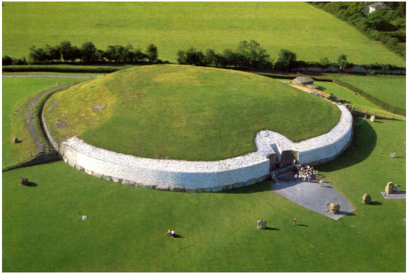
What have people used it for? Why have they cared about it?

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

Early Science: Seasonal Tracking

Many early civilizations wanted to accurately track seasons, to aid farming.

Newgrange, a Neolithic civilization (3,300 – 2,900 BC), Ireland.



arial view, reconstructed façade

Sunlight shaft

[1] Left http://beautifulmeath.com; Right from Wikipedia

Early Science: Seasonal Tracking

Abu Simbal Temple of Rameses II, near Aswan, Egypt

The interior statues (except Ptah, an underworld god) are lit on October 21 and February 21, Rameses' birthday and coronation day.

[1]Right photo from http://www.vacationstogotravel.net, cropped.

Early Science: Seasonal Tracking

Fajada Butte "sun dagger", Chaco civilization (AD 900 – 1150), New Mexico

Summer solstice

Winter solstice

[1]Photo by Harrison Lapahie Jr.

Early Science: Seasonal Tracking

Uxmal, Maya civilization (500 – 1000 AD), Mexico.

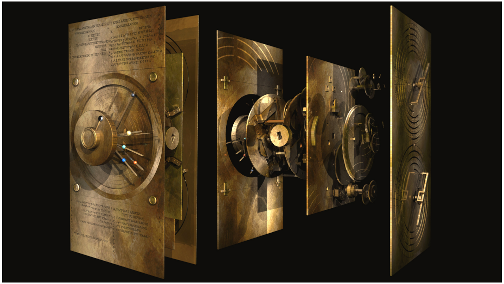
Uxmal

Governor's palace

[1] Left by Palimp Sesto; Rigth by Régis Lachaume.

Early Science: Seasonal Tracking

The Antikythera mechanism, an ancient Greek calculator for astronomical events (200 – 100 BC).



[1]Left from Wikipedia; right pbs.org.

Scientific Statements

A *scientific fact* or *scientific statement* must be

- quantitative and
- falsifiable.

quantitiative

able to be measured, precise

falisifiable

able to be proven wrong

The Scientific Method

The process:

1. Ask a question.
2. Make a guess about the answer: a **hypothesis**
3. Make predictions based on the guess
4. Do experiments to confirm or disprove the guess

   IF the guess is wrong: go back to step 2.
5. If the guess is right, formulate it into the simplest possible rule.

The Scientific Hypotheses

This is not a scientific hypothesis:

The outcomes of any experiment are the result of the undetectable influence of a noodly appendage.

The Scientific Hypotheses

This is not a scientific hypothesis:

The outcomes of any experiment are the result of the undetectable influence of a noodly appendage.

This is a scientific hypothesis:

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.

Quantities, Units, Measurement

If we want to make *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!

An Early Scientific Measurement: the Size of the Earth

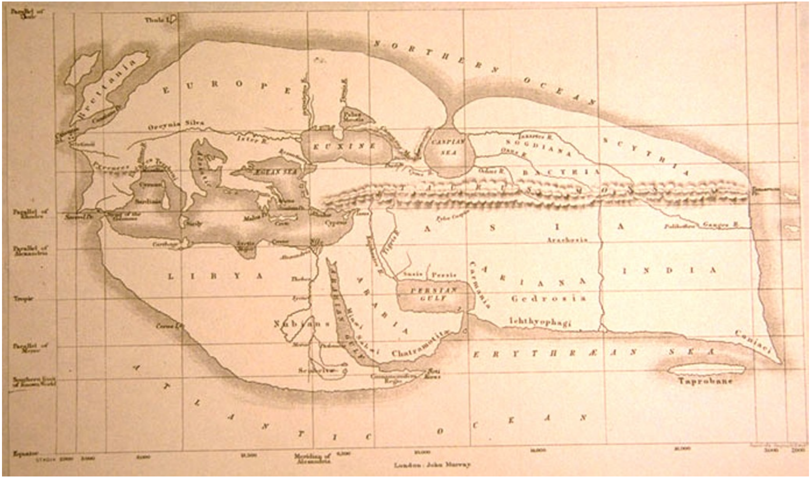
Eratosthenes was a Greek-North African poet, mathematician, geographer and astronomer.

He was the chief librarian of the Library of Alexandria.

Around 235 BCE he came up with a way to measure the size of the Earth.

An Early Scientific Measurement: the Size of the Earth

Eratosthenes was interested in geography and created a map of the known world, thought to look like this:



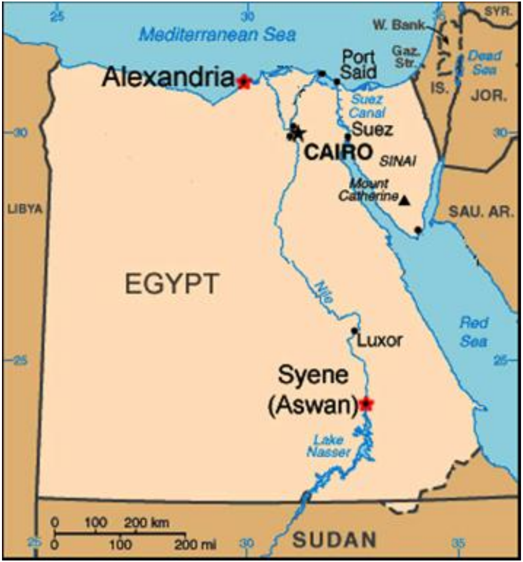
[1]Map from Wikipedia.

Measuring the Size of the Earth

Eratosthenes knew

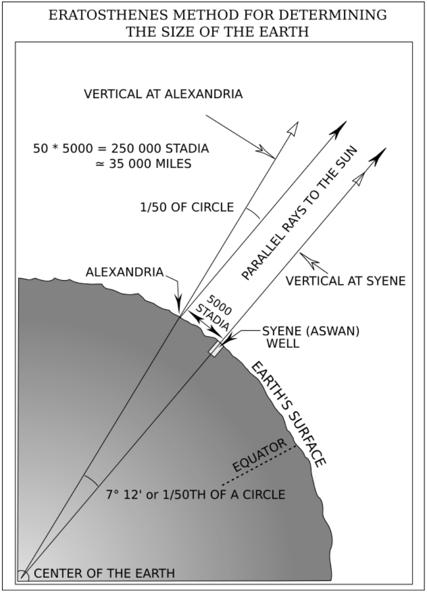
- At noon on the summer solstice (June 22) the sunlight shines directly downward in Syene (now called Aswan).
- Alexandria is 5000 stadia (800 km) north of Syene.
- The sun casts shadows at that time in Alexandria.

Measuring the Size of the Earth



[1]Map from http://www.iucaa.ernet.in/~scipop

Measuring the Size of the Earth



[1]Map from Wikipedia.

Measuring the Size of the Earth

Eratosthenes was able to estimate the size of the Earth:

- The angle between Syene and Alexandria is 1/50-th of a circle ($7.1^\circ/360^\circ$).

Measuring the Size of the Earth

Eratosthenes was able to estimate the size of the Earth:

- The angle between Syene and Alexandria is 1/50-th of a circle ($7.1^\circ/360^\circ$).
- That means that the distance from Syene to Alexandria is 1/50-th of the circumference of the Earth!
- The circumference of the Earth is $\sim 40,000$ km.

Using $C = 2\pi r$, we can find the radius of the Earth, 6370 km.

Measuring the Size of the Earth

Eratosthenes was able to estimate the size of the Earth:

- The angle between Syene and Alexandria is 1/50-th of a circle ($7.1^\circ/360^\circ$).
- That means that the distance from Syene to Alexandria is 1/50-th of the circumference of the Earth!
- The circumference of the Earth is $\sim 40,000$ km.

Using $C = 2\pi r$, we can find the radius of the Earth, 6370 km.

Interestingly, Christopher Columbus did not believe this calculation was right...

Scientific Statements

The size of the Earth is scientific fact, given with some precision.

Currently, NASA quotes the

- polar radius of the Earth as 6356.8 ± 0.05 km
- equatorial radius of the Earth as 6378.1 ± 0.05 km

Some Questions from Hewitt

Page 16,

8. The shadow cast by a vertical pillar in Alexandria at noon on the summer solstice is found to be 1/8 the height of the pillar. The distance from Alexandria to Syene is 1/8 of the Earth's radius. Is there a geometric connection between these two 1-to-8 ratios?

Some Questions from Hewitt

Page 16,

8. The shadow cast by a vertical pillar in Alexandria at noon on the summer solstice is found to be 1/8 the height of the pillar. The distance from Alexandria to Syene is 1/8 of the Earth's radius. Is there a geometric connection between these two 1-to-8 ratios?

9. If the Earth were smaller than it is, but the Alexandria-to-Syene distance were the same, would the shadow of the vertical pillar in Alexandria be longer or shorter at noon during the summer solstice?

Other Early Scientific Measurements

Aristarchus of Samos was a Greek astronomer and mathematician.

He came up with a way to measure[1]

- the size of the Moon
- the Moon's distance from the Earth
- the distance to the Sun
- the size of the Sun

[1] Aristarchus, *On the Sizes and Distances of the Sun and Moon*

Other Early Scientific Measurements

He came up with a way to measure

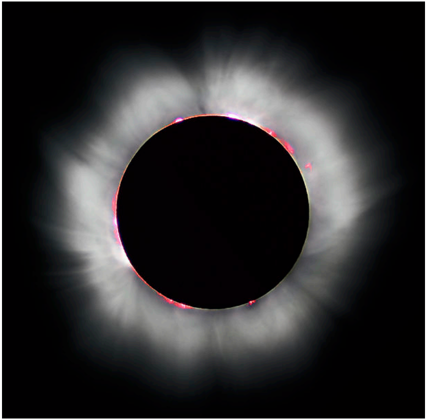
- the size of the Moon...

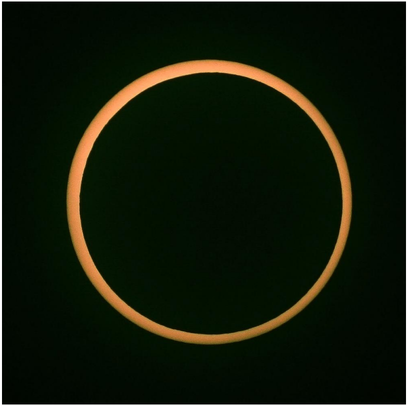
[2]Total solar eclipse, Wikipedia, Luc Viatour.
[3]Annular (ring) eclipse, Wikipedia, Jefferson Teng.

Other Early Scientific Measurements

He came up with a way to measure

- the size of the Moon...





[2]Total solar eclipse, Wikipedia, Luc Viatour.
[3]Annular (ring) eclipse, Wikipedia, Jefferson Teng.

Other Early Scientific Measurements

- the size of the Moon
- the Moon's distance from the Earth
- the distance to the Sun
- the size of the Sun

Other Early Scientific Measurements

- the size of the Moon
- the Moon's distance from the Earth
- the distance to the Sun
- the size of the Sun

$$\frac{\text{diameter}}{\text{distance}} = \frac{1}{110}$$

Other Early Scientific Measurements

- the size of the Moon
- the Moon's distance from the Earth
- the distance to the Sun
- the size of the Sun

$$\frac{\text{diameter}}{\text{distance}} = \frac{1}{110}$$

$$\text{diam}_{\text{Moon}} = 3,474 \text{ km}$$

$$\text{dist}_{\text{Moon}} = 384,400 \text{ km}$$

$$\text{diam}_{\text{Sun}} = 1,391,684 \text{ km}$$

$$\text{dist}_{\text{Sun}} = 149,600,000 \text{ km}$$

What is Physics?

We've seen some examples early scientific measurements, but are they part of physics?

Physics is the science of fundamental interactions of matter and energy.

What is Physics?

We've seen some examples early scientific measurements, but are they part of physics?

Physics is the science of fundamental interactions of matter and energy.

How is it done?

Make a simplified model of the system of interest, then apply a principle to make a quantitative prediction.

What is Physics?

We've seen some examples early scientific measurements, but are they part of physics?

Physics is the science of fundamental interactions of matter and energy.

How is it done?

Make a simplified model of the system of interest, then apply a principle to make a quantitative prediction.

System

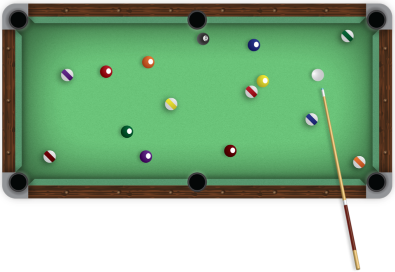
Any physical object or group of objects about which we would like to make quantitative predictions.

What is Physics?

System

Any physical object or group of objects about which we would like to make quantitative predictions.

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.



[1]Image from http://vhuzi.com/.

What is Physics?

Model

A simplified description of a system and its interactions that includes only what is necessary to make predictions.

What is Physics?

Model

A simplified description of a system and its interactions that includes only what is necessary to make predictions.

eg. the billiard balls are made up of atoms, but we can make very accurate predictions about their motion and collisions by just pretending they are uniform rigid spheres.

What is Physics?

Model

A simplified description of a system and its interactions that includes only what is necessary to make predictions.

eg. the billiard balls are made up of atoms, but we can make very accurate predictions about their motion and collisions by just pretending they are uniform rigid spheres.

Hypothesis

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

What is Physics?

Theory

A refined quantitative model for making predictions that has been verified by multiple groups of researchers and is understood to have some regime of validity.

What is Physics?

Theory

A refined quantitative model for making predictions that has been verified by multiple groups of researchers and is understood to have some regime of validity.

eg. Newtonian Mechanics - very accurately predicts the motion of billiard balls and the motion of planets,

- but not the perihelion precession of Mercury,
- and not the behavior of electrons in atoms.

What is Physics?

Theory

A refined quantitative model for making predictions that has been verified by multiple groups of researchers and is understood to have some regime of validity.

eg. Newtonian Mechanics - very accurately predicts the motion of billiard balls and the motion of planets,

- but <u>not</u> the perihelion precession of Mercury,
- and <u>not</u> the behavior of electrons in atoms.

Valid when

- object's velocities $v << c$, the speed of light,
- gravitational fields are not too strong,
- distances are much bigger than ℓ_p (Planck length), etc.

What is Physics?

Law

A pattern in nature that can be described very concisely, often in a single mathematical equation.

What is Physics?

Law

A pattern in nature that can be described very concisely, often in a single mathematical equation.

eg. $\mathbf{F} = m\,\mathbf{a}$

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

What is Physics?

Theories and laws are expressed in terms of mathematics and equations.

They are precise and quantitative.

Mathematics is the language of science.

What Physical Theories Do You Know Of?

?

Quantities, Units, Measurement

If we want to make *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!

Quantities, Units, Measurement

If we want to make *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!

Make sure you include units! Also, units can be helpful...

Defining Units

Originally, units were arbitrary.

One unit of length (the cubit) was the length of a forearm and hand.

This is convenient, but not very precise since different people have different length arms.

Defining Units

Originally, units were arbitrary.

One unit of length (the cubit) was the length of a forearm and hand.

This is convenient, but not very precise since different people have different length arms.

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.

However, this is not any easy distance to measure.

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.

However, this is not any easy distance to measure.

In 1799 a physical bar was made that was officially declared to have marks on it 1 meter apart.

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.

However, this is not any easy distance to measure.

In 1799 a physical bar was made that was officially declared to have marks on it 1 meter apart.

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.

Units: Time

The SI unit of time is the *second*, s.

The second was originally defined (via the minute and hour) as 1/86,400-th of a day.

Units: Time

The SI unit of time is the *second*, s.

The second was originally defined (via the minute and hour) as 1/86,400-th of a day.

All clocks are based on oscillating systems - systems that repeat the same motion over and over again.

Units: Time

The SI unit of time is the *second*, s.

The second was originally defined (via the minute and hour) as 1/86,400-th of a day.

All clocks are based on oscillating systems - systems that repeat the same motion over and over again.

For example, the Earth rotates over and over again. A pendulum swings back and forth.

Units: Time

The SI unit of time is the *second*, s.

The second was originally defined (via the minute and hour) as 1/86,400-th of a day.

All clocks are based on oscillating systems - systems that repeat the same motion over and over again.

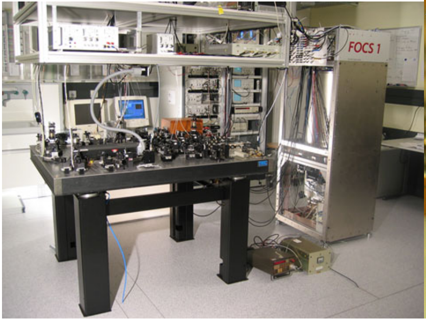
For example, the Earth rotates over and over again. A pendulum swings back and forth.

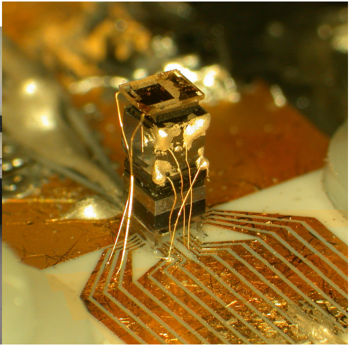
It is now more precisely defined in terms of the behavior of Cesium atoms. (Rubiduim and other elements are also used.)

Units: Time

The second is now more precisely defined in terms of the behavior of Cesium atoms. (Rubiduim and other elements are also used.)

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.

Units: Time

Measuring time accurately is very important for navigation.

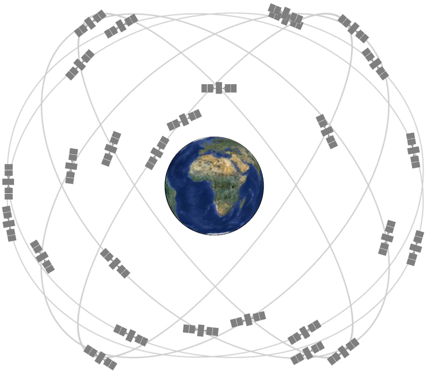
Accurate clocks were needed to help ships determine their longitude (East-West position) in the 1700s.

This lead to the development of clocks that worked based on the oscillations of springs rather than pendulums.

[1]Harrison H5 naval chronometer. Photo from user Racklever, Wikipedia.

Units: Time

Measuring time accurately is very important for navigation.



Now most navigation systems use the Global Positioning System (GPS) a constellation of satellites carrying atomic clocks.

[1]Image from GPS.gov.

Units: Mass

The *kilogram*, kg, is the SI unit of mass.

Loosely speaking, mass is a measure of the amount of matter in an object.

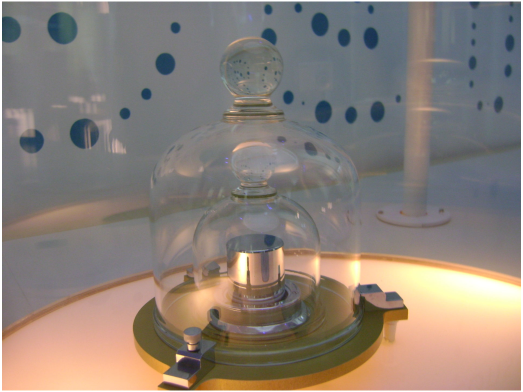
The kilogram currently does not have a definition in terms of natural phenomena.

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.

Units: Mass

Now the official 1-kilogram sample, the *international prototype kilogram* is a cylinder of platinum and iridium stored near Paris.



An alternative definition of the kilogram in terms of a fundamental constant has been proposed and at some point may be adopted.

[1]A replica of the prototype kilogram, Wikipedia.

Summary

- Scientific facts, hypotheses, theories, and laws
- Mearesurements
- Physics as modeling the natural world

Homework

- Get the book: Conceptual Physics, 11th Edition, Hewitt
- Read Chapter 1