PHYC10003 Physics 1

Lecture 1: Motion

Mass, length and time

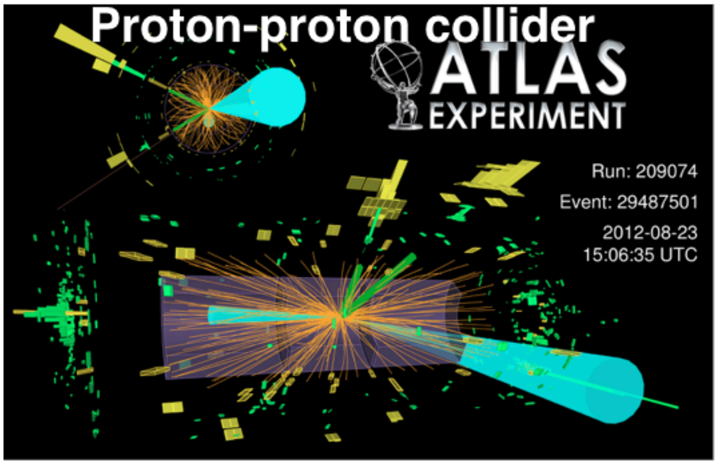
Who am I?

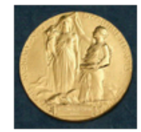
- Associate Professor Phillip Urquijo, purquijo@unimelb.edu.au
- Experimental Particle Physics

- **Origin of mass of fundamental particles**? ATLAS experiment at the Large Hadron Collider at CERN in Switzerland
- **Where did the anti-matter go**? Belle and Belle II experiments at SuperKEKB at KEK in Japan
- **What is the particle nature of dark matter**? SABRE experiment at Stawell Underground Physics Laboratory, in Stawell

Origin of Mass: ATLAS experiment

After over 30 years, the LHC experiments ATLAS and CMS discovered a particle consistent with the Higgs boson





Nobel Prize in Physics 2013: François Englert & Peter W. Higgs

Academics

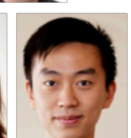
Prof
E Barberio

Prof
G Taylor

A/Prof
P Urquijo

Postdocs

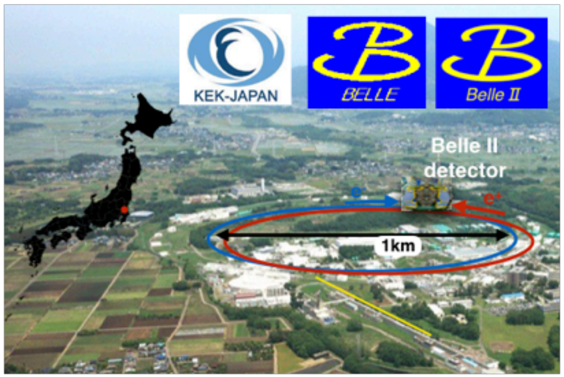
PhD

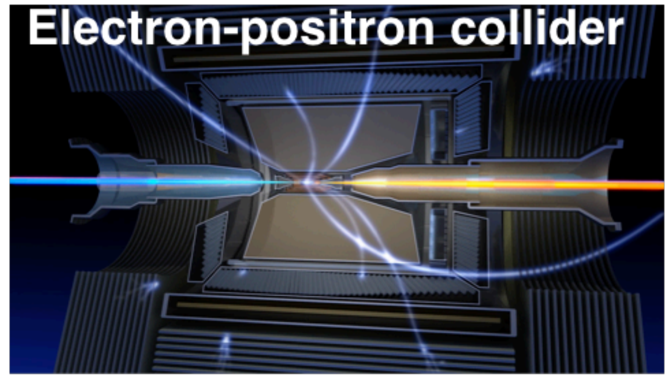


+ MSc

Antimatter disappearance: Belle(II) experiment

The Belle experiment discovered matter-antimatter asymmetries in the 3rd generation of quarks. It led to the Nobel prize in 2008. The successor Belle II starts in 2019!

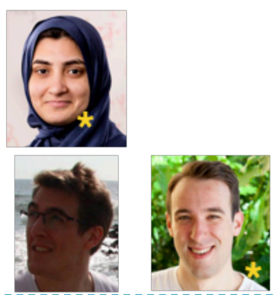




Academics

A/Prof M Sevior

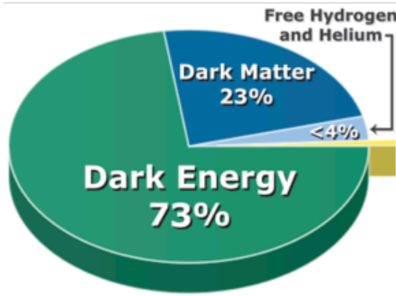
Postdocs



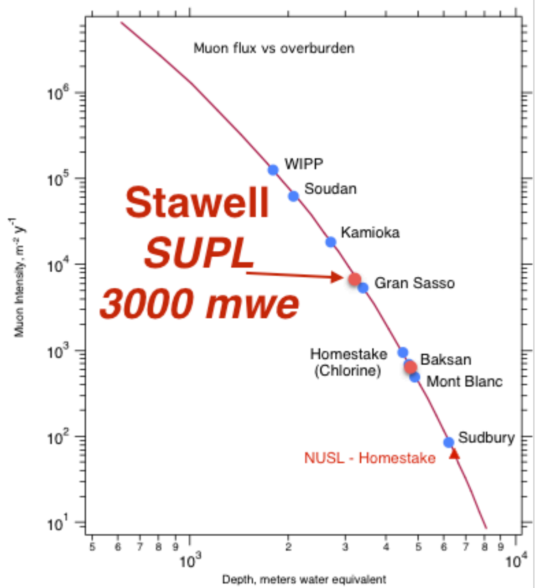
PhDs

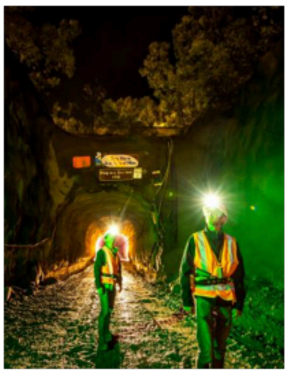
+ MSc

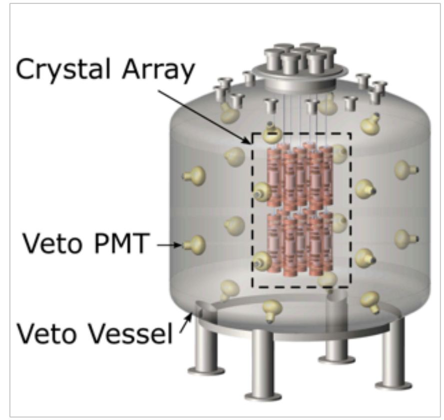
Dark matter: SABRE experiment @ Stawell



First deep underground lab in Southern Hemisphere

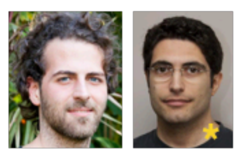




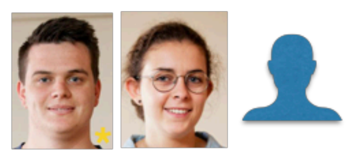


Academics

Postdocs



PhD



+ MSc

How can I get help with Physics?

- *Everything* you need to know is on the Learning Management System (LMS): www.lms.unimelb.edu.au

- First Year Coordinator: Jacinta den Besten
- Laboratory manager: Melaku Alemu
- You will be assigned a tutorial time with a tutor – *your tutor is there to help*!
- Laby IDEAS Centre – a drop-in facility for Physics

PHYC10003: Assessment

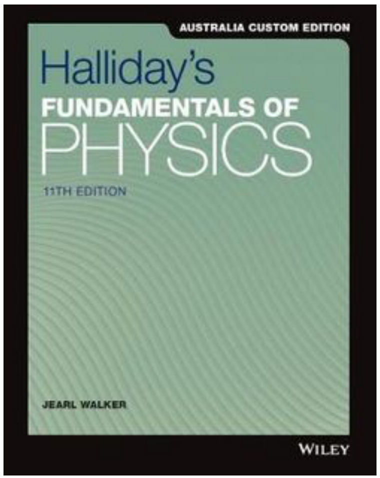
- Final examination: 60%
- Ten online homework exercises for assessment and feedback: 15%
- Laboratory work: 25%

Note that to pass the subject you must satisfactorily complete the Laboratory work with at least 80% attendance and submission.

Past examination papers for *all* UoM subjects are available online from the University Library

PHYC10003: Essential Resources

- Text: Resnick and Halliday, Fundamentals of Physics 11^{th} Edition, Jearl Walker, John Wiley and Sons



Instructions for acquiring the hardcopy and e-book versions of the text and the Laboratory Book may be found on LMS

- Laboratory Book: you require a blue University of Melbourne Physics Laboratory Book (loose sheets or exercise books are *not* acceptable)

SSLC-Staff-Student Liaison Committee

- Each Lecture Stream elects a student representative
- Student rep reports on lectures, practicals, tutorials, teaching materials or anything of concern
- Committee meets twice a Semester
- Report goes direct to Head of School of Physics
- We really do want to make the entire subject as effective as possible
- There's pizza!

Mechanics…let the Physics begin!

In the first six weeks we will discuss *classical mechanics*:

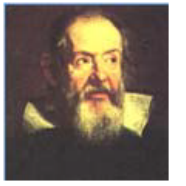
1. Motion and Vectors
2. Force and Newton's Laws
3. Energy, work and power
4. Rotational motion
5. Angular momentum

What, if anything, do these phenomena have in common?

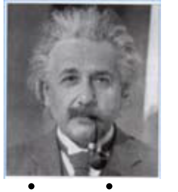
Mechanics

The three principles of relativity!

i. **Galilean relativity.** Galileo (1632): Laws of mechanics independent of the speed of the laboratory



i. **Special Relativity**. Einstein (1905): laws of motion independent of speed of laboratory ***and*** speed of light is a constant for all observers



ii. **General Relativity**. Einstein (1915): laws of physics in an accelerating laboratory are the same as those for a laboratory in a gravitational field.

Mechanics

- **Galileo's Principle:** two 'laboratories' moving at *uniform* relative speed, v, will describe a single physical event using the variables (x, t) and (x', t'), where

$$x' = x + vt$$
$$t' = t$$

The laws of mechanics are the same in any *inertial frame* (ie moving at constant speed). Whatever these "laws" are, they are invariant under the transformation $(x, t) \rightarrow (x', t')$.

These 'laws' are valid for $v \ll c$; they connect **mass, length and time.**

1.1 Measurement

- Physics and engineering are based on the precise measurement of physical quantities
- Therefore, we need:
  1. Rules for measurement and comparison
  2. Units for measurement
- A **unit**:
  - Is the unique name assigned to the measure of a quantity (mass, time, length, pressure, etc.)
  - Corresponds to a **standard**, a physical quantity with value 1.0 unit (e.g. 1.0 metre = distance traveled by light in a vacuum over a certain fraction of a second)

1.1 Measurement

- There are many different physical quantities, but not all are independent: distance vs. speed (distance/time)
- **Base quantities**:
  - Are *seven* fundamental quantities but only three are needed for mechanics: length, time, mass
  - All have been assigned standards
  - Are used to define all other physical quantities

1.1 Units – base units (pre May 2019)

1. **metre:** distance travelled by light in a vacuum in 1/299792458 sec
2. **kilogram:** defined by a particular object in France.
3. **second:** 9192631770 periods of a particular wavelength of light emitted by cesium 133.
4. **ampere:** the current that produces a force of $2\text{x}10^{-7}$ newton on two infinite parallel wires one metre apart.
5. **kelvin:** 1/273.16 of the thermodynamic temperature of the triple point of water.
6. **mole:** the amount of a substance that contains as many elementary entities as there atoms in 0.012 kg of pure carbon 12.
7. **candela:** luminous intensity of a source emitting light of frequency $540\text{x}10^{12}$ Hz that has radiant intensity of 1/683 watt per steradian.

1.1 Units- physical standards

National prototype kilogram K20, platinum and iridium alloy.

Standard metre: National prototype metre bar. Given to the US in 1887, it served as the standard until 1960!

Images: wikicommons

1.1 Units – who maintains them?

NIST National Institute of Standards and Technology
U.S. Department of Commerce

NPL
National Physical Laboratory

Australian Government
Department of Industry, Innovation and Science
National Measurement Institute

1.1 Units

- **SI units** (the metric system) form the International System of Units
- SI has many derived units, which are written in terms of base units
  - Joules (work-energy): 1 J = 1 kg m^2/s^2
  - Watts (power): 1 W = 1 J/s = 1 kg m^2/s^3

1.1 Units

- **Scientific notation** employs powers of 10 to write large or small numbers

$$3\,560\,000\,000 \text{ m} = 3.56 \times 10^9 \text{ m}$$

$$0.000\,000\,492 \text{ s} = 4.92 \times 10^{-7} \text{ s.}$$

- A **conversion factor** is
  - A ratio of units that is equal
  - Used to convert between units

- Units obey the same algebraic rules as variables and numbers

$$2 \text{ min} = (2 \text{ min})(1) = (2 \cancel{\text{min}})\left(\frac{60 \text{ s}}{1 \cancel{\text{min}}}\right) = 120 \text{ s.}$$

1.1 Units

- **Significant figures** are meaningful digits
- Generally, round to the least number of significant figures of the given data
  - 25 x 18 → 2 significant figures; 25 x 18975 → still 2
  - Round up for 5+ (13.5 → 14, but 13.4 → 13)
- Significant figures are not decimal places
  - 0.00356 has 5 decimal places, 3 significant figures
- In general, trailing zeros are not significant

  In other words, 3000 *may* have 4 significant figures

  but usually 3000 will have only 1 significant figure!

When in doubt, use scientific notation 3.000×10^3 or 3×10^3

1.1 Units

Examples Chain-link conversions:

- $1.3\text{ km} \times (1000\text{ m})/(1\text{ km}) = 1300\text{ m} = 1.3 \times 10^3$
- $0.8\text{ km} \times (1000\text{ m})/(1\text{ km}) \times (100\text{ cm})/(1\text{ m}) = 80\,000\text{ cm}$

  $= 8 \times 10^4$
- $2845\text{ mm} \times (1\text{ m})/(1000\text{ mm}) \times (3.281\text{ ft})/(1\text{ m}) = 9.334\text{ ft}$

1.1 Length

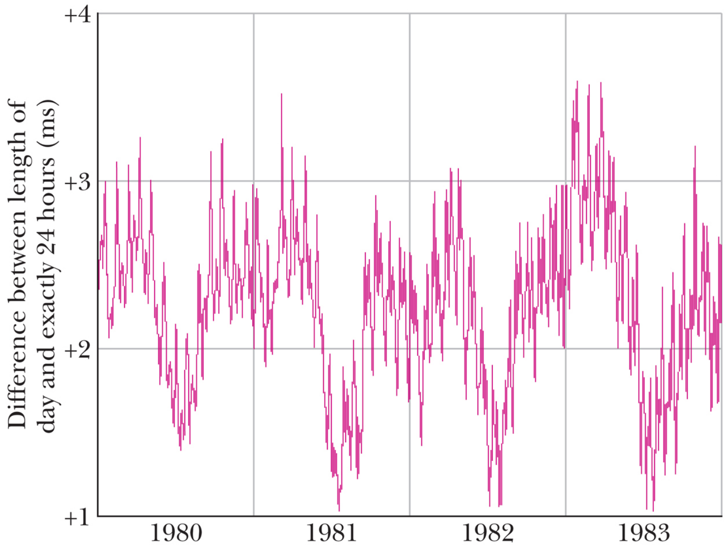
- Needs for accuracy in science have driven changes in the standards for units
- In the past, 1 metre has been defined by:
  1. One ten-millionth of the distance from the North pole to the equator
  2. A platinum-iridium **standard metre bar** kept in France
  3. 1 650 763.73 wavelengths of an emission line of Kr-86
- In each transition, the new distance was chosen so that the approximate length of 1 metre was preserved

1.2 Time

- Any standard of time needs to be able to answer:
  - *When* did a thing happen?
  - What was its *duration*?
- Times follow the same conversion process as lengths
- Standards of time in the past have included:
  1. Rotation of Earth
  2. Quartz vibrations
  3. Atomic clocks (cesium), with time signals sent out by radio so others can calibrate their clocks

1.2 Time

- The variation in the length of a day as measured by an atomic clock:



 halliday_10e_fig_01_02

- The vertical scale here amounts to only 3 ms, or 0.003 s.
- This shows the precision of atomic clocks, and the relative imprecision of Earth's rotation (affected by tides, winds)

1. **Figure 1-2**

1.3 Mass

- The **standard kilogram** is a cylinder of platinum and iridium stored in France.
- Accurate copies have been sent around the world, other masses can be measured by comparing them against these copies
- The **atomic mass unit** (u) is a second mass standard
  - 1 atom of carbon-12 is assigned a mass 12 u
  - Used for measuring masses of atoms and molecules
  - 1 u = $1.660\ 538\ 86 \times 10^{-27}$ kg (+/- 10×10^{-35} kg)

1.3 Mass and density

- Mass per unit volume is called **density**

$$\rho = \frac{m}{V}$$

Eq. (1-8)

Examples Calculate . . .

- Density of material: (18 kg) / (0.032 m^3) = 560 kg/m^3
- Mass of object: (380 kg/m^3) x (0.0040 m^3) = 1.5 kg
- Volume of object: (250 kg) / (1280 kg/m^3) = 0.20 m^3

Summary

Measurement

- Defined by relationships to base quantities
- Each defined by a standard, and given a unit

SI Units

- International System of Units
- Each base unit has an accessible standard of measurement

Changing Units

- Use chain-link conversions
- Write conversion factors as unity
- Manipulate units as algebraic quantities

Length

- Meter is defined by the distance traveled by light in a vacuum in a specified time interval

Summary

Time

- Second is defined in terms of oscillations of light emitted by a cesium-133 source
- Atomic clocks are used as the time standard

Density

- Mass/volume

$$\rho = \frac{m}{V}$$ **Eq. (1-8)**

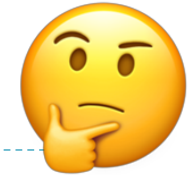
Mass

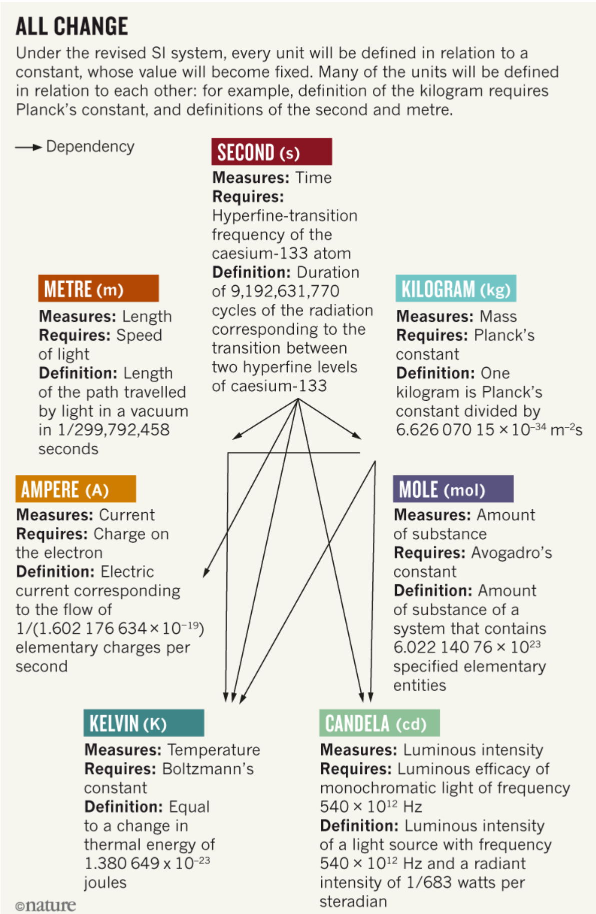
- Kilogram is defined in terms of a platinum-iridium standard mass
- Atomic-scale masses are measured in u, defined as mass of a carbon-12 atom

Preparation for the next lecture

1. Read 2.1-2.6 of the text
2. You will find short answers to the odd-numbered problems in each chapter at the back of the book and further resources on LMS. You should try a few of the simple odd numbered problems from each section (the simple questions have one or two dots next to the question number).

Aside: New system of units (May 20)





To change: the ampere, the kilogram, the kelvin and the mole.