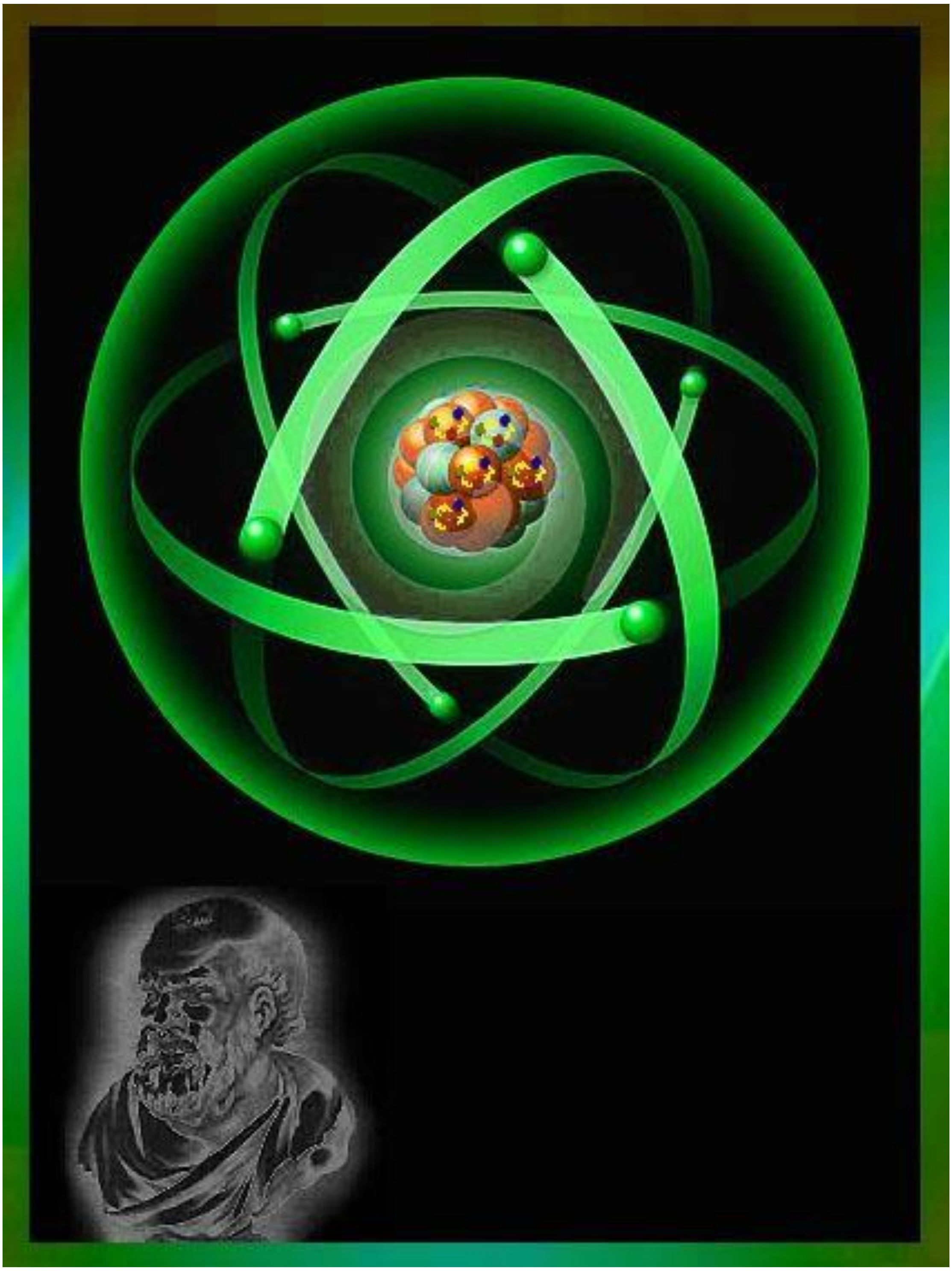
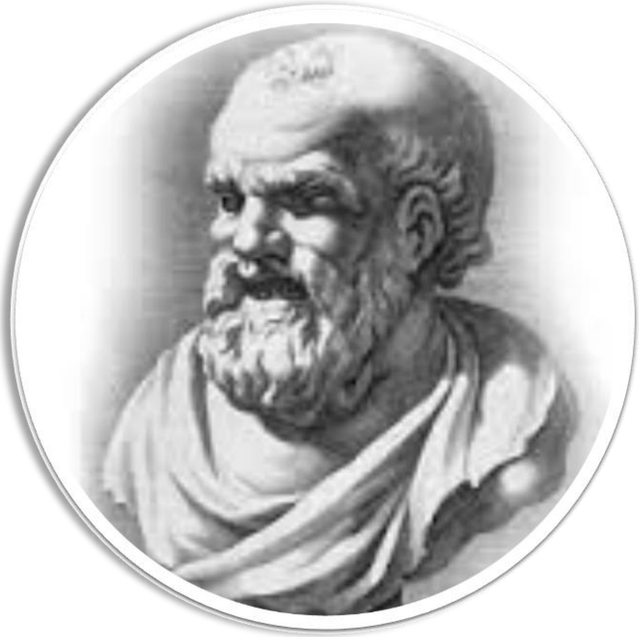


FROM DEMOCRITUS' ATOM TO QUARKS

PART 1	
Topic	” Pleased to meet you, Mr Democritus”, a little chat with an ancient scientist
Subjects	Social Science, History, Science
Level	★★☆
Aims	understand the atomic theory has evolved and has had an impact on society
Skills	reflections, conclusions
Duration	10 minutes introduction – 90 minutes after all the lessons
Resources	webpages - lessons

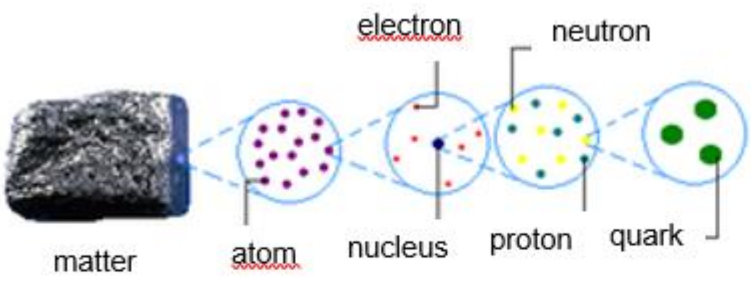
INTRODUCTION

Who was Democritus?



Democritus (460 BCE - 370 BCE) was a Greek philosopher, born in Abdera, who was the first to propose an atomic universe. He was known as the 'laughing philosopher' because of the importance he placed on 'cheerfulness'. Democritus was the first philosopher to put forward that what we refer to as the 'Milky Way' was the light of stars reaching our perception and that the universe may in fact be a multi-verse with other planets sustaining life. He argued that the world, including human beings, is composed of very small particles which he called 'atomos' ("un-cuttables" in Greek) and that these atoms make up everything we see and are. Atoms differ in size, shape, weight and temperature, are always moving, and are invisible. He believed that there is an infinite number of atoms.

Now we know that this theory is outdated and that atoms consist of electrons, protons and neutrons. In 1964 the physicist Marray Gell-Mann even predicted the existence of quarks. Protons and neutrons consist of 3 quarks.



Apart from the atomic theory Democritus also practised mathematics, especially geometry. According to Archimedes he was the first to come up with the idea that the volume of a cone was one third of the volume of a cylinder. You will learn more about that later on.

A last peculiarity we don't want to keep from you is the fact that Democritus also wrote about music. Not so very strange, since different atoms also lead to differences in sound and pitch.

Activity 1

In the upcoming lessons you will learn a little about Democritus. At the end of the activity we will ask you to play a role play. Subdivide the class into groups of 4 students.

One of the students is Democritus. He is wondering about how the world has changed since his own days. Based on the lessons you have within this topic, someone will tell him how his theory has evolved through time. You can clarify this story with a PowerPoint presentation showing pictures about the lesson content.

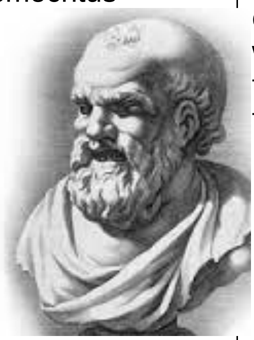
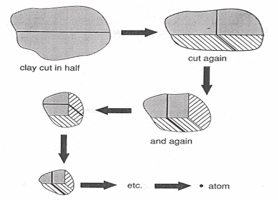
Of course Democritus is also curious about the advantages and disadvantages his insights have led to. The two remaining students will try to demonstrate these with some historical examples. And perhaps Democritus may even end the conversation with a message for the present-day world and its inhabitants.

That's for you to decide.

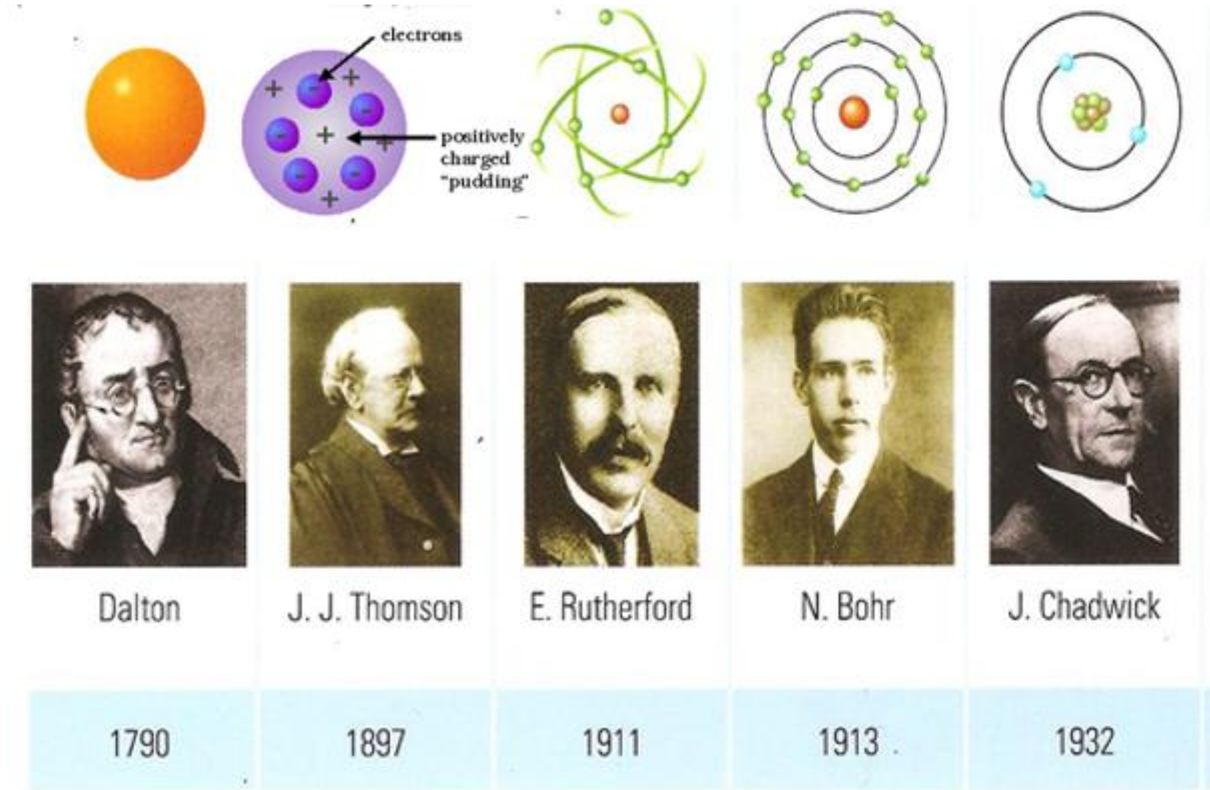
PART 2	
Topic	CERN
Subjects	Computing, Engineering, Chemistry
Level	★
Aims	Students understand the development of atomic theory. Students are aware of the significance of CERN, its meaning and organization. Students comprehend how the particle accelerators work.
Skills	Students are able to answer the questions about the given topic. Students accomplish the activities concerning the given topic/ subject matter/ theme.
Duration	100 minutes of classroom work
Resources	• a computer • internet

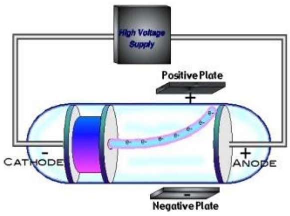
INTRODUCTION

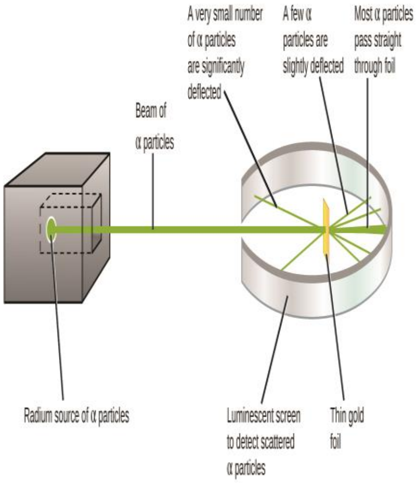
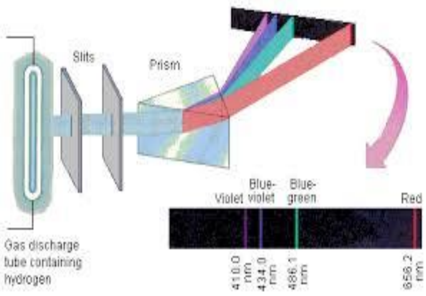
Democritus

When	Who	Technology	Theory
400 B.C.	Democritus 	He took a seashell and broke it in half. He then took half of it and broke it in half over and over and over again until he was finally left with a fine powder. He then took the smallest piece of it and tried to cut it but he could not.  Democritus' concept of the atom	• Atoms are small hard particles. They differ in size, shape, mass. • They are always moving. • They form different materials by joining together.

The evolution of the atomic theory after Democritus



When	Who	Technology	Theory
1790	John Dalton 	Experiments with gases	• Elements are made of extremely small particles called atoms. • Atoms of a given element are identical in size, mass and other properties. • Atoms can't be subdivided, created or destroyed. • In chemical reactions, atoms are combined, separated or rearranged.
1897	John Thomson 	• a cathode ray tube with a positive and negative side • two plates on the outside- positive and negative • The cathode ray was deflected towards the positive plate. • This suggests that the ray is negative. 	• An atom consists of a sphere of positive charge with negatively charged electrons embedded in it. • The positive and the negative charges in an atom are equal in magnitude, due to which an atom is electrically neutral.

When	Who	Technology	Theory
1911	Ernest Rutherford 	He shot α-particles onto a gold foil.  	• The entire positive charge is confined in a small core, called the nucleus. The positively charged particle is called a proton. • Most of the volume of an atom is empty space. • The negatively charged electrons circle outside the nucleus. • An atom is electrically neutral.
1913	Niels Bohr 	The atomic emissions spectrum of the hydrogen atom When white light is diffracted with a prism, all the colours of the visible spectrum can be seen. However when the light given off by the hydrogen atom passes through a prism, only certain colours of light can be seen.  	• The electron travels in circular orbits around the nucleus. • Each orbit can hold a specific number of electrons. • Each orbit has its own energy level. • Energy is emitted from the atom when the electron jumps from one orbit to another closer to the nucleus.

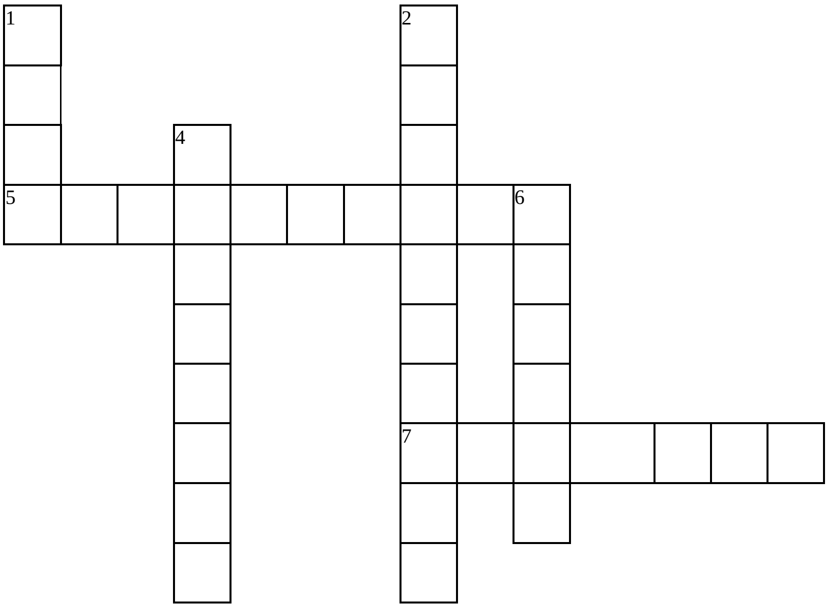
When	Who	Technology	Theory
1932	James Chadwick 	He bombarded beryllium atoms with alpha particles.	• The nucleus consists of protons and neutrons.
1968-	Different scientists	New elements have been created by bombarding the existing nuclei with various subatomic particles.	• Protons and neutrons are made up of smaller particles, called quarks. • Quarks are held to each other by particles scientists called gluons.

Activity 1

Join a partner and try to solve the crossword puzzle without looking back at the information above.

How many can you fill in?

To complete the exercise you can use the available information above.



Across

5. He shot α-particles onto a gold foil.

7. With a cathode ray tube he discovered the electron.

Down

1. observations of the atomic emissions spectrum

2. Matter consists of invisible particles called atoms.

4. He realized the nucleus consist of protons and neutrons.

6. He made experiments with gases.

Activity 2

Use the internet.

1) Where is CERN located?

____

2) What does CERN stand for?

____

3) What is CERN's objective?

____

WHAT ABOUT CERN?

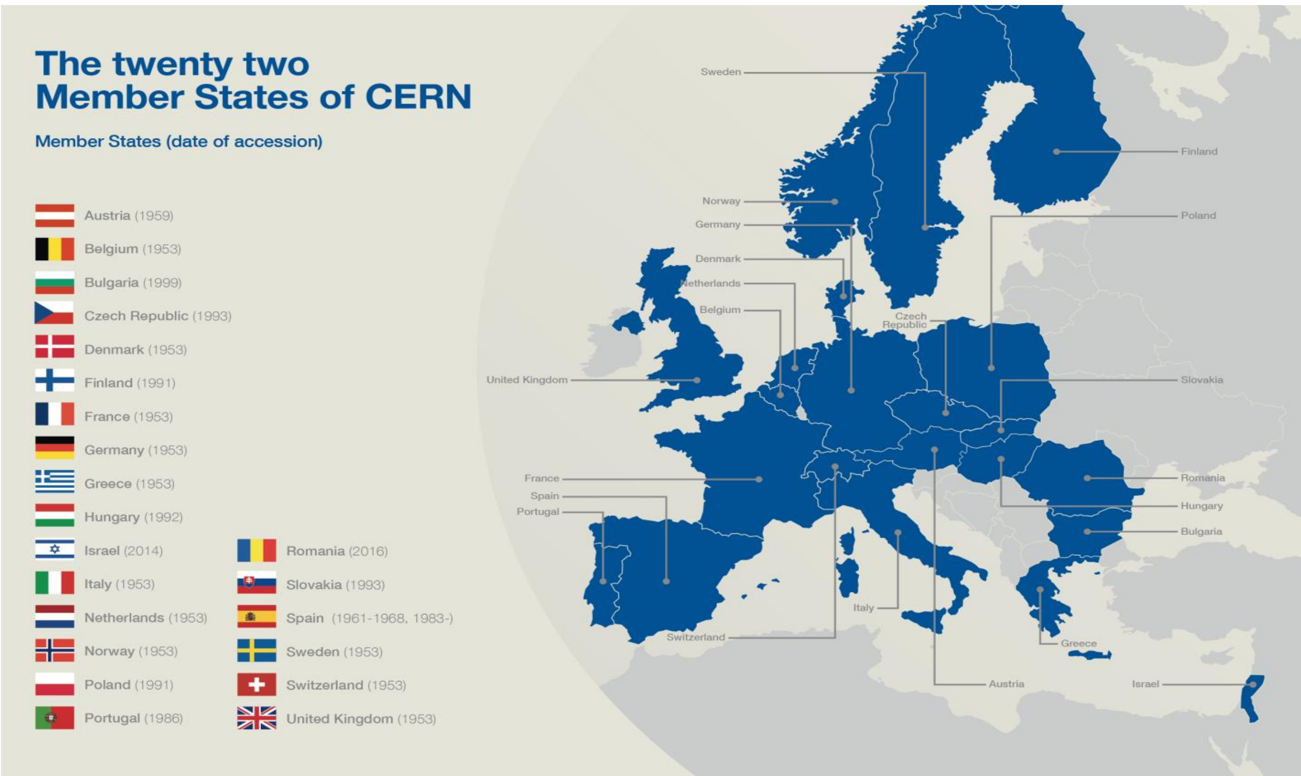
The name CERN is an acronym derived from the French "Conseil Européen pour la Recherche Nucléaire", or European Council for Nuclear Research.

The organization is based in a northwest suburb of Geneva on the Franco–Swiss border, ([46°14′3″N 6°3′19″E](#))

Cern was founded in 1954. The 12 founding states were Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and Yugoslavia. Today CERN has 22 member states, that make a contribution to the capital and operating costs. Many other states participate as non-members or observers.

At CERN physicists and engineers are probing the fundamental structure of the universe. They use the world's largest and most complex scientific instruments to study the basic constituents of matter – the fundamental particles. The particles are made to collide together at close to the speed of light. The process gives the physicists clues about how the particles interact, and provides insights into the fundamental laws of nature.

Over 600 institutes and universities around the world use CERN's facilities.



Kinds of accelerators

An accelerator is a device that accelerates charged particles to very high speeds using electric and/or magnetic fields.

Modern accelerators fall into two basic categories:

- **Linear Accelerators**

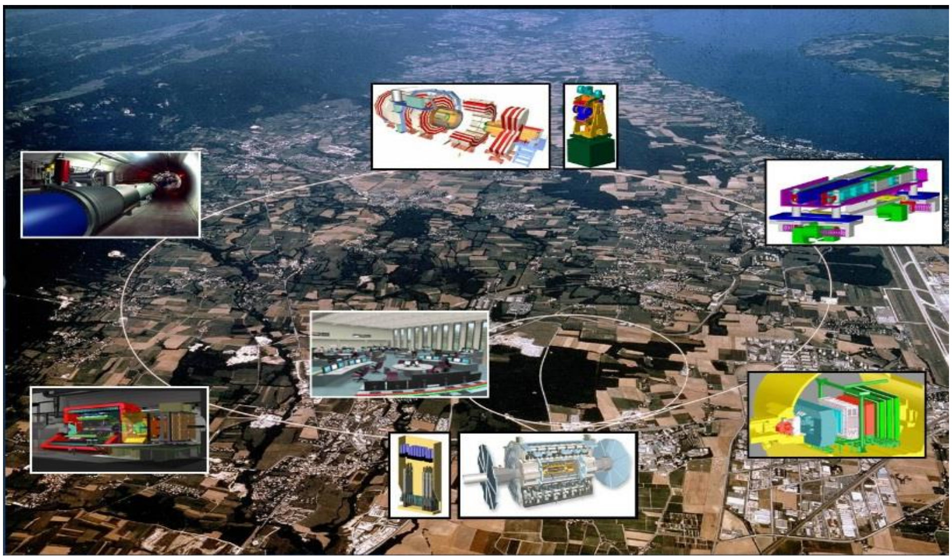
In linear accelerators, particles are accelerated in a straight line, often with a target to create a collision.

- **Circular Accelerators**

Circular accelerators propel particles along a circular path using electromagnets until the particles reach desired speeds/energies.

Particles are accelerated in one direction around the accelerator, while anti-particles are accelerated in the opposite direction.

CERN's current and future accelerators



Accelerator	Function
Linear accelerator 2	is the starting point for the protons.
Linear accelerator 3	is the starting point for the ions used in physics experiments at CERN.
Linear accelerator 4	boosts negative hydrogen ions to high energies. It will become the source of proton beams for the Large Hadron Collider in 2020.
The Antiproton Decelerator	Not all "accelerators" increase a particle's speed. The AD slows down antiprotons so they can be used to study antimatter.
The Large Hadron Collider	The 27-kilometre LHC is the world's largest particle accelerator. It collides protons or lead ions at energies approaching the speed of light.
The Low Energy Ion Ring	LEIR takes long pulses of lead ions from Linac 3 and transforms them into the short, dense bunches suitable for injection into the Large Hadron Collider.
The Proton Synchrotron	A workhorse of CERN's accelerator complex, the Proton Synchrotron has juggled many types of particles since it was first switched on in 1959.
The Proton Synchrotron Booster	Four superimposed synchrotron rings receive protons from the linear accelerator, boost them to 800 MeV and inject them into the Proton Synchrotron.
The Super Proton Synchrotron	The second-largest machine in CERN's accelerator complex provides a stepping stone between the Proton Synchrotron and the LHC.

The Large Hadron Collider (LHC)

The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator. It first started up on 10 September 2008. The LHC consists of a 27-kilometre ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way.

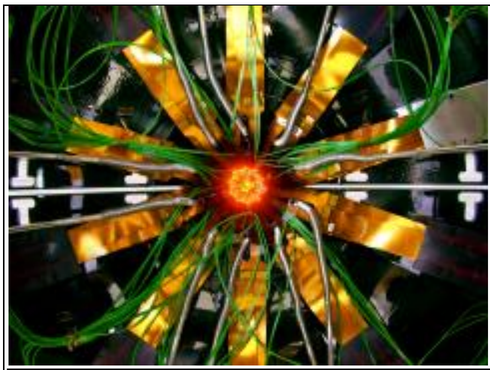
Inside the accelerator, two high-energy particle beams travel at close to the speed of light before they are made to collide. The beams travel in opposite directions in separate beam pipes – two tubes kept at ultrahigh vacuum. They are guided around the accelerator ring by a strong magnetic field maintained by superconducting electromagnets.

The LHC is helping physicists to:

- create new particles and identify their components
- reveal the nature of the interactions between particles
- create an environment similar to the one present at the origin of our Universe: the Big Bang

The LHC involves four experiments, with detectors as ‘big as cathedrals’:

ALICE, ATLAS, CMS and LHCb .



ALICE

ATLAS

CMS

LHCb

Particles collide at high energies inside these detectors, creating new particles that decay in complex ways as they move through layers of subdetectors.

The subdetectors register each particle's passage and microprocessors convert the particles' paths and energies into electrical signals, combining the information to create a digital summary of the "collision event".

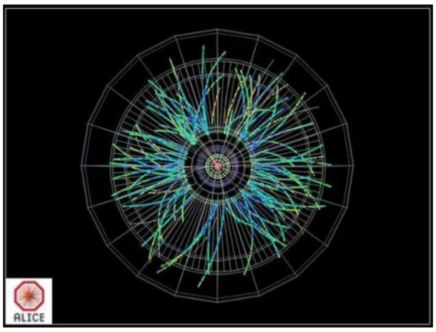
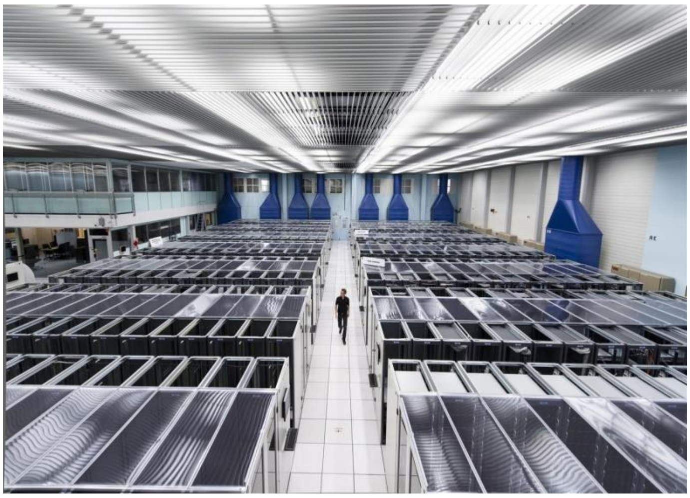


Fig : Cascade of particles after the collision of a lead ion and a proton

Some incredible facts about LHC

- the largest most complex electronic instrument on the planet
- one of the coldest places in the Galaxy -271^{o}C (South Pole: -80^{o}C, outer space:-270^o C)
- one of the hottest places in the Universe 10 billion °C (sun: 20 million °C)
- emptier than outer space
- It is at 100 m depth in a 27 km circular tunnel.
- 9,000 magnets guide two beams of protons in a circular path.
- The accelerated protons reach 99.9% of the speed of light (300,000 km/s).
- Every second 2 billion protons smash against each other inside the LHC.
- It takes 120 MW to run the LHC (the power used by 120,000 houses per month).

Computing



Experiments at CERN generate colossal amounts of data. The Data Centre stores it, and sends it around the world for analysis.

The LHC produces 600 million events per second. These events are filtered to 100,000 per second and sent for digital reconstruction. Specialized algorithms further process the data, leaving only 100 or 200 events of interest per second. These raw data are recorded onto servers at the CERN Data Centre at a rate around 1.5 CDs per second (1 GB per second).

Interesting facts about the Data Centre

- The Data Centre processes about one petabyte of data every day - the equivalent of around 210,000 DVDs.
- 6,000 changes in the database are performed every second.
- The centre hosts 11,000 servers with 100,000 processor cores.
- Disks are used for short-term storage. Magnetic tapes, retrieved by robots, are used for long-term storage
- Cooled air is distributed to cool the servers.
- The power capacity is 3.5 MW.
- Batteries protect all the equipment from short-term power cuts and diesel generators protect from long-term power cuts.
- 18 kV high voltage is converted to 220 V.
- 35,000 km of optical fiber transfer the data from and to the Data Centre.

WLHC Computing Grid

The WLHC Computing Grid was launched in 2002 to provide a resource to store, distribute and analyze the 15 petabytes (15 million gigabytes) of data generated every year. It is a global collaboration of computer centres. It is composed of four levels, or “Tiers”, called 0, 1, 2 and 3. Each Tier is made up of several computer centres and provides a specific set of services.

The WorldWide LHC Computing Grid

Tier 0

It is the CERN DATA CENTRE. All of the data from the LHC pass through this central hub, but it provides less than 20% of the GRID’s total computing capacity.

Tier 1

consists of 13 computer centres around the world. They

1) provide support for the Grid,

2) are responsible for storing a proportional share of raw and reconstructed data,

3) perform large-scale reprocessing and storing the corresponding output,

4) distribute data to Tier 2,

5) store a share of the simulated data that the Tier 2 produces.

Optical-fibre links working at 10 gigabits per second connect CERN to each of the 13 major Tier 1 centres around the world.

Tier 2

Tier 2s are typically universities and other scientific institutes that can store sufficient data and provide adequate computing power for specific analysis tasks. They handle a proportional share of the production and reconstruction of simulated events. There are around 155 Tier 2 sites around the world.

Tier 3

Individual scientists can access the Grid through local computing resources.

Difference between World Wide Web and the Computing Grid

The Grid builds on the technology of the World Wide Web which was invented in CERN in 1989 by Tim Berners Lee.

The World Wide Web was originally conceived and developed to meet the demand for automatic information-sharing between scientists in universities and institutes around the world. On 30 April 1993 CERN put the World Wide Web software in the public domain. CERN made the next release available with an open licence, as a more secure way to maximize its dissemination. Through these actions, making the software required to run a web server freely available, along with a basic browser and a library of code, the web was allowed to flourish.

The Web provides seamless **access to information** that is stored in many millions of different geographical locations.

Grid computing provides seamless **access to computing power and data storage capacity** distributed over the globe.

Activity 3

Join a partner and try to solve the puzzles without looking back at the information above.

The LHC involves four experiments with detectors. Find the four detectors.

X	D	L	I	K	T	Y
W	A	T	L	A	S	N
E	L	Z	T	M	K	B
A	I	W	Q	R	T	E
O	C	P	J	C	M	S
D	E	F	X	L	I	A
P	Y	R	T	D	N	O
K	O	L	H	C	B	E

Did you find them all?

To complete the exercise you can use the available information above.

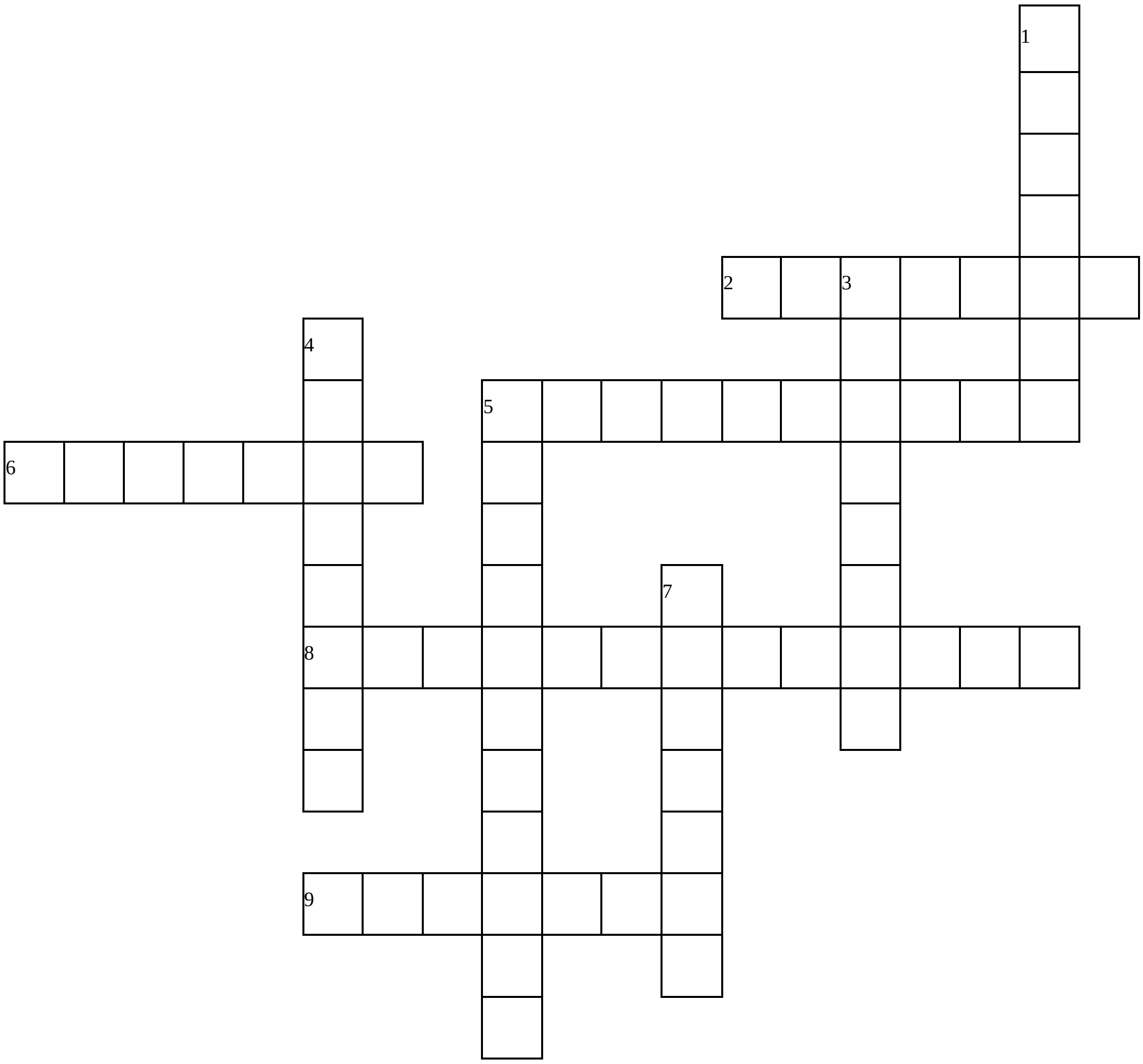
Cern

Join a partner and try to solve the crossword puzzle without looking back at the information above.

How many can you fill in?

To complete the exercise you can use the available information above.

1. CROSSWORD



Across

2. The LHC is __________ than outer space.

5. Specialized ________ process the data, leaving only 100 or 200 events of interest per second.

6. Cern's Data centre hosts 11,000 ______.

8. The Worldwide LHC computer grid is a global __________ of computer centres.

9. The accelerated ______ reach 99.9% of the speed of light.

Down

1. 9,000 ___ guide two beams of protons in a circular path to achieve a collision.

3. The Data Centre processes about one _______ of data every day.

4. CERN's objective is pure basic research in _______ physics.

5. any device that accelerates charged particles to very high speeds using electric and/or magnetic fields

7. The LHC is one of the _______ places in the Galaxy. (-271^{o} C)

Activity 4

And now you have to manage this on your own. Click on this link and answer the questions.

https://learningapps.org/3762837

How long does it take you to reach the highest level?

Time :

PART 3	
Topic	Experimenting with the ratio between the volume of a cylinder, a cone and a sphere and deriving the formulas from these experiments.
Subjects	Mathematics – History
Level	★ ★ ☆
Aims	- introducing students into the early days of mathematics, when “Pi” and our metric system were still unknown. - training students using fractions and the greatest common devisor
Skills	- being able to calculate the ratio between the volume of geometric shapes - being able to derive the formulas for calculating the volume of a cone or sphere, from the formula for calculating the volume of a cylinder
Duration	100 min
Resources	calculator, ruler, computer or laptop

INTRODUCTION

Democritus developed an atomic theory that was based on continuously splitting matter into smaller and smaller particles.

We already mentioned that he also wrote about mathematics, especially geometry. And that according to Archimedes he was the first to come up with the idea that the volume of a cone was one third of the volume of a cylinder. But he couldn't mathematically prove this insight.

In Democritus' days the number "Pi" was still unknown. It appears for the first time in 17^{th} century texts. Also the number"0" was not used in Democritus' time. It was not until the 5^{th} century AD before the number "0" appeared in India, and even the 12^{th} century before it reached Europe.

Since Democritus partitioned matter in ever smaller particles, we believe that he understood the concept of and working with "fractions". This lead him to conclude that the volume of a cone is one third of the volume of a cylinder with the same height and radius.

Activity 1

What do you think? Was Democritus right?

Take a cylinder and a cone with the same radius and height and check this theory.

https://www.youtube.com/watch?v=0ZACAU4SGyM

Since they didn't know our metric system in Democritus' days we will use "l.u." (length unit) as a unit of length and "v.u."(volume unit) as a unit of volume.

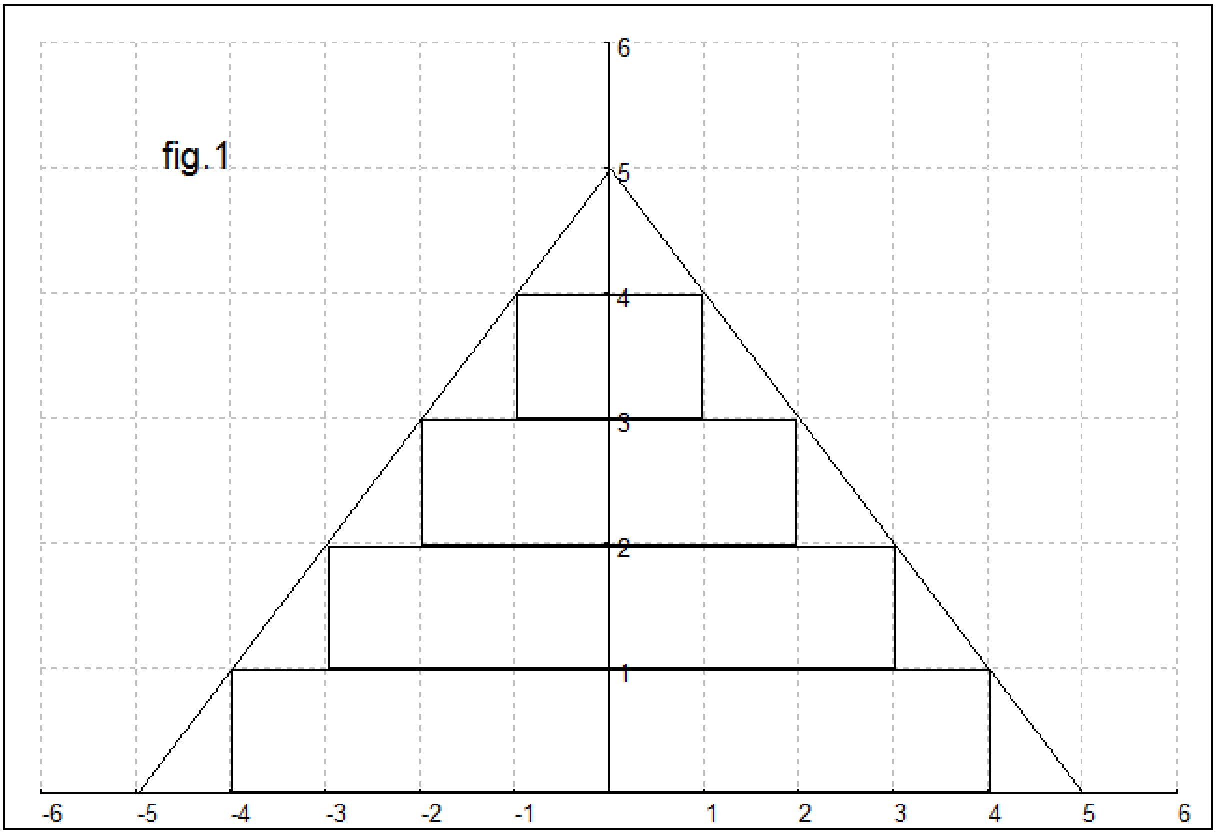
Since the old Greeks didn't know "Pi" we will use the number "k" for the ratio between the circumference of a circle and its diameter.

We consider a cylinder with a diameter of 10 l.u. and a height of 5 l.u.

What is the volume of this cylinder :

4 cylinders with a height of 1 l.u. are drawn within the shape of the cone in fig 1.

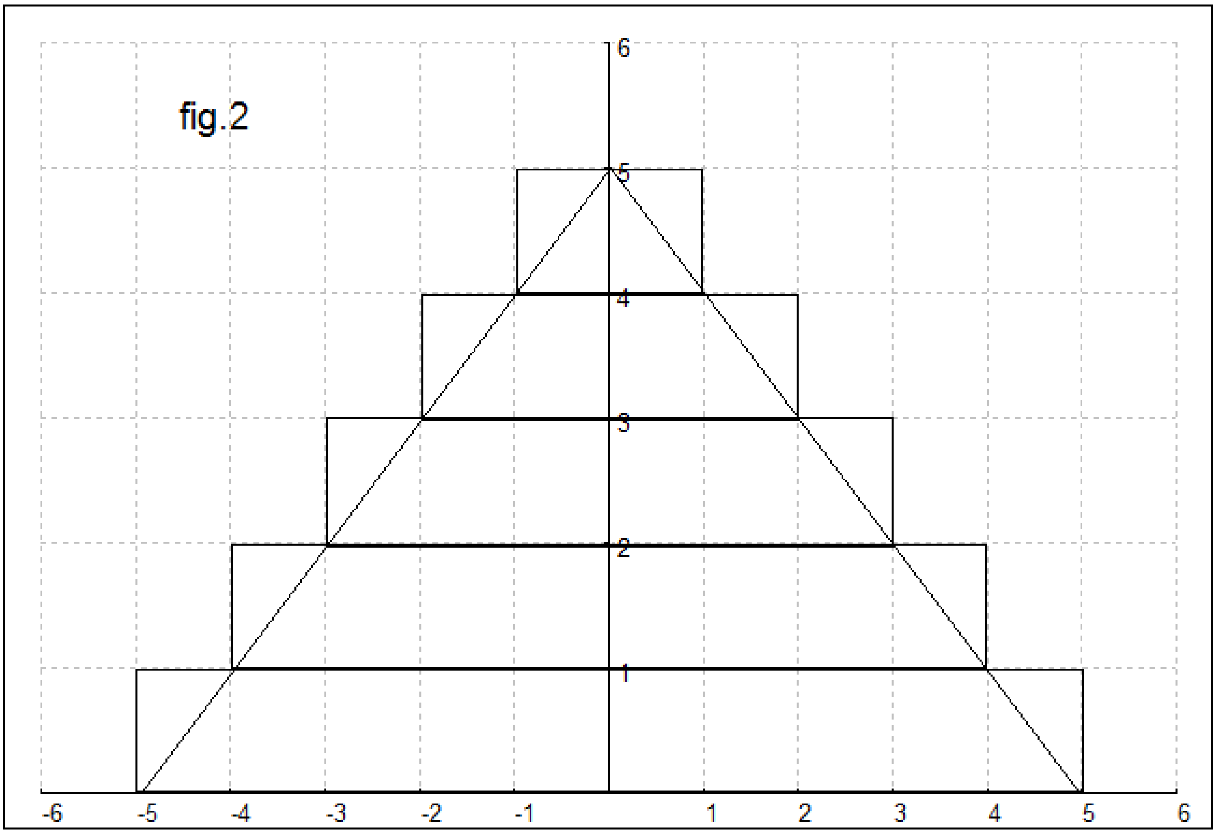
The volume of the cone is larger than the sum of the volumes of the 4 cylinders in fig 1.



Calculate the sum S_1 of the volumes of these 4 cylinders.

5 cylinders with a height of 1 l.u. are drawn outside the cone in fig 2.

The volume of the cone is smaller than the sum of the volumes of the 5 cylinders in fig 2.



Calculate the sum S_2 of the volumes of these five cylinders.

Take a close look at the drawings..

Can you come to an estimate of the content of the cone, using S_1 and S_2

Finally, calculate the ratio between the volume of the cone and the volume of the cylinder.

$$\frac{volume\ cone}{volume\ cylinder} = \frac{\qquad\qquad}{\square} \quad =$$

We consider a cylinder and a cone with a diameter of 12 l.u. and a height of 6 l.u.
What is the volume of the cylinder :

Draw 5 cylinders with a height of 1 l.u. within the shape of the cone, like in fig 1.
Draw 6 cylinders with a height of 1 l.u. outside the cone, like in fig 2.
Again calculate the ratio between the volume of the cone and the volume of the cylinder.

Calculate the sum S_1 and S_2 of the volumes of these cylinders.

S_1 =

S_2 =

Volume cone =

$$\frac{volume\ cone}{volume\ cylinder} = \frac{\qquad\qquad}{\square} \quad =$$

Activity 4

Form pairs. Depending on class size have some pairs doing the calculations underneath.

We consider a cylinder and a cone with a diameter of 14 l.u. and a height of 7 l.u.
What is the volume of the cylinder :

Draw 6 cylinders with a height of 1 l.u. within the shape of the cone, like in fig 1.
Draw 7cylinders with a height of 1 l.u. outside the cone, like in fig 2.
Again calculate the ratio between the volume of the cone and the volume of the cylinder.

Some other pairs do the calculations for a cylinder and a cone with a diameter of 16 l.u. and a height of 8 l.u.
The remaining pairs do the same thing for a cylinder and a cone with a diameter of 18 l.u. and a height of 9 l.u.

Calculate the sum S_1 and S_2 of the volumes of these cylinders.

$S_1 =$

$S_2 =$

Volume cone =

$$\frac{volume\ cone}{volume\ cylinder} = \frac{\qquad}{\square} =$$

What do you see when you compare the results?

first ratio :

second ratio :

third ratio :

When you continue to repeat this method you will come to the ratio …..

Therefore the volume of a cone is of the volume of a cylinder with the same height and diameter.

Do you know the formula for calculating the volume of a cylinder with radius “r” and height “h”?

volume cylinder =

Consequently :

volume cone =

Activity 5

Now, let’s take it even a bit further.

What is the volume of the sphere underneath?

Consider the measurements of a cone and a sphere. Use the film to derive a formula for calculating the volume of a sphere.

volume sphere =

Watch this film: https://www.youtube.com/watch?v=PaA-g_z_E2E

PART 4	
Topic	Research into the agility of atoms in a material: designing and constructing a xylophone
Subjects	Maths, Engineering, IT, Music
Level	Activity 1-2-3 : ★☆☆ Activity 4-5 : ★★☆
Aims	- Students explore the relation between the pitch of a sound and material. - Students design and build a xyolophone. - Students play music.
Skills	Activity 1-2-3 : using IT to study sound Activity 4-5 : using technology, engineering and maths to design and construct a musical instrument
Duration	Activity 1-2-3 : 50 minutes Activity 4-5 : 2 x 50 minutes (with 4 students per group)
Resources	calculator, computer with internet connection, different kinds of material

INTRODUCTION

Who was Democritus?

Together with his tutor Leucippus, Democritus was the founder of the atomism. In those days atoms were considered to be particles from which a matter is built. Democritus wrote among many different topics, also about music.

In this engineering lesson we will therefore study the relation between kinds of material and their sound. Sound is determined by the vibrations of atoms or molecules of the medium in which the sound propagates itself. We will limit ourselves to percussion instruments. In these instruments the vibrations are propagated through the material and the material itself produces the sound.

Activity1

Take two small wooden beams and position them parallel to one another.

Cover them with a piece of cloth to avoid that the (sound) bar touches the wood.

Make or take a wooden bar of about 35 by 5 by 2 cm and put it onto the underlying framework you made. Position the bar across the two wooden beams underneath.

Choose a hard kind of wood, like oak, to make this bar. Hard types of wood are easier to tune.

Use a baton to hit the bar and produce a sound. A chestnut on a stick will be fine. A cork will do the trick as well, but the sound will be fainter.

Use the app “Soundcorset” to determine the pitch of the sound.

What is the pitch of your sound?

The A tone is an important tone because it is the general tuning standard for musical pitch. In 1885 it was established that the A tone needs to have a frequency of 440 Hz at a temperature of 20°C.


Shorten the stick. / Take a shorter stick. Is the pitch higher of lower?

Activity 2

Use different kinds of wood (oak, birch, spruce, douglas fir,…) to produce sound.

What tone does a 35x5x2 stick produce?

Type of wood	Pitch (Hz)

What is your conclusion?

Activity 3

Design your own musical instrument based on the principle of a xylophone. Choose your material and use the app to determine the correct length of the bars or tubes, the correct content of the bottles, …




What is the pitch of the note “re” that follows the last note “do”?

	do	re	mi	fa	sol	la	si	do
pitch(Hz)								
length (m) / content (l)								

In the equal temperament (a system for tuning) the frequency interval between every pair of adjacent notes has the same ratio. This ratio is equal to the 12^{th} root of two.

What is the pitch of the note “re” that follows the last note “do”?

	do	re
pitch(Hz)		
length (m) / content (l)		

When you multiply the pitch of the note “la” with the 12^{th} root of 2, you will get the pitch of the note “si”.

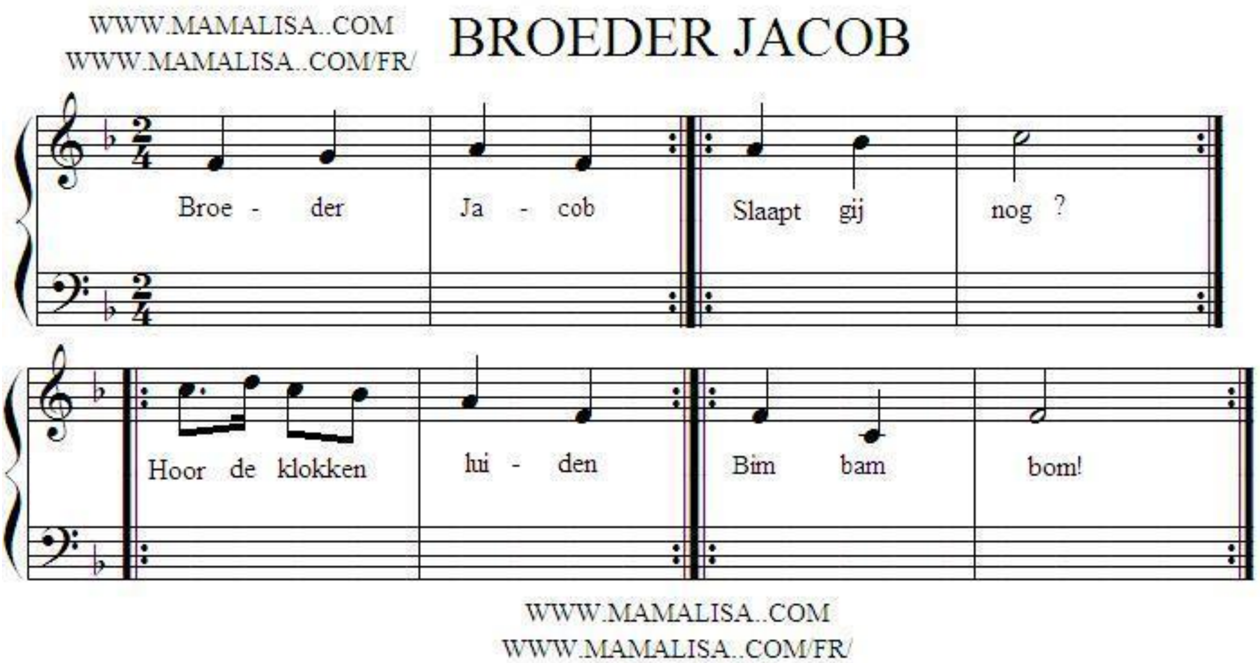
Make a mathematical graph that represents the relation between the object and material (and its length or content) you chose and the pitch.

Make your own musical instrument with which you can play all these notes.

	do	re	mi	fa	sol	la	si	do	re
pitch(Hz)									
length (m) / content (l)									

Activity 4

Use your own musical instrument to play this song.



Don’t you hear that one particular note sounds strange?

Which note?

This is because there is a “b” at the front of the staff. This means that this note should sound half a tone lower.

What should we do with the stick / tube / bottle? Shorten? Lengthen? /Fill up? Pour some water out?

This note needs a pitch of 415.3 Hz. Make a matching stick / tube / bottle ….

Does the song sound better now?

Activity 5

Use different kinds of material (aluminium, PVC, cardboard tubes, bottles filled with water) to make a new object that produces a tone. When using bottles it is better to suspend them on a thread. Otherwise they are difficult to tune.

What tone does your object produce?

Type of object and material	Pitch (Hz)

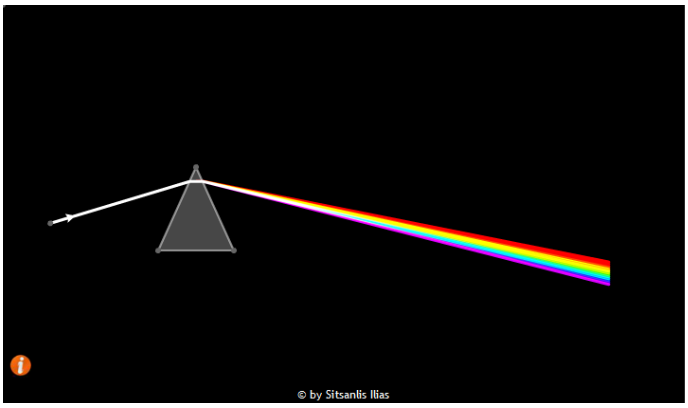
What is your conclusion?

PART 5	
Topic	Spectrum
Subjects	Physics
Level	★ ★ ☆
Aims	• to confirm experimentally that the spectrum of a light is continuous • to measure the area of filters' absorbing • to explain the colour of the Sun at noon and during the sunset • to confirm experimentally that a gas emission spectrum is linear • to measure the wavelengths of the emitted lines
Skills	• observation and collection of data from natural phenomena • collaboration with other students
Duration	120 minutes of classroom work (without making a spectrometer)
Resources	• spectrometer • filters • different lights • different gasses • computer

INTRODUCTION

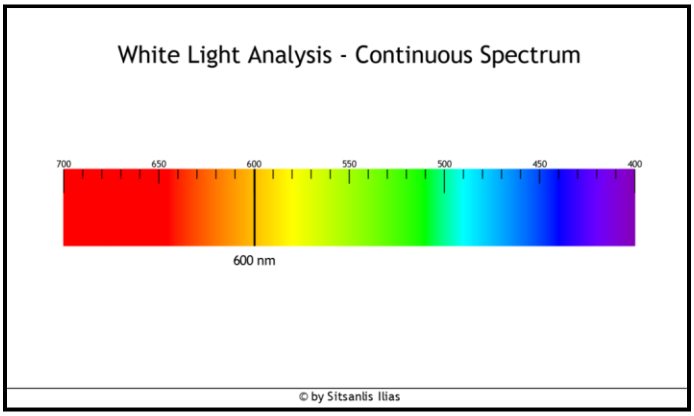
What colour would you use to paint the Sun?

The sunlight is white. White is not just a plain colour (like other colours). It consists of a variety of colours. When these colours are coming simultaneously to our eye, we perceive it as white. Newton was the first to analyze the light. He analyzed each colour by aiming the sunlight at a prism.



Light Spectrum

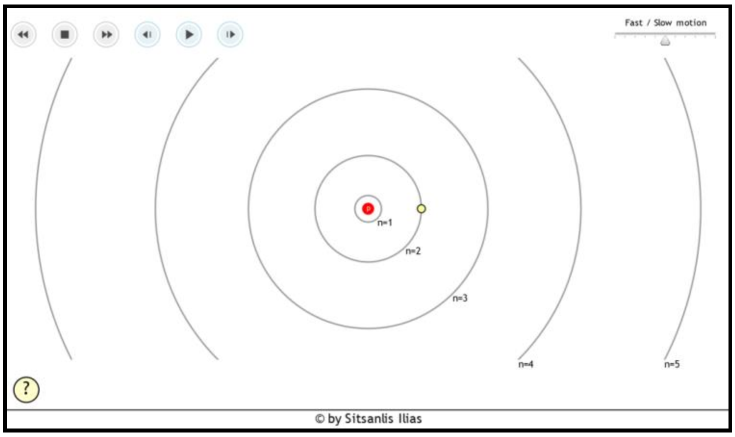
The whole range of colours in which the light is analyzed is called light the spectrum. This spectrum is continuous, in other words it contains every colour from red to violet. Each colour is characterized by a number. This number is called the wave length. Red colour's wave length is $\lambda = 700\ \mathrm{nm}$ while violet has wave length $\lambda = 400\ \mathrm{nm}$.



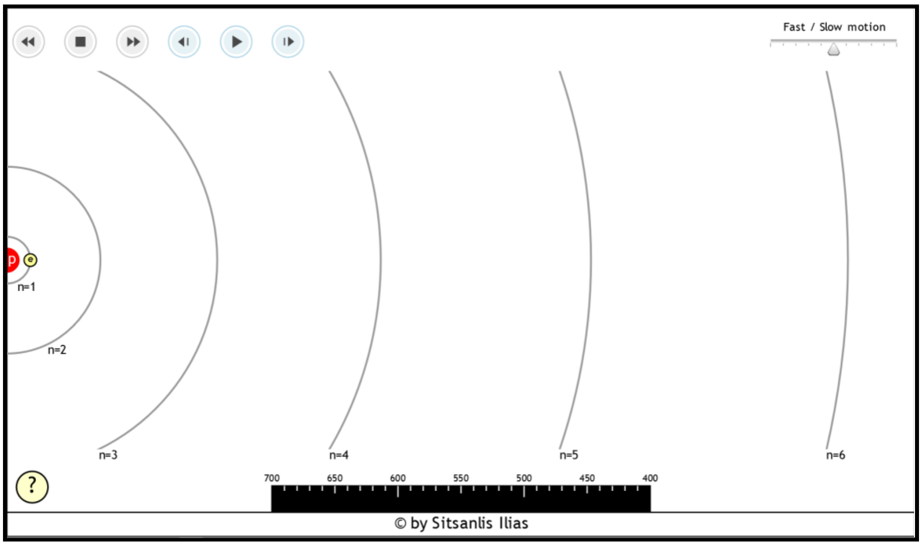
There seems to be no relation between what is mentioned above and atoms. Yet, there is a certain relation. The light is created inside atoms. These little and invisible structures are responsible for whatever we see.

Bohr's model

A model for the Hydrogen atom (the simplest one) which can explain how the light is created, is the Bohr's model. The Hydrogen atom consists of one proton and one electron. The electron revolves in certain circular stable orbits called shells. Each shell has a number (n). The first shell has $n = 1$, the second one has $n = 2$ etc. The electron cannot be found in a middle position but only in specific orbits

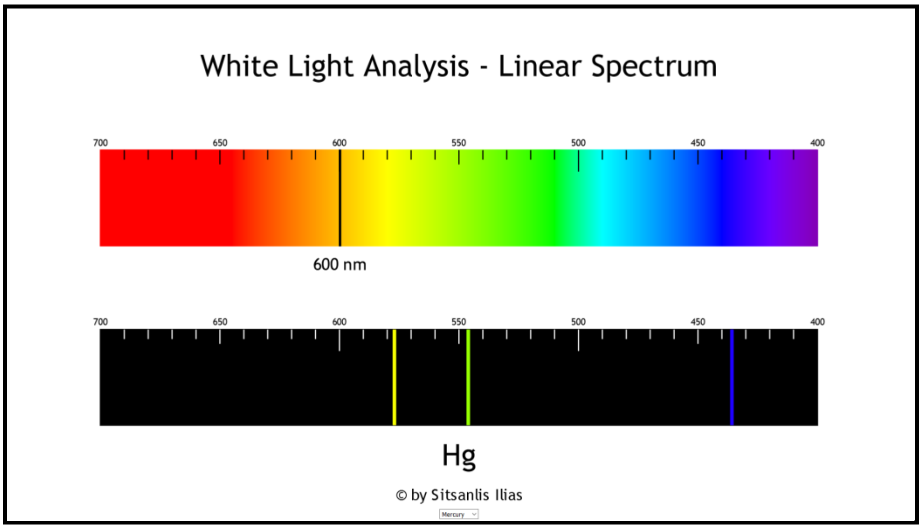


The electron ends up on the first orbit $n = 1$, the orbit with the lowest energy (ground state). The electron can absorb energy in various ways e.g. collision. When this happens it may be excited and jump to a higher orbit. The electron does not remain in an excited state for long and drops to the lowest energy state emitting light by releasing a particle which is called a photon. The colour of the light that is emitted is related to the initial and final orbit and it is visible only when the electron drops to the orbit $n = 2$. In any other case the light is not visible. You may wonder how there can be light if we cannot see it. In Physics, light may be rays that warm us or can be any radio or television broadcast signal.



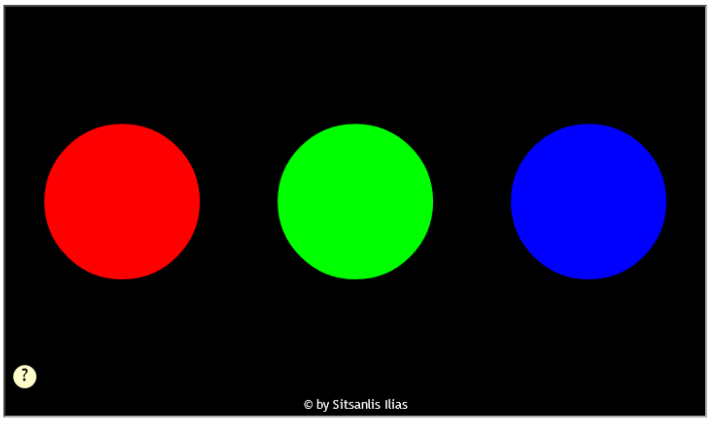
Linear spectra of gas emission

The spectrum emitted by Hydrogen consists of lines and differs from the spectrum of a solid being in high temperature (lamp) or the Sun. When atoms are very close to each other, like in solid bodies, the lines are close to each other as well and the spectrum becomes continuous. Each gas has a unique set of emitted lines. This set identifies the gas.



A few words about filters

Filters consist of substances that can absorb a specific part of the spectrum. The light that comes to our eyes is called the complementary of the absorbed light. For example, the yellow filter absorbs the blue light since if blue is removed from the white light, the remaining light seems yellow to us. When you see a yellow colour on your computer screen, it means that two pixels, a green and a red one, send light and as a result yellow is created.



Activity 1

Join a partner and try to solve the questions below without looking back at the information above.

1. The first one who analyzed the sunlight was: ………………… (Newton, Democritus)
2. The sunlight consists of: ………………… (one colour, many colours)
3. The wavelength of red colour is: ………………… (bigger, smaller) than the wavelength of blue.
4. The following spectrum  is ………………… (linear, continuous)
5. The spectrum of the sunlight is ………………… (linear, continuous)
6. Gases emit ………………… (linear, continuous) spectrum.
7. The light that Hydrogen emits, is visible only when the electrons fall into the shell with ………………… $(n = 1, n = 2)$
8. The emission spectra of Hydrogen and Mercury are ………………… (the same, different)
9. Light is divided into three large areas: red, green and blue. If we remove blue from white light, then the colour that we will see is: ………………… (red, yellow)
10. The complementary colour of blue is ………………… (red, yellow)
11. The complementary colour of green is ………………… (cyan, magenta)
12. Light is created in the atoms ………………… (true, false)

How many can you fill in?

To complete the exercise you can use the available information above.

http://www.seilias.gr/erasmus/spectrum/en

Activity 2

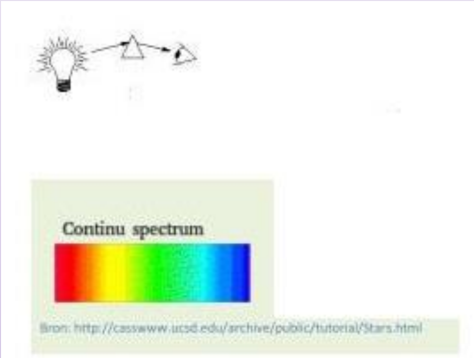
The white light is composed of all the others colours. When these come to our eye simultaneously, then it looks to us as white. The light can be analyzed by the colours that it consists of when it passes through a prism. Each colour is characterized by one number, which is called wave length and it is symbolized with λ. Red has wave length $\lambda = 700\ \mathrm{nm}$ and blue has $\lambda = 400\ \mathrm{nm}$, while all the other are in between them

On the internet you can find many ways to make a cheap spectrometer yourself or je can choose to buy a cheap model.

If your teachers gives you enough time, you can make it yourself.

https://youtu.be/IA5BTD-aelo
https://www.youtube.com/watch?v=FJ1xOWl5Axk
https://www.youtube.com/watch?v=aTAFBd1EQcE
If there is not enough time, you can buy one.
https://www.astromarket.org/spectrografie-5/educational-5/

Observe the light of an incandescent light bulb through your spectrometer.



- When you observe the bulb with the naked eye you see white light being emitted. When you observe the bulb through the spectrometer, what can you see?

  ………

- In which order do the colours appear?

  ………

- When your spectrometer is calibrated, you can answer the question underneath. Which is the minimum and the maximum wave length of the spectrum?

  $\lambda_{\min} = \ldots\ldots \qquad \lambda_{\max} = \ldots\ldots$

Make observations with other light sources such as fluorescent light, a computer screen, candle light, LED light, ….

Do you see any differences? Can you describe these differences?

Observe these light sources through a colour filter.

- Put the filter F/17 (yellow) in front of the bulb. What colour is the light you can see ....?
  Now observe the light of the bulb through the spectrometer. Which area is dark (has been absorbed) ....? Which is the minimum and the maximum of the absorbed wave length?

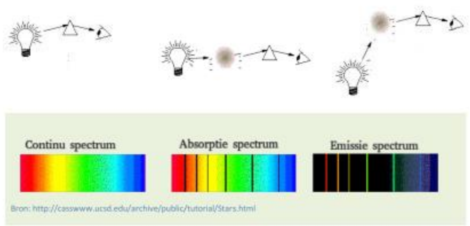
$$\lambda_{\min} = \ldots\ldots \qquad \lambda_{\max} = \ldots\ldots$$

- Put the filter F/16 (magenta) together with the yellow filter (F/17). What colour is the light that you see ....?
  Now observe the light of the bulb through the spectrometer. Which colours are missing ....? Which is the absorbed wave length?

$$\lambda_{\min} = \ldots\ldots \qquad \lambda_{\max} = \ldots\ldots$$

- Why does the Sun appear to be yellow in midday? Which colours have been absorbed by the atmosphere?
  Why does the Sun appear to be red during the sunset?
  (Take care : never look straight into the sun through your spectrometer!)

Activity 3



In this activity we use a spectrometer to look at a gas.
We can do this in two ways.

If we look at a light bulb through a gas, we will obtain an absorption spectrum (see above). The gas absorbs the light of the lamp and this creates black lines in the spectrum.

If we look straight at the gas and not through a lamp, we will get an emission spectrum.

Each gas has a unique set of emitted lines and they are characteristic for each gas. In this lab experiment we will see emission spectra of H_2, He, Ne and the vapour of Hg.

Observe the emission spectrum of the gas tube from the diopter of the spectroscope.

1. Define the wavelengths of spectral lines and fill in

Tube Hg	Spectral lines					
wavelength spectral line (λ)						
spectral colour line						

2. Repeat the same procedure with the light H_2 and fill in

Tube H_2	Spectral lines					
wavelength spectral line						
spectral colour line						

3. Repeat the same procedure with the light Ne and fill in

Tube Ne	Spectral lines					
wavelength spectral line						
spectral colour line						

4. Repeat the same procedure with the light He and fill in

Tube He	Spectral lines					
wavelength spectral line						
spectral colour line						