PHYSICS KIT
RESOURCES FOR TEACHERS

For more information on our engagement / outreach activities, go to our website
www.ph.qmul.ac.uk   www.sepnet.ac.uk/outreach
or email us at spa-outreach@qmul.ac.uk

SEPnet South East Physics Network **Outreach**

Queen Mary University of London

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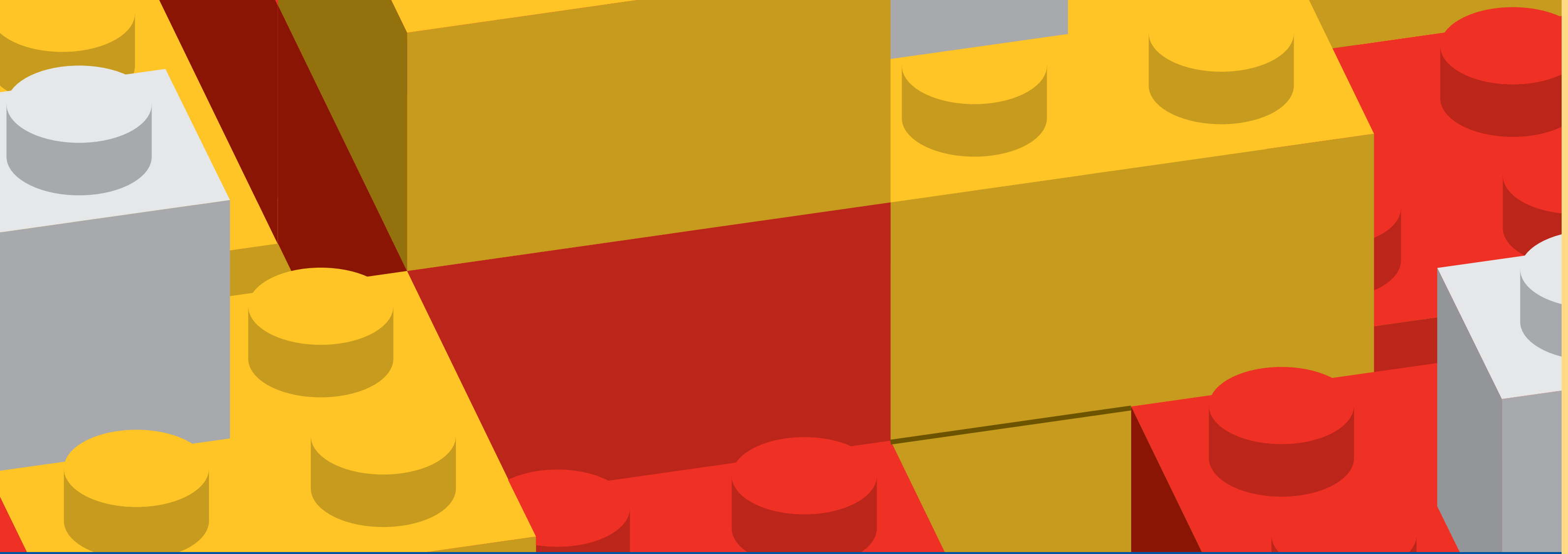


CONTENTS

This guide is designed to help you deliver the principles of particle and nuclear physics through engaging activities using LEGO® bricks. Inside you will find lesson plans, activity sheets and suggestions for extension activities. The complementary Physics Kit booklets and presentations mean that you can select the most appropriate activities and tailor your session to the age and ability of your students.

HOW TO USE THIS GUIDE

All supporting material is available for download at:
ph.qmul.ac.uk/engagement/physics-kits

This guide is split into three topics: evolution of the universe, nuclear reactions and particle physics. All the resources in each topic are colour-coded to match.

In each section of this booklet you will find a lesson plan, stand-alone activity sheets and extension/homework ideas, as well as a research spotlight linking the content to cutting-edge research, which provides scope for further discussion.

Each lesson plan covers one of the topics and is supplemented by a presentation. You may like to add to the lesson plan, omit certain parts or just use the stand-alone activities described on the activity sheets. The activity sheets are written for your students and are also available for download, along with the presentations.

To support the teaching of the topics in this booklet, we have also produced three Physics Kit booklets to sum up the topics in this resource. These booklets can be handed out to pupils to use in class reading or additional tasks. They also support some of the activities in the lesson plans.

SOURCING LEGO® BRICKS

A class set of LEGO® bricks and hardcopy resources are available from us, through our website at: ph.qmul.ac.uk/engagement/physics-kits
On this web page you will also find additional extensions and supporting resources.

For more information about our other outreach activities, please visit:
ph.qmul.ac.uk/engagement/outreach-activities and sepnet.ac.uk/outreach

LESSON PLAN: **BUILD YOUR OWN UNIVERSE**

Timing	70 minutes
Session aim	Explore the history of the universe by examining the particle physics from the Big Bang to the creation of heavy elements.
Preparation	Read activity sheets and Build Your Own Universe booklet, download presentation, print activity sheet PDF's, and set up activity resources.
Resources	Build Your Own Universe booklets Activity sheets 1, 2, 3 and 4 Red, yellow and white bricks (as shown in the Build Your Own Universe booklet) Balloons
After this session students should understand that...	The early universe was a mix of fundamental particles.
	Protons and neutrons are made of quarks.
	Helium was created by the fusion of protons and neutrons.
	Electrons began to orbit atomic nuclei to form atoms when the universe was cool enough.
	Heavier atoms, like carbon, were created by fusion in the heart of stars.
Key	Key learning points are included as bullets. Suggested things to say are in italics.

Time (min)	Section	Resources
4	**SLIDE: SESSION INTRODUCTION** *"Over the next hour we will uncover the history of the universe, turning the clocks back nearly 14 billion years to the Big Bang to discover how the basic building blocks of matter were created. We will learn how the first atoms were formed and how the heavy elements that we are made of were born in the heart of stars, before considering the end of the universe."* Distribute Build Your Own Universe booklets and explain that you will be using building bricks, booklets and slides.	Slide Build Your Own Universe booklets
4	**DISCUSSION** What does your group know about the Big Bang? Did atoms, dust and gas pop into existence fully formed or was there something more fundamental first?	

Time (min)	Section	Resources
5	**SLIDE – THE FIRST FEW SECONDS** Fundamental particles were created in the Big Bang. - Physicists believe that these particles are indivisible i.e. not made of smaller pieces. - As the temperature drops the **strong force** pulls the quarks together to form protons and neutrons.	Slide
10	**ACTIVITY 1 - MUSICAL QUARKS** This activity works best with 12 or more students. Explain that you will be making protons and neutrons from quarks – just like in the early universe. Once the students are ready, start the activity by shouting, "Go!" Sum up key points at the end. If you wish to run the activity more than once, points can be awarded to the individuals in the winning team, for each round. This activity can also be run in the style of "musical chairs" with particles formed when the music stops.	Activity sheet 1 Equal number of bricks, one per student Build Your Own Universe booklets
3	**SLIDE – THE FIRST TWO ELEMENTS** - Helium is formed through the fusion of hydrogen nuclei.	Slide
10	**ACTIVITY 2 – JUMBLED UNIVERSE** This activity works best in pairs or small groups.	Activity sheet 2 Red, yellow and white bricks Build Your Own Universe booklets
3	**SLIDE – THE BIRTH OF NEUTRAL ATOMS** - As the universe cooled further, electrons stuck to atomic nuclei because of the electromagnetic force, forming atoms.	Slide
10	**ACTIVITY 3 – FEEL THE FORCE** This activity works best in pairs or small groups.	Activity sheet 3 Balloon for each group

LESSON PLAN: **BUILD YOUR OWN UNIVERSE**

Time (min)	Section	Resources
10	**ACTIVITY 4 – HISTORY OF THE UNIVERSE: FILL IN THE BLANKS** **Answers:** Quarks, electrons, photons, neutrinos, positrons, protons, neutrons, helium, fusion, electrons, gravity, fusion, carbon.	Activity sheet 4 Build Your Own Universe booklets
2	**DISCUSSION: MADE OF STARS** *"What are we made of? What are all living things made of? What is the earth made of? Where does this material come from? How did it reach our little bit of space?"* Most matter in and on the earth, is made up of a number of heavier elements like carbon, oxygen, silicon and iron. These were all made in the centre of a star by nuclear fusion and are distributed when the stars reach the end of their lives in a supernovae, a huge stellar explosion. We are all literally made of stardust.	
4	**SLIDE – TIME = 100 MILLION YEARS** • Stars are formed when material is pulled together and heated by gravity until it gets hot enough to kick start nuclear fusion. • Nuclear fusion in stars is responsible for the creation of all the heavier elements. • The most important element for life on Earth is carbon.	Slide
3	**SLIDE – THE END** • If there is enough matter in the universe, gravity will stop the universe expanding and pull it back together in a "big crunch". • If gravity is not strong enough to overcome the forces causing the universe to expand, the universe will continue to expand forever. Eventually all stars will die and the universe will be cold and dark. • The latest experimental data suggest that the expansion of the universe is speeding up, and that the force of gravity will not be strong enough to prevent continued expansion.	Slide
2	**ROUNDUP** Congratulate your students for making it through your whistle stop tour of the history of the universe. Ask the group to sum up the key learning points.	

ACTIVITY 1 **MUSICAL QUARKS**

GROUP SIZE: 12+
TIME: 10 MINUTES
EQUIPMENT: RED AND YELLOW BRICKS BRICKS;
BUILD YOUR OWN UNIVERSE BOOKLET

BACKGROUND INFORMATION

In the early universe protons and neutrons formed from fundamental particles called quarks. The quarks are arranged in groups of three and differently in a proton than in a neutron. Read page 4 and 5 of the Build Your Own Universe booklet to find out more about quarks.

INSTRUCTIONS

The aim of this activity is to form protons and neutrons from quarks in the fastest time possible.

1. You will be given a brick that represents either an up quark or a down quark.
2. There should be roughly equal numbers of up quarks and down quarks in the group.
3. Take your quark and spread out, away from other players.
4. On the word, "Go!" find the nearest quarks to you and bond with them to make a proton or a neutron.
5. If you are part of a group with a completed particle, stand still, raise it in the air and call out "proton" or "neutron".
6. The winning group is the first to make and correctly identify a particle. You might get left behind if you do not manage to join a group quick enough!

ACTIVITY 2 **JUMBLED UNIVERSE**

GROUP SIZE: PAIRS OR SMALL GROUPS
TIME: 10 MINUTES
EQUIPMENT: RED, YELLOW AND WHITE BRICKS;
BUILD YOUR OWN UNIVERSE BOOKLET

INSTRUCTIONS

Use the bricks to make the following stages of the early universe. Once you have built them, see if you can put them in order of when they formed using the information in the Build Your Own Universe booklet.

1. A helium-4 atom with electrons
2. A carbon nucleus found in a star (too hot to have electrons)
3. Individual protons and neutrons
4. Individual up and down quarks and an individual electron

ACTIVITY 3 **FEEL THE FORCE**

GROUPS SIZE: PAIRS OR SMALL GROUPS
TIME: 10 MINUTES
EQUIPMENT: BALLOON

BACKGROUND INFORMATION

The electromagnetic force is responsible for holding negatively charged electrons to positively charged atomic nuclei (you can find out more about this process on page 8 of the Build Your Own Universe booklet). This activity will allow you to feel the electromagnetic force attracting positively charged protons to negatively charged electrons.

INSTRUCTIONS

1. Inflate the balloon fully and tie off.
2. Rub the balloon vigorously back and forth on your head (works best with dry hair, with no products).
3. Hold the balloon gently up to a non-metallic wall or ceiling.
4. Remove your hand: the balloon should stay where it is.

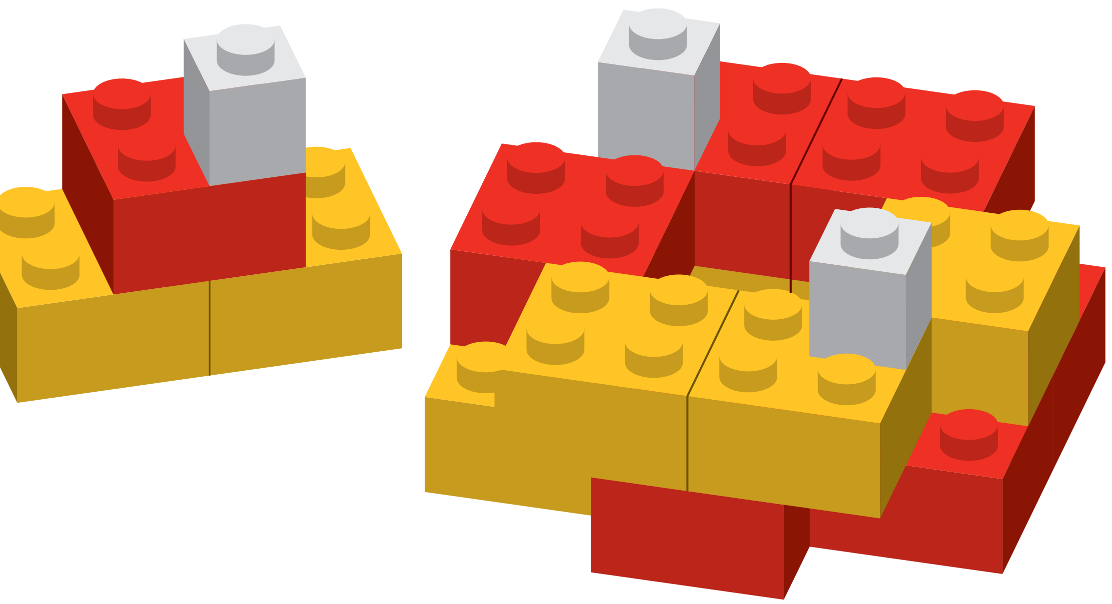
EXPLANATION

All of the objects we can see with the naked eye are made up of atoms. These atoms contain positively charged protons and negatively charged electrons as well as neutrons, which have no charge.

By rubbing the balloon on your hair you are gathering extra electrons on its surface. When you bring the balloon close to the wall, the negatively charged electrons on the balloon repel the negatively charged electrons in the wall. This leaves behind more protons than electrons. The electrons on the balloon are attracted to the protons in the wall via the electromagnetic force.

EXTENSION

Try using the charged balloon to lift a friend’s hair, levitate table salt, bend a stream of water or pull an empty drinks can along a flat surface.



ACTIVITY 4 **HISTORY OF THE UNIVERSE: FILL IN THE BLANKS**

GROUP SIZE: INDIVIDUALS
TIME: 10 MINUTES
EQUIPMENT: BUILD YOUR OWN UNIVERSE BOOKLET

INSTRUCTIONS

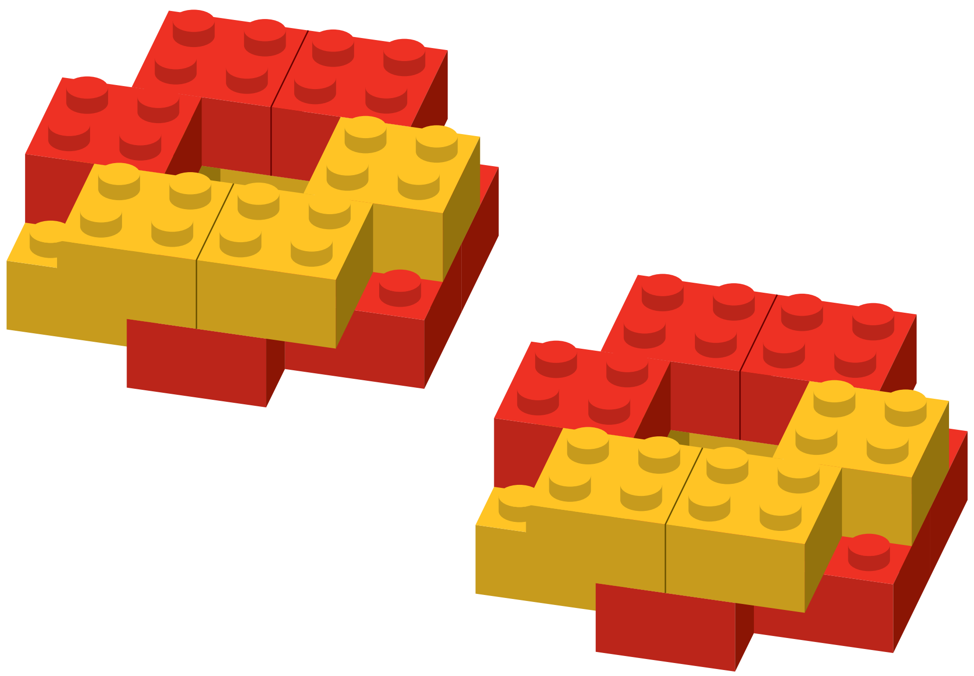
Read through pages 4 to 10 of the Build Your Own Universe booklet and use the information to fill in the blanks in this short history of the universe:

The early universe was a very hot, dense mass of particles including individual _______, which are now most often found in groups of three; ________ which carry electric charge and particles of light called _______. The mix also included particles that interact very little with ordinary matter called _______ as well as _______, which have the same properties as electrons but carry the opposite charge.

As the temperature of the early universe decreased, quarks were able to stick together in threes to form _______ and _______. These later formed the core of the atoms that make up the matter that we can see with the naked eye. These atomic nuclei could form larger ones such as _______ through a process called _______.

After nearly 400 million years the universe was cool enough for _______ to stick to hydrogen and helium nuclei, forming atoms.

Even after millions of years, the universe was still without stars. Clumps of matter, pulled together by _______, heated up as they became denser. These clumps became stars once they started giving off energy via _______. In stars, this process joins three helium nuclei to form _______, one of the most important substances for life on Earth.



RESEARCH SPOTLIGHT

UNDERSTANDING THE IMBALANCE OF MATTER AND ANTIMATTER

Professor Francesca Di Lodovico

RESEARCH GROUP	PARTICLE PHYSICS RESEARCH CENTRE
SPECIALISM	PARTICLE PHYSICS
RESEARCH TOPIC	WHY DO WE LIVE IN A UNIVERSE FILLED WITH MATTER?

Picture: Professor Francesca di Lodovico seen through part of a light detector

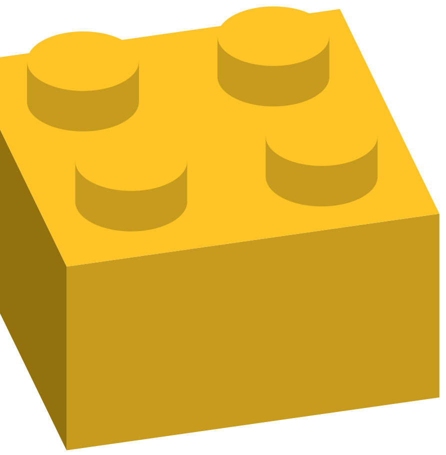
Professor Francesca Di Lodovico is a particle physicist at Queen Mary, University of London who spends her time studying elusive fundamental particles to try and understand one of the most puzzling questions in particle physics: Why do we live in a universe filled with matter?

Matter and antimatter particles were created in equal amounts during the Big Bang. If the proportion of these particles had stayed the same, they would have been able to completely "annihilate" each other, effectively cancelling each other out in a flash of energy.

The fact that we live in a universe full of matter and not just energy shows that at some stage, the balance of matter and antimatter must have shifted to leave some extra matter. There is currently no explanation of how this might have happened. In a bid to try and solve this mystery, Professor Di Lodovico carries out experiments at the Super Kamiokande detector in Japan. This huge instrument is made up of a tank filled with fifty thousand tonnes of ultra-pure water, surrounded by super sensitive light detectors. These detectors are used to record rare flashes of light created when an atomic nucleus in a water molecule is struck by a particle called a neutrino.

Professor Di Lodovico hopes to see a difference in behaviour between neutrinos and their antimatter partners as they interact with matter. This difference in behaviour could point to a way in which the imbalance in matter and antimatter came about.

EXTENSION/HOMEWORK



- Build the different stages illustrated in the Build Your Own Universe booklet and photograph them. You can print the photos and incorporate them into a poster about the history of the universe.
- Use bricks along with a digital camera, smart phone or tablet with the appropriate software or app to make a stop motion animation of some of the processes shown in the booklet.
- Use the internet to research different theories about the end of the universe. Choose one theory and present the idea to your classmates. Some key words are *heat death*, *big crunch* and *big rip*.

LESSON PLAN: **FISSION AND FUSION**

Timing	53 minutes
Session aim	A whistle stop tour of radioactivity, nuclear fusion and nuclear fission.
Preparation	Read activity sheets and Fission and Fusion booklet, download presentation, print activity sheets, and set up activity resources.
Resources	Activity sheets 1, 2 and 3 Red, yellow and white bricks (as shown in the Fission and Fusion booklet) Fission and Fusion Booklet
After this session students should understand…	Atomic structure
	The nature of different types of radiation
	How helium is formed via nuclear fusion
	The process of nuclear fission
Key	Key learning points are included as bullets. Suggested things to say are in italics.

Time (min)	Section	Resources
2	**SESSION INTRODUCTION**	Slide
	"We are going to look into the heart of atoms, at the particles that make up the atomic nucleus. We will uncover how these particles behave and how we can harness that behaviour to create useable energy." Hand out Fission and Fusion booklets and explain that you will be using building bricks, booklets and slides.	Fission and Fusion booklets
3	**DISCUSSION** What does your group know about radioactivity? What do the words "nuclear" and "radiation" mean to them?	
3	**SLIDE: ATOMIC STRUCTURE** - Atoms are made up of a central nucleus of protons and neutrons with electrons orbiting this nucleus.	Slide

Time (min)	Section	Resources
3	**SLIDE: ISOTOPES** - Isotopes of a chemical element have the same number of protons but a different number of neutrons.	Slide

5	**SLIDE: RADIOACTIVITY**
	- The strong force prevents positively charged protons in the atomic nucleus from flying apart.
	- If there are too many protons in a nucleus, the nucleus is unstable and can split apart or fire out a particle.
	- There are three different particles that can be fired out of an unstable nucleus:
	  - An alpha particle: made of 2 protons and 2 neutrons.
	  - A beta particle: Just an electron on its own.
	  - A gamma ray: A high energy particle of light (a photon).
		Slide

10	**ACTIVITY 1: RADIATION SPOT THE DIFFERENCE** This is an individual activity. **Answers:** Protons, neutrons, isotope, large, beta, aluminium.	Activity sheet 1 Red, yellow and white bricks Fission and Fusion booklets
3	**SLIDE: NUCLEAR FUSION** - Helium can be created by the nuclear fusion of hydrogen nuclei. - Fusion of light elements gives out lots of energy.	Slide
10	**ACTIVITY 2: CONFUSED FUSION** This activity works best in pairs.	Activity sheet 2 Red and yellow bricks Fission and Fusion booklets
3	**SLIDE: NUCLEAR FISSION** - Some heavy elements can become unstable when a neutron is fired at them. - They release energy by splitting into parts.	Slide

Time (min)	Section	Resources
5	**ACTIVITY 3: FISSION DIVISION** This is an individual activity. **Answers:** Fusion, fission, fusion, both (but fusion releases more energy than fission), fission, fission.	Activity sheet 3 Fission and Fusion booklets
3	**SLIDE: CHAIN REACTIONS** - Neutrons released during fission can go on to induce more fission reactions. This is called a chain reaction. - This process takes place in nuclear weapons.	Slide
3	**SLIDE: ROUNDUP** Ask the group to sum up the key learning points.	Slide

ACTIVITY 1 **RADIATION SPOT THE DIFFERENCE**

GROUP SIZE: INDIVIDUALS
TIME: 10 MINUTES
EQUIPMENT: RED, YELLOW AND WHITE BRICKS; FISSION AND FUSION BOOKLET

BACKGROUND INFORMATION

Radioactive decay, also known as nuclear decay or radioactivity, is the process by which a nucleus of an unstable atom loses energy by emitting particles of ionizing radiation. A material that spontaneously emits this kind of radiation is considered radioactive.

INSTRUCTIONS

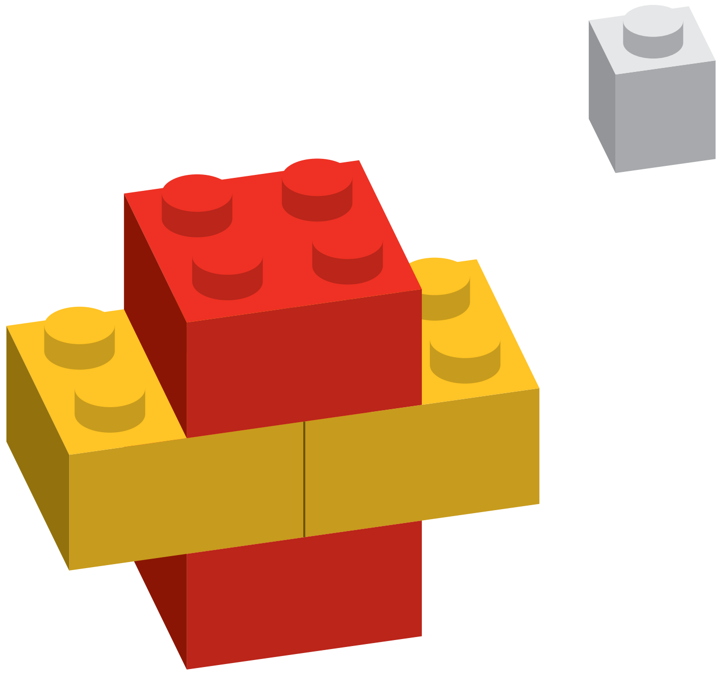
1 Build an alpha particle and a beta particle using the illustrations on page 5 of the Fission and Fusion booklet.

2 Close the booklet, answer the following questions using your models to help you.
a What two particles is the alpha particle made up of?
b Which particle does beta radiation consist of?
c Which is the bigger of the two: an alpha particle or a beta particle?

Read the text on pages 4 and 5 and then complete the following sentences:

The nucleus of an atom is made up of _______ and _______. The number of neutrons in an element can vary slightly. Each variation is called an _______.

An alpha particle can be stopped easily by a sheet of paper because it is quite _______. In comparison, the _______ particle is very light and can travel quite a long way in air. It can be stopped by a thick sheet of _______.



ACTIVITY 2 **CONFUSED FUSION**

GROUP SIZE: PAIRS
TIME: 10 MINUTES
EQUIPMENT: RED AND YELLOW BRICKS; FISSION AND FUSION BOOKLET

BACKGROUND INFORMATION

Fusion is a nuclear reaction in which two or more nuclei of atoms collide at very high speeds to form a nucleus of another element. This process takes place at the centre of stars, including the Sun, where it is hot (20 million K) and dense enough.

INSTRUCTIONS

In this activity you will set a challenge for your partner to test how much they know about fusion. Both partners will need to:

1 Read and understand pages 6 and 7 of the Fission and Fusion booklet.

2 Build a number of stages of the fusion process as they appear in the booklet.

3 Lay the pieces out on a sheet of plain paper in front of you in a jumbled up order.

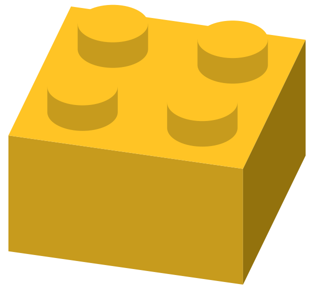
4 Challenge your partner to put the pieces in the correct order and label them, using only the information on pages 4 and 5 as a guide.

5 Check pages 6 and 7 to see if you are right.

EXTENSION

You could photograph your fusion models and annotate them in a presentation or a poster.

ACTIVITY 3 **FISSION DIVISION**



GROUP SIZE: INDIVIDUAL
TIME: 5 MINUTES
EQUIPMENT: FISSION AND FUSION BOOKLET

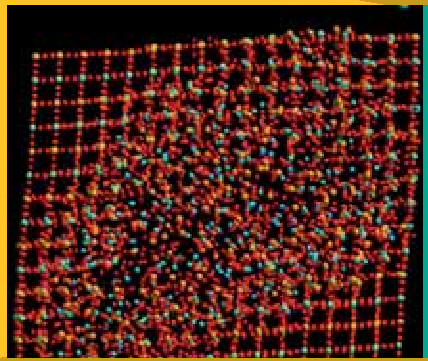
Which of the following sentences apply to nuclear fission and which ones to fusion? Find the answers in the Fission and Fusion booklet and write “fission”, “fusion” or “both” next to each sentence.

a Creates heavy elements by joining lighter elements:_______
b Happens when heavy nuclei absorb a neutron and become unstable: ______
c The process that makes stars shine: _______
d Gives out lots of energy: _______
e Is used in nuclear power stations to heat water: _______
f Is involved in nuclear chain reactions in atomic bombs:_______

RESEARCH SPOTLIGHT

STORING RADIOACTIVE WASTE

Dr Kostya Trachenko and Professor Martin Dove



RESEARCH GROUP	CENTRE FOR CONDENSED MATTER AND MATERIALS PHYSICS
SPECIALISM	ENCAPSULATING RADIOACTIVE WASTE
RESEARCH TOPIC	NEW AND IMPROVED WAYS OF SAFELY STORING HAZARDOUS RADIOACTIVE WASTE

Picture: Simulation of how an alpha particle damages the crystal lattice of a ceramic material

Hazardous radioactive waste from fission in nuclear power stations can remain highly radioactive for up to millions of years. Because of this, it must be stored in a way that minimises the chance of leakage into the environment.

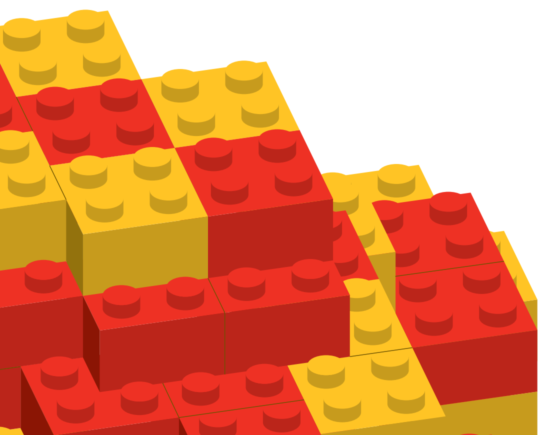
A team of physicists at Queen Mary University of London are trying to find new and improved ways of safely storing hazardous radioactive waste.

The team, led by Dr Kostya Trachenko and Professor Martin Dove are looking at how radioactive elements can be incorporated into or "encapsulated" in ceramics. The atoms in these materials are arranged in a regular structure known as a lattice. When radioactive waste is encapsulated in the ceramic, individual atoms of radioactive material are built into this lattice.

Certain ceramics are well suited to waste encapsulation as they are not easily damaged by the radiation from waste.

It is important to find out how materials used in encapsulation can be damaged by radiation as damage done to the encapsulating material may increase the chance of waste escaping. To study how radiation interacts with the ceramic lattice, researchers run computer simulations of many millions of atoms to model the damage done by alpha particles (from the nuclei of radioactive atoms) as they smash into the surrounding structure.

EXTENSION/HOMEWORK



As a class, build a giant uranium 235 nucleus. This is the fuel used in many nuclear fusion reactors. You will need 143 red bricks and 92 yellow bricks. You may need to split into smaller groups to each build a chunk of the nucleus.

LESSON PLAN: **PARTICLE PHYSICS**

Timing	64 minutes
Session aim	Introduce students to the fascinating and unusual world of particle physics.
Preparation	Read activity sheets and booklet, download presentation, print activity sheets, and set up activity resources.
Resources	Activity sheets 1, 2 and 3 All coloured bricks (as shown in the Particle Physics booklet) Particle Physics booklets
After this session students should understand that…	Quarks combine to make a number of different particles including baryons and mesons. Not all combinations of quarks are allowed; charge and colour must be considered. Particles can decay into other types of particles.
Key	Key learning points are included as bullets. Suggestions for things to say are in italics.

Time (min)	Section	Resources
2	**SLIDE: SESSION INTRODUCTION** *"This session involves the most fundamental building blocks of our universe. We will be talking about fundamental particles and the strange world they inhabit. We will learn some of the subtle rules that govern their behaviour and see how this strange behaviour defines our familiar world."* Hand out Particle Physics booklet and explain that you will be using building bricks, booklets and slides.	Slide Particle Physics booklets
5	**SLIDE: THE SMALLEST THINGS** - Physicists believe that quarks are amongst the smallest things in the universe. They are not made of anything else. - Quarks combine to make other particles. - There are 6 types of quarks including their antiparticles, here are three of them.	Slide
5	**SLIDE: SLIGHTLY BIGGER THINGS** - Baryons are made of three quarks. - Mesons are made of a quark and an antiquark. - Leptons are not made of quarks and include the electron and the muon.	Slide

Time (min)	Section	Resources
5	**SLIDE: RULES FOR COMBINATION OF QUARKS - CHARGE** - Quarks combine according to certain rules. - When combining them, all of the quarks’ charges together must add up to make a whole number.	Slide Particle Physics booklet
5	**ACTIVITY 1: BUILD A BARYON** This is an individual activity.	Activity sheet 1 All coloured bricks Particle Physics booklet
5	**ACTIVITY 2: MAKE A MESON** This is an individual activity. **Answers:** п-, пo, п+, k- They are all whole numbers; particles cannot have fractional charge.	Activity sheet 2 All coloured bricks Particle Physics booklet
10	**ACTIVITY 3: COMBINATION CONUNDRUM** This activity works best in pairs.	Activity sheet 3 All coloured bricks Particle Physics booklet
5	**SLIDE: CONSERVATIONS** - When particles interact, they must obey certain rules called conservations. - Certain interactions obey certain conservation rules and not others.	Slide

Time (min)	Section	Resources
10	**INTERACTIONS QUIZ: P7** Students should use the information on pages 3, 8 and the Force Summary table on the back of the booklet to help them. Students will need to know: charge on antimuon = +1; charge on neutrino = 0 **Answers:** Lambda baryon: 0, 1, 0, -1 Proton: 1, 1, 0, 0 Pion: -1, 0, 0, 0 weak Pion: -1, 0, 0, 0 Antimuon: 1, 0, -1, 0 Neutrino: 0, 0, 1, 0 weak	Particle Physics booklet
5	**SLIDES: HOW FORCES WORK** - Forces work though the exchange of particles. - Gravity doesn’t affect particle interactions.	Slides
5	**SLIDE: BETA DECAY** - Beta decay is governed by the weak force, which turns a down quark into an up quark.	Slide
2	**SLIDE: ROUNDUP** Run over everything you have covered. Ask the group to sum up the key learning points.	Slide

ACTIVITY 1 **BUILD A BARYON**

GROUP SIZE: INDIVIDUAL
TIME: 5 MINUTES
EQUIPMENT: ALL COLOURED BRICKS; PARTICLE PHYSICS BOOKLET

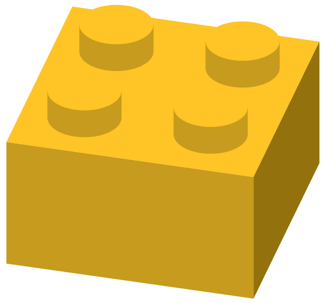
BACKGROUND INFORMATION

Baryons are particles made of three quarks. The most common types of baryon are protons (+1 charge) and neutrons (0 charge), which are both made from a mixture of up and down quarks.

INSTRUCTIONS

Use the information about quarks on page 3 of the Particle Physics booklet to build a proton and a neutron from quarks.

Hint: you need to make sure the charges of the quarks add up together to yield the correct charge for the proton and neutron.



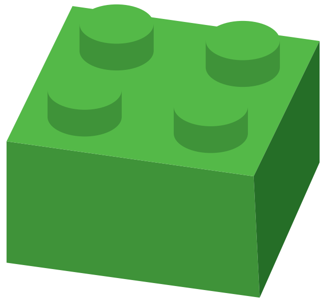
Once you've tried this, have a go at making an antiproton and an antineutron

Hint: use the related antiquarks.

What is the charge on your two new antiparticles?

The answers are on page 4 – no peeking!

ACTIVITY 2 **MAKE A MESON**



GROUP SIZE: INDIVIDUAL
TIME: 5 MINUTES
EQUIPMENT: ALL COLOURED BRICKS; PARTICLE PHYSICS BOOKLET

BACKGROUND INFORMATION

Mesons are particles made up of a quark and an antiquark.

INSTRUCTIONS

Build the following pairings of quarks and antiquarks and calculate their charge. Once you have finished, turn to page 4 and find the names of the mesons you have built.

Antiup quark + down quark	Charge:____	name:________
Antiup quark + up quark	Charge:____	name:________
Antidown quark + up quark	Charge:____	name:________
Strange quark + antiup quark	Charge:____	name:________

Do you notice anything about the charges that your particles have?

ACTIVITY 3 **COMBINATION CONUNDRUM**

GROUP SIZE: PAIRS
TIME: 10 MINUTES
EQUIPMENT: ALL COLOURED BRICKS; PARTICLE PHYSICS BOOKLET

BACKGROUND INFORMATION

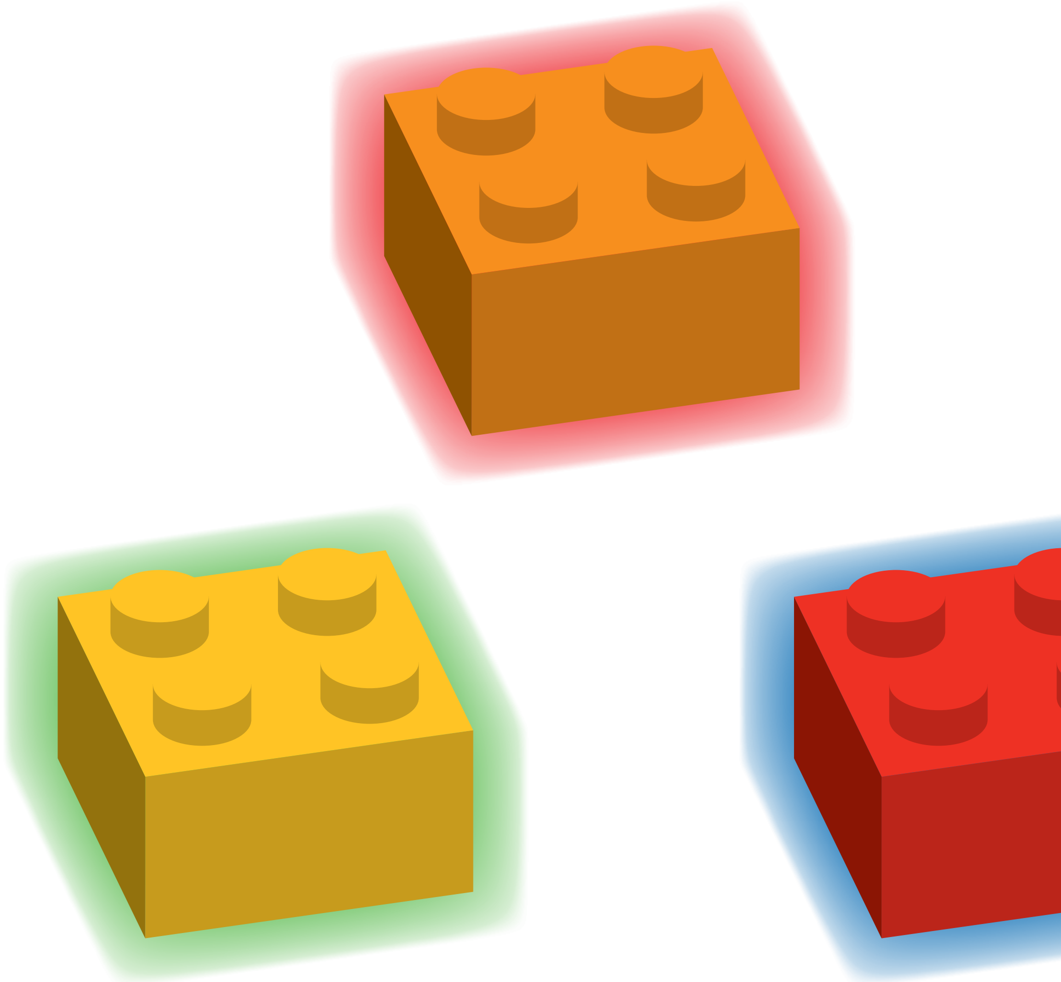
Read the rules for combination of quarks on pages 5 and 6 of the Particle Physics booklet.

INSTRUCTIONS

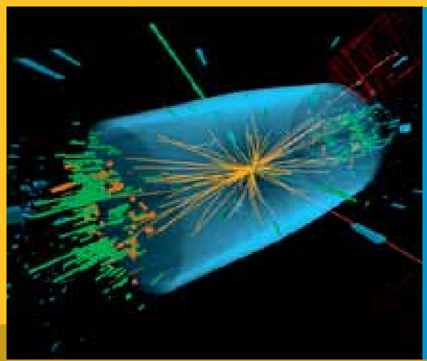
1 Each partner needs to build a series of baryons and mesons (as many as you like). Make sure some are allowed by the rules and some are forbidden.

2 Challenge your partner to spot the forbidden particles using only the information on pages 3, 5 and 6.

Hint: You need to consider the charge of the particles and if they combine for the "colour charge" to be white.



RESEARCH SPOTLIGHT
THE SEARCH FOR EXTRA PARTICLES
Dr Jon Hays



RESEARCH GROUP	PARTICLE PHYSICS RESEARCH CENTRE
SPECIALISM	PARTICLE PHYSICS
RESEARCH TOPIC	PARTICLE PHYSICS OUTSIDE THE STANDARD MODEL

Picture: Proton collision creating a shower of particles at the CMS detector at CERN

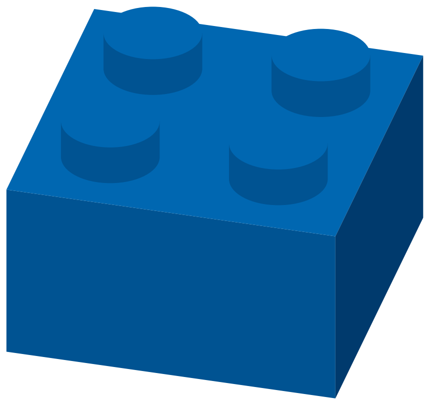
Dr Jon Hays is a particle physicist at Queen Mary University of London whose work played an important part in the discovery of what many believe could be a Higgs boson – a particle that by its existence would explain how fundamental particles get their mass. Dr Hays is interested in understanding the origin of the mass of quarks and other fundamental particles and exploring the possibility that our accepted interpretation of the workings of particle physics could be overly simplistic.

The standard model, our most straight-forward understanding of particle physics, predicts the existence of a Higgs boson. There are viable extensions of the standard model that predict a richer collection of particles including the possibility of multiple Higgs bosons.

By looking at the production of pairs of particles in particle collisions at the research facility CERN, Dr Hays and his team hope to see an unusually high number of heavy quarks called bottom quarks. The presence of extra bottom quarks could support ideas about additional particles and would suggest that there is more than one Higgs boson.

Image courtesy of CERN

EXTENSION/HOMEWORK



Use the internet or other sources to research different kinds of particle accelerators and detectors. Prepare a short presentation including information about how the detector/accelerator works and what particles are involved.